



HAL
open science

Decisioning Workshop 2023

Daniel Andres Feriz Garcia, Luis Freddy Muñoz Sanabria, Cesar Collazos, Diego Torres, Mario Lezoche, Vanessa Agredo, Pablo Ruiz, Julio Hurtado

► **To cite this version:**

Daniel Andres Feriz Garcia, Luis Freddy Muñoz Sanabria, Cesar Collazos, Diego Torres, Mario Lezoche, et al.. Decisioning Workshop 2023: Collaborarion in knowledge discovery and decisioning making. Decisioning workshop 2023, 2023. hal-04535962

HAL Id: hal-04535962

<https://hal.science/hal-04535962>

Submitted on 7 Apr 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Public Domain

DECISIONING

2023



THE SECOND WORKSHOP ON
"COLLABORATION IN KNOWLEDGE
DISCOVERY AND DECISIONING MAKING"

DECISIONING 2023

The second workshop on
“Collaboration in knowledge
discovery and decision making.”


*Freddy Muñoz Sanabria · Cesar A Collazos ·
Diego Torres · Mario Lezoche ·
Vanessa Agredo · Pablo H. Ruiz ·
Julio A Hurtado*

Editors


Daniel Andres Feriz Garcia 
Luis Freddy Muñoz Sanabria 
Cesar A. Collazos 

Compilers

Luis Freddy Muñoz Sanabria 
Fundación Universitaria de Popayán
Popayán, Colombia


Cesar A. Collazos 
Universidad del Cauca
Popayán, Colombia

Diego Torres 
Universidad Nacional de La Plata
Argentina

Mario Lezoche 
University of Lorraine
Francia

Vanessa Agredo 
Corporación Universitaria Comfacauca
Popayán, Colombia

Pablo H Ruiz 
Corporación Universitaria Comfacauca
Popayán, Colombia

Julio A Hurtado 
Universidad del Cauca
Popayán, Colombia

Editorial:

Fundación Universitaria de Popayán
ISBN:

2023



FUNDACIÓN
UNIVERSITARIA
DE POPAYÁN

DECISIONING 2023:

The second workshop on “Collaboration in knowledge discovery and decision making.”

In a knowledge society, the term knowledge must be considered a core resource for organizations. So, beyond being a medium to progress and to innovate, knowledge is one of our most important resources: something necessary to decide. Organizations that are embracing knowledge retention activities are gaining a competitive advantage. Organizational rearrangements from companies, notably outsourcing, increase a possible loss of knowledge, making knowledge retention an essential need for them. When Knowledge is less shared, collaborative decision-making seems harder to obtain insofar as a “communication breakdown” characterizes participants’ discourse. At best, stakeholders have to find a consensus according to their knowledge. Sharing knowledge ensures its retention and catalyzes the construction of this consensus.

Our vision of collaborative decision-making aims not only at increasing the quality of the first parts of the decision-making process: intelligence and design, but also at increasing the acceptance of the choice. Intelligence and design will be done by more than one individual and constructed together; the decision is more easily accepted. The decided choice will then be shared. Thereby where decision-making could be seen as a constructed model, collaborative decision-making, for us, is seen as the use of socio-technical media to improve decision-making performance and acceptability. The shared decision making is a core activity in a lot of human activities. For example, the sustainable decision-making is the job of not only governments and institutions but also broader society. Recognizing the urgent need for sustainability, we can argue that to realize sustainable development, it must be considered as a decision-making strategy. The location of knowledge in the realization of collaborative decision-making has to be regarded insofar as knowledge sharing leads to improve collaborative decision-making: a “static view” has to be structured and constitutes the “collaborative knowledge.” Knowledge has an important role in individual decision-making, and we consider that for collaborative decision-making, knowledge has to be shared. What is required is a better understanding of the nature of group work”. Knowledge has to be shared, but how do we share knowledge?

Decisioning 2023 is the second workshop on Collaboration in knowledge discovery and decision-making: It has been organized by six research teams from France, Argentina, and Colombia to explore the current frontier of knowledge and applications in different areas related to knowledge discovery and decision-making. The format of this workshop is hybrid (face-to-face or virtual), aims at the discussion and knowledge exchange between the academy and industry members. This workshop has been partially supported by STIC-AmSud projects: AGROFAIR (Agro-Knowledge Integration: Developing a FAIR data science approach for adding value to the agricultural supply chain) and AICODA: Artificial Intelligence Collaborative Decision making Agriculture.

This workshop was organized in the city of Popayan (Colombia) during June 21 to 23 – 2023, and brought together researchers from different countries and regions of Colombia. Seven long articles, five short articles, and two posters were presented in this edition.

Chairs and Committee

General Chairs

Dr. Cesar Collazos, *Universidad del Cauca, Colombia.*

<ccollazo@unicauca.edu.co>

Dr. Diego Torres, *Universidad Nacional de La Plata-Universidad Nacional de Quilmes, Argentina.* <diego.torres@lifa.info.unlp.edu.ar>

Dr. Mario Lezoche, *University of Lorraine, France*

<mario.lezoche@univ-lorraine.fr>

Organizing Committee

Dr. Julio Hurtado, *Universidad del Cauca, Colombia.*

<ahurtado@unicauca.edu.co>

Dr. Freddy Muñoz, *Fundación Universitaria de Popayán,*

<freddy.munoz@docente.fup.edu.co>

Dr. Julio César Chavarro, *Universidad Tecnológica de Pereira, Colombia,*

<jchavar@utp.edu.co>

Mag. Clara Eugenia Satizábal Serna, *Fundación Universitaria de Popayán,*

<sistemas@fup.edu.co>

Mag. Daniela Iboth Gutiérrez Idrobo, *Fundación Universitaria de Popayán,* <daniela.gutierrez@docente.fup.edu.co>

Mag. Luis Alfonso Vejarano, *Fundación Universitaria de Popayán*

Mag. Daniel Andrés Feriz García, *Fundación Universitaria de Popayán*

Mag. Sonia Del Consuelo Gaviria Armero, *Fundación Universitaria de Popayán*

Doctoral Symposium Chair

Dr. Cesar Collazos, *Universidad del Cauca, Colombia.*

<ccollazo@unicauca.edu.co>

Dr. Alejandro Fernández, *Universidad Nacional de La Plata-Universidad Nacional de Quilmes, Argentina* <alejandro.fernandez@lifa.info.unlp.edu.ar>

Publicity Chairs

Dr. Vanessa Agredo Delgado, *Corporación Universitaria ComfacaUCA- UnicomfacaUCA, Colombia.* <vagredo@unicomfacaUCA.edu.co>

Dr. Pablo H. Ruiz, *Corporación Universitaria ComfacaUCA- UnicomfacaUCA, Colombia.* <pruiz@unicomfacaUCA.edu.co>

Dr. Leandro Antonelli, *Universidad Nacional de La Plata, Argentina.* <leandro.antonelli@lifa.info.unlp.edu.ar>

Program Committee Members

Alfonso	Infante	<i>alfonso.infante@decd.uhu.es</i>
Alicia	Mon	<i>amon@unlam.edu.ar</i>
Ana	Esteso	<i>aesteso@cigip.upv.es</i>
Ana Isabel	Molina Díaz	<i>AnaIsabel.Molina@uclm.es</i>
Ana Paula	Costa	<i>apcabral@cdsid.org.br</i>
Andres	Rodriguez	<i>asrodriguez@gmail.com</i>
Andres	Rodriguez	<i>arodrig@lifa.info.unlp.edu.ar</i>
Antonio	Silva Sprock	<i>asilva.sprock@gmail.com</i>
Carlos	Buil Aranda	<i>cbuilaranda@gmail.com</i>
Claudia	Pons	<i>cpons@info.unlp.edu.ar</i>
Cristina	Manresa-Yee	<i>cristina.manresa@uib.es</i>
Danielle	Morais	<i>dcmorais@insid.org.br</i>
Diego	Firmenich	<i>diego.firmenich@gmail.com</i>
Fernando	Moreira	<i>fmoreira@upt.pt</i>
Francesca	Pozzi	<i>pozzi@itd.cnr.it</i>
Francisco Luis	Gutiérrez Vela	<i>fgutierr@ugr.es</i>
Gabriela	Arevalo	<i>gabriela.b.arevalo@gmail.com</i>
Germán Ezequiel	Lescano	<i>gelescano@unse.edu.ar</i>
Gineth Magaly	Cerón Rios	<i>gceron@unicomfacaUCA.edu.co</i>
Gustavo	Constain Moreno	<i>gustavo.constain@gmail.com</i>
Guy	Camilleri	<i>Guy.Camilleri@irit.fr</i>
Horacio	Del Giorgio	<i>horacio.delgiorgio@gmail.com</i>
Horacio	Del Giorgio	<i>hdelgiorgio@ing.unlam.edu.ar</i>
Huizilopoztli	Luna-García	<i>hlugar@uaz.edu.mx</i>
Isabelle	Linden	<i>isabelle.linden@unamur.be</i>
Jaime	Díaz	<i>jaime.diaz87@gmail.com</i>
Jaime	Muñoz-Arteaga	<i>jmauaa@gmail.com</i>
Jason	Papathanasiou	<i>jasonp@uom.gr</i>
Javier Alejandro	Jiménez Toledo	<i>javierjx@gmail.com</i>
Javier	Berrocal	<i>jberolm@unex.es</i>
Jesús	Gallardo Casero	<i>jesus.gallardo@unizar.es</i>
Jose	García-Alonso	<i>jgaralo@unex.es</i>
Jose	Pow	<i>japowsang@pucp.pe</i>
Juan Enrique	Garrido Navarro	<i>juanenrique.garrido@udl.cat</i>
Juan Manuel	Murillo Rodríguez	<i>juanmamu@unex.es</i>
Julián	Muñoz	<i>julianfer87@gmail.com</i>

Julio	Hurtado	<i>jhurtado@dcc.uchile.cl</i>
Julio	Ponce	<i>julk_cpg@hotmail.com</i>
Klinge Orlando	Villalba-Condori	<i>kvillalbac@unsa.edu.pe</i>
Leandro	Antonelli	<i>leandro.antonelli@lifia.info.unlp.edu.ar</i>
Leandro	Fernandes	<i>leandro.fernandes@mackenzie.br</i>
Liliana	Vizzuett	<i>lilianavizz@hotmail.com</i>
Luis Freddy	Muñoz Sanabria	<i>lfreddyms@hotmail.com</i>
Luis Mariano	Bibbo	<i>lmbibbo@lifia.info.unlp.edu.ar</i>
Manuel	Ibarra	<i>manuelibarra@gmail.com</i>
Marco Javier	Suarez Baron	<i>marcojaviersuarezbaron@gmail.com</i>
María Del Mar	Alemaný-Díaz	<i>mareva@omp.upv.es</i>
Maria Dolores	Lozano	<i>maria.lozano@uclm.es</i>
Miguel	Redondo	<i>Miguel.Redondo@uclm.es</i>
Natalia	Padilla	<i>natalia.padilla@unir.net</i>
Nathalie	Aussenac-Gilles	<i>aussenac@irit.fr</i>
Oscar	Revelo Sánchez	<i>orevelo@udenar.edu.co</i>
Oscar	Franco	<i>oscarhf2002@hotmail.com</i>
Pablo	Torres-Carrion	<i>pvtorres@utpl.edu.ec</i>
Pablo	Santana Mansilla	<i>psantana@unse.edu.ar</i>
Pablo E.	Martínez López	<i>fidel@unq.edu.ar</i>
Pablo Hernando	Ruiz Melenje	<i>pruiz@unicomfacauca.edu.co</i>
Patricia	Paderewski	<i>patricia@ugr.es</i>
Pascale	Zárate	<i>pascale.zarate@ut-capitole.fr</i>
Patricio	Galdames	<i>pgaldames@ubiobio.cl</i>
Pavlos	Delias	<i>pdelias@af.ihu.gr</i>
Philippe	Palanque	<i>palanque@irit.fr</i>
Pierre-mmanuel	Arduin	<i>pierre-emmanuel.arduin@dauphine.psl.eu</i>
Ricardo	Tesoriero	<i>ricardo.tesoriero@uclm.es</i>
Rosanna	Costaguta	<i>rcostaguta@hotmail.com</i>
Sergio	Ochoa	<i>sochoa@dcc.uchile.cl</i>
Silvana	Acíar	<i>silvanav.aciar@gmail.com</i>
Susana	Bautista	<i>susana.bautista@ufv.es</i>
Wilson Javier	Sarmiento	<i>wilson.sarmiento@unimilitar.edu.co</i>
Yasamin	Eslami	<i>yasamin.eslami@ec-nantes.fr</i>
Yosly Caridad	Hernandez	<i>yoslyhernandez@gmail.com</i>

Contents

SEMIoTICA - Security Scenarios Modeling forIoT-based Agriculture Solutions.....	12
1 Introduction.....	13
2 Background.....	14
3 Related work.....	16
4 Our approach.....	17
5 Assessment of the approach.....	20
6 Prototype of the tool support.....	21
7 Conclusion.....	21
References.....	22
Application of the Methodological Framework forDesigning Collaborative Systems with Awareness Mechanisms. Case study of the Miski bakery.....	24
1 Introduction.....	24
2 Conceptual Framework.....	27
3 Methodological Framework.....	28
4 Application of the Methodological Framework to design collaborative systems with awareness mechanisms for theMiski bakery.....	29
5 Discussion of results.....	33
6 Conclusions and future work.....	36
7 References.....	36
A Method to obtain a Knowledge Representation from a NaturalLanguage Specification of the Domain using the Glossary LEL.....	38
1. Introduction.....	38
2. Background.....	39
3. Related works.....	41
4. The proposed approach.....	42
5. Tool support.....	45
6. Evaluation.....	47
6. Conclusions.....	47
Acknowledgment.....	48
References.....	48
Quantum Computing meets Software Engineering: a Road Map for CollaborativeResearch.....	50
1 Introducion.....	50
2 A research road map.....	51
3 An Iberoamerican Seedbed for Quantum SoftwareEngineering.....	53
Acknowledgements.....	53
References.....	54
Biomechanical Analysis of Basketball Free Throw Shooting Technique in Athletes of The Pedagogical andTechnological University of Colombia.....	55
1 Introduction.....	55
2 Materials and methods.....	56
Informationprocessing.....	57
Learningmodel.....	57
4 Conclusions.....	61
References.....	62

A Bayesian Approach to Duplicate Detection for Real Estate Listings.....	63
1 Introduction.....	63
2 Related Work.....	64
3 Problem Definition	65
4 Knowledge Graph.....	66
5 Metrics.....	68
6 Bayesian Approach.....	68
7 Evaluation.....	71
8 Conclusions and Future Work	72
References.....	73
Identification of Collaboration issues during the adoption of Scrum in Software development teams	74
1 Introduction.....	74
2 Background.....	75
3 Qualitative Study on the collaborative aspects taken into account by development teams during Scrum adoption.....	76
4 Conclusions and future work.....	81
References	83
A literature review to enabling strategic decision support systems for crisis management.....	84
1 Introduction.....	84
2 Research Methodology.....	85
3 Strategic Decision Support Systems.....	86
4 Discussion.....	86
5 Conclusion	87
References	87
Rayuela: a pluggable adaptive gamification approach for CLCS.....	90
1 Introduction.....	90
2 Approach	2
3 Conclusion and Future work	6
Acknowledgements	6
References.....	7
Named Entity Extraction in Requirement Specification: A Comparison	4
1 Introduction.....	4
2 Related Work.....	5
3 Evaluation Method.....	5
4 Results	6
5 Conclusions.....	7
References.....	9
1 Introduction.....	11
2 Bibliographic Review	12
3 Methodology	13
3.1 Description of the Data Set.....	13
3.2 Data Preparation	13
3.3 Random Forest Spatial Interpolation.....	13
3.4 Accuracy Evaluation.....	13
4 Final Considerations.....	14
References.....	14

Multidimensional Energy Analysis in Agricultural Coffee Production

Systems to Assess Sustainability.....	15
1 Introduction.....	15
2 Methodology.....	16
3 Results and Discussion.....	17
4 Conclusions.....	20
References	21

Un sistema de recomendación para la reutilización de fármacos utilizando embeddings sobre Grafos de Conocimiento.....

1 Introducción	26
2 Trabajos Relacionados	2
3 Problemática.....	2
4 Contexto.....	2
5 Propuesta	3
6 Conclusión.....	3
References	4

Collaborative Framework for the Implementation of Digital Transformation Processes in Higher Education.....

1 Introduction.....	4
2 State of the art	4
3 Problem statement and contributions	5
4 Methodology and research approach.....	5
5 Evaluation plan	5
6 Preliminary or intermediate results.....	5
7 Conclusions and Lessons Learned.....	5
8 Doctor. Stage: Early.....	5

SEMIoTICA - Security Scenarios Modeling forIoT-based Agriculture Solutions

Julio Ariel Hurtado¹, Leandro Antonelli², Santiago López¹, Adriana Gómez³, Juliana Delle Ville², Frey Giovanni Zambrano¹, Andrés Solís^{1,4}, Marta Cecilia Camacho⁵, Miguel Solinas⁶, Gladys Kaplan⁷, and Freddy Muñoz⁸

¹ IDIS, Universidad del Cauca, Colombia

{ahurtado, santiagolopez94, freyzambrano, afsolis}@unicauca.edu.co

² Lifia - Facultad de Informática, Universidad Nacional de La Plata, Argentina

{lanto, jdelleville}@lifia.info.unlp.edu.ar

³ universidad Tecnologica de Pereira, Colombia
adrianagomezr@utp.edu.co

⁴ Corporacion Universitaria Comfacauca, Colombia

⁵ Institución Universitaria Colegio Mayor del Cauca, Colombia
cecamacho@unimayor.edu.co

⁶ LARYC, FCEFyN, Universidad Nacional de Cordoba, Argentina
miguel.solinas@unc.edu.ar

⁷ Universidad Nacional de La Matanza, Argentina
gladyskaplan@gmail.com

⁸ Fundacion Universitaria de Popayan, Colombia
lfreddyms@gmail.com

Abstract. Agriculture is a vital human activity contributing to sustainable development. A few decades ago, the agricultural sector introduced the Internet of Things (IoT), playing a relevant role in precision and smart farming. IoT developments in farms require a lot of connected devices working cooperatively. It increases the vulnerability of IoT devices mostly because it lacks the necessary built-in security due to their constrained context and computational capacity. Additionally, storage and data processing connecting with edge or cloud servers are the reason for many security threats. To ensure that IoT-based solutions meet functional and non-functional requirements, particularly security, software companies should adopt a security-focused approach to their specification. This paper proposes a method for specifying security scenarios integrating requirements and architecture viewpoints in the context of the IoT in agriculture solutions. The method comprises four activities. First, the description of scenarios for the intended software. After that, scenarios with incorrect system use should be described. Then, these are translated into security scenarios using a set of rules. Finally, the security scenarios are improved. Additionally, this paper describes a preliminary validation of the approach, which software engineers in Argentina and Colombia performed. The results show that the approach proposed allows software engineers to define and analyze security scenarios in the IoT and agriculture contexts with good results.

Keywords: *IoT · Quality Scenario · IoT Requirements · Smart Farming Industry 4.0*

1 Introduction

The International Telecommunication Union (ITU) defines IoT (Internet of the Things) as a "global infrastructure for the information society that provides advanced services through the connection of objects (physical and virtual) relying on the interoperability of current and future knowledge and communication technologies" [31]. According to [17] as an interconnected network, IoT contributes to making decisions based on the information collected, and its interaction does not need human intervention. The definition includes the concept of a Cyber-Physical system, which is a complex abstraction that requires a conceptual map [5] rather than a simple definition to state its concept.

Regarding software development, requirements analysis is a critical activity for defining software functionalities, attributes, and quality properties. This process is particularly different for software construction by using emergent technologies like IoT. Traditional software development practices must adapt to these new technologies and business contexts [17]. Requirements engineering involves collaboration between clients and development teams for incorporating the right features into the finished product [27]. Inconsistencies between initial requirements and the final product can lead to re-engineering processes, increasing the project scope and cost [26]. Requirements engineering works with both types of knowledge, explicit and tacit [1]. Tacit knowledge is difficult to communicate because experts and development teams often have different backgrounds and use distinct terminologies [20], making it challenging to elicit information from stakeholders.

Software products are defined by a set of functional and non-functional requirements. The latter is responsible for the software product's quality and is most frequently considered when developing an IoT system according to its specific application domain [17]. A way to specify software requirements is to describe use scenarios through storytelling techniques. This approach is effective because it is a way to incorporate details that are essential to provide a rich consolidation of knowledge. Scenarios employ natural language, allowing experts to use them without complex formalisms. This makes them highly effective in promoting communication and collaboration among diverse groups of experts [3].

The main challenges associated with these requirements in developing these products are limited processing and storage capacity, performance reliability, availability, accessibility, interoperability, security, privacy, scalability flexibility, and context awareness [17, 19]. Following this reasoning, security is an aspect that is highly relevant in IoT-based software because it protects resources such as modules, code, and others from unauthorized access [19]. With scenarios, experts can describe various situations and work together to improve them, learning from one another in the process. This can be especially valuable when dealing with complex problems that require inputs from multiple perspectives. Overall, scenarios can be a powerful tool for fostering cooperation and achieving better outcomes in a wide range of domains.

The software architect must consider designing the whole system when stakeholders identify security concerns rather than adding security technologies in an ad-hoc manner [15]. As Bruce Schneier points out [25], security is a process and a chain that is only as strong as its weakest link. Therefore, software providers must adopt a security-centric approach to designing and developing IoT-based solutions that conform to functional and non-functional requirements like security [14].

The agricultural sector now requires data collection and advanced technologies to improve production while using limited resources. Sustainable agriculture can help preserve nature without compromising the needs of future generations [6, 13]. The Food and Agriculture Organization (FAO) has identified population growth, resource scarcity, and degradation as key challenges. There is a need to increase efficiency, productivity, and quality in agrifood systems while protecting the environment [24]. To achieve this, new developments and technologies must be introduced to automate traditional farming

methods and make farm labor more efficient. The Internet of Things (IoT) appears as technology to transform conventional processes [6, 13].

IoT systems encounter distinct security challenges when compared to traditional IT systems primarily due to the presence of resource-constrained devices. These limitations make IoT systems more susceptible to a wide range of attack vectors, posing potential threats to their security [7]. Therefore, accurately identifying and understanding the specific security requirements is crucial when developing such systems.

This paper proposes a scenario-based method for specifying the architecture's security aspects. The method is composed of four essential activities. The first activity consists in describing scenarios of the intended software application. The second activity consists in describing scenarios related to the previous ones but referring to incorrect usage of the application. The third activity consists in applying a set of rules to map attributes from the previous scenarios to the architecture scenarios. Finally, the fourth activity consists in describing the architectural scenarios in more detail. Moreover, this document describes a preliminary evaluation of the proposed approach. Given the security challenges facing IoT agriculture, the research question in this paper is: how adequately elicit security requirements in IoT-based smart agriculture solutions?

The paper is organized in the following way. Section 2 describes some background about the scenarios. Then, section 3 describes some related work. Section 4 details our contribution, which is the proposed approach. Section 5 describes the tool to support the proposed method. Section 6 presents the preliminary evaluation. Finally, Section 7 discusses some conclusions.

2 Background

This section describes two types of scenarios. First, it describes scenarios that focus on the functionality of a software application. Afterward, the section describes scenarios that focus on architectural security concerns.

2.1 Scenarios for describing functionality

A scenario [3] is an artifact that describes situations (in the application or the software domain) using natural language. It describes a specific situation that arises in a certain context to achieve some goal. There is a set of steps (the episodes) to reach that goal. In the episodes, active agents as actors use materials, tools, and data as resources to perform some specific action. Although there are many templates to describe scenarios, this paper will use the scenarios proposed by Leite et al. [21]. Figure 1 summarizes the template.

Attribute	Scenario title	Goal	Context	Actors	Resources	Episodes
Description	Id	Objective	Starting point (time, place, activities previously achieved)	Active agents	Passive elements (tools, materials, data)	List of actions, simple breakdown with no conditions, no iterations

Fig. 1. Template for describing scenarios that focus on functionality.

Let's consider the following example that describes a scenario about how the irrigation system is activated. This task can be done in different ways regarding the technological infrastructure that the farm has. For example, an operator can manually start the irrigation by physically accessing the

machine room with the pumps. In this situation, there is no IoT software application. This paper is going to focus on another scenario where a software application performs the activation of the pumps. For example, an agriculture expert evaluates the field conditions to determine whether irrigating is necessary and provides the information to the farm supervisor. Then, the supervisor activates the irrigation pipeline through an IoT-based web application. Table 2 summarizes the situation.

Attribute	Scenario title	Goal	Context	Actors	Resources	Episodes
Description	Attempt to access the water irrigation infrastructure by an authorized person.	Protect access to the water irrigation system to ensure responsible use of the water.	The field counts with an irrigation infrastructure (pipes, tanks, pumps, and valves) to water (irrigate) the field.	Expert Supervisor	The checklist to determine whether it is necessary to irrigate the field. The security protocol to access and operate the pump and valves.	An expert evaluates the conditions of the field to determine whether it is necessary to irrigate. The expert writes a report to the supervisor with the recommendation to irrigate. The supervisor logs in to the IoT web application. The supervisor starts the pump and opens the valves.

Fig. 2. Authorized attempt to start the irrigation system.

The previous scenario describes an authorized person's legitimate use of the software application to activate the irrigation system. This scenario could be similar to Use Cases or User Stories [20]. Nevertheless, the software system can be vulnerable to hack attacks, where a malicious user desires to break into the web software application to start the irrigation system just for fun or to destroy the crop. This incorrect and harmful description of the software application is related to misuse cases [12].

2.2 Scenarios for describing architectural security concerns

Software architecture is the designing process of the system's fundamental structure and organization to achieve specific quality attributes, which are the critical non-functional characteristics determining the system's overall effectiveness. Quality attributes are specified through quality scenarios, which define how the system should behave under various conditions. A Quality Attribute (QA) Scenario is a specific, testable scenario that demonstrates how a quality attribute requirement is satisfied. A QA scenario is typically structured with an id, a stimulus that triggers the interaction with the software application, the environment where the interaction occurs, the artifact affected, the response, and some quantitative description of the response. Table 3 summarizes the template.

Attribute	Scenario Id	Source of the stimulus	Stimulus	Environment	Artifact	Response	Response measure
Description	Unique identification of the scenario	Some human, system, or any other actor generates a stimulus to the system.	It is an input condition that generates a response from the system	The stimulus occurs under a certain context. The system may have an overload context, normal operation, or some other relevant state. For many systems, "normal" operation can refer to one of a number of modes. For these kinds of systems, the environment should specify in which mode the system is executing	The stimulated artifact. This may be an ecosystem, a whole system, a component, or some set of components.	It is the response as the result of the arrival of the stimulus.	The response should be measurable so that the requirement can be tested.

Fig. 3. Security scenario template.

Security refers to the system’s capability to defend against danger, ensure its safety, and protect system data from unauthorized disclosure, modification, or destruction. Security involves protecting computer systems themselves through technical and administrative safeguards. Additionally, security can refer to the degree to which a particular security policy is enforced with some level of assurance. The three fundamental types of security concerns are confidentiality, integrity, and availability. Confidentiality refers to the protection of data and processes from unauthorized disclosure or access by individuals or entities that are not authorized to access it. Integrity refers to protecting data and processes from unauthorized modification, intentional or accidental. It includes ensuring that data is not tampered with or corrupted during storage, processing, or transmission. And availability refers to the protection of data and processes from denial of service attacks or other forms of disruption that can prevent authorized users from accessing or using them. This includes ensuring that systems are available and responsive when needed and that they can handle high levels of traffic or activity without becoming overloaded or crashing. Figure 4 describes an example of a security scenario that refers to the same situation of the requirements scenario described in Figure 2.

Attribute	Identification	Source of the stimulus	Stimulus	Environment	Artifact	Response	Response measure
Description	S01	An unauthorized individual attempts to access the water irrigation system through an IoT connected device.	The individual attempts to gain access to sensitive data (sensor measurements) or to manipulate the system's functionality (change valve behavior).	Normal execution. The system counts with IoT connected devices used to access the functionality of the solution, such as sensors, actuators, processors.	The security protocols and access control subsystem.	The security protocols detect the unauthorized access attempt and block the individual from accessing the access control subsystem.	Ensure the security of the system, it's important that attacks are detected quickly, ideally within 0.5 seconds. Additionally, the system must have a high rate of success in resisting attack attempts, with a target of greater than 95%.

Fig. 4. Security scenario example.

3 Related work

The complexity of IoT software applications is a concern identified several researchers. Thus, there are some proposals to deal with this complexity. Nguyen et al. [16] propose FRASAD, a model-driven software development framework to manage the complexity of Internet of Things (IoT) applications. Karaduman et al. [11] is another proposal to deal with the complexity. Their approach includes activities such as requirements development, domain-specific design, verification, simulation, analysis, calibration, deployment, code generation, and execution. Nevertheless, these proposals do not consider security, which is our main concern.

Some other approaches consider the security issue, but it is considered in terms of implementation, while our proposal considers the security in terms of the specification of requirements. Cardenas et al. [2] propose a process and a tool to apply formal methods in Internet of Things (IoT) applications using the Unified Modeling Language (UML). They have developed a plug-in tool to validate UML software models regarding the design of a secure software application. Slovenec et al. [28] present a taxonomy of security requirements to consider them when designing and implementing the software application. El-Gendy et al. [7] propose a security architecture to provide security enabled IoT services, and provide a baseline for security deployment. The architecture solution outlined in this context plays a crucial role in addressing the security requirements of IoT systems. These security requirements are useful components of our security scenarios proposal. By focusing these requirements, we can effectively establish a robust security

framework at requirements level. Sotoudeh et al. [29] study aims to establish security requirements for IoT systems, with a focus on enhancing the security of smart home applications. The identified requirements complement our proposal as they introduce a significant vocabulary for expressing security scenarios in the IoT and smart farm context. By incorporating these elicited requirements, we can effectively address the specific security challenges and considerations associated with IoT and smart farm environments.

There are some approaches that consider security in requirements, but they do not emphasize the way to specify security requirements precisely. Iqbal et al. [9] present a literature review about an In-Depth Analysis of IoT Security Requirements, but the work they present does not refer about how to specify them. Özkaya et al. [18] proposal deal with different non-functional requirements: security, scalability, and performance. And they try to balance the different requirements or decide which one to satisfy when there is a conflict. Carvalho et al, [4] also deals with conflicts, but their approach deals with non-functional Requirements.

Finally, Kammuller et al. [10] present an approach to specify security requirements for IoT applications. They combine a framework for requirement elicitation with automated reasoning to provide secure IoT for vulnerable users in healthcare scenarios. They map technical system requirements using high-level logical modeling. Then they perform an attack tree analysis. And finally, a security protocol analysis. Their work pays more attention to the tree analysis to identify the situation, while our approach pays attention to how to describe security requirements precisely.

4 Our approach

This section is organized in the following manner: firstly, we provide a description of the general approach, followed by a detailed explanation of each step.

4.1 Our approach in a nutshell

Our proposed approach consists of several steps. Firstly, we describe scenarios that outline the intended usage of the software. Next, we create scenarios that describe incorrect usage of the application in an attempt to exploit any vulnerabilities. We then establish rules for converting these scenarios into security scenarios. Lastly, we refine and improve the security scenarios. Figure 5 provides a summary of our approach.

4.2 Description of the scenarios with the correct use of the intended software application

This step describes the scenarios that focus on the correct use of the software application regarding security concerns. This step should be executed by a requirements engineer or analyst (or a group of them) that must interact with the

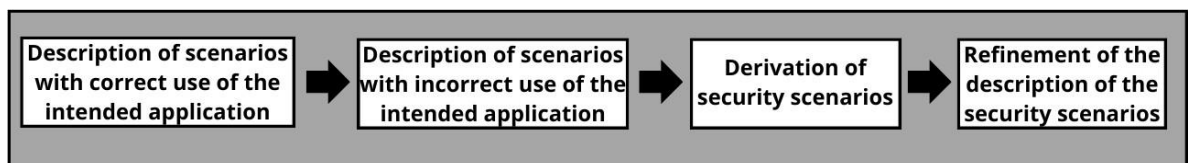


Fig. 5. Our approach in a nutshell.

Experts of the domain (clients, users, and stakeholders in general) to capture the software application's requirements and specify scenarios. Those should describe the functionality of the intended software, and they should also consider security concerns. That is why the analyst eliciting and defining scenarios should have some background in security non-functional requirements to consider this concern in the specification. The result of this step is a set of scenarios that describes the functionality like the one described in Figure 2.

4.3 Description of the scenarios with the incorrect use of the intended software application

This step consists in analyzing the scenarios described in the previous step to find security issues and describing the ones that explode the problems and compromise the security of the software application. Ideally, this step should be done by the same requirement engineer (or group of them) that participated in the previous tasks. They should analyze every scenario in detail, and considering guides like the ones proposed by Gupta et al. [8] and Yazdinejad [32], they must describe scenarios of incorrect use of the software application. Basically, they should describe scenarios that explode possible vulnerabilities.

For example, considering the scenario that describes the correct use of the software application to activate the irrigation system (Figure 2), the requirements engineer can determine that the access to the system (and therefore the access to the activation of the pumps) determine a security breach. Hence, the analyst describes a scenario where an unauthorized person gets access to the software application and, consequently to the irrigation infrastructure). Figure 6 describes the complete scenario.

Attribute	Scenario title	Goal	Context	Actors	Resources	Episodes
Description	Attempt to access the water irrigation infrastructure by an unauthorized person.	Protect access to the water irrigation infrastructure to ensure responsible use of the water.	The field counts with an irrigation infrastructure (pipes, tanks, pumps, and valves) to water (irrigate) the field. An unauthorized person attempts to manipulate the pump and the valve to irrigate the field.	An unauthorized person	The checklist to determine whether it is necessary or not to irrigate the field. The security protocol to access and operate the pump and valves.	An unauthorized gains access to the IoT web application. An unauthorized person starts the pump and opens the valves.

Fig. 6. Unauthorized attempt to start the irrigation system.

4.4 Derivation of security scenarios

This step describes a set of rules to map the information contained in a scenario that describes the incorrect use of the intended system to obtain a first draft of a scenario to describe security concerns. It is essential to mention that the scenario with incorrect usage will not provide complete information about the security scenario. The rules proposed will use only four attributes (title, context, actors, and resources), and this information will be used to fill four attributes to the security scenario (stimulus, environment, source of the stimulus, and artifact). Therefore, with this information, the following step can refine the security scenario. Figure 7 summarizes the mapping between attributes of both types of scenarios. Following the example of the scenario that describes the incorrect use of the software application described in Figure 6, the scenario obtained applying the proposed rules is the one described in Figure 8. It is important to mention that this scenario (the resulting from the mapping rules) needs to be refined in the following step, which is why this simple mapped security scenario is still far from the security scenario (like the one described in Figure 4).

The attribute of the incorrect usage scenario	Title	Context	Actors	Resources
Attribute of the security scenario	Stimulus	Environment + Source of the stimulus	Sources of the stimulus	Artifact

Fig. 7. Mapping rules between attributes of the incorrect and security scenarios.

Attribute	Stimulus	Environment + Source of stimulus	Source of stimulus	Artifact
Description	Attempt to access the water irrigation infrastructure by an unauthorized person.	The field counts with an irrigation infrastructure (pipes, tanks, pumps) to water (irrigate) the field. An unauthorized person attempts to manipulate the pump and the valve to irrigate the field.	Unauthorized person.	The checklist to determine whether it is necessary or not to irrigate the field. The security protocol to access and operate the pump and valves.

Fig. 8. Mapping rules between attributes of the incorrect and security scenarios.

4.5 Refinement of the security scenarios

Some adjustments and improvements should be made to the scenarios derived from the mapping rules in the previous step. Some new information should be added, and some information should be rephrased. Consequently, the requirements engineering should use his experience and knowledge to provide further information and paraphrase some others based on the elicitation meeting and his expertise in the field. For example, the identification of the security scenario should be provided. But this is a minor issue since the indication must be an id to identify the scenario inside the software development process, and it is more related to documentation definitions. Afterward, the attributes of stimulus, environment, source of stimulus, and artifact should be rephrased considering the information obtained in the previous step. The attributes environment and source of stimulus mainly captured data from the same attribute in the incorrect usage scenario, so in the security scenario, the information should be split and divided into two attributes. Finally, the attributes response and response measure should be completed. Although the mapping rules do not provide information to meet these attributes, the information provided in the rest of the scenario provides the context necessary so the requirement engineers can describe these two attributes. It is important to mention that the response measure attribute, in particular, should be described with quantitative measures. Therefore, engineering requirements should pay attention to that, although the tool described in the following section provides some support. Figure 9 summarizes the refinements. Then, the scenario described at the beginning of this paper in Figure 4 is an example of the scenario that this approach pursues to obtain.

1. Identification must be provided	2. The stimulus must be rephrased	3. The environment and the source of stimulus must be split into two attributes
4. The source of stimulus must be rephrased.	5. The artifact must be rephrased.	6. The response and the response measure must be added.

Fig. 9. Refinement to the security scenarios.

Security scenarios in smart farms and IoT require a specific vocabulary for accurately expressing them. There are several concerns taken into account as part of these scenarios as proposed [29]. One such concern is technology-dependent security for IoT devices (artifact), which refers to the security

measures required in the IoT context (environment). Another important aspect is the authentication of IoT objects and individuals (sources of stimulus) using various mechanisms to prevent or detect attacks (responses). These responses to potential security threats have several limits (response measurement). Requirements engineers could use this vocabulary as a lexicon and semiotic tool.

5 Assessment of the approach

5.1 Assessment Design

Our aim is to assess the acceptance of our approach by security experts in the context of IoT-based smart agriculture, using the Technology Acceptance Model (TAM) to guide our evaluation. Specifically, we are interested in understanding how much our approach is accepted by this target audience. To evaluate the usefulness and ease of use of our approach, we have adopted the well-known and widely used metrics of Perceived Usefulness and Perceived Ease of Use as defined in Fred D. Davis's work. To this end, we have designed and administered a survey to a group of expert security professionals who are representative of our target audience and possess experience in eliciting security requirements. By administering the survey to a group of expert security professionals who are representative of our target audience and possess experience in eliciting security requirements, we will be able to gather valuable feedback and insights. These insights will help us identify areas of strength and weakness in our approach, and ultimately guide improvements that enhance its overall acceptance.

5.2 Survey Application and Data Collection

We conducted a survey with a group of five experts in the software and networking security field. Prior to the survey, we presented our methodology to the group and spent approximately 40 minutes discussing and addressing any questions they had. Once we presented our approach, we administered a survey that included 17 closed-ended questions and three open-ended questions. The survey aimed to gather insights from the experts on the easy to use and usefulness perception of our method. Most of the experts found the proposed security scenario method to be a useful tool for specifying the requirements of agricultural IoT solutions. Half of the experts surveyed agreed that the proposed method simplifies the process of specifying security requirements, resulting in better quality and control of the specification. The experts noted that the proposed method is well-defined, easy to understand, and flexible, making it ideal for defining scenarios. Additionally, the evaluation revealed that the majority (over 60 percent) found it to be clear, well-structured, and interactive in its development.

5.3 Results and Analysis

While the method was generally perceived as useful and easy to use for developing security scenarios, it was suggested that it needs to be more specific to determine its usefulness in practice. The experts suggested that the method can be enhanced to include specific aspects of cybersecurity, as well as development and implementation elements that are essential to ensuring the security of agricultural IoT systems. This would enable a complete specification of the security requirements of these systems. Furthermore, it was noted that users need to interact with the method to remember its steps. During the evaluation, experts identified some areas for improvement such as incorporating vulnerabilities and risks commonly found in IoT systems, considering different types of users and adversaries, and taking into account various attack vectors.

By doing so, the proposed method can be further refined to better meet the needs of users and enhance the security of agricultural IoT systems, particularly adding this information in the lexicon associated.

6 Prototype of the tool support

A software tool was prototyped in order to provide support to the proposed approach. The tool was implemented in Python [22] using libraries such as Spacy [30], an nlp processing library and textblob [23]. This tool consists of a web application, that can be used on desktop computers as well as mobile phones. The application manages different projects and different kinds of artifacts using natural language. Scenarios are one kind of artifact, but the application can be extended easily to manage other artifacts (User Stories, Use Cases, etc.). The prototype provides support for the different activities of the approach. The prototype provides some edition form to allow users to write scenarios of correct and incorrect use of the software application.

The prototype also provides a form to list all the scenarios describing the functionality of the intended software, and by selecting one or more scenarios, the prototype performs the derivation of security scenarios by applying the mapping rules proposed. Then, the security scenarios can be edited in order to improve their description.

The prototype includes some natural language processing tools that make it possible to provide support to assist the requirements engineering to describe the security scenarios. For example, the prototype can verify the use of terms that belong to a glossary. Thus, using Lemmatization and Stemming techniques, the prototype can verify whether certain expressions are used. This is very important in the attributes of response to ensure the use of the correct technique to cope with the issue the scenario is describing. Another feature is the identification of quantitative descriptions. Natural language processing tools make it possible to assess whether this type of expression is present (for example, in the response measure attribute) to be sure that the scenario is correctly written.

7 Conclusion

This paper proposed an approach to describing security scenarios to design a robust software architecture considering IoT technology in the agricultural domain. Developers of IoT applications should be concerned about security (and some other non-functional requirements) since the risk of exposing physical artifacts to intruders is considerable. Moreover, it is difficult to identify the threat and design a countermeasure. Generally, these issues are identified when it is too late when some intruder exploits the vulnerability. Therefore, this paper presents a lightweight approach that begins with a description of the functional requirements. The misuse of the application is identified in order to design countermeasures to deal with it. The paper also described a prototype tool to help apply the proposed approach. Finally, a preliminary assessment was also provided.

The survey applied to five security experts found that the proposed security scenario method is generally useful for specifying agricultural IoT solutions, but needs improvement in certain areas. Experts suggested incorporating specific cybersecurity aspects, vulnerabilities and risks commonly found in IoT systems, and different types of users and adversaries. They also noted the method needs to be more specific and interactive for users to remember its steps. The results provide valuable insights for refining and improving the method to meet user needs and enhance security.

Currently, the most widely used development process is agile development, but we propose a complementary and lightweight technique specifically for IoT applications in the smart farm field. As future work, we aim to enrich the proposal with additional guidelines for writing scenarios for each stage. Additionally, further experimentation is necessary before we make the approach more complex. However, we firmly believe that the approach should be strengthened and made more robust.

Acknowledgements This paper is partially supported by funding provided by the STIC AmSud program, Project 22STIC-01.

References

1. Ahmed, U.: A review on knowledge management in requirement engineering. *IEEE* **5** (2018)
2. Cardenas, H., Zimmerman, R., Viesca, A.R., Al Lail, M., Perez, A.J.: Formal uml-based modeling and analysis for securing location-based iot applications. In: 2022 IEEE 19th International Conference on Mobile Ad Hoc and Smart Systems (MASS). pp. 722–723 (2022). <https://doi.org/10.1109/MASS56207.2022.00109>
3. Carrol, J.: Five reasons for scenario-based design. In: Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences. 1999. HICSS-
4. Abstracts and CD-ROM of Full Papers. vol. Track3, pp. 11 pp.– (1999). <https://doi.org/10.1109/HICSS.1999.772890>
5. Carvalho, R.M.: Dealing with conflicts between non-functional requirements of ubi-comp and iot applications. In: 2017 IEEE 25th International Requirements Engineering Conference (RE). pp. 544–549 (2017). <https://doi.org/10.1109/RE.2017.51>
6. CPS2023: Cyber-physical systems. [https://ptolemy.berkeley.edu/projects/cps/\(2023\)](https://ptolemy.berkeley.edu/projects/cps/(2023))
7. Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, S., Kaliaperumal, R.: Smart farming: Internet of things (iot)-based sustainable agriculture. *Agri-culture* **12**(10), 1745 (2022)
8. El-Gendy, S., Azer, M.A.: Security framework for internet of things (iot). In: 2020 15th International Conference on Computer Engineering and Systems (ICCES). pp. 1–6 (2020). <https://doi.org/10.1109/ICCES51560.2020.9334589>
9. Gupta, M., Abdelsalam, M., Khorsandroo, S., Mittal, S.: Security and privacy in smart farming: Challenges and opportunities. *IEEE Access* **8**, 34564–34584 (2020). <https://doi.org/10.1109/ACCESS.2020.2975142>
10. Iqbal, W., Abbas, H., Daneshmand, M., Rauf, B., Bangash, Y.A.: An in-depth analysis of iot security requirements, challenges, and their countermeasures via software-defined security. *IEEE Internet of Things Journal* **7**(10), 10250–10276 (2020). <https://doi.org/10.1109/JIOT.2020.2997651>
11. Kammüller, F., Augusto, J.C., Jones, S.: Security and privacy requirements engineering for human centric iot systems using efriend and isabelle. In: 2017 IEEE 15th International Conference on Software Engineering Research, Management and Applications (SERA). pp. 401–406 (2017). <https://doi.org/10.1109/SERA.2017.7965758>
12. Karaduman, B., Mustafiz, S., Challenger, M.: Ftg+pm for the model-driven development of wireless sensor network based iot systems. In: 2021 ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C). pp. 306–316 (2021). <https://doi.org/10.1109/MODELS-C53483.2021.00052>
13. Khamaiseh, S., Xu, D.: Software security testing via misuse case modeling. In: 2017 IEEE 15th Intl Conf on Dependable, Autonomic and Secure Computing, 15th Intl Conf on Pervasive Intelligence and Computing, 3rd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress (DASC/PiCom/DataCom/CyberSciTech). pp. 534–541 (2017). <https://doi.org/10.1109/DASC-PiCom-DataCom-CyberSciTec.2017.98>

14. Khan, N., Ray, R.L., Sargani, G.R., Ihtisham, M., Khayyam, M., Ismail, S.: Current progress and future prospects of agriculture technology: Gateway to sustainable agriculture. *Sustainability* **13**(9), 4883 (2021)
15. Martin, T., Geneiatakis, D., Kounelis, I., Kerckhof, S., Nai Fovino, I.: Towards a formal iot security model. *Symmetry* **12**(8) (2020). <https://doi.org/10.3390/sym12081305>, <https://www.mdpi.com/2073-8994/12/8/1305>
16. Myagmar, S., Lee, A.J., Yurcik, W.: Threat modeling as a basis for security requirements. In: *Symposium on Requirements Engineering for Information Security (SREIS)*. University of Pittsburgh (August 2005), <http://d-scholarship.pitt.edu/16516/>
17. Nguyen, X.T., Tran, H.T., Baraki, H., Geih, K.: Frasad: A framework for model-driven iot application development. In: *2015 IEEE 2nd World Forum on Internet of Things (WF-IoT)*. pp. 387–392 (2015). <https://doi.org/10.1109/WF-IoT.2015.7389085>
18. Ojo-Gonzalez, K., Bonilla-Morales, B.: Requerimientos no funcionales para sistemas basados en el internet de las cosas (iot): Una revisión. *I+D Tecnológico* **17**(2), 30–40 (2021)
19. Ozkaya, O., Ors, B.: Model based node design methodology for secure iot applications. In: *2018 26th Signal Processing and Communications Applications Conference (SIU)*. pp. 1–4 (2018). <https://doi.org/10.1109/SIU.2018.8404490>
20. Pal, S., Hitchens, M., Rabehaja, T., Mukhopadhyay, S.: Security requirements for the internet of things: A systematic approach. *Sensors* **20**(20), 5897 (2020)
21. Potts, C.: Using schematic scenarios to understand user needs. In: *Proceedings of the 1st Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*. p. 247–256. DIS '95, Association for Computing Machinery, New York, NY, USA (1995). <https://doi.org/10.1145/225434.225462>, <https://doi.org/10.1145/225434.225462>
22. do Prado Leite, J.C.S., Hadad, G.D.S., Doorn, J.H., Kaplan, G.N.: A scenario construction process. *Requirements Engineering* **5**, 38–61 (2000)
23. Python: Python framework. <https://www.python.org/> (2023), accessed: 2023-03-11
24. Python: Textblob library. <https://pypi.org/project/textblob/> (2023), accessed: 2023-03-11
25. Rose, D.C., Wheeler, R., Winter, M., Loble, M., Chivers, C.A.: Agriculture 4.0: Making it work for people, production, and the planet. *Land use policy* **100**, 104933(2021)
26. Schneier, B.: Cryptography is harder than it looks. *IEEE Security & Privacy* **14**(1), 87–88 (2016). <https://doi.org/10.1109/MSP.2016.7>
27. Serna M, E., Serna A, A.: Proceso y progreso de la formalización de requisitos en ingeniería del software. *Ingeniare. Revista chilena de ingeniería* **28**(3), 411–423(2020)
28. Shankar, P., Morkos, B., Yadav, D., Summers, J.D.: Towards the formalization of non-functional requirements in conceptual design. *Research in engineering design* **31**, 449–469 (2020)
29. Slovenec, K., Vuković, M., Salopek, D., Mikuc, M.: Securing iot services based on security requirement categories. In: *2022 International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*. pp. 1–6 (2022). <https://doi.org/10.23919/SoftCOM55329.2022.9911319>
30. Sotoudeh, S., Hashemi, S., Garakani, H.G.: Security framework of iot-based smart home. In: *2020 10th International Symposium on Telecommunications (IST)*. pp. 251–256 (2020). <https://doi.org/10.1109/IST50524.2020.9345886>
31. Spacy: Spacy library. <https://spacy.io/> (2023), accessed: 2023-03-11
31. Y.2060, I.T.: Itu-t y.2060. <https://handle.itu.int/11.1002/1000/11559> (2012)
32. Yazdinejad, A., Zolfaghari, B., Azmoodeh, A., Dehghantanha, A., Karimipour, H., Fraser, E.D.G., Green, A.G., Russell, C., Duncan, E.: A review on security of smart farming and precision agriculture: Security aspects, attacks, threats and countermeasures. *Applied Sciences* (2021)

Application of the Methodological Framework for Designing Collaborative Systems with Awareness Mechanisms. Case study of the Miski bakery

Arboleda. J.D.¹ César A. Collazos²

¹ Universidad del Cauca, Facultad de Ingeniería Electrónica y Telecomunicaciones. Maestría en Computación. Popayán, Cauca. juanarboleda@unicauca.edu.co

² Grupo IDIS, Universidad del Cauca, Facultad de Ingeniería Electrónica y Telecomunicaciones. Popayán, Cauca, ccollazo@unicauca.edu.co

Abstract. In the commercial processes of companies specialized in the elaboration of customized cakes, a negotiation activity is performed with the client to collaboratively create the design of the decoration of the product. Currently, this activity is performed through different digital communication channels, mainly WhatsApp chat and social network chats such as Facebook and Instagram, as these allow the exchange of images, facilitate synchronous or asynchronous communication, and a record of the conversations remains in the history. The current dynamics of e-commerce mark a trend oriented to the digital transformation of business processes, which is why the need to design a software tool that facilitates computer-assisted cooperative work has been identified. The objective of this research paper is to apply a methodological framework to incorporate Awareness mechanisms to the design of a software that will provide strategic support in the collaborative negotiation process with the purpose of improving communication and shared understanding among the actors of the pastry shop. To achieve the objective, the methodological framework proposed by the Awareness theory is applied for the development of the groupware, which is composed of five stages: Identify the objective of the Awareness information in the process to be intervened. Identify the components of the Awareness information in the communication context. Modeling of the software process to achieve an integration of Awareness mechanisms in the business process to be intervened. Design of the information distribution strategy among the actors involved in the process. Creation of the user interface with Awareness mechanisms.

Keywords: *Awareness, CSCW, Cake Decoration.*

1 Introduction.

1.1 Context.

In Colombia in 2022 it was determined [1] that 80% of Micro, Small and Medium Enterprises (MSMEs) are in a state of digital transformation, which consists mainly in the tactical appropriation of technologies that allow them to be more competitive, improve their productivity levels and better adapt to the dynamics, trends and challenges imposed by e-commerce.

For the case study, a microenterprise in the city of Popayán called Miski Pastelería was selected. The bakery is currently conducting a diagnosis of the digital status of the business [2] in order to start the process of formulating the digital transformation path, which will allow it to implement technological solutions relevant to its cultural context [3]. An analysis of all the processes involved in the elaboration of a customized cake in the Miski bakery was carried out. To facilitate the interpretation of its context, a modeling of the processes is made in Business Process Modeling Notation (BPMN)[4], which allows to identify graphically and categorically, the beginning (Customer Need), the three macro-processes: Strategic (Commercial), Productive, Support, and the end of the process (customer satisfaction).

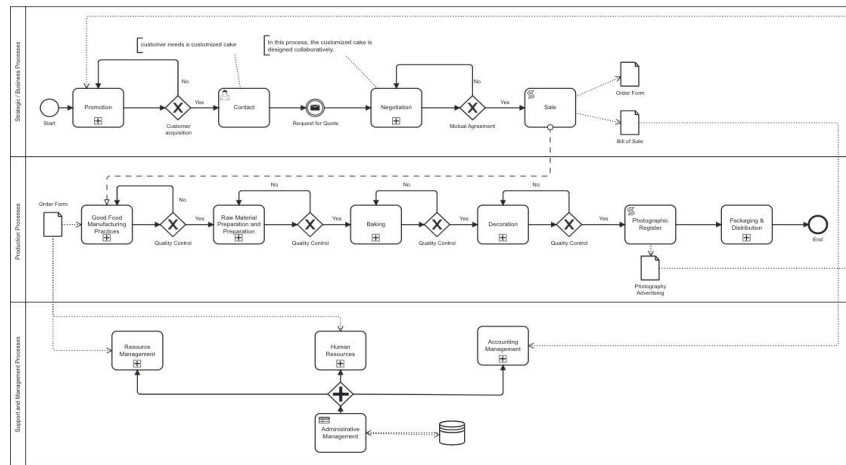


Fig. 1. Model of the pastry processes.

1.2 Brief description of the pastry processes.

The process starts with the customer's need for the bakery. Regarding the needs of the pastry shop's customers, it was identified that 81% of the customer archetype corresponds to women, 70% of whom are mothers, and 57% are between 25 and 34 years of age. These customers need 60% of the time a birthday cake for children between 0 and 10 years old. The design of a customized cake is the result of a collaborative process between the client and different members of the bakery, which is why each product is unique and unrepeatable.

Strategic Processes (Business Processes). This macro-process is composed of four processes: Promotion, Contact, Negotiation and Sale. The Promotion process corresponds to all advertising activities, positioning and visibility in social networks and Internet search engines. In addition, marketing strategy activities (Get, Keep, Grow) are carried out to capture the interest, loyalty and recommendation of the customer archetype described. The contact process is developed through various communication channels, the customer can go directly to the store and talk to the seller or can use digital media when they are geographically dispersed. In the Miski pastry shop 60% of contacts are made through the chat of (WhatsApp 40%, Instagram 35%, Facebook 25%), 10% by e-mail, 20% by phone calls, and 10% through the web. The activity carried out by the company in this process is to apply the customer service protocol; which, mainly consists of giving timely response to the quotations made and helping the customer to make decisions in front of the product. The customer frequently uses images of reference cakes that he/she has previously searched for on the Internet, or that he/she has seen in the bakery's catalog. The image is a support tool that allows the customer to express his desires, expectations and requirements for the customized product, and satisfies the limitations of natural language representation [5].

In the Negotiation process, a mediation is made between the customer's requirements (imagined cake object of desire), the company's production capacity, and the customer's purchasing power (what he is willing to pay) this activity is known as quotation. This negotiation is a collaborative process [6], as the customer, the vendor and the pastry chef have a common goal, to design a customized cake decoration for a special event.

The negotiation process ends when a mutual agreement is reached regarding the formal characteristics of the product and its price. It is the duty of the bakery's salesperson to initiate the activities that correspond to the formal survey of the requirements of the customized cake. The requirements gathering is documented through the use of a paper form called an order form. The order form is in charge of storing the customer information (Id, contact...), the product delivery and distribution information (date, time...), and the information of the formal characteristics of the cake (Size, Flavor, Color, Type of Decoration).

The productive macro-processes correspond to the materialization of the design of the cake product of the negotiation. To carry out this task, seven processes are carried out, categorized as follows: Production Process 1: Good Manufacturing Practices. Productive Process 2: Preparation of raw materials. Productive Process 3: Baking. Productive Process 4: Decoration. Productive Process 5: Photographic Registration. Productive Process 6: Packaging and storage. Productive Process 7: Distribution. At the end of the productive macro-processes, the project of elaboration of a personalized cake is finished, thus achieving the satisfaction of the needs of the company's client. To guarantee the success of the productive macro-processes, there are the support macro-processes, whose core is composed of administrative processes, accounting management processes, human management processes, and resource management processes.

1.3 Description of the observed problem.

Particularly, ambiguities have been identified in the use of natural language to describe the chromatic characteristics of the cake, for example: "I need it to be blue", the problem is that, with the colorants used in food, more than 50 different shades of blue can be achieved, therefore, there is a high probability that the blue color imagined by the baker is different from the color imagined by the customer. The decoration of a personalized cake obeys the theme of the event, and is loaded with a high symbolic [7] and emotional value [8], the emotional aspects of cake decoration make the client have very high design expectations, which generally imply a high degree of technical difficulty for the decorator, which translates into a high selling price of the product, and sometimes customers are not willing to pay such a high value, which is why the customer with the help of the seller and the pastry chef begin to make more realistic expectations of the product and initiate a process of co-creation to design the right cake for the customer's needs and budget, and that is within the production capabilities of the company.

The paper format plays a fundamental role in the production processes; in addition to storing the customer's requirements, it is a communication object [9] that interacts with the different actors, processes and production units of the bakery. It was observed that copies of the order form are generated and sent to the accounting processes, where the information is recorded in the cash flow, daily balance, and income forms. Another copy goes to the client and is delivered as an invoice/ticket to receive the cake. The last copy goes to the production processes to be interpreted by the pastry chef/decorator [10].

When the pastry chef must read and interpret [11], [12] the paper format, problems of understanding arise due to different factors such as: the order form must be filled out in calligraphy by the salesperson, the salesperson must fill in more than 90 boxes where different data are requested to create a written description of the customer's wishes, the layout of the visual elements that make up the order form are subject to the size of the paper, This results in illegible texts due to the size of the font, or tight spaces, which, when filling out manually, force the overlapping of lines when writing, or that the written words overflow the margins of the form. These factors make it difficult for the baker to interpret the requirements, since the elicitation of requirements through paper forms is constantly susceptible to human error.

The requirements documentation process, which is carried out in a traditional (hand-made) way, causes frequent spelling errors, legibility problems and crossings out, problems for easy reading and interpretation due to the high rate of grammatical, syntax, semantic or pragmatic errors made by the person in charge, which directly affects the production processes, hinders mental processes related to hermeneutics [13] and therefore reduces the understanding of the tasks to be performed by the pastry chef/decorator. This causes that the customized product is not elaborated under the requested requirements, and, therefore, generates a high degree of dissatisfaction, frustration and sadness [11] in the customer at the moment of receiving the product. For traditional bakeries, this situation manifests itself as a critical problem of communication and understanding between production units, since the main processes depend on paper formats [10]. Therefore, it is presumed that the design of these

formats does not allow the generation of a representation of an efficient mental model of the user [10], thus causing confusion, reprocessing and errors in repetitive tasks.

To approach this problem, Section 2 of the article establishes a conceptual framework, which allows us to analyze the state of the art of the existing literature on the situation of the pastry industry. Section 3 defines a methodological approach to identify and apply awareness mechanisms in collaborative processes. In section 4, the methodological framework defined is applied in the Miski bakery. Section 5 discusses the results, and section 6 discusses future work.

2 Conceptual Framework.

It is necessary to investigate the existing literature to identify trends in technologies and methodologies that can contribute to the closing of technological gaps identified in the communication processes where customers and micro enterprises of the niche corresponding to Bakeries / Pastry Shops participate collaboratively.

The aim is to provide a possible solution approached from a scientific (Computing) and methodological (Design) approach, to the communication problems that affect the different actors when working as a team, due to cultural aspects [14] representation and understanding, which arise in business processes, and hinder understanding when capturing data related to the requirements for the development of customized cakes (Food Industry).

Nucleus 1: Computer Science. The research in this area of knowledge focuses on software engineering. Emphasis is placed on the search of scientific literature related to the processes of elicitation and requirements analysis. In addition, it is important to inquire about modeling languages. It is desired to know the application of models, methods and tools provided by collaboration engineering; therefore, it is important to investigate about the concepts related to Groupware, Awareness, Thinklets and specially to shared understanding in virtual environments.

Nucleus 2: Communication and graphic design. It is very useful to learn about methodologies and processes related to user-centered design (UCD) and culture-centered design (CCD), since these methodologies allow a detailed and empathetic understanding of the context of the actors involved in the process to be intervened. In addition, these methodologies favor the creation of software models with better levels of communication and understanding between users, thus generating a better interaction.

Nucleus 3: Business Administration / Food Industry. In this area of knowledge, it is of interest for the research to analyze the trends, dynamics and processes of companies in the gastronomic sector, particularly in the market niche corresponding to pastry shops specialized in the elaboration of customized cakes, for this reason, it is necessary to investigate the existing literature on the food industry and the technological innovations that exist in this field such as 3D printing of food, biodegradable packaging, and environmentally friendly manufacturing. It is necessary to know case studies where optimization or automation of production systems is performed through software, to analyze the impact of digital transformation in supply chains, in the manufacture of customized artifacts, and in customer service processes, and thus, to obtain references of technologies applied to the food industry.

Systematic literature mapping. For the selection of the subject of the systematic mapping a research protocol [15] consisting of three phases was designed: First, the preparatory phase, whose activities consist of: Identifying the thematic nuclei related to the situation or problem to be addressed. Perform a critical and strategic analysis of each thematic nucleus. Analyze the key words, categorize them and make a list of selected words. Second, execution phase: Create and apply inclusion and exclusion criteria. Construct the final search string. Execute the search string. Select the database. Compile found studies. Narrow down articles. Perform snowball sampling. Third, documentation phase: Categorize articles by level of relevance and contribution. Conduct a literature review. Analysis of main findings and trends. Draw conclusions.

The key words of each core are listed and categorized from the most general to the most specific thematic areas according to their level of contribution to the project. A superficial search is performed in the meta-search engine Scopus, using the filter: (Search within: Article title, Abstract, Keywords). This work was carried out for each term to estimate its potential in terms of number of publications. For the construction of the search string, the keywords considered to be of greatest relevance and contribution to the research should be selected, and it should also be verified that there is a considerable number of articles.

Search chain. ((("Awareness" AND "groupware" AND "CSCW" AND "Work- space")) OR ("Cake design" OR ("Gastronomy" AND "Supply Chain")) OR ("Foodindustry" AND "Bakery" AND "software") OR ("collaborative cooking" OR "cake Decoration")) OR (("Semiotic Engineering" AND "Usability") OR ("User Experience" AND "Web Design" AND "User Interfaces" AND "User Centered Design") OR ("Se-miotic Engineering" AND "collaborative design")) AND NOT (("health" OR "Farm- ing" OR "farm" OR "Agriculture" OR "Chemical" OR "tourism" OR "Video" OR "Medical" OR "chemistry" OR "Healthcare" OR "School" OR "Medical images" OR "fruits"))

A total of 114 related documents were obtained as a result of applying the search string. An analysis was carried out and those articles considered to contribute to the interests of the project were selected. Twenty-three articles were identified that are aligned with the research interests of the project. This is equivalent to 20.17% of the total number of documents resulting from the search chain. The articles were evaluated and categorized according to their level of contribution in order to narrow down the research. At the time of narrowing down the 23 resulting articles, the following results were obtained: 6 articles categorized as being of greater relevance and contribution (26.08%). 7 articles were identified as highly relevant (30.43%). 5 articles defined as medium relevance (21.73%). 5 articles identified as low relevance (21.73%). It can be concluded that 56.51% of the articles delimited are considered for in-depth literature review. In the process of analysis and documentation of the findings, researches such as CakeVr [16] validate the relevance of the communication problem identified in the collaborative activities of cake shops. A language pattern for collaborative cooking [17], and interactive cake decorating models [18] were identified. The most important theoretical contribution is related to the methodological framework for designing collaborative systems with awareness mechanisms [19].

On the other hand, in the area of software process engineering [20], the main contribution is in the understanding and identification [21] of critical processes that can be supported through software. In the area of Semiotic Engineering the contributions are related to the construction of graphical interfaces oriented to communicability and understanding [22] based on elements of Culture-Centered Design [22] & User-Centered Design [23] and tools were discovered to perform an emotional evaluation of the usability [24], Interaction [25] and Accessibility of the software model.

3 Methodological Framework.

Collaborative work involves the effort of two or more people to achieve a common goal [26], collaborative work increases group efficiency, fosters social relationships and improves individual well-being [27] Understanding the characteristics of group work enables the design of appropriate information technology to support collaborative work processes. CSCW studies the impact of technology on group interaction within shared virtual spaces [19] For efficient interaction, it is important that members feel part of the group and obtain sufficient information to perceive, understand and adapt to the shared work environment. This contextual information, which group members need to reduce metacognitive effort, is known as awareness [19] Awareness mechanisms require the identification of the type of information that is needed for the group members to understand and adapt to the shared work environment.

Awareness mechanisms require identifying the type of information to be provided, information distribution strategies, and a method of representing contextual information. Group members interact through artifacts or direct communication channels and must be aware of other group members

(activities, changes, states...). In groupware, people can communicate information either explicitly, or implicitly through interaction with shared artifacts, which involve non-verbal, more symbolic communication.

The methodological framework for designing collaborative systems with awareness mechanisms [19] is based on five stages: Awareness goals and support: consists of identifying the type of information that the members of the work group should perceive, and the context in which it is produced. Awareness Information identification: allows to obtain a semantic interpretation of the information model and to give it meaning. Modeling, it is necessary to define and model the information to be provided and its content once the awareness objectives have been established. Distribution allows to have an explicit knowledge of the information and its mechanisms for socialization. awareness User Interfaces: define how the awareness information is going to be represented to be used.

4 Application of the Methodological Framework to design collaborative systems with awareness mechanisms for the Miski bakery.

The methodology is applied to the case study of the pastry shop Miski in the city of Popayán.

PHASE 1: Awareness Information Goals.

It is necessary to determine the most important type of Awareness to successfully perform the activity of negotiating the requirements of the customized product. To design the decoration of a cake in a collaborative manner requires synchronous or asynchronous interaction between the three main actors identified in the process, which are geographically dispersed: the customer, the seller and the baker. At the beginning of this process, it is necessary for the client to obtain information regarding the status of the other members of the group, i.e. the client wants to know if there is another human being accompanying him/her in the process, who that person is, what expertise he/she has, what position he/she holds, will he/she understand my tastes and desires for the cake, etc. Another relevant factor is the level of urgency with which the customer needs the product, if the level is low, the communication is generally asynchronous, but if the level of urgency is high, the communication is synchronous.

The cultural context in which the customer's special event takes place directly influences the customer's imaginary construct of the cake. Due to the limitations to describe the cake through natural language, the client uses images of reference, which visually allow him to make explicit his requirements regarding the product, for this reason, it is important that the client is informed about the shared work space, because that is where the decoration design is going to be made, therefore, first, he must be able to visualize the cake (work area), second, the client must know the different tools and decoration possibilities that the software allows (context), as well as its restrictions and third, the client must have a practical understanding of each of the steps (Activities) that are followed for the elaboration of a personalized cake, thus, through the information provided by the software, the client is guided or immersed in the decoration process. Each element used in the workspace is a visual metaphor that emulates the elements and utensils used in the decoration station, therefore, it must provide a context and a background meaning, so that the client can use them and thus achieve the desired design, also generating a good user experience.

Every time a client generates a design, this information is available so that the pastry chef, from his perspective and expertise, can make recommendations to improve the aesthetic quality of the product, to achieve this activity, it is necessary to have clear information about the preferences and interests shared by the client.

Table 1. Different types of awareness in pastry business processes.

Awareness	Importance	Explanation
Group	High	The customer wants to know about her cake design partners.
Workspace	Very High	The customer must be able to visualize the cake and interact with the decoration elements in the shared workspace.
Context	Very High	The customer must be familiar with the tools and elements that make up the shared workspace.
Peripheral	Low	For the time being, they are not considered important.
Activity	Very High	For the pastry chef, it is important to know and visualize the customer's requirements and the latest modifications to the product.
Availability	High	The customer wants to know when the salesperson or pastry chef is available to provide support if needed.
Perspective	Very High	The salesperson needs to capture and understand the customer's expectations and desires for the cake.
Community	High	The customer expresses his ideas in front of the cake, the baker helps to make aesthetic decisions and the salesperson calculates and informs the costs of the product.
Presence	Medium	the salesperson must be informed each time a customer enters the shared workspace.
Rhythm	Medium	The customer wants to track the processing status of his product.

PHASE 2: Awareness Information Identification.

Component 1: People.

2.1.1. People's Structure: Social norms, Conventions, and roles. In the negotiation process, the three main actors of the process (Client, Pastry Chef, Salesperson) interact directly. The salesperson must act according to customer service protocol, must respond as quickly as possible, and must be very courteous and polite following social norms. The salesperson is the mediator between the natural language used by the customer and the technical language used by the pastry chef and must also capture all the customer's requirements for the product in order to calculate the costs. The pastry chef is the expert in decoration, his role is to guide the customer in the decoration decisions, to achieve aesthetic quality levels, and to capture all the requirements, expectations and desires of the imagined product. The client is the actor who initiates the process, needs a cake, gets in touch, shares information about how he imagines the product object of desire, and expects his expectations to be fully satisfied. In short, the customer communicates his ideas, the pastry chef cooperates with his expertise in the design of the cake decoration, and the seller coordinates the requirements, costs, and available resources.

2.1.2 People's State: Availability, activity and emotions. The salesperson needs to be informed about the customer's emotions during the interaction with the shared workspace artifacts, e.g., is everything going well, is the customer confused, does the customer need help? The customer must know if he/she has the company of a human in the process. The pastry chef must understand the customer's need for support and know the degree of satisfaction with the product decoration. All stakeholders must visualize the current status of the customized cake.

2.1.3. People's Location: Presence, distance, visibility, space-place, and metaphors. The negotiation process is done through digital media because they are geographically dispersed, the shared workspace to be designed for the software is a metaphor of the processes, it is based on the production logic followed by the company, it simulates in the virtual environment the elements of decoration, the utensils that are used in the company, and the decoration space, which gives context to the artifacts with which the customer interacts when designing the cake.

2.1.4. People's actions: events and distortion (aggregation, animation, etc.). The pastry chef must be informed and updated regarding changes made by the client to the decoration of the product. Likewise, he/she must be informed about the raw material inventories that are necessary for the elaboration of the product, he/she must know the availability of human resources, time and raw materials during the negotiation process with the client in order to determine the production capacity of

the company. The Client must be aware that each action performed in the cake decoration activity in the shared space work has a cost, for example; each figure or decoration motif that is added to the cake has a price, therefore, the more figures, the higher the monetary value of the cake. The client with his actions, and if he is well informed, can adjust the price of the cake to his purchasing power or established budget. The salesperson in his role as coordinator is in charge of generating the order form according to customer requirements and decoration elements used in the shared space, and his duty is to guide the customer's actions so that the process is satisfactory.

2.1.5. People's activity: activity and goals. The software design is based on the production logic where first the size of the cake is chosen from different options ranging from ¼ of a pound (8 portions for the client) to 4 pounds and can be from 1 floor to 3, also its shape is defined (round or square). Second, the flavor is chosen, where the customer must select their favorite flavors, and even make combinations, or choose any type of filling available. Third, the customer must choose the base color, and finally the type of decoration is chosen, each activity is sequential, and the change of activity, tasks to be performed, and the tasks performed, or achievements obtained are explicitly reported.

2.2. Component 2: Task or project.

2.2.1. Task structure: process planning. The salesperson should guide the customer and let him/her know how the shared workspace behavior works. The client in the shared workspace must be able to easily understand the dynamics and mechanics of decorating a cake virtually. The pastry chef must know the complexity of the decoration to be able to organize his work team in production (number of people in the team, expertise of the work team).

2.2.2. Task or project state: state-based workflow. The customer must obtain information regarding each phase of decoration performed, and must be able to evaluate the interaction experience, and ask for help if necessary. The salesperson must follow up and must know when all the tasks have been completed in order to generate the order form, and the Pastry Chef needs to be updated to know in which task the customer needs support, or if he/she can start the productive macro-processes.

2.3. Component 3: Resources.

2.3.1. Resource structure: spatial and semantic networks. In the shared virtual workspace, interaction artifacts that emulate furnishing elements and utensils are in charge of providing information regarding their use, value and formal characteristics. It is the task of the vendor to familiarize the customer with the concepts assigned to each interactive artifact, creating a network of meanings associated with each phase of cake decoration. Being able to visualize the cake in the shared work area allows to generate a shared understanding among the actors involved in the process.

2.3.2. Resources state: availability. Make informed decisions and plan contingent actions by knowing the state of resources, e.g., knowing how many decoration elements are being used and their cost.

2.3.3. Resources location: availability and resource discovery. In the shared virtual space, artifacts are virtual representations of physical objects that are available for the customer to decorate his cake.

PHASE 3: Modeling.

To model a collaborative process in UML, a collaboration diagram can be used. This diagram shows how the elements interact with each other to achieve a common goal. First, the key elements must be identified: start by identifying the key elements involved in the collaborative process, such as users, systems and resources. Then a collaboration diagram is created. Add awareness information elements to the diagram. The interactions between the elements are established, showing the communications and data exchanges that occur during the collaborative process. Then labels are added to the communications and data exchanges to describe the type of message being sent. Implement constraints. If there are constraints on the process, such as response time or resource availability, the diagram is analyzed for constraints. The diagram is reviewed and validated.

It is important to keep in mind that collaborative processes are often complex and may require several collaboration diagrams to fully model all interactions. It is also important to document the collaborative process in a specification or requirements document so that all stakeholders can clearly understand how it works.

PHASE 4: Distribution.

The following are used for the distribution of awareness information:

4.1 Notification Mechanisms. Notification mechanisms are very important to guide the client during the decoration process through the graphical interface.

4.2. User-driven discovery. The information design allows the user to discover within the interface the Logical Model to decorate a cake, the client is guided through a series of steps.

PHASE 5: Awareness User Interfaces.

A prototype of a graphical interface is designed where the awareness mechanisms are applied. The interface is a metaphor that simulates in a virtual way the work space that exists in a pastry shop, simulates the tools and utensils necessary for the decoration, and invites the client to follow a collaborative design process, where he has the possibility to interact and visualize 3D graphics with the rendering of the cake decoration. The interface must be composed of the following awareness mechanisms.

People structure: It is necessary to identify the role of each actor in the cake design process. For the client it is important to differentiate the seller from the baker. The graphic interface will make use of avatars to identify each actor, and the tasks in which each actor can actively collaborate, and their hierarchy will be presented in a kind of organization chart.

People's status: Different people's statuses can be represented, the first one is the availability status, which determines if the communication is going to be synchronous or not. When the actor is available, a green circle will light up around the avatar image, blue when the actor is busy or slow to respond, and gray when the actor is not available. It is important to evaluate the emotional states of the actors, mainly that of the customers, since they are not as familiar with the interface as the bakery workers. In this case the avatar will have the ability to represent emotions through its facial gestures, so it can represent emotions that can be generated at the time of design as: Confusion if you do not understand the task to be developed, or can represent sadness if the customer is frustrated because it fails to successfully complete a task, or can represent happiness, if everything is going in order. If a group member notices a negative emotion in the client's avatar, it is his or her duty to go immediately. To generate support for the task being performed in order to generate a good user experience.

Placement of people: The idea is to generate a visual metaphor in the virtual environment that simulates the cake decorating station, so that the customer can interact with the design artifacts and can immersively decorate the cake.

People actions: The customer can logically interact with the artifacts that are used in the cake decorating process, each interaction with a design element. Each time an object is interacted with, it responds by enlarging its size to make it easy to identify and manipulate. In the interface a diagram is designed that represents the activities and tasks and indicates in certain tasks what actions have been performed by the actors in the process.

People's activity: An activity log is generated that allows the actors to track changes and modifications made in each activity and its corresponding tasks, this allows group members to be informed of developments against the product design.

Task structure: A structure of activities is created whose workflow is similar to the decoration process in the real environment, through four basic steps such as choosing the size, choosing the flavor, choosing the topping and its color, and choosing the decoration design. Each of the activities is supported by a series of tasks that allow at the end of the process to have an accurate visual representation of the requirements that the customer has in front of the cake.

Resource structure: Each task is related to a particular type of resource, for example, when choosing the flavor of the cake, the available flavors must be shown in the interface, and so each structured activity is in charge of its own resources.

Status of resources: For the customer it is important to know the availability of decoration elements that he has to achieve his goal, he must also know the value of each element, for this task, an element counter is designed that adds up the price of each object used exactly, so that the customer can know when the type of decoration chosen exceeds his budget, and so he can have control over his expenses. In the same way, the pastry chef must know what resources he has available for the elaboration of the cake.

5 Discussion of results.

By applying the methodological framework, it was possible to identify the actors involved, their roles within the process, their specific activities and tasks, and to categorize the activities into three types: individual, cooperative, or collaborative.

By identifying the roles and tasks of each actor (Table 2), the awareness mechanisms necessary to support the collaborative process can be established.

Table 3 shows the type of awareness mechanisms assigned to each activity of the negotiation process. The process of defining the elements of decoration is used to exemplify the type of awareness elements that were used at the time of designing the prototype of the client interface for this activity (Figure 2).

To satisfy the client's needs for awareness information during the process of defining decoration elements, a low-resolution prototype of the client's interface was designed, where the semiotic representation of the awareness mechanisms applied and the type of information, they transmit can be graphically visualized (Table 4). When validating the graphical user interfaces designed with awareness mechanisms with the actors involved, a high degree of acceptance was identified by the users because the design of the metaphor that simulates the virtual environment of decorating a cake is based on business logic, and takes part of the symbolic language of the environment to generate a shared vocabulary, which allows generating a better understanding compared to the paper format, since the groupware tool to be designed allows visualizing in real time how the personalized cake looks like.



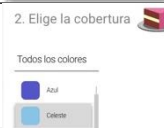
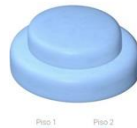

Table 2. Table of participation in the negotiation process of a cake.

Activity / Roles	Customer	Salesperson	Pastry chef	type
Request for quote	x			Individual
Respond to request		x		Individual
Define delivery conditions	x	x		Cooperative
Define type of celebration	x	x		Cooperative
Define cake flavor	x	x	x	Collaborative
Define cake size	x	x	x	Collaborative
Define decoration elements	x	x	x	Collaborative
Define price of the cake.	x	x	x	Cooperative

Table 3. Table of Awareness mechanisms used in each activity within the negotiation process of a customized cake.

Activity / Roles	Awareness Mechanisms		
	Customer	Salesperson	Pastry chef
Request for quote	- People's State: Availability		
Respond to request		- People's State: Availability - People's action: Event alert - People's Activity: goals	
Define delivery conditions	People's action: Event alert - Norms: Time constraint	- People's action: Event alert - Resources state: Availability	
Define type of celebration	- People's State: Availability - Task Structure: workflow - Task State: started / in process / done	- People's State: Availability - Task State: started / in process / done	- People's State: Availability - Task State - People's State: Emotions
Define cake flavor	- Task Structure: Workflow. - Resources State: Availability - People's Actions: decision tracking. - Task State: started / in process / done	- Task Structure: Workflow. - Resources State: Availability - People's Actions: decision tracking. - Task State: started / in process / done	- Task Structure: Workflow. - Resources State: Availability - People's Actions: decision tracking. - Task State: started / in process / done
Define cake size	- Task Structure: Workflow. - Resources state: Availability - People's Actions: decision tracking.	- Task Structure: Workflow. - Resources state: Availability - People's Actions: decision tracking.	- Task Structure: Workflow. - Resources state: Availability - People's Actions: decision tracking.
Define Decoration elements	- People's State: Availability - Task Structure: Workflow. - Resources state: Availability - People's Actions: Event Modify (add, move, quit) - Task State: started / in process / done - People's Action: Perspective.	- People's Actions: decision tracking. - Task State: Done	- People's action: Event alert - People's Action: Perspective. - People's State: Availability - Task Structure: Workflow. - Resources state: Availability - People's Actions: Event (modify). - Task State: started / in process / done - People's State: Emotions - People's
Define price of the cake.	- Task Structure: Workflow. - People's Actions: price tracking. - Task State: Done	- People's Actions: decision tracking. - Task State: Done	- Actions: decision tracking. - People's State: Emotions - Task State: Done

Table 4. Association of the information needs of the client, the assigned awareness mechanism, and its graphical representation in the interface.

Activity Define decoration elements		
Customer needs	Awareness Mechanisms	Graphical representation on the interface
The customer needs to know if the pastry chef is available.	- People's State: Availability	
The customer needs to know where he is in the process and what the tasks are.	- Task Structure: Workflow.	
The customer needs to know what resources are available to perform the task.	- Resources state: Availability	
The customer needs to visualize the effect of his actions.	- People's Actions: Event Modify (add, move, quit)	
The client should be aware of the cost of his choices before finalizing the process.	- Task State: started / in process / done	

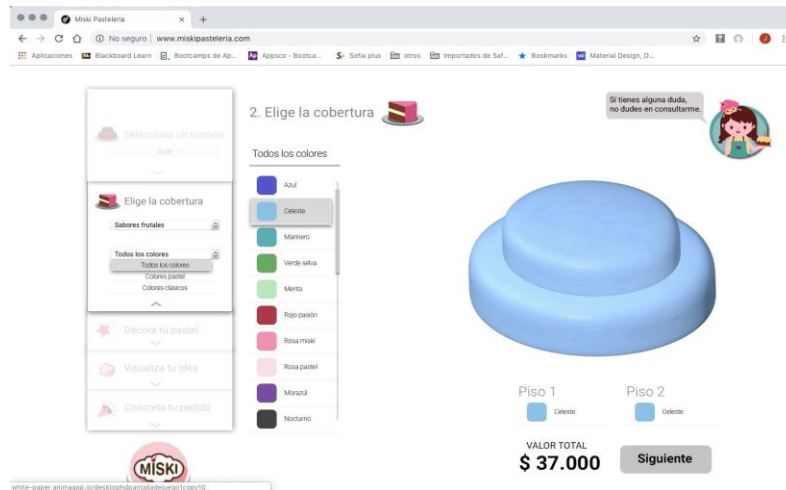


Fig. 2. prototype image of graphical user interface with awareness mechanisms.



Fig. 3. Avatar representing the pastry chef during the decoration process, this awareness information mechanism allows to guide the customer during the activities.

6 Conclusions and future work.

The prototype was validated with the actors of the bakery, and feedback was received to improve the interface and the workflow. The importance of the articulation of the natural and technical language within the processes and their graphic representation was emphasized.

Using awareness mechanisms in the negotiation process of the bakery improves the understanding and comprehension of the requirements of the customized cake. It allows the customer to make informed decisions regarding the cost of his requirements, increases motivation since he can visualize the imagined product, strengthens relationships between people since the customer does not feel alone, on the contrary, he knows that he can count on the support of experts whenever necessary and generates an improvement in satisfaction levels due to the reduction of misunderstandings caused by communication problems.

A clear example is the awareness mechanism that allows the client to be informed about the cost of his decoration decisions. The placement of this element before the "next" button (end activity) allows the client to reflect and mediate between his expectations and his budget before moving on to the next activity.

In the future, it is expected to be more formal in the notation and to be able to apply more precise methodologies [28], when describing collaborative processes that need awareness mechanisms within a groupware system.

7 References

1. MinTIC and Innpulsa, "Centros de transformación digital empresarial," <https://www.centrosdetransformaciondigital.gov.co/695/w3-channel.html>, 2023.
2. MinTIC and Innpulsa, "MODELO DE MADUREZ PARA LA TRANSFORMACIÓN DIGITAL INNPULSA COLOMBIA-INNPULSA DIGITAL MINTIC-DIRECCION DE TRANSFORMACIÓN DIGITAL," 2019.
3. C. A. Collazos and R. Gil, "Using cross-cultural features in web design patterns," in *Proceedings - 2011 8th International Conference on Information Technology: New Generations, ITNG 2011*, IEEE Computer Society, 2011, pp. 514–519. doi: 10.1109/ITNG.2011.95.
4. T. Djatna, M. F. Koswara, and D. K. R. Kuncoro, "A system analysis and design for mobile digital business traceability at a food manufacturing," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics, 2022. doi: 10.1088/1755-1315/1063/1/012051.
5. P. Bourdieu, *Capital Cultural, Escuela y Espacio Social* ISBN. 968-23-2054-2, Primera. 1997.
6. D. Marc Kilgour Colin Eden, "Second Edition Handbook of Group Decision and Negotiation."
7. E. Johansson and D. Berthelsen, "The birthday cake: Social relations and professional practices around mealtimes with toddlers in child care," in *Lived Spaces of Infant-Toddler Education and Care: Exploring Diverse Perspectives on Theory, Research and Practice*, Springer Netherlands, 2014, pp. 75–88. doi: 10.1007/978-94-017-8838-0_6.
8. S. R. Charsley, "Wedding cakes and cultural history ISBN 0-203-40414-9 Master e-book ISBN," 1992.

9. H. Fuks, A. Raposo, M. A. Gerosa, M. Pimental, and C. J. P. Lucena, "The 3C collaboration model," in *Encyclopedia of E-Collaboration*, IGI Global, 2007, pp. 637–644. doi: 10.4018/978-1-59904-000-4.ch097.
10. J. Iván and T. Arbelaez, "Generación de la interfaz de usuario de negocio a partir de patrones de negocios basadas en los fundamentos metodológicos de TD-MBUID," 2016.
11. L. Correa, "Revista Faz / N° 2 - Julio 2008."
12. S. Valtolina, B. R. Barricelli, and Y. Dittrich, "Participatory knowledge-management design: A semiotic approach," *J Vis Lang Comput*, vol. 23, no. 2, pp. 103–115, Apr. 2012, doi: 10.1016/J.JVLC.2011.11.007.
13. G. Stahl, "Group Cognition Computer Support for Building Collaborative Knowledge Acting with Tech- nology Series MIT Press 2006 Contents Group Cognition: Computer Support for Building Collaborative Knowledge."
14. F. Dong, S. Sterling, D. Schaefer, and H. Forbes, "BUILDING the HISTORY of the FUTURE: A TOOL for CULTURE-CENTRED DESIGN for the SPECULATIVE FUTURE," in *Proceedings of the Design Society: DESIGN Conference*, Cambridge University Press, 2020, pp. 1883–1890. doi: 10.1017/dsd.2020.63.
15. K. Petersen, S. Vakkalanka, and L. Kuzniarz, "Guidelines for conducting systematic mapping studies in software engineering: An update," *Inf Softw Technol*, vol. 64, pp. 1–18, Aug. 2015, doi: 10.1016/j.infsof.2015.03.007.
16. Y. Mei, J. Li, H. De Ridder, and P. Cesar, "Cakevr: A social virtual reality (vr) tool for co-designing cakes," *Conference on Human Factors in Computing Systems - Proceedings*, May 2021, doi: 10.1145/3411764.3445503.
17. T. Isaku and T. Iba, "Creative cocooking patterns: A pattern language for creative collaborative cooking," in *ACM International Conference Proceeding Series*, Association for Computing Machinery, Jul. 2015. doi: 10.1145/2855321.2855366.
18. M. Miyatake, A. Watanabe, and Y. Kawahara, "Interactive Cake Decoration with Whipped Cream," vol. 5, no. 20, 2020, doi: 10.1145/3379175.
19. C. A. Collazos, F. L. Gutiérrez, J. Gallardo, M. Ortega, H. M. Fardoun, and A. I. Molina, "Descriptive theory of awareness for groupware development," *J Ambient Intell Humaniz Comput*, vol. 10, no. 12, pp. 4789–4818, Dec. 2019, doi: 10.1007/s12652-018-1165-9.
20. J. Münch, O. Armbrust, M. Soto, and M. Kowalczyk, "Software Engineering for Embedded Systems Software Process Definition and Improvement."
21. L. García-Borgoñón, M. A. Barcelona, J. A. García-García, M. Alba, and M. J. Escalona, "Software pro- cess modeling languages: A systematic literature review," *Information and Software Technology*, vol. 56, no. 2, pp. 103–116, Feb. 2014. doi: 10.1016/j.infsof.2013.10.001.
22. C. A. Collazos, M. Paula González, A. Neyem, and C. Sturm, "LNCS 4560 - Guidelines to Develop Emotional Awareness Devices from a Cultural-Perspective: A Latin American Example," 2007. [Online]. Available: <http://www.we-make-money-not-art.com/archives/007274.php>
23. A. Moquillaza *et al.*, "Developing an ATM Interface Using User-Centered Design Techniques," 2017, doi: 10.1007/978-3-319-58640-3_49.
24. T. Clemmensen, Q. Shi, J. Kumar, H. Li, X. Sun, and P. Yammiyavar, "LNCS 4559 - Cultural Usability Tests – How Usability Tests Are Not the Same All over the World," 2007.
25. F. Nake and S. Grabowski, "Human–computer interaction viewed as pseudo-communication," *Knowl Based Syst*, vol. 14, no. 8, pp. 441–447, Dec. 2001, doi: 10.1016/S0950-7051(01)00140-X.
26. A. Herrera, D. Rodríguez, and R. García-Martínez, "Taxonomía de Mecanismos de Awareness."
27. C. Collazos, A. Solano, and H. M. Fardoun, "Collaboration engineering: Supporting the collaborative processes design for the accessible and usable interactive systems design," in *ICSOF 2018 - Proceedings of the 13th International Conference on Software Technologies*, SciTePress, 2019, pp. 786–793. doi: 10.5220/0006941407860793.
28. J. Gallardo, C. Bravo, and A. I. Molina, "A framework for the descriptive specification of awareness support in multimodal user interfaces for collaborative activities," *Journal on Multimodal User Interfaces*, vol. 12, no. 2, pp. 145–159, Jun. 2018, doi: 10.1007/s12193-017-0255-x.

A Method to obtain a Knowledge Representation from a Natural Language Specification of the Domain using the Glossary LEL

Leandro Antonelli¹, Mario Lezoche², Juliana Delle Ville¹

¹Lifia, Fac. de Informática, UNLP, La Plata, Bs As, Argentina

²Université de Lorraine, Nancy, Lorraine, France

leandro.antonelli, juliana.delleville}@lifia.info.unlp.edu.armario.lezoche@univ-lorraine.fr

Abstract— Good requirements (correct, consistent, unambiguous, etc.) are crucial to software development success. Errors made in the requirements stage can cost up to 200 times if they are discovered once the software is delivered to the client. Natural language artifacts are the most used tool to write requirements, since they are understandable by the both parties that participate in the software development: the stakeholders and the development team. Nevertheless, natural language can introduce many defects (ambiguity, vagueness, generality, etc.). Formal reasoning is a good strategy to check whether requirements satisfy the attributes of good requirements or not, but formal reasoning cannot be applied to natural language specification with defects. Thus, this paper proposes an approach to write a good specification and obtain knowledge from it. The approach uses a particular lexicon, the glossary LEL, and it suggest guidelines to write good specification, and it also suggest rules to obtain knowledge (concepts and relations) from the glossary LEL. The paper also presents a prototype to assist to this approach, and a preliminary evaluation of the approach.

Keywords- *Requirements specification, knowledge representation, natural language, artificial intelligence*

1. Introduction

Good requirements are crucial to software development success. If requirements are not good, the software application developed from them will not satisfy the need, wishes and expectations of the stakeholders. Moreover, if requirements are not good, a lot of work will need to be done to repair the software application to satisfy their needs. It is estimated that errors made in requirements stage can cost up to 200 times if they are discovered when the software is delivered to the client [7].

The expression “good requirements” has a broad meaning. There are many characteristics that are desirable that a software specification has. Does not matter if the development process is agile with minimum of documentation or if it classic with an orthodox software requirements specification of hundreds of pages. It is desirable that the specification would be correct, consistent, unambiguous, etc. These are called quality attributes. Although it is impossible to satisfy all of them, since there is a huge effort of rework to correct errors, it is necessary to invest the effort in trying to produce the best specification as possible.

Natural language is the most used tool to write requirements [21]. Requirements are specified usually requirements engineering or business analysts, and they should interact with the stakeholder who has the requirements and the knowledge to include in the software application. And the specification also needs to be understandable and precise enough so the software development team can develop the application from it. Natural language specifications are understandable for these both sides [26]. Nevertheless, natural language can introduce many defects: ambiguity, vagueness, generality, etc. [6].

Formal reasoning means infer knowledge from a specification. For example, considering an agriculture specification that states that “plants need water, and tomato is a plant”, it can be inferred that “tomatoes need water”. It is necessary to have requirements without defects originated by the natural language in order to make possible the formal reasoning [25]. Moreover, with formal reasoning it will be possible to automatize many tasks in order to obtain good requirements [15] [17]. For example, consistency is one of the quality attributes of the specification. And consistency means that there is no contradiction in any given pairs of requirements. Having the specification “plants need water, tomato is a plant, and tomato does not need water” it can be inferred that “tomato needs water and tomato does not need water”. Since it is a contradiction, it can be concluded that the specification is not consistent.

The glossary LEL is a semi structured artifact with the goal of describing the language of the domain. The glossary LEL is easy to learn, it is easy to use, and it has good expressiveness. We have used the glossary LEL in many domains, some of them very complex, and we had good results. Cysneiros et al. [11] report the use of LEL in a complex domain as the health domain. The glossary LEL uses natural language to describe the language, but it also categorize the vocabulary in 4 categories: subjects, objects, verbs and states. The description of each term is done through two attributes: notion and behavioral responses. Thus, the glossary LEL is more than a simple glossary, it represents the knowledge of a domain (captured through its language) in natural language.

The concept of the kernel sentence was introduced in 1957 by linguist Z.S. Harris [16] and featured in the early work of linguist Noam Chomsky [10]. Kernel sentences are also known as basic sentences. They are declarative constructions, in active voice, always affirmative with only one verb. We argue that the use of kernel sentences in the description of the glossary LEL, as well as some other guidelines to make the natural language near a controlled language, allow us to obtain a good specification.

Having a good specification, it is feasible to perform a formal reasoning to infer new knowledge. Nevertheless, before performing formal reasoning, it is necessary to synthesize the knowledge captured in the language through the glossary LEL. Thus, this paper proposes an approach to obtain the knowledge (concepts and relationships) from a glossary LEL. The inference of the new knowledge is outside the scope of this proposal. This paper also presents a prototype, that is, a tool to assist during the application of the proposed approach. Moreover, a preliminary evaluation of the approach is also described.

The rest of the paper is organized in the following way. Section 2 describes some background about glossary LEL and kernel sentences. Section 3 reviews some related work. Section 4 details our contribution namely, the proposed approach. Section 5 describes the tool to support the process. Section 6 presents the preliminary evaluation. Finally, Section 7 discusses some conclusions.

2. Background

This section describes basic concepts of the glossary LEL and the kernel sentences.

2.1. Glossary LEL

The Language Extended Lexicon (LEL) is a glossary that describes the language of an application domain, where not necessarily there is a definition of a software application. The glossary LEL is tied to a simple idea: “understand the language of a problem without worrying about the problem” [19]. The language is captured through symbols that can be terms or short expressions. They are defined through two attributes: notion and behavioral responses. Notion describes the denotation, that is, the intrinsic and substantial characteristics of the symbol, while behavioral responses describe symbol connotation, that is, the relationship between the term being described and other terms (Fig. 1). Each symbol of the LEL belongs to one of four categories: subject, object, verb or state. This categorization guides and assists the requirements engineer during the description of the attributes. Table 1 shows each category with its characteristics and guidelines to describe them.

Category: symbol
Notion: description
Behavioral responses:
 Behavioral response 1
 Behavioral response 2

Fig. 1. Template to describe a LEL symbol

Table 1. Template to describe LEL symbols according to its category

Category	Notion	Behavioral Responses
Subject	Who is he?	What does he do?
Object	What is it?	What actions does it receive?
Verb	What goal does it pursue?	How is the goal achieved?
State	What situation does it represent?	How this situation is checked?

Let’s consider a bank domain where there are clients that open account in order to save money. The client can deposit money into his account, and he can also withdraw money if the account has a positive balance. In this simple example there are many terms that should be defined into the glossary LEL to capture the language. For example, “client” should be a symbol of subject category. Then, “account”

should be a symbol of object category. “Deposit” and “withdraw” should be symbols of verb category. Finally, “positive balance” should be a symbol of state category. According to the template described in Table 1, the symbols “client”, “account”, “withdraw” and “positive balance” are described in Table 2.

The behavioral responses of symbol “client” describes just two responsibilities: to open and to withdraw money, but there are other for example to deposit that is not mentioned. Then, the behavioral responses of the account only describes the responsibility of the bank to calculate interest, but the responsibilities of the client: open, deposit and withdraw should also be mentioned if the glossary LEL is complete. Then, the behavioral responses, of the verb “withdraw” describe how the task is performed by the bank, who first reduces the balance, then check if the resulting balance is positive, and in that case provide the money to the client. Otherwise, the balance is increased to its original value and no money is provided to the client. Finally, the behavioral responses of the state “positive balance” describe in detail what “positive” means. In this cases, it means greater or equal to zero.

Table 2. Glossary LEL symbols for the banking example

Category	Notion	Behavioral Responses
Subject: Client	Person that saves money in the bank.	The client opens an account. The client withdraws money from the account.
Object: Account	Instrument used by the client to save money.	The bank calculates interest for the account.
Verb: Withdraw	Act of extracting money from an account.	The bank reduces the balance of the account. If the account has a positive balance the bank provides the money to the client. If the account has not a positive balance the bank increases the balance of the account.
State: Positive balance	Situation where the account has money.	The balance is greater or equal to zero.

2.2. Kernel Sentences

A kernel sentence is a simple construction with only one verb. It is also active, positive and declarative. This basic sentence does not contain any mood. It is termed as “kernel” since it is the basis upon which other more complex sentences are formed.

For example, Fig. 2 describes two kernel sentences. The first one states that a subject (“client”) performs an action (“opens”) on a certain object (“account”). The second sentence has the same structure while it describes a different action (“deposits”) and the object is a little bit more complex because it states that the object “money” is deposited into the object “account”. Fig. 3 shows two sentences that are not kernel. The first sentence (“The client deposits money and calculates interest into the account”) has two verbs, that is why it is not a kernel sentences. Moreover, the sentence is partially correct, since it is true that the client deposits money into the account. But, it is not true that the client calculates the interests. It is the bank who performs this calculation. That is why simple (kernel sentences) are suggested to describe specification. A simple sentence is more probable to be completely true or false. The second sentence (“The account is opened”) is written in passive voice, while kernel sentences should be written in active voice. Since it is written in passive voice, the subject of the sentence (“the account”), is not the subject who performs the action. In fact, the real subject who performs the action is not mentioned. According to the example provided, the real subject should be “the client”, but it could also be the company that the client work for and the company is the one who decided to open an account to pay his salary. These are two simple examples about how can kernel sentences writing style help to improve specifications.

The client opens an account.
The client deposits money into the account.

Fig. 2 Kernel Sentences

The client deposits money and calculates interest into the account.
The account is opened.

Fig. 3 No Kernel Sentences

3. Related works

Vu et al. [34] propose a method to transform specification to source code. Their approach systematically extracts the formal semantics of ARM instructions from their natural language specifications. Although ARM is based on RISC architecture and the number of instructions is relatively small, there are various series including Cortex-A, Cortex-M, and Cortex-R. Their approach applies translation rules enriched by the sentences similarity analysis.

Some other proposal deal with more abstract representation of the knowledge, for example data base table, schemas or object oriented designs. Geetha et al. [14] identify the schema and relationship of a data base from the natural language requirements specification. Their work starts with identifying the table schema and their properties. Then the Primary Key attribute is identified based on adjectives. It is done with rules and also with a machine learning component trained with statistical data. The relationships are identified using the primary key to identify the Foreign Key.

Bargui et al. [5] propose an approach to specify requirements through a template that represents the concepts of a decision making process. They also provide a linguistic pattern for the acquisition of analytical queries. This pattern facilitates the automatic analysis of the queries without being too restrictive to the writing styles.

Kuchta et al. [18] propose a method and a tool to extract concepts based on a grammatical analysis of requirements written in English without the need to refer to specialized ontology. These concepts can be further expressed in the class model, which then can be the basis for the object-oriented analysis of the problem. The method uses natural language processing techniques to recognize parts of speech and to divide sentences into phrases and also the WordNet dictionary to search for known concepts and recognize relationships between them.

Rigou et al. [28] are concerned about a formal or a semi-formal model description of functional requirements in the context of a model-driven engineering approach, where a platform-independent model, is used to derive automatically or semi-automatically the source code of a system. They claim that generally, the approaches use a predefined set of rules which impose several restrictions on the way a specification is written. Thus, they propose a deep learning approach.

Then, there are proposal that deals with conceptual model earlier in the software development life cycle. For example, domain models, concepts, and entities, some approaches are based on syntactic rules and some other are enriched with semantic. Shen et al. [31] propose an approach to assist the phases of requirements elicitation and analysis using masked language models, which have been used to learn contextual information from natural language sentences and transfer this learning to natural language processing (NLP) tasks. They claim that the masked language models can be used to predict the most likely missing word in a sentence, and thus be used to explore domain concepts encoded in a word embedding. Their approach extracts domain knowledge from user-authored scenarios using typed dependency parsing techniques. They also explore the efficacy of a complementary approach of using a BERT-based masked language models to identify entities and associated qualities to build a domain model from a single-word seed term.

Szwed et al. [33] propose an approach to extract concepts from unstructured Polish texts with special focus the morphological forms. Since Polish is a highly inflected language, detected names need to be transformed following Polish grammar rules. They propose a method for specification of transformation patterns, which is based on a simple annotations language. Annotations prepared by a user are compiled into transformation rules. During the concept extraction process the input document is split into sentences and the rules are applied to sequences of words comprised in sentences. Recognized strings forming concept names are aggregated at various levels and assigned with scores.

Lit et al. [20] presents an approach that employs LSTM-CRF model for requirement entity extraction. Their proposal consist of four phases: (i) model construction, where it is built a LSTM-CRF model and an isomorphic LSTM language model for transfer learning; (ii) LSTM language model training, where it is captured the general knowledge and adapt it to requirement context; (iii) LSTM-CRF training, where it is trained the LSTM-CRF model with the transferred layers; (iv) requirement entity extraction, where it is applied the trained LSTM-CRF model to a new-coming requirement, and automatically extracts its requirement entities.

Wang et al. [35] propose an approach that selects frequent verbs from software requirement specification documents in the e-commerce domain, and built the semantic frames for those verbs. Then the selected sentences are labeled manually and the result is used as training examples for machine learning. They also correct the parsing result of the Stanford Parser. During the labeling process, they adopt a sequential way in which the previous labeled results will be used to construct dynamic features for the identification of the subsequent semantic roles.

Sadoun et al. [29] presents an approach that model the domain knowledge through an ontology and to formally represent user requirements by its population. Their approach of ontology population focuses on instance property identification from texts. They use extraction rules automatically acquired from a training corpus and a bootstrapping terminology. These rules aim at identifying instance property mentions represented by triples of terms, using lexical, syntactic and semantic levels of analysis. They are regenerated from recurrent syntactic paths between terms denoting instances of concepts and properties.

Finally, some approaches are concerned in obtaining knowledge representation similar to our proposal.

Schlutter et al. [30] propose a knowledge extraction approach based on an explicit knowledge representation of the content of natural language requirements as a semantic relation graph. Their approach is fully automated and includes an NLP pipeline to transform unrestricted natural language requirements into a graph. They split the natural language into different parts and relate them to each other based on their semantic relation.

An et al. [1] explore a set of state-of-the-art pre-trained general-purpose and domain-specific language models to extract knowledge triples for metal-organic frameworks. They created a knowledge graph benchmark with 7 relations for 1248 published metal-organic frameworks synonyms.

4. The proposed approach

This section describes the proposed approach. First, it describes the generality of the approach, that consist of three steps: (i) glossary LEL description, (ii) glossary LEL revision, and (iii) knowledge extraction. Then, every of the step is described in a different subsection.

4.1. Our approach in a nutshell

The proposed approach has the objective of obtaining a synthetic representation of the knowledge captured in the language of the application domain captured through the glossary LEL.

The proposed approach needs the knowledge as input and produces a knowledge representation as output. The knowledge can be obtained from different sources. It can be obtained mainly directly from the stakeholders, though interviews or other type of technic (focus group, questionnaires, etc.). But the knowledge can be obtained from documentation.

Thus, the proposed approach is thought to be applied by a requirements engineer or a business analyst who describe the glossary LEL, review it and finally synthetize the knowledge. Moreover, the approach can be used not only by one persona, many people can participate. That is, many requirements engineering can participate describing the glossary LEL in a collaborative way. Moreover, stakeholder experts of the domain can participate writing symbols of the glossary LEL. That is why, the approach consists of three steps: (i) glossary LEL description, (ii) glossary LEL revision, and (iii) knowledge extraction. When more than one person participate of the construction of the LEL, the step (ii) is vital. Nevertheless, when only one person participate, and the volume of information is huge, the step (ii) is also vital. Moreover, the need of a tool to automatize the revision is crucial.

Summing up, the proposed approach can be applied in different situations: (i) to summarize documents produced by other people, (ii) to consolidate and summarize documents produced by only one analyst eliciting from multiple sources, and (iii) to consolidate and summarize documents produced collaboratively by a group of analyst or experts.

The three steps that compose the proposed approach are: (i) glossary LEL description, (ii) glossary LEL revision, and (iii) knowledge extraction. The first step proposes a set of guidelines to help people to describe the glossary LEL. The second step proposes a set of guidelines to review some aspects of the description. Some revision (not all of them) are linked with guidelines of the step (i). Finally, the step (iii) provides rules to obtain knowledge from the glossary LEL specified, which is described in terms of concepts and relations. Fig. 4 summarizes the approach.

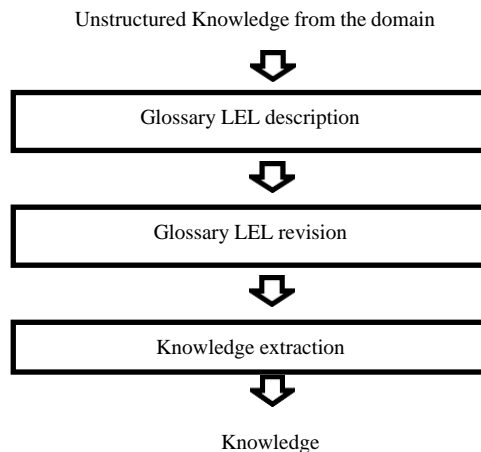


Fig. 4. Our approach in a nutshell

Let's consider the glossary LEL described in Table 2. We can assume that it was described in the step 1 of the proposed approach, and reviewed in the step 2. In fact, the example of the Table 2 satisfies all the guidelines suggested. If step 3 is applied to that LEL it will be obtained that the concept "client" and the concept "account" are linked by the relation "withdraw". Then, the whole relation ("client", "withdraw", "account") is restricted by the condition "positive balance".

4.2. Step 1, guidelines to write the glossary LEL

This section describes every one of the six guidelines proposed to describe the glossary LEL. There are some other proposals about how to describe the glossary LEL. Some of them suggest the basic template described in Table 1 and some other suggests specific structures [2] [3] [Antonelli 2023]. These guidelines reinforce the need to use kernel sentences and reference to symbol already defined, and moreover, this guideline provides suggestion about how to write compound sentences using subordination (if then), negation (no) and coordination (and). Finally, these guidelines also consider the use of state symbols in subordination expressions. The rest of the section describes and provides example for every one of the guidelines.

Guideline 1. Sentences to describe behavioral responses must suit kernel sentences philosophy. Behavioral responses of every category (subject, object, verb and state) must be written according to the philosophy of kernel sentence, that is, an explicit subject followed by only one verb in turn followed by an object that receives the action. Fig. 2 shows examples of sentences well written according to this guideline that are used to describe the behavioral responses of the symbol "client" in Table 2.

Guideline 2. Terms used to describe behavioral responses must be defined in the LEL glossary. This guideline suggests that the subject, the verb and the object mentioned in the previous guidelines, should also be symbols already defined in the glossary LEL. For example, the symbol "client" defined in Table 2, has the following description in the behavioral responses "The client opens an account. The client withdraws money from the account." If it is considered that Table 2 has a complete description of a glossary LEL, the symbols "client", "account" and "withdraws" are defined. But the symbol "opens" is not defined and it should be defined according to this guideline.

Guideline 3. Use subordination (if then) in behavioral responses of verb symbols to describe conditions. Let's consider the example of verb "Withdraw" in Table 2. One of the behavioral responses states "If the account has a positive balance then bank provides the money to the client.". That means that the bank only provides the money to the client, when the account has positive money after reducing the balance with the amount that the client want to withdraw. That is, it is checked whether the balance remains positive after the extraction. It is important to mention that the application of this guideline is not a contradiction to the guideline 1, since the use of a subordination requires kernel sentences, although there are two kernel sentences in the same sentence, there are still kernel sentences associated.

Guideline 4. State symbols should be used in the condition of a subordinated sentence. Since the state symbols describes situation, this situation should be used as a condition of the subordinated sentence. Moreover, the condition should be included in the kernel sentence. For example, let's consider the verb "Withdraw" in Table 2. One of the behavioral responses states "If the account has a positive balance then ...", "positive balance" is a state symbol describe in Table 2, and the expression "the account has a positive balance" suit the rules of kernel sentences.

Guideline 5. Use negation (not) to invert a condition or an action. For example, the verb "Withdraw" in Table 2 contains a behavioral response that states "If the account has not a positive balance, then ...". Nevertheless, the negation can be used to deny some behavioral response. That is, behavioral response of subject for example, describe all the activities that subject can perform. The symbol "client" defined in Table 2, has the following description in the behavioral responses "The client opens an account. The client withdraws money from the account." Generally, (and according to guideline 1 that recommends the use of kernel sentences that should be positive by definition), behavioral responses should be positive. Nevertheless, some times, it is very important to make explicitly definition that something cannot be done. In this case, the negation can be used. For example, considering a bank that only works with organization and not with private clients, the responsibility of opening account relies on the organization and not into the client. Thus, a behavioral response of a client could state "The client does not open an account".

Guideline 6. Use coordination (and) to join two subjects, objects or kernel sentences. Although multiple kernel sentences can be written, using the coordinator "and" more simple and natural sentences can be written. For example, instead of writing "The client deposits money in the account. The bank deposits money in the account", it could be written "The client and the bank deposits money in the account".

4.2.- Step 2, guidelines to review the glossary LEL

This section describes some guidelines to review the glossary LEL described with the guidelines of the previous sections. These guidelines are simply a way of checking whether the previous guidelines were used correctly. Although these guidelines can be used as a checklist after some description was done, the following section describes a prototype that can perform these checks automatically.

Guideline 1. Check for explicit subject and only one verb written in active voice in a behavioral response. This guideline has the objective to be sure that kernel sentences are used to describe behavioral responses. Thus, the use of only one verb, written in active voice should be used. Moreover, the sentence should have at least one explicit subject.

Guideline 2. Check for the definition of every subject, verb and object in a behavioral response. This guideline complements the guideline number 2 of the previous section. The objective is to check that every element (with semantic meaning) used in a sentence is describes within the glossary LEL.

Guideline 3. Check for the definition of every condition of a subordination as a state. This guideline complements guideline number 4 of the previous section. The objective is similar to the objective of guideline 2 of this section.

Guideline 4. Replace modal verbs with a subordination. The expression “The client withdraws money from the account” states that the client is allowed to do that and he will do it when he need. If a modal verb is used “The client might withdraw money from the account” it means that there is certain condition. Thus, the sentence should be rewritten as “If (some condition related to the client) then the client withdraw money from the account”

Guideline 5. Rephrase expressions with “no” to be sure of expressing prohibition. Guideline 5 of the previous section suggest the use of negation to invert a condition or an action. When it is used to invert an action, that is, to state that some subject does not do some action, it is important to be sure that the description states a prohibition to perform that action. For example, the expression “The client does not open an account” can be rephrased as “The client is not allowed to open an account” to be sure that a prohibition is described.

Guideline 6. Check for unambiguous terms used in notion. When technical specification are written, the goal to be precise and unambiguous is naturally pursued, that is why it is not added a complementary guideline in the previous section. Nevertheless, it is important to pay attention to this issue and to consider this guideline for the revision. Although this guideline can be applied manually, maybe the tool support using some tool of word-sense disambiguation is more useful.

4.3.- Step 3, knowledge extraction

This section describes some rules to extract knowledge form the glossary LEL described and reviewed with the guidelines of the previous sections.

Rule 1. Concepts are obtained from symbols of subject and objects categories. Considering the glossary LEL described in Table 2 two concepts are obtained: “client” and “account”, the first one is a subject and the second one is an object, but both of them are concepts.

Rule 2. Relations are obtained from symbols of verbs categories. Considering the glossary LEL described in Table 2 one relation is obtained: “withdraw”. According to the behavioral response of the symbol “client”, this action (“withdraw”) relates the concepts “client” and “account”.

Rule 3. Conditions are obtained from symbols of state categories. Considering the glossary LEL described in Table 2 one condition is obtained: “positive balance”.

Rule 4. Relations obtained by rule 2 are restricted by conditions. Considering the glossary LEL described in Table 2 the state: “positive balance” gives origin to a condition. This state is mentioned in the “withdraw” verb that gives origin to the relation between “client” and “account”. Thus, the whole relation (“client”, “withdraw”, “account”) is restricted by the condition “positive balance”.

5. Tool support

A software prototype was implemented that can be used to support the application of the proposed approach. The prototype is a web application implemented following a service-oriented architecture. The core of the application and its services are implemented in Python [27], while the web component is implemented with Django [12], and the APIs are implemented with Flask [13]. Python [27] is also used to communicate to the Spacy [32] and NTLK libraries [23] used to deal with natural language processing.

The application is responsive, that means, the interface of the application adapts itself to the device used: a computer (desktop or laptop) or mobile device (phone or tablet). Thus, the application provides a variety of platforms to be used and experts will have a wide range of possibilities to contribute with knowledge acquisition.

The prototype implements two roles of users: (i) administrators of the projects and (ii) experts. The administrator of the tool can create project and the experts contribute with knowledge to the projects. The prototype is in fact a framework, since it can manage different type of artifacts based on natural language (Fig. 5). And the prototype also is easily extended to perform different process to derive more information from the artifacts.

```

Class LelElement():
symbol (length = 255, label "Symbol") category
(length = 10, label "Category")Notion (length = 1000,
label "Notion")
BehavioralResponses (length = 1000, label "Behavioral responses")

```

Fig. 5. Configuration of artifacts

The prototype uses Spacy [32] and NLTK [23] libraries to perform natural language processing. The POS (part of speech) tagging is an appropriate tool to determine the revisions suggested by guideline 1 as well as the identification of modal verbs mentioned in guideline 4. Then, word disambiguation is another powerful tool mentioned in guideline 6. Then, guidelines 2 and 3 requires to check the presence of some words as symbols of the glossary LEL. In order to do that, the stemming and lemmatization tools are very useful, since they convert words to their root form in order to make the comparison. Fig. 6 shows how the tool check kernel sentences.

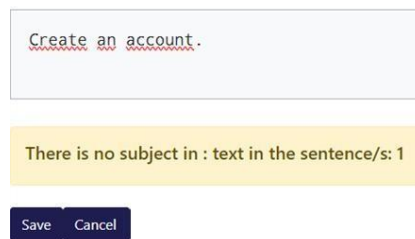


Fig. 6. Kernel sentence checking

The framework Plant UML [24] is used to display the model (Figure Fig. 7).

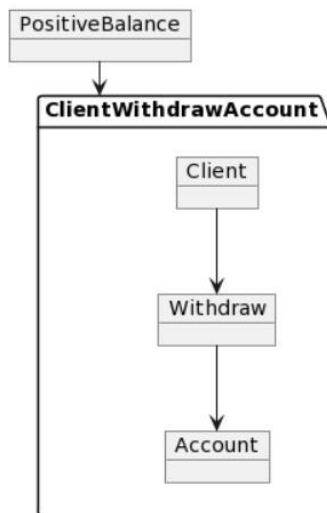


Fig. 7. Knowledge represented graphically

6. Evaluation

The proposed approach was evaluated, although the prototype was not used in the evaluation because the goal of the evaluation was to assess the perceived usability of the proposed approach instead of evaluating the tool.

The Systems Usability Scale (SUS) was used to perform the evaluation [8] [9] in terms of the usability of the proposed approach. Although SUS is mainly used to assess usability of software systems, it was found to be effective to assess products and processes [Bangor 2008].

The System Usability Scale (SUS) consists of a 10-item questionnaire; every question must be answered in a five-options scale, ranging from "1" (" Strongly Disagree") to "5" (" Strongly Agree"). Although there are 10 questions, they are related by pairs, asking the same question but in a complementary point of view in order to obtain a result of high confidence. The questions are the following:

- 1.- I like to use this approach.
- 2.- I find this approach to be more complicated than it should be.
- 3.- I think the approach is simple and easy to use.
- 4.- I need technical support to use this approach.
- 5.- I find the approach functioning smoothly and is well integrated.
- 6.- I think there are a lot of irregularities in the approach.
- 7.- I think most people can learn this approach quickly.
- 8.- I find this approach to be time-consuming.
- 9.- I feel confident using this approach.
- 10.- I think there are a lot of things to learn before I can start using this approach.

The participants of the evaluation were 5 students (with an age average of 24.8 years old) that participate in research project. It is important to mention that all of the students have experience in industry since in Argentina, students generally begin to work in industry in second year of their undergraduate studies. Thus, participants are suitable to this evaluation since they have experience in reading specification and deciding about the understandability of it. So, their opinion about whether the knowledge summarization is good or not to is important to us. They received training on the proposed approach and they were requested to answer the questionnaire.

The calculation of the SUS score is performed in the following way. First, items 1, 3, 5, 7, and 9 are scored considering the value ranked minus 1. Then, items 2, 4, 6, 8 and 10, are scored considering 5 minus the value ranked. After that, every participant's scores are summed up and then multiplied by 2.5 to obtain a new value ranging from 0 to 100. Finally, the average is calculated. The approach can have one of the following results: "Non acceptable" 0-64, "Acceptable" 65-84, and "Excellent" 85-100 [22]. The score obtained was 88.5. Thus, the approach can be considered as "Excellent".

6. Conclusions

This paper has presented an approach to obtain knowledge specification from a natural language specification. Particularly, we proposed the use of the glossary LEL to capture the language of the domain, hence, its knowledge. The proposed approach consists in a set of guidelines to help to capture and organize the natural language specification, in order to obtain the knowledge. The knowledge obtained can be used in different way. It synthesizes the glossary LEL, so it can be used to provide a global view. But it also make possible to infer new knowledge, and this is very important to provide complete and consistent specifications, moreover if we consider that they use natural language. This is our main further work. We plan to extend this proposal to infer new knowledge to be used to add to the glossary LEL so stakeholder can validate and use them. And also to identify inconsistencies and conflict, so they can be solved. Another further work is related to improve the glossary LEL with a categorization of subjects as countable and uncountable. This categorization will make possible to be precise in certain descriptions involving them. We plan to enrich the LEL with magnitudes (numbers with a unit) and categorical elements (a list of possible value). We think that both characteristics are important to write precise specification and obtaining inferred knowledge. Particularly, this will make possible to verify requirements and designing tests from it.

Acknowledgment

This paper is partially supported by funding provided by the STIC AmSud program, Project 22STIC-01.

References

1. An, Y. et al.: "Exploring Pre-Trained Language Models to Build Knowledge Graph for Metal- Organic Frameworks (MOFs)" 2022 IEEE International Conference on Big Data (Big Data), Osaka, Japan, pp. 3651-3658 (2022)
2. Antonelli, L., Leite, J.C.S.P., Oliveros, A., Rossi, G.: "Specification Cases: a lightweight approach based on Natural Language", Workshop in Requirements Engineering (WER), Brasilia, Brasil, Agosto 23 – 27 (2021)
3. Antonelli, L., Fernandez, A., Ruffolo, N., Sansone, E., Torres, D.: "A Collaborative Approach to specify Kernel Sentences using Natural Language", Workshop in Requirements Engineering (WER), Natal, Brasil, Agosto 23 – 26 (2022).
4. Antonelli, L., Delle Ville, J., Dioguardi, F., Fernandez, A., Tanevitch, L., Torres, D.: "An Iterative and Collaborative Approach to Specify Scenarios using Natural Language", Workshop in Requirements Engineering (WER), Natal, Brasil, Agosto 23 – 26 (2022).
5. Bargui, F., Ben-Abdallah, H., Feki, J.: "Multidimensional concept extraction and validation from OLAP requirements in NL," 2009 International Conference on Natural Language Processing and Knowledge Engineering, Dalian, China, pp. 1-8 (2009)
6. Berry, D., Kamsties, E. and M. Krieger. From Contract Drafting to Software Specification:
7. Linguistic Sources of Ambiguity. University of Waterloo. 2003
8. Boehm, B.W.: Software Engineering, Computer society Press, IEEE, 1997.
9. Brooke, J.: "SUS-A quick and dirty usability scale" Usability evaluation in industry, 189(194),pp. 4-7, 1996.
10. Brooke, J: "SUS: a retrospective", Journal of usability studies 8.2, pp.29-40, 2013.
11. Chomsky, N.: The Logical Structure of Linguistic Theory. Plenum Press, New York, 1975.
12. McLellan, S., Muddimer, A., Peres, S. C.: "The effect of experience on System Usability Scale ratings." Journal of usability studies 7.2, pp. 56-67, 2012.
13. NLTK, <https://www.nltk.org/>, accessed: 2023-03-05
14. PlantUML, available at: <https://plantuml.com/>, accessed on 27th February 2023
15. K. Pohl, The Three Dimensions of Requirements Engineering, in: Proc. 5th Int. Conf. of Advanced Information Systems Engineering 1993, Paris, Springer, Berlin, pp. 275-292, 1993
16. Potts, C.: "Using schematic scenarios to understand user needs," in Proceedings of the 1st conference on Designing interactive systems: processes, practices, methods, & techniques, 1995
17. Python, <https://www.python.org/>, accessed: 2023-03-05
18. Rigou, Y., Lamontagne, D., Khriess, I.: "A Sketch of a Deep Learning Approach for Discovering UML Class Diagrams from System's Textual Specification," 2020 1st International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET), Meknes, Morocco, pp. 1-6 (2020).
19. Sadoun, D., Dubois, C., Ghamri-Doudane, Y., Grau, B.: "From Natural Language Requirements to Formal Specification Using an Ontology," 2013 IEEE 25th International Conference on Tools with Artificial Intelligence, Herndon, VA, USA, pp. 755-760 (2013).
20. Schlutter, A., Vogelsang, A.: "Knowledge Extraction from Natural Language Requirements into a Semantic Relation Graph". In Proceedings of the IEEE/ACM 42nd International Conference on Software Engineering Workshops (ICSEW'20). Association for Computing Machinery, New York, NY, USA, pp 373–379 (2020)
21. Shen, Y., Breaux, T.: "Domain Model Extraction from User-authored Scenarios and Word Embeddings" 2022 IEEE 30th International Requirements Engineering Conference Workshops (REW), Melbourne, Australia, pp. 143-151 (2022)

22. Spacy <https://spacy.io/>, accessed 2023-03-05
23. Szwed, P.: "Concepts extraction from unstructured Polish texts: A rule based approach," 2015 Federated Conference on Computer Science and Information Systems (FedCSIS), Lodz, Poland, pp. 355- 364 (2015).
24. Vu, A.V., Ogawa, M.: "Formal Semantics Extraction from Natural Language Specifications forARM". In: ter Beek, M., McIver, A., Oliveira, J. (eds) Formal Methods – The Next 30 Years. FM 2019. Lecture Notes in Computer Science (), vol 11800. Springer, Cham (2019)
25. Wang, Y.: "Semantic information extraction for software requirements using semantic role labeling," 2015 IEEE International Conference on Progress in Informatics and Computing (PIC), Nanjing,China, pp. 332-337 (2015)

Quantum Computing meets Software Engineering: a Road Map for Collaborative Research

Jose Garcia-Alonso¹, Julio Ariel Hurtado Alegria², Juan M. Murillo³, Juan Braña⁴,
and Alejandro Fernandez⁵

¹ Universidad de Extremadura, España

² Universidad del Cauca, Colombia

³ CénitS - COMPUTAEX, España

⁴ I-314, Argentina

⁵ Universidad Nacional de La Plata, Argentina

Abstract. Software quantum developers need to implement efficient solutions taking advantage of the quantum computing properties. However, quantum computing is still in its early stages, and software development that exploits the advantages of quantum computing remains a challenge, as a lot of methodologies and tools are rooted in the essential concepts of classical computation. In this paper, we introduce the Iberoamerican Seedbed for Quantum Software Engineering initiative, which aims to promote research, innovation, and teaching at the intersection of software engineering and quantum computing. The initiative will facilitate joint research and innovation projects, staff and student exchange programs, and seminars and workshops. It will also establish a network of quantum simulators, create a learning program for quantum software engineering, and disseminate research findings to the scientific community and the public.

Keywords: *Quantum Computing · Software Engineering · Collaborative Research*

1 Introduction

The principles of quantum mechanics were established by Max Planck and Niels Bohr. Since then, advances in both quantum hardware and quantum information theory have made Quantum Computing an undeniable reality.

Quantum computers rely on the use of quantum bits or qubits, the basic unit of information in a quantum computer, instead of the classical bits in traditional computers. These qubits use the quantum concepts of superposition and entanglement to open the gates to a new type of computing. The use of superposition allow qubits to be on multiple states at the same time, until they are measured. While entanglement allow qubits to be related to other qubits in a way that their state cannot be described independently of the state of the others.

The use of these properties allow quantum computers to solve bounded-error quantum polynomial time problems (BQP). A class of decision problems solvable by a quantum computer in polynomial time within a margin of error. It is suspected that BQP contains P and that there are some problems in the BQP class which are outside the P class.

To be able to address BQP problems, quantum developers need to implement efficient algorithms that take advantage of the quantum properties. There are already some well-known algorithms of this type like Grover algorithm [4] that searches in an unordered database faster than any classical algorithm or Shor algorithm [7] that factorizes an integer faster than any known classical algorithm.

However, as classical software engineering has demonstrated, is not enough to develop efficient algorithms. Modern software solutions are complex systems that rely on multiple layer of infrastructure, tools and techniques that allow software engineers to create high quality solutions. Most of these elements are still in a very early stage in quantum computing [2].

The field of quantum software engineering is an emerging topic that focus on bringing the advantages of software engineering to the development of quantum software. Discussion forums like the International Workshop on Quantum Software Engineering at ICSE, the IEEE International Conference on Quantum Software at IEEE Services or the Quantum Software Engineering and Technology Workshop at IEEE Quantum Week are starting to appear.

Nevertheless, additional efforts are needed to advance quantum software engineering [6]. There is still a low critical mass of researchers and, therefore, there is a need for training researchers and students in the specifics of quantum software engineering. The amount of resources needed to develop and test quantum solutions is still important, therefore, there is a need to join efforts between groups and institutions interested in this field. Also, due to the intrinsic interdisciplinary nature of quantum development, with the necessary input from mathematicians and physicist, collaborative approaches are necessary.

Specifically, we propose a road map for the creation of a collaborative research initiative in the field of quantum software engineering. To do that we present a research road map. Then, we propose the creation of a Seedbed for Quantum Software Engineering and provide some initial planning and expected outcomes for this initiative.

2 A research road map

As mentioned above, quantum software engineering is still in an early stage of development. Therefore, additional research is needed in almost every aspect of this new discipline [5]. In this section we focus on those topics that we consider the most relevant given the current state of the area.

2.1 Software tools to support quantum computing

As a classical software engineering has evolved, so have done the tools that support it. Nowadays, software engineers are used to have at their disposal a wide range of advanced tools, frameworks, and SDKs that help them in their daily task.

To simplify the transitions from classical software engineering to quantum software engineering and to train new quantum software engineers similar tools are needed. Not only because they make life easier to software engineers, but because they help develop software with better quality attributes [3].

Current quantum computing systems rely on initial versions of these tools. Most vendors provide environments and SDKs to help developers. For example, IBM offers developers a set of real hardware quantum computers up to 5 qubits and several simulators up to 5000 qubits for free through its platform "IBM QUANTUM EXPERIENCE". This offering is very useful for developing proof of concept projects, writing academic papers and learning to program quantum computers. Other companies like Google, Microsoft, Amazon and startups around the world provide different SDKs and tools for these tasks.

These SDKs are based on some of the existing quantum programming languages like Qiskit (IBM) and Cirq (Google), both written in Python or "Q-Sharp" (Microsoft). Amazon offers an environment named "Amazon Braket" to get started in the quantum computing world, for academic or commercial projects, and this company also offers one hour of its suite for free to try this technology. Other language that is often used to program Amazon Braket computers is Julia, through its library "Braket.jl". These languages, although usually based on a high-abstraction level programming language like python provide a very low-abstraction level language for the programming of quantum hardware, based on the use of quantum gates and quantum annealing approaches.

Another example, is the intersection between quantum computing and machine learning. Several libraries have been developed for this purpose, one of the most well known framework is "quantum-tensorflow", published by Google.

Other tools in this domain are the transpilers that allow developers to translate their quantum program so it can be run on a different quantum computer using a different set of gates or with a different architecture. Also, some frameworks are starting to appear that focus on the application of quantum computing to specific domains like machine learning or chemistry.

All these tools, although they provide important advantages for the development of quantum software, are still very limited in terms of software engineering. The low abstraction levels at which quantum hardware is operated and the focus on addressing some of the hardware limitations, like noise or decoherence time, make the concerns about software quality attributes seem very far away. However, as quantum hardware evolves and more advanced quantum software is created, quality attributes of software will rise in relevance, as happened in classical software engineering, and quantum software engineers will need tool support.

2.2 Hybrid quantum-classical systems

Additionally, although quantum computers can solve some problems quicker than classical computers, modern software almost never works in an isolated way.

Current systems usually are created as a global, interconnected set of software components. It seems natural, that quantum software would follow a similar pattern in which hybrid system will be the standard way of development [8].

In fact, the initial steps of quantum computing are taking that hybrid shape. Several relevant quantum algorithms already need a classical part. Also, most quantum computers are still managed through classical systems. So efforts are needed to define hybrid architectures for quantum software engineering.

Moreover, most of the existing quantum computers are offered through the cloud. This kind of access is well known for classical software engineers and provides important advantages to software that justify its omnipresence in modern software. Starting from this point it seems reasonable to address quantum software engineering from a Service Oriented Computing point of view.

All of these, make clear the relevance of working on hybrid quantum-classical systems for a quantum software engineering.

2.3 Collaboration and quantum computing

Finally, advances in quantum software engineering need a collaborative approach. Not only between software engineers, which is always a requirement for complex systems, but also with professionals of other disciplines [1]

Nowadays, advances in quantum computing are mostly created by professionals with strong backgrounds in mathematics or physics. The low abstraction level at which quantum software is developed makes these professionals irreplaceable. However, they lack the skills and the background needed to create software with the appropriate quality attributes. On the other side, software engineers with the abilities to create quality software usually lack the background and skills needed to create quantum software in its current state. Therefore, collaboration is needed to produce contributions in the quantum software engineering domain.

Additionally, other kind of collaborations are needed to develop useful software. Collaboration with domain experts are needed to understand the domain requirements and co-creation processes have been proven as one of the best approaches for that. Also, collaboration with super-computing centers where quantum computers or powerful simulators are hosted are also required in order to obtain access to the resources needed for development.

Again, all of these make clear the need of a collaborative approach for research on quantum software engineering.

3 An Iberoamerican Seedbed for Quantum Software Engineering

Quantum computing is still in its early stages, and the development of software that exploits the advantages of quantum computing is still a challenge. Existing software development methodologies and tools are based on the computer model proposed by Von Neumann and Turing's conception of a program, which may not be adequate to the quantum computing paradigm. The Iberoamerican Seedbed for Quantum Software Engineering initiative aims to foster research, innovation, and teaching in the intersection of software engineering and quantum computing and explore alternative methods and tools for quantum software engineering. The primary outcomes of this initiative will be:

- Foster the creation of joint research and innovation projects in quantum software engineering, focusing on developing new methodologies and tools that take into account the specific features of quantum computing.
- Promote staff and student exchange programs between Iberoamerican countries to facilitate the exchange of knowledge and expertise in quantum software engineering and alternative methods and tools.
- Conduct joint seminars and workshops to share knowledge and expertise in quantum software engineering and alternative methods and tools.
- Establish a network of quantum simulators in supercomputing centers or other computing infrastructures able of offering to other researchers and to the industry the possibility of exploring the use of quantum technologies.
- Create a learning program for quantum software engineering that includes practical training using simulators or real quantum hardware.
- Disseminate the results of the research and innovation projects and the exploration of alternative methods and tools to the scientific community and the general public.

With this goals in mind, a three stage plans is proposed: planning, implementation, and consolidation. During the planning stage (first year of project) the following activities will be carried out:

- Create a website and social media accounts for the Iberoamerican Seedbed for Quantum Software Engineering.
- Define the research lines and projects that will be developed in the next two years, focusing on developing new methodologies and tools that take into account the specific features of quantum computing.
- Identify and recruit researchers, professionals, and students with expertise in computer science, physics, and engineering to participate in the initiative.
- Define the guidelines for the exchange programs and joint seminars, focusing on the exchange of knowledge and expertise in quantum software engineering and alternative methods and tools.
- Organize a first joint seminar to share knowledge and expertise in quantum software engineering and alternative methods and tools.
- Secure funding for the implementation of staff and student exchange during the second year of the project, and to implement multi-year collaborative research projects.

Acknowledgements

This work has been financially supported by the Ministry of Economic Affairs and Digital Transformation of the Spanish Government through the QUANTUM ENIA project call - Quantum Spain project, by the Spanish Ministry of Science and Innovation under project PID2021-124054OB-C31, by the Regional Ministry of Economy, Science and Digital Agenda, and the Department of Economy and Infrastructure of the Government of Extremadura under project GR21133, and by the European Union through the Recovery, Transformation and Resilience Plan - NextGenerationEU within the framework of the Digital Spain 2026 Agenda.

References

1. Barzen, J., Leymann, F., Falkenthal, M., Vietz, D., Weder, B., Wild, K.: Relevance of near-term quantum computing in the cloud: A humanities perspective. In: Ferguson, D., Pahl, C., Helfert, M. (eds.) *Cloud Computing and Services Science*. pp. 25–58. *Communications in Computer and Information Science*, Springer International Publishing (2021). https://doi.org/10.1007/978-3-030-72369-9_2
2. Enrique Moguel, Javier Berrocal, Jose García-Alonso, Juan Manuel Murillo: A roadmap for quantum software engineering: applying the lessons learned from the classics. In: *Short Papers Proceedings of the 1st International Workshop on Software Engineering & Technology (Q-SET'20) co-located with IEEE International Conference on Quantum Computing and Engineering (IEEE Quantum Week 2020)*. vol. 2705. CEUR (2020)
3. Garcia-Alonso, J., Rojo, J., Valencia, D., Moguel, E., Berrocal, J., Murillo, J.M.: Quantum software as a service through a quantum api gateway. *IEEE Internet Computing* **26**(1), 34–41 (2021)
4. Grover, L.K.: A fast quantum mechanical algorithm for database search (1996). <https://doi.org/10.48550/ARXIV.QUANT-PH/9605043>, <https://arxiv.org/abs/quant-ph/9605043>
5. Moguel, E., Rojo, J., Valencia, D., Berrocal, J., Garcia-Alonso, J., Murillo, J.M.: Quantum service-oriented computing: current landscape and challenges. *Software Quality Journal* **30**(4), 983–1002 (2022)
6. Rojo, J., Valencia, D., Berrocal, J., Moguel, E., Garcia-Alonso, J., Rodriguez, J.M.M.: Trials and tribulations of developing hybrid quantum-classical microservices systems. arXiv preprint arXiv:2105.04421 (2021)
7. Shor, P.W.: Algorithms for quantum computation: discrete logarithms and factoring. In: *Proceedings 35th annual symposium on foundations of computer science*. pp.124–134. Ieee (1994)
8. Valencia, D., Garcia-Alonso, J., Rojo, J., Moguel, E., Berrocal, J., Murillo, J.M.: Hybrid classical-quantum software services systems: Exploration of the rough edges. In: *Quality of Information and Communications Technology: 14th International Conference, QUATIC 2021, Algarve, Portugal, September 8–11, 2021, Proceedings 14*. pp. 225–238. Springer (2021)

Biomechanical Analysis of Basketball Free Throw Shooting Technique in Athletes of The Pedagogical and Technological University of Colombia

Jorge Armando Abril¹, Jose Charris
and Marco Javier Suarez Baron

¹ Universidad Pedagogica y Tecnologica de Colombia-UPTC, Sogamoso, Colombia² Faculty of Systems and Computing marco.suarez@uptc.edu.co

Abstract. Biomechanics is one of the most complete fields of the study of the metric composition of the human body and its relationship with physical and me-chanical variables characteristic of motion kinematics analysis, which is a great advantage when conducting studies on the performance of athletes and the anal-ysis of their technical and tactical skills, since it gives us a more concrete per- spective on them. For this research process, it has been decided to carry out a series of tests to launch free basketball shots in two athletes from the Pedagogicaland Technological University of Colombia.

Keywords: *Kinetics, Kinematics, Biomechanics, Basketball, Technical ability, Tactical ability.*

1 Introduction

This section will specify everything related to the development of the field work, such as the classification and selection of the biomechanical variables to be analyzed, in addition to this, the population sample that will be studied for the analysis of the freethrow mechanics will be delimited and the techniques and procedures that will be usedfor the development of the biomechanical study will be mentioned.

In order to successfully perform the biomechanical analysis of the technical skill ofbasketball free throw shooting in athletes of the Pedagogical and Technological Uni- versity of Colombia, within the fieldwork, data collection, analysis and procedures, it is proposed:

- To characterize in a specific and adequate way the biomechanical variables thataffect the development of the technical-tactical skill in basketball free-throw shooting.
- Establish through a biomechanical analysis methodology, a classification of rou-tines suitable for improving basketball free-throw shooting technique.
- Design a visualization system for anthropometric data and results using MLframeworks

The analysis of the basketball free throw shooting technique is essential to under- stand the success of some athletes, because the effectiveness of this technique has a high impact on this sport. However, the studies that have been conducted on the anthro-pometric and biomechanical relationship to reach an optimal characterization of the variables involved in the technical ability of an athlete are usually focused on other disciplines or are very ambiguous, so that also the use of technological tools and data analytics in such studies is very small, despite being tools that give us great reliability to make forecasts and analysis accurately and effectively.

Throwing is a movement that determines the action of sending an object to another place, this action has its own characteristics of the intention with which it is performed,from this consideration there have been several studies on the biomechanical factors ofthrowing depending on the specialty to be analyzed, such as the sports and military area, among others. The investigations carried out allow to evidence the incidence of variables such as angles, planes, positions and articulations that adjust to the character-istics of the human body and how they interact with the mechanics required to fulfill the objective of the action [1]

In order to make a biomechanical description of the throwing action, it is necessary to identify the phases that make up the throwing action, and how the athlete's body parts behave within each of these phases, that is, to identify the behavior patterns of the upper limbs and their joints, their measurements, and their variation as the movement is executed [2]. It is essential to bear in mind that the execution of free throws does not have a rigid and predetermined standard, however, there are techniques associated with the effectiveness of the free throw [3]. In the anthropometric study of the upper limbs, the values corresponding to the dimensions of the arms, forearms, hands, and their length and extension, among other variables, are treated [5].

The specific study of upper limbs has been widely used for the creation of prostheses as it allows through the results obtained to make products appropriate for the needs of people who have suffered malformations, injuries, or loss of any of their limbs, as it allows to establish ideal characteristics in terms of optimal materials for use, and different components involved in the design and production of prostheses according to ISO 13405-1 standard, such as interface components (interaction with the patient), functional, alignment, structural and cosmetic (appearance as close as possible to a natural human limb) [6]. In this way, the relationship between these dimensions and the execution of movements can be established by means of a dynamic anthropometric analysis of the upper limbs.

2 Materials and methods

2.1 Method

Phase 1. Information collection.

Analyses were carried out based on the study of a population sample composed of players of the men's basketball team of the Pedagogical and Technological University of Colombia Sogamoso Sectional Faculty, whose ages range between 17 and 24 years, who also meet the requirement of being active students of an undergraduate career.

For the purpose of this research, the process was segmented into phases as follows.

Phase 2. Information processing

- Capture of participants' movements during the execution of the free-throw shooting technique, using high-definition cameras and Motive Optitrack software.
- Processing of images collected from high-definition cameras using the Python programming language.
- Storage of data extracted through image processing, this will be done by integrating it with the documentation in flat files obtained in the measurement and anthropometric characterization of the participants.

Phase 3. Learning model

- Extraction of data obtained in flat files with the Motive Optitrack software, and subsequent integration with the flat file containing the anthropometric characterization and digital processing data.
- Classification of variables according to successes during motion capture sessions.
- Use of Weka software for data analysis and statistical processing of the data stored in the flat file, according to the classification assigned to the variables. This will allow us to demonstrate by means of correlation matrices the interaction of the variables during the execution of the movement, and its relation with an optimal technique according to the successes or deficiencies in the attainment of scores by the players according to their throwing technique.

- From the above, using the software, a classification tree is generated, which will give results of the behavior of the variables to achieve an optimal launching technique.

Phase 4. Evaluation and training

- Finally, a classification of the adequate behavior of the variables in the throwing technique will be made, for the construction of an optimal training methodology, by means of routines, based on the results obtained in the classification tree, for the improvement of the free-throw throwing technique.
- In addition, a teaching/learning process of free throw shooting will be designed, through sessions and routines established according to the optimal characterization made in the study, this will serve as a guide to adequately develop the sports training process, thus making a contribution to basketball instructors and players.

Phase 5. Design and codification

- Finally, the methodological design of development, generation of schemes of actions, packages and others corresponding to a software development is planned, where the deductive model is already established with the results in accordance with the objectives, it will be embodied in coding to obtain as an expected result a system where the capture of movement and level of assertiveness of the linguistic sign of the exposed model can be observed

Detailed description of the method steps can be seen in figure 1.

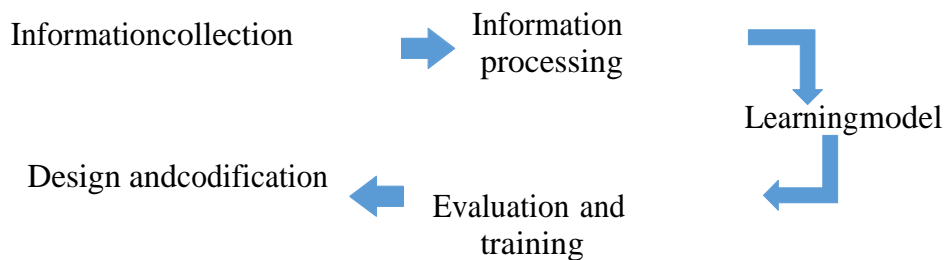


Fig 1. Applied Method

2.2 Measuring instruments and techniques

- High-definition camera: Which will allow us to perform motion capture in natural environments (basketball court)
- Software Motive Optitrack: The Motive Optitrack software allows us to capture movements by means of a hardware consisting of 12 cameras, and an integration with a system of capture and digital processing of video material, from which a data extraction is performed through flat files that give us detailed information of the behavior of the variables mentioned above.
- Python programming language for digital image processing.
- Anthropometric and goniometric measurement techniques: To obtain the data and characteristics of the upper limbs of each player in the sample under study.
- Weka Software: For analysis of measures of central tendency, correlational analysis of variables (to establish how variables interact and their relationship to an effective technique), and classification trees to analyze results. Motion capture is performed with Motive Optitrack software and hardware or with a high-definition camera as can be seen on figure 2.

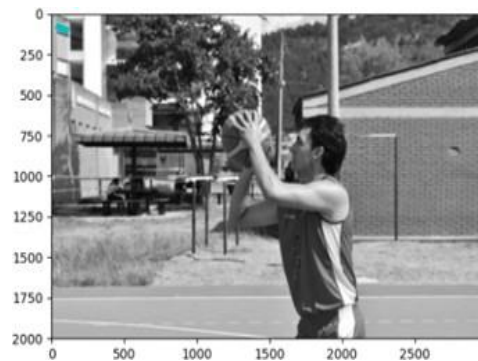


Fig 2. Motion capture.

2.3 Analysis procedure sequence

- Capture of participants movements during the execution of the free-throw shooting technique, using high-definition cameras and motive optitrack software.
- Processing of images collected from high-definition cameras using the Python programming language.
- Storage of data extracted through image processing, this will be done by integrating it with the documentation in flat files obtained in the measurement and anthropometric characterization of the participants.
- Extraction of data obtained in flat files with the motive optitrack software, and subsequent integration with the flat file containing the anthropometric characterization and digital processing data.
- Classification of variables according to successes during motion capture sessions.
- Use of Weka software for data analysis and statistical processing of the data stored in the flat file, according to the classification assigned to the variables. This will allow us to demonstrate by means of correlation matrices the interaction of the variables during the execution of the movement, and its relation with an optimal technique according to the successes or deficiencies in the attainment of scores by the players according to their throwing technique.
- From the above, using the software, a classification tree is generated, which will give us results of the behavior of the variables to achieve an optimal launching technique. Based on the data collected from the free throw capture as seen in figure 3.



Fig 3. Free throw capture

2.4 Data structure for analysis

The data structure presented is non-linear, therefore, it behaves as a tree within which different components are correlated and whose trends and projections in terms of behavior are related to external variables [8].

For this particular case, the level structure of the data is reflected in a first level that represents the general data of the athlete, the next level corresponds to the variables to be analyzed, after this analysis a result of data that affect the behavior of the throwing mechanics is obtained (Incident variables) and those that do not meet this condition are discarded. From this, a weight is assigned to each variable depending on its incidence in the launching technique, from which a probabilistic estimation is made by means of a Poisson distribution, because the result of a free throw launching is subject to several external conditions and the probability of occurrence of a high effectiveness must be taken as an event that occurs, but not in a constant way [9]. Finally, we have the final result corresponding to the execution of the free throws by the athletes. Data structure can be seen in figure 4.

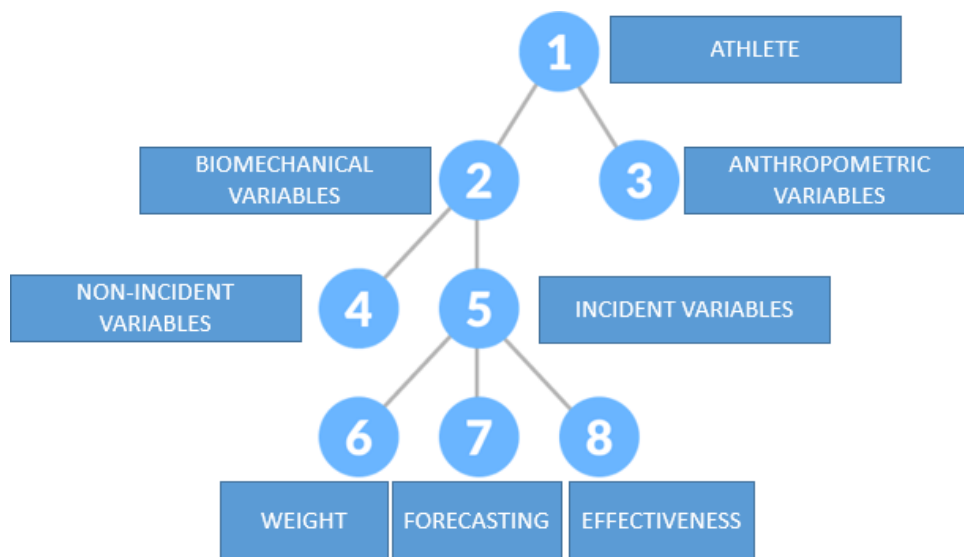


Fig 4. Data Structure

3 Results and discussion

Anthropometric characterization

An anthropometric characterization of the length of the upper limbs that interact within the mechanics of free-throw shooting was carried out, which provides us with an indicator of the variables analyzed in order to interpret their correlation with the effectiveness of free-throw shooting. The characterization was performed as shown in table 1.

Table 1. Characterization

Athlete	Height	Arms length	Hands length	Forearm length	Elbow-Shoulder
Player 1	175 cm	168 cm	17 cm	32.5 cm	40 cm
Player 2	184 cm	189 cm	20 cm	28 cm	35 cm
Player 3	173 cm	175 cm	20 cm	27 cm	28 cm
Player 4	178 cm	181 cm	20 cm	27 cm	35 cm
Player 5	191 cm	190 cm	20 cm	32 cm	49 cm
Player 6	188 cm	183 cm	20 cm	27 cm	37 cm

Arm-forearm angle

The analysis of the angle formed between arm and forearm gives us information about the correct execution of the throwing technique because the angle called α , can oscillate between 45° at the beginning of the movement and 85° at the end of it.

Wrist flexion

The flexion of the wrist is analyzed in the final sequence of the free throw, what we intend to measure for the purpose of this study are the initial and final angle corresponding to the flexion from its beginning until the moment in which the player gets rid of the ball.

Effectiveness analysis by classification

A classification analysis was performed by means of the J48 algorithm, taking as a reference class the effectiveness presented by the players during the free throw sessions, in which the classification gave us results about the behavior of the variables according to the value of the class, the class was defined as high, medium and low according to the percentage of successes for every 10 free throws made as can be seen in table 2.

Table 2. Standard definition of classification

Launches	Successful	Effectiveness (Class defined)
Quantity 10	0 - 4	Low
Quantity 10	5 - 6	Regular
Quantity 10	7 - 10	High

Based on this definition, a classification is made with respect to each of the variables, which yields the following results from the analysis carried out with respect to the height of the athletes, which shows a higher effectiveness in athletes with greater stature, and establishes a relationship between those who meet the denomination of effectiveness (Low/Regular/High) for every 5 athletes as shown in table 3.

Table 3. Analysis of the height variable by classification

Height	Effectiveness	Relation (Compliant/Total)
≤ 175 cm	Low	3/5 Low – 2/5 High
> 175 cm	High	1/5 Low – 4/5 High

In the same way, analyses were performed with respect to the other variables corresponding to upper limb extension such as elbow-shoulder length, forearm length, and arm length. These variables do not yield results that indicate a direct correlation with respect to the effectiveness of. As described in table 4.

Table 4. Analysis of the elbow/shoulder length variable by classification

Elbow/shoulder length	Effectiveness	Relation (Compliant/Total)
≤ 35 cm	High	2/5 Low – 3/5 High
> 35 cm	Low	3/5 Low – 2/5 High

In addition, a classification analysis was performed for the biomechanical variables established for the study, such as the angle formed between the arm/forearm, and wrist flexion. This can be seen in table 5 and table 6.

Table 5. Result of analysis by classification of the arm/forearm angle

Arm/forearm angle Initial	Arm/forearm angle Final	Effectiveness	Relation (Compliant/Total)
45°	85°	High	1/5 Low – 4/5 High
55°	85°	Regular	2/5 Low – 3/5 High
>55°	≥ 85°	Low	5/5 Low – 0/5 High

Table 6. Result of analysis by classification of the wrist angle

Wrist angle Initial	Wrist angle Final	Effectiveness	Relation (Compliant/Total)
110°	95°	High	1/5 Low – 4/5 High
<110°	>95	Low	3/5 Low – 2/5 High
<100°	> 90°	Low	4/5 Low – 1/5 High

4 Conclusions

The results obtained from the analysis allow us to infer that athletes with a greater height tend to have better effectiveness in terms of free-throw shooting, however, it is perhaps the anthropometric factor that has more impact in relation to the effectiveness and efficiency of the technique, because the anthropometric measurements of upper limbs do not show such a direct relationship and represent only a characterization of the athlete.

The biomechanical variables analyzed, such as the initial and final angles of the wrist, arm and forearm at the moment of executing the technique, have a direct relationship with the effectiveness of the throw, that is, if the technique is effective it is reflected in the behavior of these variables through the angles, this allows us to demonstrate the displacement of the upper limbs during the execution of the technique and subsequent scores.

References

1. Arora, C., Singh, P., and Varghese, V., "Biomechanics of core musculature on upper extremity performance in basketball players," *Journal of Bodywork and Movement Therapies*, vol. 27, pp. 127-133, 2021.
2. Lam, W. K., Kan, W. H., Chia, J. S., and Kong, P. W., "Effect of shoe modifications on biomechanical changes in basketball: A systematic review," *Sports Biomechanics*, vol. 21, no. 5, pp. 577-603, 2022.
3. Lempke, L. B., Oh, J., Johnson, R. S., Schmidt, J. D., and Lynall, R. C., "Single-versus dual-task functional movement paradigms: a biomechanical analysis," *Journal of Sport Rehabilitation*, vol. 30, no. 5, pp. 774-785, 2021.
4. Martínez, S. P. A., Quintero, Y. J. V., Huertas, L. M. R., and Salazar, L. G., "Métodos ergonómicos observacionales para la evaluación del riesgo biomecánico asociado a desordenes musculoesqueléticos de miembros superiores en trabajadores 2014-2019," *Revista Colombiana de Salud Ocupacional*, vol. 10, no. 2, pp. 31-42, 2020.
5. Medina Cabrera, M. L., Toledo Ríos, R., and Sánchez Oms, A. B., "Procedimiento para el análisis biomecánico de la variabilidad del movimiento en el lanzamiento de disco."
6. Pan, H., Li, J., Wang, H., and Zhang, K., "Biomechanical analysis of shooting performance for basketball players based on Computer Vision," in *Journal of Physics:Conference Series*, vol. 2024, no. 1, p. 012016, Sept. 2021.
7. Pérez Toasa, R. D., "Evaluación biomecánica en el proceso de aprendizaje de la técnica del lanzamiento libre del baloncesto en escolares de la Unidad Educativa TeresaFlor en el periodo abril-agosto 2021," Bachelor's thesis, Universidad Técnica de Ambato-Facultad de Ciencias Humanas y de la Educación-Carrera de Pedagogía de la Actividad Física y Deporte, 2021.
8. Srinivas, T. A. S., Somula, R., Aravind, K., and Manivannan, S. S., "Pattern Prediction Using Binary Trees," in *Innovations in Computer Science and Engineering: Proceedings of 8th ICICSE*, vol. 171, pp. 43, 2021.
9. Yang, C., and Jia, M., "Health condition identification for rolling bearing based on hierarchical multiscale symbolic dynamic entropy and least squares support tensor machine-based binary tree," *Structural Health Monitoring*, vol. 20, no. 1, pp. 151-172, 2021.
10. Zhang, J., Chi, B., Singh, K. M., Zhong, Y., and Ju, C., "A binary-tree element subdivision method for evaluation of singular domain integrals with continuous or discontinuous kernel," *Engineering Analysis with Boundary Elements*, vol. 116, pp. 14-30, 2020.

A Bayesian Approach to Duplicate Detection for Real Estate Listings

Felipe Dioguardi¹, Leandro Antonelli¹, Marcos May³, Juan Pablo del Río³, and Diego Torres^{1,2}

¹ LIFIA, CICPBA-Facultad de Informática, UNLP, Argentina
{name.surname}@lifia.info.unlp.edu.ar

² Departamento de Ciencia y Tecnología, UNQ, Argentina

³ LINTA-CICPBA, FaHCE, UNLP, Argentina

⁴ CONICET, Argentina

Abstract. The availability of large amounts of real estate data on the internet presents a great opportunity for analysts and statisticians to derive insights. However, ensuring the quality of the data can be challenging due to the presence of duplicate listings. This study proposes a duplicate detection strategy for a real estate knowledge graph containing listings scraped from different web pages. The presented approach involves using Duke to discover the implicit owl:sameAs links between records, which achieved a precision of 66.8%, a recall of 70.4%, and an F-measure of 68.6%. Although many strategies are based on using a single metric function to compare records, it was found that segmenting this comparison according to the attributes compared and giving each segment a different weight on the matching result is a successful method for solving this problem. The strategy was evaluated through a ground truth dataset created by domain experts, which consisted of a real estate listing knowledge graph with duplicate and unique entities. This approach effectively cleaned the knowledge graph of noisy data and can be useful for making accurate statistical analyses in real estate domains. The suggested approach can be used to create a real estate observatory that analyses real estate listings knowledge from different sources to generate useful statistics. Analysts can use this tool to extract valuable information and make data-driven decisions in the real estate market.

Keywords: *Duplicate detection · Knowledge base · Real estate listings*

1 Introduction

The sheer volume of online information poses advantages and disadvantages when extracting insights from it. While more data can provide new ways of measuring and understanding the domain, poor-quality data can lead to inaccurate conclusions and bad decision-making [3]. Therefore, prioritizing data quality over quantity is crucial when managing a large knowledge base. For this reason, duplicate detection is a key task during the preprocessing stage of information.

Over the years, many researchers have proposed strategies to detect duplicate records [1,9]. Still, their effectiveness varies depending on factors such as the amount of knowledge, the type of information, and the domain it belongs to. This paper evaluates the performance of a duplicate detection strategy based on a Bayesian Classifier over a real estate listings knowledge base built from records extracted from different websites.

Duplicate detection, often called record linkage, entity resolution, and data deduplication, is the process of identifying different records that refer to the same entity [5]. Such a problem is not trivial, as it involves some challenging steps, from the careful selection of record pairs to be compared to the method of comparison of these records and the final linking process. Removing duplicate records from a knowledge base is critical for ensuring reliable and trustworthy data [10], as their presence can impair statistical analysis and undermine their results.

Numerous tools and strategies have been proposed to address duplicate detection. For instance, vectorization techniques [13] and fuzzy matching [7] have been suggested to identify potential matches. Likewise, both machine learning models [2] and rule-based systems [11] have been explored to compare potentially matching records. Finally, comprehensive frameworks that automate all aspects of instance matching have also been developed [15]. However, the success of these methods heavily relies on their adaptability to the specific characteristics of each domain, and the selection of an appropriate method can be influenced by factors such as the size of the dataset, the data quality, the nature of the matching functions, and the requirements of the application.

Specifically, in real estate listings, the challenges of deduplication intensify further. The real estate market involves having the same building appear in multiple listings. This can happen if, for example, more than one real estate agent offers the building, and each of the agents publishes it in separate listings on the same site. The same logic can apply when the agents publish the same building on different sites. Additionally, completely different listings can have similar descriptions due to templates used by real estate agents or websites. The geographic coordinates of the offered properties can also pose challenges, depending on who publishes them and how. On top of that, naming conventions can vary across sources, making it difficult to identify duplicates without a comprehensive approach that considers all relevant attributes of each listing.

This research aims to assess the efficacy of a duplicate detection strategy that leverages Bayes' Theorem to aggregate probabilities, applied to a knowledge base of real estate listings. The performance of this approach is evaluated using the precision, recall, and F-measure metrics, and an unbiased test is ensured by using a knowledge base with a manually curated ground truth dataset.

The remainder of this paper is organized as follows. Section 2 provides an overview of related work in the field of duplicate detection. Section 3 defines the problem of duplicate detection and outlines the challenges specific to real estate listings. Section 4 describes the knowledge graph used in the study, including its sources and characteristics. In Section 5, the paper presents the metrics used to evaluate the effectiveness of our duplicate detection strategy. Section 6 describes in detail the duplicate detection tool used in this study. Section 7 presents the results of the evaluation. Finally, in Section 8 the paper concludes the evaluation and provides insights into the relative strengths and weaknesses of the different approaches while discussing potential areas for future work.

2 Related Work

This section provides an overview of the related work in the area of duplicate detection. Several works have surveyed the literature on duplicate detection tools, such as Elmangarmid et al. [5] in the context of databases, Assi et al. [1] with their survey on instance matching systems, and Huaman et al. [9] with their review of the state-of-the-art for duplicate detection in knowledge graphs.

Niu et al. [14] conducted a thorough analysis of the literature on duplicate record detection, covering various techniques, algorithms, and tools used to detect duplicate records in databases. They also discussed common errors that can make duplicate matching difficult and presented methods for improving efficiency and scalability in approximate duplicate detection algorithms. Zong et al. [16] proposed an approach for deduplication that involves extracting semantic information from the material record names and representing it in a form that allows for effective comparisons to be made.

Manku et al. [12] developed a near-duplicate detection system for a multi-billion-page repository, demonstrating the applicability of Charikar's fingerprinting technique for this goal, and evaluating it over real data to confirm the practicality of their design.

Dong et al. [4] studied how to improve truth discovery by detecting dependence between sources and analysing the accuracy of sources. They developed Bayesian models that discover copiers by analysing values shared between sources, and the results of their models can be considered as a probabilistic database, where each object is associated with a probability distribution of various values in the underlying domain. Experimental results showed that their algorithms can significantly improve the accuracy of truth discovery and are scalable when there are numerous data sources.

3 Problem Definition

This section will explore the problem of detecting duplicates in knowledge graphs, examining its complexity and the common structure of potential solutions. Firstly, essential concepts related to knowledge representation and the definition of duplicates will be introduced.

A knowledge base is a collection of concepts related to a specific domain that can be stored in various formats, such as XML or RDF. These formats allow for the creation of a knowledge graph, which represents knowledge as a network of entities linked by relations, capturing their semantic relationships and enabling the discovery of new knowledge through implicit connections. Ontologies are a key component of knowledge bases, providing a formal and structured way of representing concepts and their relationships within a domain. They define the vocabulary and rules for describing entities and their relationships, allowing for interoperability between different knowledge bases and the sharing of knowledge across domains.

Duplicates in knowledge graphs occur when two nodes representing the same entity have different identifiers. Nodes that share the same attributes but differ in their identifiers are called exact duplicates. On the other hand, nodes that differ in some or all of their attributes but still refer to the same entity, are called near-exact or fuzzy duplicates. For example, consider the two nodes shown in Figure 1. Despite having identical attributes (e.g., title, location, price), they have different identifiers. Similarly, in Figure 2, the nodes show some attribute differences (e.g., title, price), but still refer to the same real estate. To capture this fact, it is important to establish an owl: sameAs relationship between these nodes as well, indicating they both represent the same entity. All these duplicates should be linked through the owl: sameAs relationship to indicate that they describe the same entity, forming the basis for detecting duplicates in knowledge graphs.

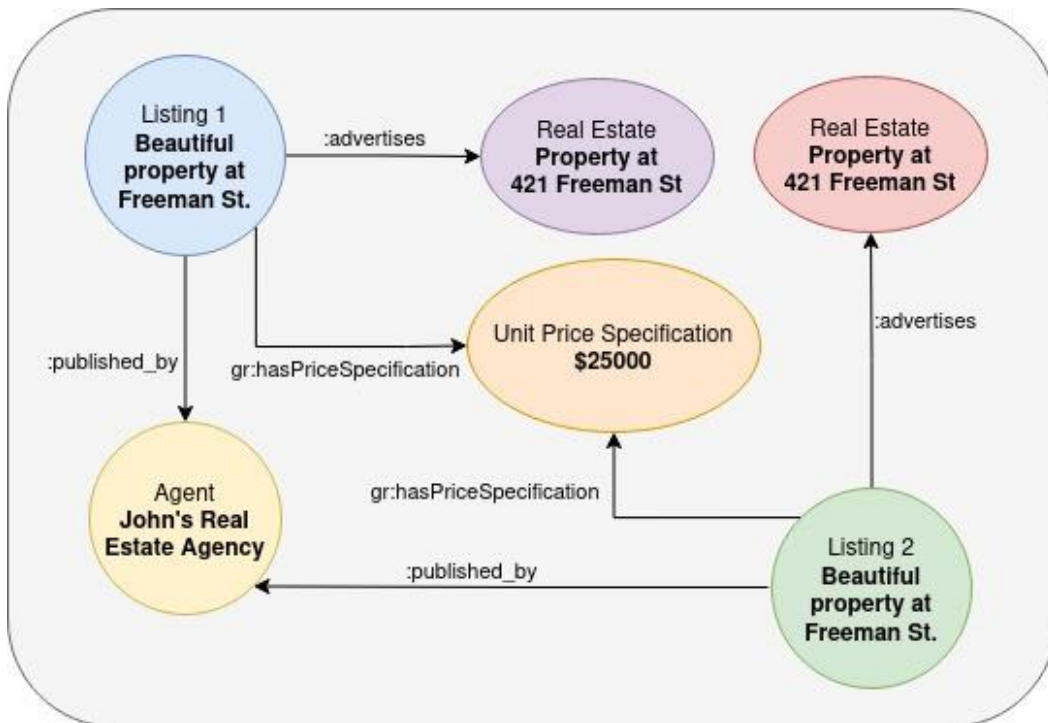


Fig. 1. Exact duplicates in a knowledge graph.

The problem of duplicate detection has different names depending on the context, such as record matching, record linkage, deduplication, entity resolution, and instance matching. Instance matching (IM) aims to discover duplicated entities between two knowledge graphs. Assi et al [1] defined it as follows:

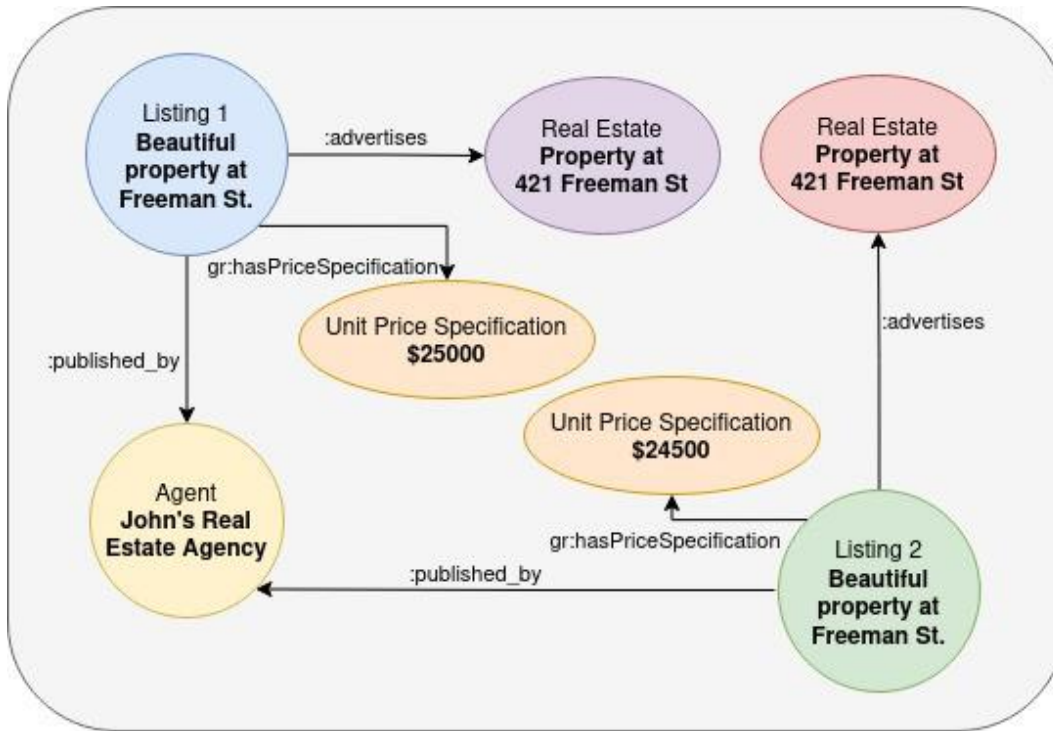


Fig. 2. Fuzzy duplicates in a knowledge graph.

Definition 1 (Instance matching). Given two sets of instances S and T belonging to two KBs (KB_1 and KB_2), the aim of IM is to discover the set M of identity links owl: sameAs, according to a chosen identity criterion, which are not already defined in the KBs. Formally, $M = \{(i_1, i_2) \mid (i_1, i_2) \in S \times T, \langle i_1, \text{owl: sameAs}, i_2 \rangle, \langle i_1, \text{owl: sameAs}, i_2 \rangle \notin KB_1 \cup KB_2\}$.

To detect duplicates within a knowledge graph, duplicate detection can be defined as an instance matching problem where the graph is compared to itself, i.e., where $KG_1 = KG_2$.

Detecting duplicates in knowledge graphs is complex and depends on the size of the graph and the nature of the duplicates. Detecting duplicates efficiently involves four steps: preprocessing, blocking, matching, and clustering. Preprocessing cleans and normalizes the data to remove syntactical and formatting differences. Blocking divides the data into smaller subsets to reduce the search space. Matching compares the attributes of candidate duplicates and determines whether they refer to the same entity. Clustering groups together duplicates that refer to the same entity.

Detecting and resolving duplicates is crucial to ensure trustworthy and reliable data in knowledge graphs. By improving the accuracy and effectiveness of duplicate detection in knowledge graphs, more informed decisions can be made and better outcomes can be achieved.

4 Knowledge Graph

This section will discuss the knowledge graph used in the context of the duplicatedetection system for real estate listings.

The knowledge graph is a critical component of the duplicate detection system, as it stores and organizes real estate listings from various sources and captures the semantic relationships between them. The real estate listings in the knowledge graph come from different websites and agents, resulting in a high level of heterogeneity in the information. This heterogeneity can make it challenging to detect duplicates due to the differences in data format and structure.

The knowledge base is stored in two different formats, CSV and RDF. CSV is a simple tabular format that is easy to work with, while RDF is a more complex graph-based format that allows for semantic relationships to be captured. The choice of format depends on the specific requirements of the duplicate detection strategy being evaluated.

The schema defines the variables used in the CSV and ensures that all listings have a consistent set of attributes. Additionally, an ontology is used to create the RDF graph and define relationships between the entities in the knowledge graph. The ontology is derived from established vocabularies and ontologies, such as GoodRelations¹, Schema.org², FOAF³, and RealEstateCore⁴ [8]. These resources provide a rich set of definitions and relationships leveraged to develop the knowledge graph. Specifically, entities such as RealEstateListing, RealEstate, and Agent are defined within the ontology, along with their corresponding relationships.

The attributes for the real estate listings include price, location, number of bedrooms, and square meters. These variables are standardized across all listings to facilitate comparison and detection of duplicates. The ontology, on the other hand, defines the relationships between entities in the graph, such as the relationship between a property and its location or between a property and its agent.

The knowledge graph example depicted in Figure 3 provides an illustration of how the ontology can be effectively used to capture the semantic relationships between different entities in real estate listings. For example, the graph demonstrates how a particular real estate listing can be associated with a specific real estate agency, such as John's Real Estate Agency. Additionally, the listing can have a relationship with its address, which is represented by the Feature entity. If two listings are advertising real estate located at the same address, they would both share a relationship with that instance. By effectively capturing and representing these semantic relationships, the knowledge graph plays a critical role in identifying potential duplicates by comparing not only the attributes of the listings themselves but also the context in which they exist.

- ¹ GoodRelations: <http://purl.org/goodrelations/>
- ² Schema.org: <https://schema.org/>
- ³ FOAF: <http://xmlns.com/foaf/0.1/>
- ⁴ RealEstateCore: <https://realestatecore.io/>

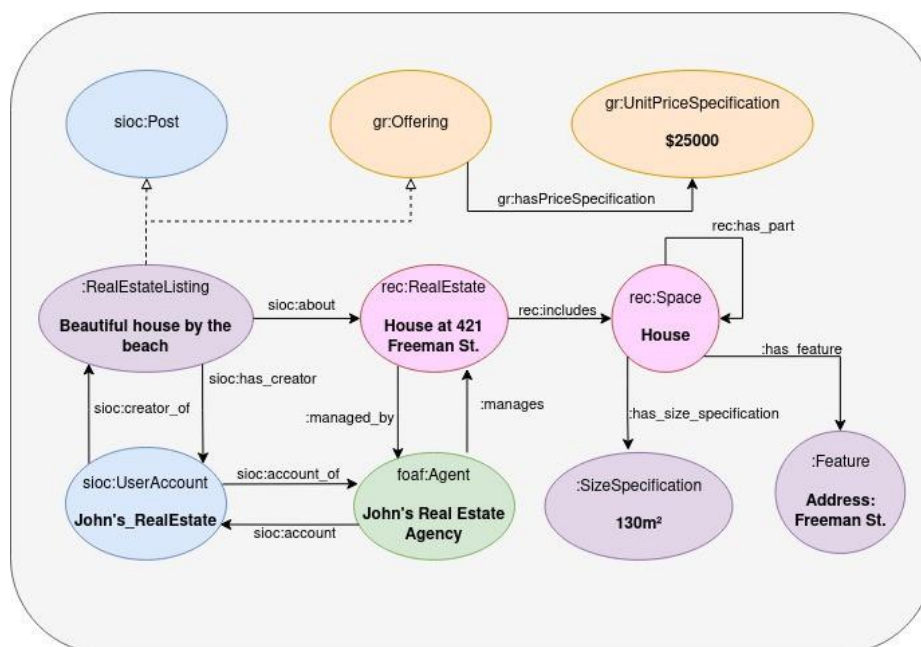


Fig. 3. Example knowledge graph featuring a real estate listing.

5 Metrics

This section defines the metrics used to evaluate the performance of duplicate detection algorithms. It will explain the insights provided by each metric and how they will be calculated.

Duplicate detection is a binary classification problem by definition, where the algorithm is provided with a pair of records and must classify them as either a match or a non-match. Each of the classifications done by the algorithm falls into one of the following categories:

- True Positive (TP): the algorithm correctly identifies a match between two records.
- False Positive (FP): the algorithm incorrectly identifies a match between two records.
- True Negative (TN): the algorithm correctly identifies that two records are not a match.
- False Negative (FN): the algorithm incorrectly identifies that two records are not a match.

The number of matches in each category will determine how well the algorithm performs overall.

Three metrics will be used for evaluation: precision, recall, and F-measure[6]. Precision is the fraction of true positive results among all positive results, thus measuring how accurate the algorithm is at classifying a pair of records as a match. It is defined as:

$$\text{Precision} = \frac{TP}{TP + FP} \quad (1)$$

Recall, on the other hand, is the proportion of true positives among all true positives. It is useful to describe how comprehensive the algorithm is in detecting duplicate pairs.

$$\text{Recall} = \frac{TP}{TP + FN} \quad (2)$$

For example, if a deduplication tool measures $Recall = 0.3$ and $Precision = 0.9$, then it means it is 90% accurate in its detection of duplicate records, but only identifies 30% of all duplicate records in the database.

The F-measure is a way to combine precision and recall into a single metric, defined as:

$$\text{F-measure} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} \quad (3)$$

6 Bayesian Approach

The following section presents the Bayesian strategy employed for duplicate detection, along with the tool chosen to implement the pipeline. Each component of the classification pipeline is described in detail, specifying how they contribute to solving the problem.

Many existing tools for record comparison in duplicate detection often rely on a single similarity function and treat all attributes uniformly as strings or character vectors. However, the evaluated approach suggests a departure from this conventional method by using a segmented matching process. This strategy advocates for segmenting the comparison based on the attributes of the listings being evaluated, assigning distinct weights to each segment to obtain an overall matching result.

To determine whether two listings are duplicates, the approach matches their respective attributes. Then, the two values of each attribute get compared to calculate a similarity score, which is assigned to that attribute. Finally, these scores are combined using Bayes' Theorem to generate an overall similarity score that represents the similarity between the two records. This approach allows for the computation of a probability, based on the available evidence, indicating the likelihood that the records are duplicates. By comparing this probability to a similarity threshold specified by the user, the determination of a match or non-match between the records can be made.

By adopting this approach, a more nuanced and comprehensive evaluation of record similarity is achieved, enabling the generation of probabilistic evidence to support the duplicate detection process. This methodology empowers users with greater control over the threshold for considering records as duplicates.

6.1 Duke

Duke⁵ is a powerful and versatile entity resolution engine written in Java. Although it was developed as part of the document archive system Sesam [7], Duke is domain-agnostic, meaning it can be used with data from any domain and structure.

While Duke operates on records as the data entities for deduplication, its output consists of links that represent owl: sameAs connections between duplicated records. Duke's duplicate detection process involves three steps, as described below.

First, Duke loads each record in the knowledge base and preprocesses its attributes using Cleaners. These Java objects implement the Cleaner interface and standardize the data by performing operations such as removing extra spaces, converting cases, and removing stop words.

Next, Duke employs a Database implementation to index each record. This allows it to call the function `findCandidateMatches(record)` for each one of the records, and match them with their most likely pair according to the index criterion.

After the blocking step, Duke matches each record pair by comparing their attributes using a Comparator. Duke's Comparator interface allows for the definition of custom comparison functions that assign similarity scores to record attributes, which are then aggregated into an overall score that represents the similarity between two records. Duke comes with several built-in comparators, including string distance measures like Jaro-Winkler and Levenshtein, and token-based measures like the Dice coefficient and Jaccard index. As with the other interfaces, Duke's Comparator interface can be extended to include custom comparison functions that consider domain-specific knowledge and characteristics.

To determine whether two records are duplicates, Duke computes a similarity score between them using the approach described for matching. This similarity score represents the likelihood of the records being duplicates. Subsequently, Duke compares the resulting probability with a user-defined threshold. If the probability exceeds the threshold, the records are classified as duplicates.

6.2 Configuration and Similarity Strategies

Detecting duplicates with this Bayesian approach involves employing a combination of similarity functions that consider the nature of the attributes being compared. Different similarity functions are used depending on the attribute type to ensure accurate matching. For instance, when comparing long strings like descriptions, the Levenshtein distance metric proves to be effective. This metric measures the number of character replacements required to transform one text into another. In the context of the real estate knowledge graph, each listing comprises several semantic properties associated with some real estate, such as the description, number of bedrooms, and location. The Bayesian approach leverages the concept of semantic similarity by composing the syntactic similarities among each specific property. This enables a comprehensive evaluation of the complex listings by integrating the results of individual attribute comparisons.

⁵ Duke: <https://github.com/larsga/Duke/>

In configuring the real estate deduplication strategy, an essential component is the utilization of a Lucene⁶ database during the blocking step. This step involves executing highly efficient full-text queries to identify potential duplicate candidates. Lucene's indexing and searching capabilities enable the strategy to effectively partition and search through the data, aiding in the identification of records with similar textual information.

In the preprocessing stage, the default cleaners were applied, primarily focusing on tasks such as removing excess spaces and converting text to lowercase. This preparation step ensures consistent and standardized data for further analysis.

During the matching process, a combination of specialized comparators was employed to handle different types of data. For long strings of text, such as descriptions or addresses, the Levenshtein comparator was utilized to measure the similarity between records. Shorter strings like district names were evaluated using the Jaro-Winkler comparator. To handle numerical attributes such as surface area and the number of rooms, dedicated numerical comparators were employed. These comparators use the ratio between the largest and smallest numbers, thus taking into account the numerical significance and proportionality of the attributes. Furthermore, a geolocation comparator was employed to assess the distance between two coordinates. If the distance exceeded 100 meters, the records were deemed completely apart, indicating a significant spatial separation. The specific values for the configuration are described in Table 1, which also shows the range of the similarity threshold selected for each variable. These represent the probability of a pair of records being duplicates, given that the values for that attribute are exactly the same or completely different, according to the comparator used. For instance, given that the titles of two real estate listings are exactly the same, the probability that the listings refer to the same entity is 70%. Similarly, if the titles are completely different, that probability reduces to 19%. The probabilities calculated for each attribute are the ones that get reduced to a single number using Bayes' Theorem.

The ranges for each attribute were selected based on how helpful they are in distinguishing between listings. For instance, if an attribute such as the title or price is very informative, it was given a wider range. This means that if two listings have the same value for that attribute, they are likely to be the same, and if they have very different values, they are likely to be different listings.

In the Bayesian approach used, probabilities closer to 0 or 1 are considered more important than those closer to 0.5. For example, the fact that two listings have the same covered surface value does not provide much information to determine if they are referring to the same or a different entity. However, if they have completely different covered surface values, they are more likely to be different listings. For that reason, the similarity threshold for the covered surface ranges from 0.09, which means that the probability of two listings being the same is 9%, to 0.55, which means the algorithm should not give it much importance. This range is set based on the degree of impact each attribute has on the similarity calculation.

⁶ Lucene: <https://lucene.apache.org/>

Table 1. Configuration used to detect duplicates in the knowledge graph.

Attributes	Comparator	Min. similarity threshold	Max. similarity threshold
Title	Levenshtein	0.19	0.90
Description	Levenshtein	0.39	0.70
Price	Numeric	0.05	0.80
Maintenance fee	Numeric	0.05	0.60
Property type	Exact	0.10	0.56
Age	Exact	0.07	0.50
Coordinates	Geoposition	0.20	0.80
Address	Levenshtein	0.09	0.90
District	Jaro-Winkler	0.39	0.51
Total surface	Numeric	0.10	0.67
Covered surface	Numeric	0.09	0.55
Land surface	Numeric	0.07	0.60
Amount of rooms	Exact	0.10	0.61
Amount of bathrooms	Exact	0.17	0.51
Amount of garages	Exact	0.10	0.60
Amount of bedrooms	Exact	0.10	0.60

7 Evaluation

This section will evaluate the performance of the duplicate detection strategy presented previously over a real estate listing knowledge base. The creation of a ground truth dataset using expert labelling will be explained first. Then, the results of the evaluation will be presented, followed by a discussion of the performances achieved by the Bayesian strategy.

7.1 Ground Truth Dataset Generation

The term ground truth refers to a dataset that contains reliable information used as a standard for evaluating different algorithms. The ground truth dataset used in this study was generated to measure the performance of the duplicate detection strategy presented earlier. It comprises two separate files: a knowledge base that contains all the information about each real estate listing, and a linkfile that specifies which listings are duplicates of one another.

To create this ground truth dataset, a team of experts began by using a web scraping tool to generate a knowledge base of real estate listings. To minimize the risk of missing any duplicates, the dataset was divided into smaller subparts based on the listings' proximity, as determined by their latitude and longitude. The experts manually reviewed each subpart to identify duplicates, comparing various attributes such as title, description, price, number of bedrooms, age, type of property, and address. They recorded the duplicates found in a spreadsheet, resulting in 3688 rows, each representing a set of listings that were duplicates of each other. Each set may contain two or more listings since multiple listings can represent the same property. The experts then removed any listings that were not labelled on the spreadsheet, resulting in a smaller knowledge base of 9333 listings.

To create the ground truth dataset, a script was developed to randomize the spreadsheet and split it in half. One half represented duplicates, while the other half represented non-duplicates. The first half was used to create a new knowledge base containing listings known to be duplicated, and the link file recorded which listings were duplicates of each other. For the second half, one random listing was selected from each set to be part of the new knowledge base, while the other listings were deleted. This ensured that the selected listings had no known duplicates in the new database.

7.2 Results

The performance of the duplicate detection strategy was evaluated using the ground truth dataset described above. Duke's output was compared with the links file in the ground truth dataset, and precision, recall, and F-measure were used as performance metrics.

The ground truth file contained 6543 records, and our strategy was able to find 3139 out of 4455 correct links, resulting in a recall of approximately 70.4%. However, it's important to note that the strategy also found 1554 links that were not in the ground truth, resulting in a precision of only 66.8%. Overall, that leads to an F-measure of 68.6%.

This finding is interesting and could be attributed to various factors. For instance, if the real estate listings were published by the same agency, it's possible that they used text templates for the description and title of the listing, leading to a higher number of false positives. In this case, it may be worth evaluating a different configuration with lower weights on these variables. Another approach could be to use a deduplication strategy that's more flexible and doesn't rely solely on Bayesian classification, which assumes that the probabilities given by each variable are independent. For example, such a strategy could assign a smaller weight to the description variable, since listings published by the same agent are likely to have similar descriptions.

Regarding the coordinates of the listings, it was found that real estate agents may not use the actual latitude and longitude of the property, either marking a point nearby or using the location of the agency itself. This can lead to many records having similar coordinate values, although they refer to different properties. Therefore, the fact that two coordinates are different or the same doesn't necessarily confirm or discard a match, respectively.

However, it cannot be confirmed that missed duplicates are actually wrong, as it is also possible that the strategy was able to find duplicate listings that the experts who created the ground truth dataset overlooked. Although this file can serve as a representative sample of the larger real estate listings knowledge base, identifying this many duplicates can be challenging, which may have led to errors in the ground truth dataset. This underscores the importance of refining the duplicate detection strategy for this domain to improve the accuracy of the results.

8 Conclusions and Future Work

This study assessed a duplicate detection strategy applied to a real estate knowledge graph compiled from various sources. The approach involved computing a probability score indicating the likelihood of two records being duplicates, allowing for the identification of implicit owl:sameAs links between them. The evaluation of this approach resulted in a precision of 66.8%, recall of 70.4%, and F-measure of 68.6%. By segmenting the record comparison process based on the considered attributes and assigning weights to each segment, the strategy effectively addressed the challenge of duplicate detection. Furthermore, the approach demonstrated its ability to cleanse the knowledge graph by eliminating noisy data, thereby enhancing the quality and reliability of the real estate information available for analysis within the domain.

The strategy was evaluated by employing a ground truth dataset created by a domain expert, which consisted of a real estate listing knowledge graph with duplicate and unique entities, as well as a links file that identified the missing owl:sameAs links in the dataset.

In the future, alternative configurations will be explored to enhance the overall accuracy of the presented approach and to identify more duplicates. Additionally, other techniques for detecting duplicate real estate listings, such as graph structural analysis, window sliding, graph embedding, and machine learning-driven solutions, will be experimented with.

References

1. Assi, A., Mcheick, H., Dhifli, W.: Data linking over RDF knowledge graphs: A survey. *Concurrency and Computation: Practice and Experience* **32**(19), e5746 (2020).
2. Barlaug, N., Gulla, J.A.: Neural Networks for Entity Matching: A Survey. *ACM Transactions on Knowledge Discovery from Data* **15**(3), 1–37 (Jun 2021). <https://doi.org/10.1145/3442200>
3. Batini, C., Scannapieco, M.: *Data Quality: Concepts, Methodologies and Techniques*. Springer Science & Business Media (Jan 2006).
4. Dong, X.L., Berti-Equille, L., Srivastava, D.: Integrating conflicting data: the role of source dependence. *Proceedings of the VLDB Endowment* **2**(1), 550–561 (Aug 2009). <https://doi.org/10.14778/1687627.1687690>, <https://dl.acm.org/doi/10.14778/1687627.1687690>
5. Elmagarmid, A., Ipeirotis, P., Verykios, V.: Duplicate Record Detection: A Survey. *Knowledge and Data Engineering, IEEE Transactions on* **19**, 1–16 (Feb 2007). <https://doi.org/10.1109/TKDE.2007.250581>
6. Ferrara, A., Lorusso, D., Montanelli, S., Varese, G.: Towards a Benchmark for Instance Matching. *The 7th International Semantic Web Conference* p. 13 (Jan2008)
7. Garshol, L.M., Borge, A.: Hafslund Sesam – An Archive on Semantics. In: *The Semantic Web: Semantics and Big Data*, vol. 7882, pp. 578–592. Springer, Berlin, Heidelberg (2013).
8. Hammar, K., Wallin, E.O., Karlberg, P., Hälleberg, D.: The RealEstateCore Ontology. In: Ghidini, C., Hartig, O., Maleshkova, M., Svátek, V., Cruz, I., Hogan, A., Song, J., Lefrançois, M., Gandon, F. (eds.) *The Semantic Web – ISWC 2019*, vol. 11779, pp. 130–145. Springer International Publishing, Cham (2019). https://doi.org/10.1007/978-3-030-30796-7_9, https://link.springer.com/10.1007/978-3-030-30796-7_9, series Title: Lecture Notes in Computer Science
9. Huaman, E., Kärle, E., Fensel, D.: Duplication Detection in Knowledge Graphs: Literature and Tools. arXiv:2004.08257 [cs] (Apr 2020), arXiv: 2004.08257
10. Huang, Y., Chiang, F.: Refining Duplicate Detection for Improved Data Quality. *TDDL/MDQual/Futurity@ TPD* (2017)
11. Koumarelas, I., Papenbrock, T., Naumann, F.: MDedup: duplicate detection with matching dependencies. *Proceedings of the VLDB Endowment* **13**(5), 712–725 (Jan2020).
12. Manku, G.S., Jain, A., Das Sarma, A.: Detecting near-duplicates for web crawling. In: *Proceedings of the 16th international conference on World Wide Web*. pp. 141–150. ACM, Banff Alberta Canada (May 2007). <https://doi.org/10.1145/1242572.1242592>, <https://dl.acm.org/doi/10.1145/1242572.1242592>
13. Mel, A., Kang, B., Lijffijt, J., De Bie, T.: FONDUE: A Framework for Node Disambiguation and Deduplication Using Network Embeddings. *Applied Sciences* **11**(21), 9884 (Jan 2021). <https://doi.org/10.3390/app11219884>, number: 21 Publisher: Multidisciplinary Digital Publishing Institute
14. Niu, J., Niu, P.: An intelligent automatic valuation system for real estate based on machine learning. In: *Proceedings of the International Conference on Artificial Intelligence, Information Processing and Cloud Computing*. pp. 1–6. ACM, Sanya China (Dec 2019). <https://doi.org/10.1145/3371425.3371454>, <https://dl.acm.org/doi/10.1145/3371425.3371454>
15. Zhu, H., Wang, X., Jiang, Y., Fan, H., Du, B., Liu, Q.: FTRLIM: Distributed Instance Matching Framework for Large-Scale Knowledge Graph Fusion. *Entropy* **23**(5), 602 (May 2021). <https://doi.org/10.3390/e23050602>
16. Zong, W., Wu, F., Chu, L.K., Sculli, D.: Identification of approximately duplicate material records in ERP systems. *Enterprise Information Systems* **11**(3), 434–451 (Mar 2017). <https://doi.org/10.1080/17517575.2015.1065513>, <https://www.tandfonline.com/doi/full/10.1080/17517575.2015.1065513>

Identification of Collaboration issues during the adoption of Scrum in Software development teams

Ingrith C. Muñoz¹, César A. Collazos¹ and Julio A. Hurtado¹

¹ IDIS Research Group, University of Cauca, 190001, Popayán, Colombia.
{ingrithc, ccollazo, ahurtado}@unicauca.edu.co

Abstract. Scrum is one of the most popular agile methodologies for software development, and its use in software development teams has been increasing in recent years. This increased use of Scrum is due in part to the benefits it offers, such as greater flexibility, greater collaboration among team members, and greater ability to adapt to changing project requirements.

Scrum is based on collaborative work among team members to achieve project goals, since team members are expected to work together interactively and collaboratively to achieve these goals. Due to the above, collaboration issues acquire a relevant role, since they can have a significant impact on the Scrum adoption process. This article presents the collaboration problems encountered in software development teams during the Scrum adoption process identified through semi-structured interviews conducted with leaders of software development teams adopting Scrum.

Keywords: *Scrum, Adoption, Collaboration, Issues.*

1 Introduction

Agile methodologies are a software product development approach characterized by its flexibility [1] [2]. One of the most used agile methodologies is Scrum [3], which is a framework for the agile management of software projects; the use of agile methodologies and specifically Scrum has become more and more frequent in small software development organizations [4] [5]. However, the lack of understanding of Scrum during its adoption has led to multiple drawbacks or obstacles [4], even when the team has received training in this framework [6]. Due to the above, the scientific community has tried to establish the determining factors in the adoption of Scrum [7], in order to serve as support in an adoption initiative.

Among the critical factors associated with Scrum adoption difficulties are those related to human behavior (personality, beliefs, culture, etc.), hereinafter the person factor [8] [7]; which is critical in the agile context considering that one of its principles promulgates: "Individuals and their interactions, about processes and tools. This implies that great importance should be given to factors such as communication, interaction, integration, organizational culture, companionship and collaboration [9].

Particularly, collaboration is an important factor in software development, since it is an effective means to achieve business objectives and increase performance, for this reason, collaborative practices acquire great value today for the software industry. Collaboration issues in software development teams can have a significant impact on the Scrum adoption process. In Scrum, collaboration is critical to team success, as team members are expected to work together interactively and collaboratively to achieve project goals [7]. If there are team collaboration issues, this can affect the effectiveness of Scrum, as team members may find it difficult to work together and achieve project goals. For example, if there is a lack of communication in the team, there can be coordination and cooperation problems, which can delay the development process. Similarly, if team members are not committed to the Scrum process, there may be a lack of motivation and enthusiasm, which can affect the quality of work and customer satisfaction. Therefore, it is important to address team collaboration issues to ensure a successful Scrum adoption.

Due to the above, there is a need to understand and identify the collaboration issues faced by software development teams during the adoption of Scrum.

This article presents in section 2 a state of the art and related works, in section 3 presents a study for the identification of collaboration factors that affect the adoption of Scrum and in section 4 the conclusions and future work.

2 Background

2.1 Agile methods

Agile methods are a set of techniques for project management and software development. They emerged as an effort to improve perceived and real weaknesses of conventional software engineering [8], but have also been extended to other types of projects. Agile methods comply with a number of principles and values stated in the agile manifesto [8]. In addition, agile methods are attentive to the project environment and stakeholders, offer a more open working environment and a much more flexible framework [1] [2]

Scrum

Scrum is an agile project management methodology specifically referred to software engineering [3]. Since it has a flexible adaptation to change, it is recommended for use in complex projects with changing or poorly defined requirements, where early and highly complex deliverables are needed. Scrum focuses on how the team members should work so that the system is flexible and adapts to constantly changing conditions, therefore, its operation is based on their roles, events, artifacts and associated rules.

Scrum adoption

Scrum adoption refers to the process of implementing and using the Scrum agile methodology in a software development team [10]. Scrum adoption may involve making changes to the organizational culture, training team members, implementing new tools and processes, and managing change at the organizational level [10].

The adoption of Scrum gives greater importance to people and their relationships, i.e., adoption must be a voluntary and conscious decision to internalize not only the Scrum process and methodology, but also the agile values and principles, so that the team's thinking changes, and to influence change in the organizational culture. Consequently, adoption generates a shared vision of the process, the agile values and principles, and the organizational culture.

2.2 Collaboration

Collaboration is working together to achieve a task or objective that would not be achieved individually under the same time, effort and cost constraints [11]. A collaborative team is a group of people with complementary skills who share tasks, resources, responsibilities and leadership, to achieve a common understanding that allows them to achieve a common goal [12], which is achieved if and only if all members achieve their individual goal [13].

Achieving collaboration in software engineering teams includes (1) adequate communication of requirements, design decisions, tasks, changes, among others; (2) group awareness of what each participant is doing and the current status of the project, their availability and knowledge; and (3) appropriate interactions to coordinate and perform tasks [14].

2.3 Existing work

L. V. Araujo and A. N. Castrillón [15] conducted a study of the main factors, problems, challenges, risks and situations that affect the adoption of Scrum through interviews with groups of experts in order to make a roadmap for the adoption of Scrum.

N. Khan, N. Ikram, and S. Imtiaz [7] focuses on the common problem of software development teams of having a large number of items in their backlog, also known as backlog. The article presents Scrum as a methodology that can help teams solve this problem and improve software development efficiency. The authors describe how Scrum helps teams prioritize and organize their backlog, and how teams can work together more effectively to achieve project goals. In addition, the author highlights the importance of communication and collaboration in the Scrum implementation process. The article concludes that adopting Scrum can be an effective solution to backlog problems and can improve the productivity and quality of the developed software. Overall, they propose a solution to backlog problems during Scrum adoption. The study focuses on a development team, and applies interviews for information gathering, in addition, it uses notes and project management tools for backlog monitoring.

Irum Inayat and Siti Salwah [16], propose a framework to study requirements-driven collaboration in distributed agile teams and determine the impact of their collaboration patterns during iteration, defining collaboration in terms of communication as information sharing among team members and awareness of each other's knowledge. The authors conducted two case studies on agile teams, whose information was collected through questionnaires, semi-structured interviews and observation. Furthermore, the authors conclude that the proposed framework may be useful for researching and improving collaboration in the future. Overall, the article provides valuable insight into collaboration in agile teams and how to improve it to achieve success in agile projects.

Batra, Weidong and Mingyu [17] explore the concept of collaboration in the context of agile software development. The authors define collaboration as an interactive process in which team members work together to achieve common goals and identify four key dimensions of collaboration in agile software development: communication, coordination, cooperation, and commitment. Each dimension is examined in detail, and factors that can affect collaboration in each area are highlighted. The authors also describe the benefits of collaboration in agile software development, including increased efficiency, improved product quality, and increased customer satisfaction. The authors note that there is little research examining the nature and dimensions of collaboration in the context of agile software development. Interview data collected from five software development outsourcing providers in China were used to develop this paper.

3 Qualitative Study on the collaborative aspects taken into account by development teams during Scrum adoption

In many organizations, drawbacks have been found when adopting Scrum as a framework in their projects [4], these are related to factors associated with human behavior such as culture, organizational, interaction, companionship, communication. etc [10]. Next, the main problems and situations that arise during the adoption of Scrum are consolidated according to the empirical perspective of work team leaders. These problems will make it possible to identify the collaborative aspects that the team recognizes and which of them represent weaknesses in both the collaborative factors and the methodology.

3.1 Design

Research question: What are the collaborative aspects that software companies identify during Scrum adoption and how well do they cover collaboration-related features?

Persons

The interviews are focused on systems engineers or similar, development team leaders in the context of the agile Scrum methodology in its adoption phase corresponding to small software development companies in the department of Cauca, Colombia.

At the time of carrying out this study, it was found that in the department of Cauca there are 95 software development companies, 36 of them are small software development companies, when contacting these companies, it was possible to determine that only 7 have equipment that is in process of Scrum adoption, of which 2 of them are in training and stated that they have no experience to report, for which only 5 companies can be studied. However, only 4 companies were interested in participating in this study and sharing their experience in adopting Scrum [18].

Table 1: Software development companies in the department of Cauca

Software development companies	95
Small software development companies	36
Small software development companies with Scrum adopter teams	7
Small software development companies with Scrum adopter teams with experience to report	5

3.2 Data collection method

The method of data collection in this study was semi-structured interview. Semi-structured interviews are an intermediate approach between standardized, mostly closed-ended surveys of individuals and free-participation sessions, with groups, are the semi-structured interviews [19].

The semi-structured interview is conducted conversationally with one respondent at a time, employing a combination of closed-ended and open-ended questions, often accompanied by backward follow-up questions (why and how). The dialogue can zigzag around agenda items, rather than rigidly adhering to literal questions as in a standardized survey, and can delve into entirely unanticipated issues. Semi-structured interviews are relaxed, engaging and, being face-to-face, can be longer than telephone surveys, although they last as long as focus groups. One hour is considered a reasonable maximum length for a structured interview to minimize fatigue for both interviewer and interviewee.

The practical steps for designing and conducting semi-structured interviews are: selecting and recruiting respondents, drafting the questions and the interview guide, applying the recommended techniques for this type of interview, and analyzing the information collected.

Questions

The questionnaire of this semi-structured interview was applied to two experts who participated as judges in the content validation and presented their opinion, which allowed refining the questions in order to obtain the most relevant information for this study. The interview consisted of 22 questions, divided into four categories: Scrum (3 questions), interaction (6 questions), communication (5 questions) and awareness (8 questions).

S	<ol style="list-style-type: none"> 1. How long have you been using the Scrum agile methodology? 2. What were the main problem(s) you encountered during the adoption of Scrum? 3. What problems do you see persisting from adoption to the present?
Interaction	<ol style="list-style-type: none"> 1. Could you describe how the team carries out its daily activities? 2. Could you describe how you conduct the meetings? 3. What benefits do you find in the way the activities are being developed? 4. Could you tell us about the problems related to the interaction among the participants during the development of the activities? What do you think are the causes? 5. Could you please detail the procedure to follow when encountering and reporting a problem? 6. On a scale of 1-5 with 1 being very little and 5 being very much, how do you consider the interaction between the team participants?
Communication	<ol style="list-style-type: none"> 1. Which digital channels and media do you use for communication? Which are the most indispensable? 2. What benefits do you find in the way your team's communications are going? What are its strengths? 3. What do you consider to be the most frequent problems during communication between participants? 4. What are the most common communication problems during meetings? What do you think are the causes? 5. On a scale of 1-5 with 1 being very little and 5 being very much. How do you consider the team's communication to be? Why?

Awareness	<ol style="list-style-type: none"> 1. How does the team achieve a shared and ongoing understanding of the problem, the product and progress of the project for the entire team? 2. How do you know at this point what the status of the project is and what issue each team member is currently resolving? 3. What are your responsibilities and those of your colleagues in software projects? 4. To what extent do you feel responsible for the success or failure of the product? Why? 5. Do you consider that each team member is responsible for the success or failure of the product? Why? 6. On a scale of 1-5 with 1 being very little and 5 being very much. How do you consider your ongoing knowledge of the product's state of progress and the current tasks that team members are addressing? 7. Could you describe problems related to unfamiliarity with aspects related to the product, the project or the work of the team members? 8. Could you describe some strategies for solving the problems identified in your work team during this interview?
-----------	---

Participants

The participants were four leaders of development teams belonging to small software development companies in the department of Cauca (Colombia), with ages between 36 - 51 years old, who voluntarily agreed to participate in the interview to deepen the collaborative aspects of Scrum during its adoption phase.

Regarding the gender of the participants, it can be highlighted that despite the fact that the study included a female participant, said participant is the leader of a larger team (15 people) and tends to behave as two teams (8 and 7 people).

Table 1: Participant information

Leader 1	Age	38
	Genre	Male
	Years of experience	10
	Equipment size	9 people
Leader 2	Age	51
	Genre	Male
	Years of experience	More than 20
	Equipment size	4 persons
Leader 3	Age	45
	Genre	Male
	Years of experience	13
	Equipment size	7 people
Leader 4	Age	36
	Genre	Female
	Years of experience	7
	Equipment size	15 people: Team divided into two, 8 -7 people

3.3 Results and data analysis

The WEFT QDA software tool [20], a qualitative research tool used for the analysis of textual data such as interview transcripts, documents and field notes, was used for the analysis of the interviews. This tool is free to use and has a public domain license and is available for Windows and Linux.

This tool allows: 1) to save the data in an organized way based on categories defined by the researcher; 2) to search and classify the data (interview transcription) in analytical categories established by the researcher; 3) to establish relationships from the data through searches, 4) to visualize the searches in the form of texts or double-entry tables [19]. Once the information from the interviews was integrated into the tool, 4 categories of analysis were generated (Interaction, Communication, Awareness and Scrum) that generate a linearity between the objectives of this article and the analysis of results.

The WEFT QDA tool classified text fragments into 4 categories:

- Interaction: Aspects related to interaction in the work team are addressed and analyzed, either with the customer or among members of the same team from the Scrum perspective.
- Communication: The tools, techniques and/or communication channels used by the work team to have a constant communication among them from the Scrum perspective are analyzed.
- Awareness: Aspects related to project awareness, roles and/or responsibilities within the project are addressed and analyzed from a Scrum perspective.
- Scrum: It deals with the Scrum methodology that could not be included in any of the previous categories.

The first three categories represent Collaboration, since, as mentioned above, they are necessary for an activity to be collaborative. This classification presented the following results: **Table 2:** *Text fragments by category*

Category	Number of text fragments
Interaction	19
Communication	40
Awareness	66
Scrum	13
Total	138

As a result of the interview, a list of activities was identified and grouped by frequency, i.e., how many teams coincided in mentioning the activity (1, 2, 3 or 4), and the activities developed by the teams were associated to collaborative activities and events or Scrum elements in order to identify activities within the methodology where the problems specified by the participants may occur.

The number of activities obtained in each category and the number of activities by frequency are presented below.

Table 3: *Activities vs. Frequency Collaboration*

Category	Number of activities	Frequency by activity
Interaction	3	3 Activities with frequency 4
Communication	5	4 Activities with frequency 3 1 Activity with frequency 2
Awareness	6	3 Activities with frequency 4 2 Activities with frequency 3 1 Activity with frequency 1

Table 4: Activities vs. Scrum Frequency

Category	Number of activities	Frequency by activity
Interaction	1	1 Frequent activity 4
Communication	2	2 Activities with frequency 4
Awareness	5	2 Activities with frequency 4 3 Activities with frequency 2

The activities with the highest incidence (frequency 4) reveal potential problems or risk factors present during adoption that may occur frequently in Scrum adopting teams. On the other hand, activities with lower incidence (frequency 1) reveal less common problems or risk factors.

Participants explicitly identified some of the potential problems they encountered during Scrum adoption based on their experience. Most of these potential problems are associated with the person factor evidenced by culture, beliefs, language, person-ality, and attitude.

For this work, risk is defined as the different factors that affect the correct adoption of Scrum. The main risks identified in this study were found from the text fragments (explicit statements of the participants) and in the associated activities. Below is the list of risks:

- Individual work thinking: some individuals prefer to work alone or develop their activities without relating to the work team.
- Downplaying the purpose of each Scrum event (lack of awareness): They do not know the purpose of the events and how they impact the process.
- Lack of participation or absence during sessions: Some team members do not wish to participate during sessions so they avoid being present, do not pay attention and/or present little or no participation.
- The person factor can affect the adoption process: the process can be affected by a person's personality, character, customs, beliefs, etc.
- Absence of collective ownership of information: team members are unaware of the progress of the process and the activities carried out by other team members.
- Lack of effective communication: Communication through multiple messaging tools or channels can lead to loss of information or confusion.
- Lack of cooperation and constant communication with the client: The customer is taken into account only at the end of the process.
- Lack of discipline in daily meetings: Meetings are extended, the objective is not met, the progress of the process is not clear.
- Lack of constant customer participation: The customer loses or has no interest so does not get involved in the process.
- Lack of understanding of agile values: team members have different understanding of agile values.
- Lack of understanding of meeting objectives: team members do not have the same perception of the purpose of Scrum meetings.

4 Conclusions and future work

Scrum is a popular agile project management methodology used in software development and other complex projects. Although Scrum focuses on collaboration among team members, there are several collaboration issues that can arise. The semi-structured interviews conducted provide insight into the potential issues that Scrum adopter teams from small software development organizations face during their adoption process regarding collaboration.

- A person who wants to work individually, with little or no interaction with other team members, and who is reluctant to change this behavior can threaten the adoption of Scrum, since individual attitudes are detrimental to teamwork and project development.
- The use of several communication channels does not guarantee good communication and can lead to confusion or information not being taken into account in a timely manner. Tools such as Skype, google, even WhatsApp, allow constant communication between team members. However, these tools do not offer a guide to manage communications.
- Team members have different understandings of agile events and values, which hinders the participation of some team members and in turn creates an absence of a shared understanding of the problem, the product, and the progress of the project.
- Some teams incorporate artifacts from traditional methodologies that they consider indispensable to the project, leading to an adaptation of these artifacts to the agile methodology. Teams are applying a modified adoption.
- The person factor, i.e., culture, beliefs, ethnicity, language, personality, attitude, etc. can affect the adoption process.
- Teams see the need for Scrum training of its members for a better adoption of the methodology. However, the adoption must be a voluntary and conscious decision to internalize not only the Scrum process and methodology, but also the agile values and principles, so that the team's thinking changes, and influence the change in the organizational culture.

In conclusion, collaboration issues in software development teams directly impact the Scrum adoption process, as they can cause team members to lose confidence in the Scrum process, which can make them reluctant to adopt the methodology in the future. In addition, they weaken one of the pillars of the methodology and hinder the adoption process, the identification of potential problems during the adoption process can be considered an alert that shallow adoption may result, although Scrum is adaptable, it requires commitment from all team members and a shared understanding of the process, so it is important to proactively address potential collaboration issues to ensure the successful adoption of Scrum.

As future work, it is planned to interview more software development companies adopting Scrum in order to identify more potential problems in a national and international context. Based on the previously identified problems, a series of recommendations will be made to strengthen collaboration during the adoption of Scrum and a case study to validate these recommendations. This in order to provide tools to Scrum adopter teams to mitigate the potential problems reported in this work.

References

1. Papadopoulos, G. Z.: Moving from Traditional to Agile Software Development Methodologies Also on Large, Distributed Projects. *Procedia - Social and Behavioral Sciences*, 175, 455-463. <https://doi.org/10.1016/j.sbspro.2015.01.1223>. (2015).
2. Rodríguez, C., & Dorado, R.: ¿Por qué implementar Scrum? *Ontare*, 3(1), 125-144. <https://doi.org/10.21158/23823399.v3.n1.2015.1253>. (2015).
3. Schwaber, K. SCRUM Development Process. En *Springer eBooks* (pp. 117-134). https://doi.org/10.1007/978-1-4471-0947-1_11. (1997).
4. González, J. J. M., Pardo, C., & Gómez, O. S.: Revisión sistemática acerca de la implementación de metodologías ágiles y otros modelos en micro, pequeñas y medianas empresas de software. *Revista Tecnológica - ESPOL*, 28(5). (2015).
5. VersionOne. *VersionOne 10th Annual State of Agile Report, VersionOne*, vol. 6, n° 2, pp. 2-8. (2006)
6. Ali, A., Rehman, M., & Anjum, M.: Framework for Applicability of Agile Scrum Methodology: A Perspective of Software Industry. *International Journal of Advanced Computer Science and Applications*, 8(9). <https://doi.org/10.14569/ijacsa.2017.080932>. (2017).
7. N. Khan, N. Ikram y S. Imtiaz.: SCRUM Adoption: A Solution to Backlog Problems. *Fifth Asian Conference on Information Systems*, At Krabi, Thailand. (2016)
8. J. López, R. Juárez, C. Huertas, S. Jiménez y C. Guerra.: Problems in the Adoption of Agile-Scrum Methodologies: A Systematic Literature Review. *4th International Conference in Software Engineering Research and Innovation (CONISOFT)*, Puebla, México. (2016).
9. C. Collazos, S. Ochoa y J. Mendoza.: Collaborative evaluation as a mechanism for improving evaluation of classroom learning. *Ingeniería e Investigación*, vol. 27, n° 2, pp. 72- 76. (2007).
10. Kanane, A. Challenges related to the adoption of Scrum. *Case study of a financial IT company*. UMEA University, Department of informatics. IT management master program, Umea, Suecia. (2014).
11. R. Owen Briggs, G. Kolfshoten, G.-J. De Vreede y D. L. Dean.: Defining Key Concepts for Collaboration Engineering. *Americas Conference on Information Systems Proceedings*, Acapulco, Mexico. (2006).
12. D. Mishra, A. Mishra y S. Ostrovska. Impact of physical ambiance on communication, collaboration and coordination in agile software development: An empirical evaluation. *Information and Software Technology*, vol. 54, n° 10, p. 1067–1078. (2012).
13. S. Werner Knoll, M. Hörning y G. Horton.: Applying a ThinkLet and ThinXel based Group Process Modeling Language: A Prototype of a Universal Group Support System. *Proceedings of the 42nd Hawaii International Conference on System Sciences*, Hawai. (2009).
14. C. Restrepo, L. Jiménez y J. A. Hurtado.: Integrating collaboration engineering with software process modeling: a visual approach. In *Proceedings of the XVIII International Conference on Human Computer Interaction* (pp. 1-2), Cancun, Mexico. (2017).
15. L. V. Araujo y A. N. Castrillón.: Una ruta de trabajo para la adopción de Scrum en pequeñas organizaciones en la industria del software. *Universidad del Cauca, Popayán, Cauca*. (2017).
16. I. Inayat y S. S. Salim.: A framework to study requirements-driven collaboration among agile teams: Findings from two case studies. *Computers in Human Behavior*, vol. 51, pp. 1367-1379. (2015).
17. Batra, Dinesh; XIA, Weidong; ZHANG, Mingyu. Collaboration in agile software development: Concept and dimensions. *Communications of the Association for Information Systems*, 2017, vol. 41, no 1, p. 20. (2017).
18. DANE, Geovisor Directorio de empresas 2023. <http://www.pressure.to/qda/>, last accessed 2023/05/27.
19. Laura Díaz-Bravo, Uri Torruco-García, Mildred Martínez-Hernández, Margarita Varela-Ruiz. La entrevista, recurso flexible y dinámico. *Universidad Nacional Autónoma de México, México D.F., México*. (2013).
20. University of Surrey, WEFT QDA. <http://www.pressure.to/qda/>, last accessed 2023/04/21.

A literature review to enabling strategic decision support systems for crisismanagement

Elandaloussi Sidahmed¹ and Zaraté Pascale ¹

¹ IRIT / Toulouse University

2 Rue du Doyen Gabriel Marty, 31042 Toulouse Cedex 9, Francesid.elandaloussi@irit.fr
Pascale.Zarate@irit.fr, web-page: <https://www.irit.fr/~Pascale.Zarate>

Abstract. This study aims to draw the main concepts in the literature concerning strategic decision support systems (SDSS) which have become widely incorporated in many specialized areas like logistics, medical, transport, trade, education...etc. However, this paper reports a literature review on decision support systems (DSS) for strategic crisis management. The paper deals with SDSS technologies to benefit from their advantages and integrates them into crisis management tasks. Moreover, managing a crisis effectively is an important component of deciding the level of crisis responsibility. In this paper we define a methodology to analyse a literature review. This analysis allows us to define four criteria to distinguish which SDSS is better.

Keywords: *Strategic Decision Support Systems, Crisis Management, Strategic planning, Strategic management.*

1 Introduction

Crisis management is described as the process by which different organizations and firms deal with a sudden emergency situation. The covid-19 crisis that began in early 2020 is a better example for now of crisis management. It has caused the most sudden and deepest global recession since the Second World War. Since this period, there exists a growing body of literature on crisis management. For instance, [1] presents a report that defines a thorough comparison and in-depth analysis of the emergency and recovery plans announced by European countries.

Our methodology is composed of two steps: first defining the research question consist of analysing the literature review for strategic decision support systems before classifying them and determining which SDSS will be better in similar situations. Although, strategic DSS is based to many DSS features. Some researchers have adopted a decision support system in their own activities in order to improve some technical aspects. However, other surveys have developed Strategical decision Support Systems. Despite the SDSS deployment complexity, previous research in several fields highlight the benefits of using SDSS such as industrial [2], supplychain management [3], medical domain [4], logistics management [5,6] especially in transport [7], crisis management [8]. The survey [9] provides some preliminary empirical evidence on what the most promising crisis strategies are to manage the COVID-19 crisis.

This article is divided into four main parts. The first part is devoted to discussing a comprehensive methodology for literature review. The second part is dedicated to outline a brief description of the most important studies in SDSS technologies. Third part is dedicated to analyze and classify the selected literature. The last part summarizes the paper and offers further insights for future studies.

2 Research Methodology

In this section we describe the research methodology adopted to collect conferences and journals articles that includes Strategic Decision support systems as keywords. However, we have used an advanced search for articles related to SDSS that appeared only in these 4 data sources: Web of knowledge, Science direct, Scopus and Google scholar by using the following keywords as important search criteria : "SDSS", "Strategic Decision Support Systems", "Crisis management", "SDSS architecture", "Strategic Management models", "Strategic planning models".

After that, we have filtered the papers to retain only those in English related to the SDSSs fields. Then, we scanned titles and abstract for each selected paper. Finally, we reviewed their citations and references.

Figure 1 shows an overview of the used searching and selecting papers methodology to demonstrate the various search efforts that are carried out. Furthermore, some findings papers are presented in this present study and the rest in an extension paper.

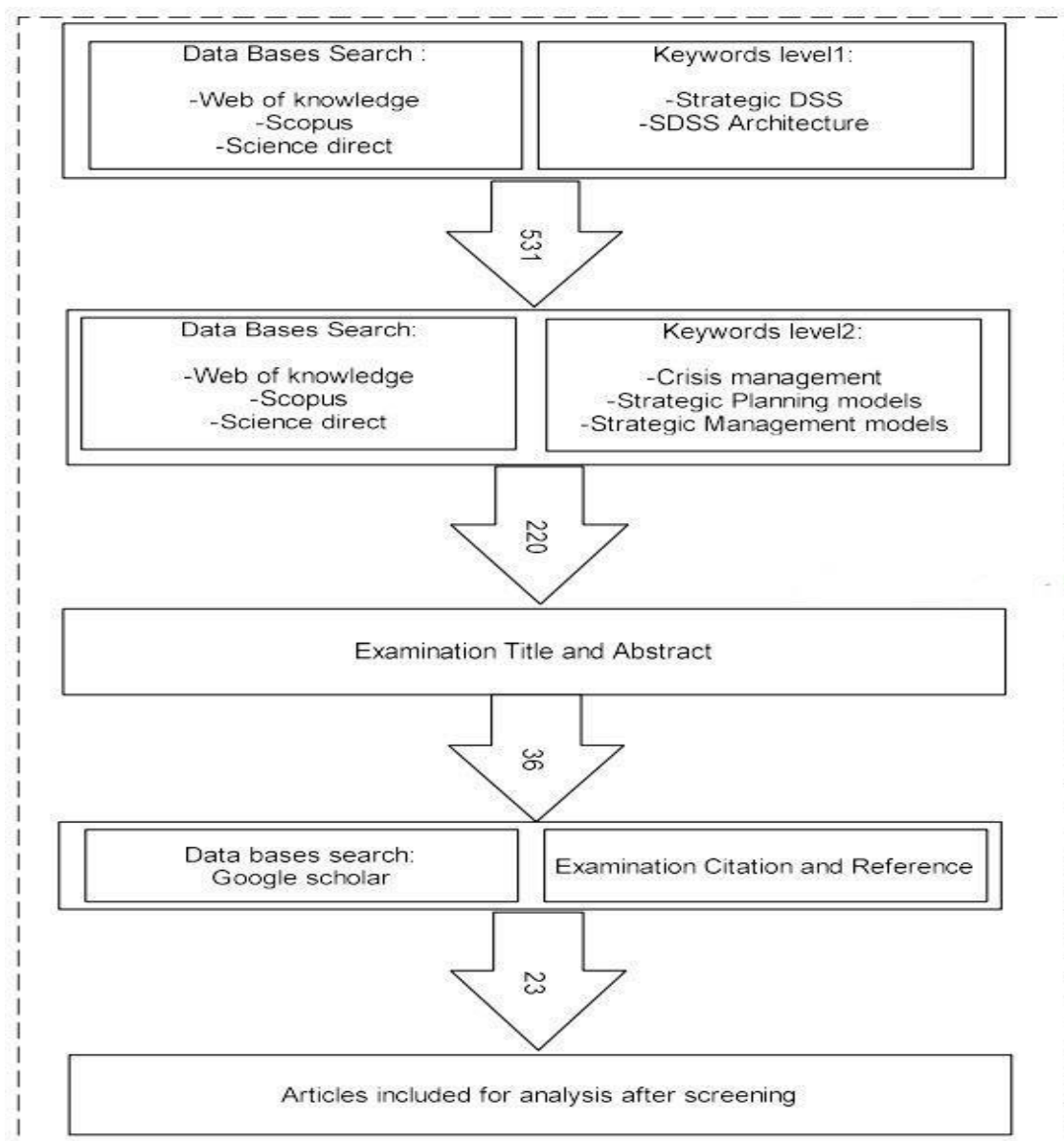


Fig. 1. Searching and selecting papers methodology.

3 Strategic Decision Support Systems

Decision support systems (DSS) are an important application of management information systems which apply different decision rules and models. [10] Consider a DSS as “an interactive and adaptable Computer Based Information System which helps non-organized management problems”.

Strategic DSS provide more explanatory information than DSS by explaining concepts and simulating thinking. According to [11] strategy has also been viewed as consisting of three processes: strategic planning [12], strategic thinking [13], and opportunistic decision making [14].

On the one hand, the technical aspects of DSS are widely considered by several surveys but strategic ones are very neglected. In fact, the combination of strategic actions with DSS is very promising and their literature is large and varies according to the SDSSs functionality. Although, without strategic methods the decision falters to achieve organizational goals.

On the other hand, previous research deals with the benefits of strategic DSS in many specialized areas (supply chain and logistics [15], the agrifood industry [16]). For instance, in order to achieve effective decision making in Logistics [15] proposes a strategic DSS framework which combines both the strategic management process and the Strategic Information Systems Planning (SISP) process. Another area of logistics where strategic DSS are used to handle storage systems based on the estimation of parameters is costs for racks and storage equipment [17]. Regarding [15] the existing strategic actions included in DSS are summarized in **Table1**.

Table. 1. The existing strategic actions including in DSS [15].

Strategic Actions including in DSS	References
Identification of environmental trends, internal trends and performance trends	[18]
Planning responses to the issues	
Assessing the impact and urgency of the issues, and prioritizing the issues	
Evaluation	[19]
Culture Analysis	
EnvironmentAnalysis	
SWOT Analysis	
Strategy Operating Subsystem	[20]
Goal-setting Subsystem	
EnvironmentalAnalysisSubsystem	

4 Discussion

After examination of the different selected SDSS that have been developed we could use a set of criteria to classify these systems: Single user based SDSS, Group user based SDSS, Methodology based SDSS and Software based

SDSS. Among the selected paper in SDSS some of them are dealt in this survey and classified according to these criteria as below:

Table. 2. Surveys classification according to the generated criteria.

Simple user based SDSS	Group user based SDSS	Methodology based SDSS	Software based SDSS
[21]	[19]	[2]	[22]
[23]	[15]	[24]	[11]
[26]	[20]	[28]	[29]
[30]	[31]	[15]	[19]
[32]	[33]	[34]	[20]
-	[35]	[17]	[31]
-	[36]	[36]	[33]

-	-	[37]	[26]
-	-	[10]	[38]
-	-	[39]	-
-	-	[15]	-
-	-	[20]	-

Based on this classification (See Table2), we can assume that SDSS methodology oriented are very largely covered. Then several SDSS software are designed and finally considering the low number of studies for Single decision makers, we can assume that SDSS is more a matter of Group of decision Makers rather than single Decision Maker. Furthermore, to make it very simple the application of all works indicated in this table will be described in detail in an extended study.

5 Conclusion

In this study, the existing literature on SDSS is reviewed and their comprehensive assessments are provided. Thus, managing a crisis efficiently is an important component for controlling and promptly preventing its negative consequences. In fact, to classify the selected literature four criteria have been introduced: Single user based SDSS, Group user based SDSS, Methodology based SDSS, Software based SDSS.

Based on this analysis, we can see that Strategic DSS is more a matter of group of decision Makers and that they are well supported more by methodologies rather than techniques. Otherwise, as future work, an extended paper of this work will include a detailed analysis of covid-19 pandemic management, will explain the different architecture of defined strategic DSS and we will demonstrate which SDSS is better to deal with each crisis.

References

1. Aussilloux, V., Mavridis, D., Baiz, A., Garrigue, M.: The effects of the covid-19 crisis on productivity and competitiveness. (2021).
2. Agostino, B., Massei, M., Sinelshnikov, K.: Enabling Strategic Decisions for the Industry of Tomorrow. Volume 42, Pages 548-553, doi.org/10.1016/j.promfg (2020).
3. Ye, F., Liu, K., Li, K., Lai, K., Zhan, Y., Kumar, A.: Digital supply chain management in the COVID-19 crisis: An asset orchestration perspective. Int. J. Production Economics 245 108396, (2022).
4. Shahparvari, S., Hassanizadeh, B., Mohammadi, A., Kiani, B., Lau, K., Chhetri, P., Abbasi, B.: A decision support system for prioritised COVID-19 two-dosage vaccination allocation and distribution. Volume 159, 102598, doi.org/10.1016/j.tre.2021.102598, (2022).
5. Kamariotou, M., Kitsios, F., Michael, A., Manthou, V.: Strategic Decision Support Systems for Logistics in the Agrifood Industry, Proceedings of 8th International Conference on Information and Communication Technologies in Agriculture, Chania, Greece (2017).
6. Henrik N., Thompson, A., Lindahl, P., Broman, G.: Introducing strategic decision support systems for sustainable product-service innovation across value chains, Proceedings of Sustainable Innovation, Malmö, Sweden, id: diva2:889466(2008)
7. Barfod, M., Salling, K.: A new composite decision support framework for strategic and sustainable

- transport appraisals, Volume 72, Pages 1-15, (2015)
8. Jaziri, R., Miralama, S.: The impact of crisis and disasters risk management in COVID-19 times: Insights and lessons learned from Saudi Arabia, *Medicine and Public Health* 18 ,100705, (2021).
 9. Klyver, K., Nielsen, S.: Which crisis strategies are (expectedly) effective among SMEs during COVID-19, doi.org/10.1016/j.jbvi.2021.e00273, (2021).
 10. Alyoubi, B.: Decision support system and knowledge-based strategic management, *Procedia Computer Science*, 65, 278-284, (2015)
 11. Belardo, S., Duchessi P., Coleman, J.: A strategic decision support system at OrellFussli, *Journal of Management Information Systems*, 10(4), 135-157, (1994).
 12. Weihrich, H.: The TOWS Matrix-A Tool for Situational Analysis. In *Long Range Planning- Vol. 15, N. 2*, (1982).
 13. Earl, J.J.: Information systems strategy formulation In R J. Boland and R A. Hirschheim (eds.), *Critical Issues in Information Systems Research*. New York: John Wiley, pp. 157, (1987).
 14. Ward, J., Griffiths, P.; Whitmore, P.: *Strategic Planning For Information Systems*. New York: John Wiley. (1990).
 15. Kitsios, F., Kamariotou, M.: Decision support systems and strategic planning: information technology and SMEs' performance. *International Journal of Decision Support Systems*, 3(1-2), 53-70, (2018).
 16. Hajimirzajana, A., Vahdat, M., Sadegheih A., Shadkam, E., El Bilali, H.: An integrated strategic framework for large- scale crop planning: sustainable climate-smart crop planning and agri-food supply chain management, volume 26, Pages 709-732, (2021)
 17. Accorsi, R., Manzini R., Maranesi, F.: A decision-support system for the design and management of warehousing systems, *Computers in Industry*, Vol. 65 No 1, pp. 175-186, (2014).
 18. Korpela, J., Tuominen, M.: A decision aid in warehouse site selection," *International Journal of Production Economics*, Elsevier, vol. 45(1-3), pages 169-180, August, (1996).
 19. Moormann, J., Lochte-Holtgreven, M.: An approach for an integrated DSS for strategic planning. *Decision Support Systems*, 10(4), 401-411, (1993).
 20. Yoo, S., Digman, L.A.: Decision support system: a new tool for strategic management', *Long Range Planning*, Vol.20, No. 2, pp.114-124.
 21. Dung, L., Giang, P.: "Strategic responses of the hotel sector to COVID-19: Toward a refined pandemic crisis management framework", Volume 94, 102808, (2021)
 22. Jiirgen, M., Lochte-Holtgreven, M., An approach for an integrated DS ~k.J for strategic planning , (1993).
 23. Saaty, T. L.: The analytic hierarchy process in conflict management". *International Journal of Conflict Management*, ISSN: 1044-4068, (1990)
 24. KyuLee, J., Lee H., ,Interaction of Strategic Planning and Short-term Planning: An Intelligent DSS by the Post-Model Analysis Approach , (1987)
 25. Belardo, S., Duchessi, P., Coleman, R. : A strategic decision support system at Orell Fussli. *Journal of Management Information Systems*, 10(4), 135-157, (1994).
 26. Hornby, R., Golder, P., Williams .A: "SDP: a strategic DSS. *Decision Support Systems*, 11(1), 45-51, (1994).
 27. Yoo, S., Digman, L., Decision support system: A new tool for strategic management". *Long Range Planning*, 20(2),114-124, (1987).
 28. Shahrooz, S., Hassanzadeh, B., Mohammadi, A., Kiani, B., Lau, K., Abbasi, B.: A decision support system for prioritised COVID-19 two-dosage vaccination allocation and distribution , (2022)
 29. P. Beraldi , A. Violi , F. De Simone A decision support system for strategic asset allocation, (2011)
 30. Cooper, R., Kaplan, R.: *The Design of Cost Management Systems: Text and Cases*.
 31. Korpela, J., Tuominen, M.: A decision support system for strategic issues management of logistics. *International journal of production economics*, 46, 605-620.
 32. Sprague, R., Carlson, E.: *Building effective decision support systems*. Prentice Hall Professional Technical Reference. (1982).
 33. Zviran, M.: ISSPSS: a decision support system for information systems strategic planning. *Information & management*, 19(5), 345-359, (1990)
 34. Fanti, M., Iacobellis, G., Ukovich, W., Boschian, V., Georgoulas, G., Stylios, C.: A simulation based Decision Support System for logistics management. *Journal of Computational Science*, Vol. 10, pp. 86-96, (2015)
 35. Finlay, P., Marples, C.: *Strategic group decision support systems a guide for the unwary*. *Long Range Planning*, 25(3), 98-107, (1992).
 36. Eden, C.: Perish the thought!. *Journal of the Operational Research Society*, 36(9), 809- 819. (1985)

37. Lee, M., Chen, I., Chen, R., Chung, C.: A target-costing based strategic decision support system. *Journal of Computer Information Systems*, 43(1), 110-116, (2002).
38. Thierauf, R.: User-oriented decision support systems: Accent on problem finding, *International Journal of Business Intelligence Research*. 9:1. (38-52), (1988).
39. Pietrzak, M., Jałosiński, K., Paliszewicz, J., Brzozowski, A.: A case study of strategic group map application used as a tool for knowledge management, *Journal of Computer Information Systems*, 55(2), 68-77, (2015).

***Rayuela*: a pluggable adaptive gamification approach for CLCS**

**Dalponte Ayastuy María^{1,2}, Alejandro Fernández¹,
and Diego Torres^{1,2}**

¹ Depto CyT, Universidad Nacional de Quilmes
Roque Saenz Peña 352, Bernal, Buenos Aires, Argentina. [/mdalponce@unq.edu.ar](mailto:mdalponce@unq.edu.ar)
LIFIA, CICPBA-Facultad de Informatica, Universidad Nacional de La Plata 50 y 120, La Plata,
Buenos Aires, Argentina.
alejandro.fernandez,diego.torres@lifia.info.unlp.edu.ar

Abstract. Collaborative location-based collecting systems (CLCS) is a particular case of collaborative systems where a community of users collaboratively collects data associated with a geo-referenced location and timestamp. This paper proposes *Rayuela* as a framework to leverage existing CLCS with adaptive game challenges through a cross-project approach. This tool allows incorporating a gamification engine in a transparent way to a set of CLCS-supported citizen science projects. The game challenges are generated and adapted considering the user's profile, the project's coverage goals, area priority configuration, and global system status. Additionally, the article describes a set of extension points to combine different challenge generation and challenge recommendation strategies.

Keywords: *Adaptive Gamification · Collaborative Location-based Collection Systems · Game Challenges · Citizen Science*

1 Introduction

Collaborative location-based collecting systems (CLCS) is a particular case of collaborative systems where a community of users collaboratively collects data associated with a geo-referenced location and timestamp. Particularly, the citizen science collecting systems that convene users to collect location-based data with a scientific goal, can be seen as CLCS. The contributions of the volunteers are known as *check-in tuples* with the structure $\langle position, timestamp, sample data \rangle$ [5].

Examples of CLCS-supported citizen science projects are AppEar project [3], GeoVin [4], or iNaturalist [12]. The collection task could require a mobile device to fulfill a survey form or capture multimedia (images, video, sound) being located in a specific area or point. In addition, this may need to be done at a particular time or time interval.

Citizen science projects depend on the sustained participation of many people, and gamification can facilitate the engagement and retention of users [10].

Gamification is the application of game elements and mechanics (like points, badges, leaderboards, storytelling, etc) in contexts where people's task is not simply to play [6]. Nevertheless, this paper will focus on game challenges, which are tasks or problems whose difficulty depends on the user's skills, abilities, motivation, and knowledge [11]; considering each collection task (or a set of them) as a game challenge and the areas of CLCS's territory as a game board. In addition, the combination of the spatial and temporal constraints of the collection tasks builds up an idea of difficulty and reward that are considered game mechanics. Despite the advances in gamification research and its demonstrated benefits related to user engagement and activity, these benefits are considered context-specific and not generalizable to all individuals [8]. The *one-size-fits-all* approach presents several limitations because of the users' different motivations, personalities, needs, and playing styles [2, 9, 1]. Currently, the research stream on adaptive gamification is considering how to dynamically adapt the game elements and mechanics each user needs in each context. The gamification approach could be adapted to the community members and the project's goals for better participation and sustained user engagement.

Assessing the impact of a given adaptive gamification strategy empirically presents several challenges. On the one hand, it is necessary to demonstrate that a scenario with adaptive gamification is better than one where gamification is not adaptive (and it is possibly also better than one without gamification). Therefore, the evaluation should develop two parallel case studies on a real-world CLCS. On the other hand, considering that CLCS can have support tools (digital or not), it is necessary to propose a mechanism that allows the application of an adaptive gamification approach transparently. Also, researchers need to be able to and with low effort change the key aspects of adaptive gamification to generate the various case studies (by tuning the challenge generation and the recommendation strategies).

With this objective in mind, this article proposes *Rayuela*, an approach to adaptively gamify existing CLCS citizen science projects as an external application. Moreover, it can be set up with more than one existing CLCS project, thus consolidating a platform of gamified projects. In addition, it offers extension points so researchers can plug in new game challenges generation and recommendation strategies. It allows managers of citizen science projects to monitor the progress of game players and assess the impact of gamification in their projects. The following sections are organized as follows. In Section 2 the approach is presented and the use cases are explained. Finally, Section 3 shares conclusions and future work.

2 Approach

An overview of the challenge-based adaptive gamification approach is provided by Figure 1. An existing citizen science project (gray box in the Figure) defines tasks for volunteers to complete, and is not yet gamified. The tasks are collection tasks characterized by time and space restrictions. Volunteers complete the tasks using the tools provided by the citizen science project managers (gray arrow), which can be a mobile application, a web application, or some non-digital technology.

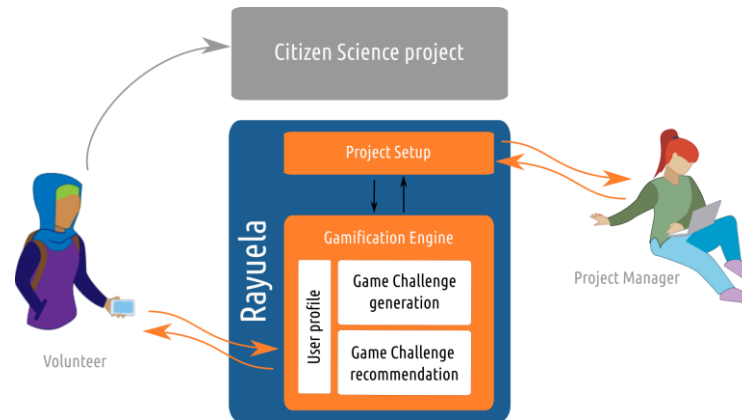


Fig. 1. Approach architecture

Rayuela platform adds an adaptive gamification layer to the citizen science project. Using it, the volunteer enriches her participation in the project, particularly by selecting in *Rayuela* the tasks to be completed and login them when finished. Playful activities are proposed to accomplish the project tasks based on criteria established by the project manager -who configures the spatial and temporal restrictions and task types-. In proposing activities, *Rayuela* also considers the profile of the volunteer (the history of solved and unsolved tasks and traveling behavior).

Rayuela architecture has two main modules, the project setup, and the game engine. The first one stores the configuration provided by the project manager. The second one has the function of providing game challenges to the volunteer. Likewise, the game engine has 3 extensible components. Firstly, the user profile gathers all the explicit and implicit information about the user's preferences, characteristics, and behavior. Secondly, the game challenge generator builds a set of game challenges by applying strategies based on the project manager configurations. Lastly, the game challenge recommender builds an ordered list of game challenges from the user's profile and the project's goals.

These components can be seen as framework extensions. For instance, the generation of the challenges can be done manually by the manager of the gamified project or automatically, applying an exhaustive strategy or taking into account both the user's historical behavior and the status of coverage of the project's goals. Also, the recommendation of challenges can be approached with different strategies, more or less computationally demanding to consider more or fewer aspects of the information retrieved about the user. For example, a recommendation system can consider multiple criteria, prioritizing tasks according to project goals, or also the spatiotemporal behavior of the user.

The framework use cases are presented through the interaction among the users and the framework, considering two user roles: on the one hand, the project manager role and, on the other hand, the volunteer role.

2.1 Project manager role interactions

As was previously mentioned in Section 2, this role is in charge of configuring the project setup that relates to the needs and objectives of the project. Each gamified project's manager must be able to describe the project, define task types (e.g. survey, photo or video capture, etc.), define work areas, define time constraints for tasks, and configure game challenges. Moreover, the definition of these aspects is a precondition for the generation/configuration of game challenges (as seen in the bottom timeline of Figure 2).

Project setup The setup of the adaptive gamified project needs the definition of the work areas, the time restriction and the task types.

Game Challenges Generation The generation of game challenges can be approached with different levels of suitability. The most straightforward approach is manual loading, with a choice of area, time restriction, type and the number of tasks. Another option is the exhaustive generation of game challenges resulting from combining all areas, time restrictions, and task types. Moreover, other approaches related to the project's coverage goals can be considered. A more complex approach can use as input, the coverage setting in terms of sample amount -by task type-, and the area priority.

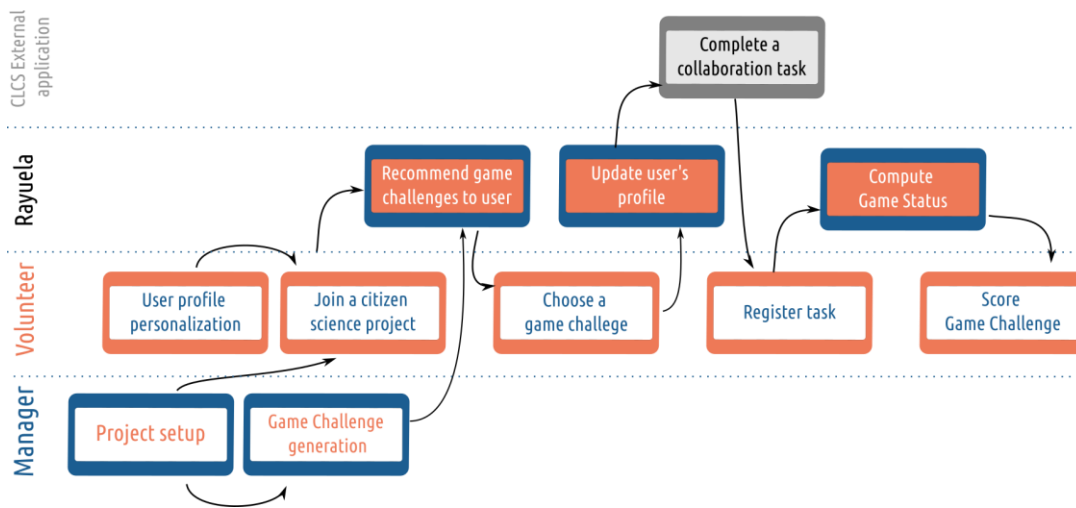


Fig. 2. Rayuela swimlanes

2.2 Volunteer role interactions

By interacting with *Rayuela* the volunteer can browse a set of game challenges that were generated from the project setup and recommended based on her profile. By choosing one game challenge from the list, she commits to performing the tasks requested by the challenge, which are carried out externally using the citizen science project. Each completed task must be logged in *Rayuela* to show progress in the game. In addition, the volunteer can express her opinion about the challenge she completed by providing a score.

The volunteer's gamified experience is composed of the interactions described in volunteer's swimlane of Figure 2.

User's registration and personalization The user registers to the application *Rayuela* and personalizes her profile. The profile personalization -the change of information, adjustments, or other parameters to a player's personal preferences, abilities, needs, or requirements [7]- is an important stage as it allows the user to take ownership of the platform. Her profile can include data about where she lives if she has a car, or how old she is. Personal information can be an input for the recommendation process.

Subscription to a project The user can browse the active citizen science projects in the platform and join one of them to enable the game challenges assignment (see Screen (A) in Figure 3). This can be seen as she wants to play that project's game.

Game challenge recommendation The user is offered a set of game elements based on her game profile and spatiotemporal behavior in relation to the CLCS. CLCS needs to optimize volunteers' work by combining the defined objectives for the CLCS with the completed tasks in the territory and the implicitly expressed volunteers' preferences. This recommendation stage can be seen as a multi-criteria recommendation since the game challenges list is built considering, on the one hand, what is needed to achieve the project objectives and, on the other hand, the user's behavior profile, preferences, and characteristics. See an example game challenge recommendation in Figure 3 B. Each game challenge sets a goal for the user, expressed by an area, a time restriction, and a type and number of tasks. Also, the game challenge presents a difficulty level and a reward to the user.

Game challenge assignment

The user chooses a game challenge from the recommended list, that represents a commitment to perform a certain task in a specific area and a specific time interval. By choosing an element from the ordered list, the user expresses her preferences. The underlying idea is to derive the user's preferences by having her choose a game element from a list sorted by the estimated user score. Assuming the example in Figure 3 (B), the user may select the third game challenge (with Area: *Reserva El destino*, time restriction: week days, task type: survey and 1 sample), which has the lowest score in the recommended list. This will trigger a profile update that will improve the recommendations.

Check-in registration The user moves to a sampling area and completes the sampling task, generating a check-in tuple through the **citizen science application**. The user does a collection task (that can be of different types -e.g. completing a scientific survey, capturing photos or videos, among others- using an external application (see the upper swimlane in Figure 2) for a specific citizen science project. The user registers the newly generated check-in through the *Rayuela* application. This action must take the data from the mobile device through the GPS and clock to ensure the user is located in the informed geographic coordinate and timestamp (as seen in Figure 3-C).

Game status feedback The user receives feedback from the gamification layer regarding the state of the game. The recently completed check-in can contribute to the progress in more than one game challenge within the project, and therefore the registration of the check-in should compute the progress in all possible active game challenges. Users must be aware of their game progress by means of some kind of gamification resource, e.g. a progress bar (see Figure 3-D).

Game challenge scoring The user can **give explicit feedback** about a completed game element through a multi-criteria scoring device. When the user completes a challenge (see bottom challenge in Figure 3-D), the possibility of rating the game challenge is enabled in three ways: through a choice between like and dislike, through an overall score for the game challenge (single criteria rating) or through a detailed score in several criteria: the area, the time restriction, the number of samples, the difficulty or the obtained reward (multi-criteria rating). These expressed preferences must be used to update the user profile and contribute to better recommendations.

3 Conclusion and Future work

Rayuela is a gamification platform that can be set up with several citizen science projects and is transparent to the collaboration tools they already have. It allows participating in more than one citizen science project, choosing among a project-specific list of generated and recommended game elements for the player, recording the completion of sampling tasks, and being aware of the progress in the game.

Citizen science projects may apply adaptive gamification to have greater participation from the general public and reach a higher project efficiency.

This tool allows incorporating a gamification engine in a transparent way to a set of CLCS-supported citizen science projects. It also allows materializing a platform of gamified projects that has several advantages. On the one hand, people's linkage for a project can be transferred to other projects, since people discover new projects through the platform. On the other hand, by joining a new project, the user does not start from scratch. This project capitalizes on the experience and knowledge the person acquired by participating in other projects.

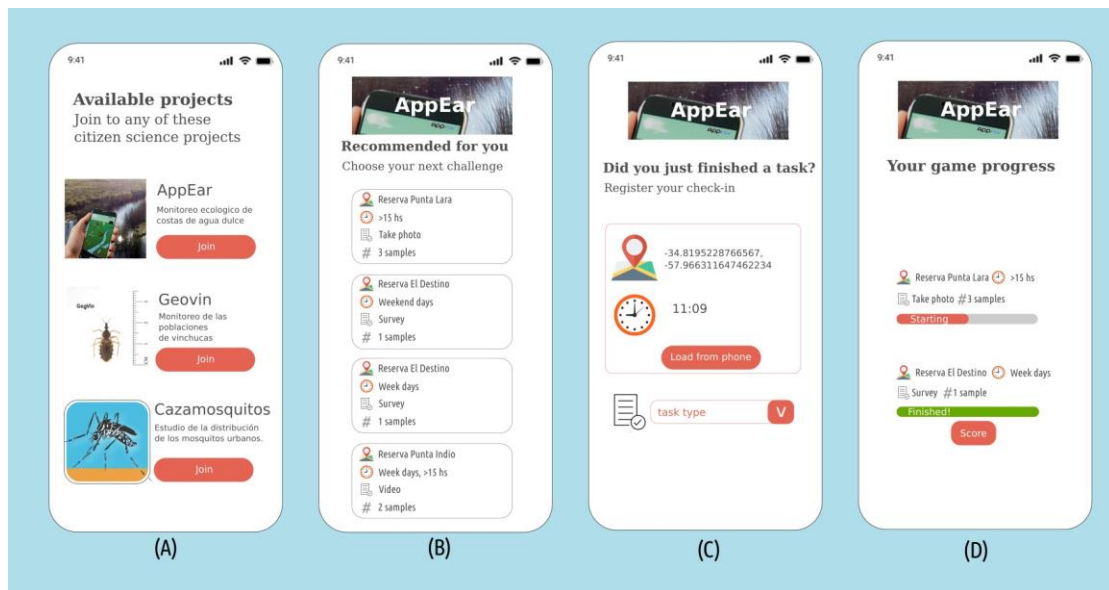


Fig. 3. *Rayuela* screens: gamified projects list (A), recommended challenges for user (B), check-in registration (C), and game layer feedback (D)

The challenge-based gamification approach considered the user's profile, the project's coverage goals, area priority configuration, and global system status to adapt the game challenges.

As further work, the inclusion of other game elements and mechanics will be analyzed.

Acknowledgements

This article publication is based upon the work of the Project *RUN Citizen science and co-creation for regeneration of urban rivers and mitigation of risks*, which has received funding from the CYTED Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo, under grant agreement No 420RT0008, <http://cyted.org/es/run>.

References

1. Busch, M., Mattheiss, E., Hochleitner, W., Hochleitner, C., Lankes, M., Fröhlich, P., Orji, R., Tscheligi, M.: Using player type models for personalized game design - an empirical investigation. *Interaction Design and Architecture(s) Journal* **28**, 145–163 (01 2016)
2. Bockle, M., Novak, J., Bick, M.: TOWARDS ADAPTIVE GAMIFICATION: A SYNTHESIS OF CURRENT DEVELOPMENTS. *Research Papers* (Jun 2017), https://aisel.aisnet.org/ecis2017_rp/11
3. Cochero, J.: Appear: A citizen science mobile app to map the habitat quality of continental waterbodies. *Ecologia Austral* **28**, 467–479 (08 2018)
4. Cochero, J., Patteri, L., Balsalobre, A., Ceccarelli, S., Marti, G.: A convolutional neural network to recognize chagas disease vectors using mobile phone images. *Ecological Informatics* **68**, 101587 (2022)
5. Dalponte Ayastuy, M., Torres, D.: Relevance of non-activity representation in traveling user behavior profiling for adaptive gamification. In: *Proceedings of the XXI International Conference on Human Computer Interaction*. Interaccion '21, Association for Computing Machinery, New York, NY, USA (2021). <https://doi.org/10.1145/3471391.3471431>, <https://doi.org/10.1145/3471391.3471431>
6. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From Game Design Elements to Gamefulness: Defining "Gamification". In: *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. pp. 9–15. MindTrek '11, ACM, New York, NY, USA (2011). <https://doi.org/10.1145/2181037.2181040>, <http://doi.acm.org/10.1145/2181037.2181040>, event-place: Tampere, Finland
7. Gobel, S., Wendel, V.: *Personalization and Adaptation*, pp. 161–210. Springer International Publishing, Cham (2016). https://doi.org/10.1007/978-3-319-40612-1_7, https://doi.org/10.1007/978-3-319-40612-1_7
8. Hamari, J., Koivisto, J., Sarsa, H.: Does gamification work? a literature review of empirical studies on gamification (01 2014). <https://doi.org/10.1109/HICSS.2014.377>
9. Heeter, C., Magerko, B., Medler, B., Lee, Y.H.: Impacts of forced serious game play on vulnerable subgroups. *Int. J. Gaming Comput. Mediat. Simul.* **3**(3), 34–53 (Jul 2011). <https://doi.org/10.4018/jgcms.2011070103>, <https://doi.org/10.4018/jgcms.2011070103>
10. Huotari, K., Hamari, J.: Defining gamification: a service marketing perspective. In: *Proceeding of the 16th international academic MindTrek conference*. pp. 17–22 (2012)
11. Iversen, S.: In the double grip of the game: Challenge and Fallout 3. *Game Studies* **12** (2012), http://www.gamestudies.org/1202/articles/in_the_double_grip_of_the_game
12. Nugent, J.: inaturalist, citizen science for 21st-century naturalists. *Science Scope* **41**(7), 12–13 (2018)

Named Entity Extraction in Requirement Specification: A Comparison

Luciana Tanevitch¹, Leandro Antonelli¹ and Diego Torres^{1,2}

¹ LIFIA, CICPBA-Facultad de Informática, UNLP, Argentina
{name.surname}@lifia.info.unlp.edu.ar

² Departamento de Ciencia y Tecnología, UNQ, Argentina

Abstract Software requirements specifications are often written in natural language, but extracting the main concepts from these documents can be challenging for computer agents. Named entity extraction is a task that involves recognizing entities in a text and linking them to a knowledge graph for disambiguation. In the domain of requirements engineering, applying this task can facilitate the representation and efficient management of complex information. This work compares different named entity extraction tools in the task of extracting entities from a requirements specification, considering technical aspects but also performance in terms of precision, recall, f1-score and accuracy.

Keywords: *Named Entity Extraction · Knowledge Graph · Requirements Engineering*

1 Introduction

Software Requirements Specifications (SRS) define in an unstructured way the requirements that a system should satisfy. Identifying and extracting the main concepts involved in a requirements specification could be useful for several automatic tasks, such as classification and categorization tasks [15]. However, computer agents are not able to process and immediately understand the content and information included in the natural language documents such as SRSs. Nevertheless, research lines introduced techniques to enable machines to convert text into information that can be processed automatically and to deal with the ambiguity of natural language [4,7].

Natural Language Processing (NLP) is a branch of Artificial Intelligence that enables computers to understand texts written in natural language [13,16]. NLP can be used to extract entities from a text using a specific technique called Named Entity Recognition (NER), which allows recognition and classification of named entities in a text into predefined classes [13]. As natural language allows for multiple meanings of the same concept, once entities are detected, it is necessary to disambiguate them to determine their true meaning according to the context in which they occur.

Knowledge Graphs (KG) allow structuring complex information in a proper format for computers [11]. Moreover, knowledge graphs are suitable for automatic data processing. Each node in the graph represents a unique concept, so linking a named entity in a text to its corresponding node enables meaning disambiguation. Al-Moslmi et al. propose a pipeline for transforming texts into KGs [3]. This process is known as Named Entity Extraction (NEE) and involves three main tasks: Named Entity Recognition (NER), Named Entity Disambiguation (NED) and Named Entity Linking (NEL).

The aim of this paper is to compare various NEE tools applied to requirements domain, considering core features (supported languages, KG used for linking and disambiguation technique), and their performance in requirements specification analysis (measured in terms of precision, recall, f1-score and accuracy). This paper is organized as follows. In Section 2, previous work in the literature in this area is introduced. Then, Section 3 defines the evaluation method including the metrics, the tools to be compared, and the data used for the evaluation. The results of the evaluation are described in Section 4. Finally, Section 5 summarizes the paper's conclusions and suggests some possible future work.

2 Related Work

Tedeschi et al. [21] evaluate NER-based strategies that help narrow down the performance gap between systems trained on limited data and those trained on massive corpora. This work is relevant to our study as it explores approaches for improving NER system performance. Checco et al. [6] develop a tool that detects named entities in fashion blogs and links them to a fashion ontology. While their focus is on a different domain, their work demonstrates the potential of entity extraction and linking techniques to discover domain-specific information. Hosseini and Bagheri [12] consider different entity linking techniques for detecting implicit entities, particularly in tweets. Given the potential ambiguity in requirement specifications, their approach is valuable for detecting and disambiguating implicit references. Vychezhanin and Kotelnikov [23] conduct a comparison of domain-independent NER tools, focusing on their characteristics and performance in recognizing specific entity types on pre-trained news datasets. Rizzo and Troncy [19] propose a framework for evaluating NEE tools based on named entity detection, entity type detection, and entity disambiguation criteria. Abdallaha et al. [2] build a framework for evaluating entity extraction tools applied to texts from various domains. Their criteria consider generic, technical, and advanced features, as well as efficiency measures.

3 Evaluation Method

3.1 Metrics

Core features Following Abdallaha et al. [2], we considered the following core features to evaluate the tools: supported language, disambiguation technique, and knowledge graph used.

The “language” feature specifies supported languages, crucial for multicultural requirements, as precise terminology may not translate well into intermediate languages. The “disambiguation technique” determines entity disambiguation based on context, impacting accuracy and performance. The tool’s “knowledge graph”, such as DBpedia and Wikidata, is essential for entity linking.

Performance According to 4 parameters are used for evaluating the performance: precision, recall, f1-score and accuracy.

Precision assesses the model's ability to accurately identify entities by considering both true positives and false positives. Recall measures the model's capability to identify all correct entities, with false negatives representing missed entities. The F1-score balances precision and recall. Accuracy verifies if the linked resource is contextually correct for the named entity.

3.2 Data

To choose the tools, a systematic review was conducted to gather various NamedEntity Extraction (NEE) tools from studies in a similar domain as this work. Additionally, we performed searches in public code repositories using the keywords *named entity extraction*, *named entity linking*, and *named entity disambiguation* to identify additional tools. Once collected, we began narrowing down the number of tools due to various reasons, such as tools no longer being hosted, unavailable source code, or limited entity recognition in the specific domain of application. Consequently, the tools we will analyze are those that are freely available, support the English language, and have shown promising results in preliminary testing using different small-scale requirement datasets (i.e., high entity detection rates). The selected tools for this work are: Wikifier [5], DBpedia Spotlight [17], Babelify[18], TagMe [10] and Spacy.

The following text was used as input for the tools, which it was written by a functional analyst, and describes a functional requirement that involves various technical concepts related to the named entity extraction pipeline: *Asa news agency, we want to automatically extract and disambiguate mentions of places, people, and organizations from newspapers. When a new article is submitted, the system should identify all named entities in the text and link them to their corresponding entities in a knowledge graph such as DBpedia or Wikidata. The system should use contextual information such as the surrounding words and the sentence structure to disambiguate entities that have multiple possible meanings. The system should also be able to handle entity coreference, where different mentions in the text refer to the same entity. The disambiguated entities should be stored in a structured format, such as RDF or JSON, for further processing and analysis. The system should be scalable and able to handle a large volume of articles in real-time. The accuracy of the system should be evaluated against a manually labeled dataset to ensure high precision and recall.* An expert analysis can be performed on this data to determine which entities should be automatically detected. It is called *ground truth* dataset because it contains the entities expected to be found by the evaluated tools, and is defined as follows: *news agency, places, persons, organization, article, system, named entity, newspapers, knowledge graph, DBpedia, Wikidata, contextual information, sentence structure, meanings, coreference, RDF, JSON, dataset, accuracy, analysis, precision, recall* A table with expected entities for each named entity is shown in this document.

4 Results

Table 2 compares the core features of the tools mentioned in Section 3. Since the tools support several languages, Babelify is the one with the most coverage. NER performance may differ in each language, as each uses a different model. They use machine learning approaches for disambiguation phase, each approach has its own advantages and disadvantages. The evaluated tools can link mentions to Wikidata, DBpedia or BabelNet. As these graphs do not describe specific concepts from the domain of software requirements, some named entities are likely to remain unlinked. The importance of BabelNet is that it includes lexical resources, which provide a foundation of structured knowledge, so using lexical and semantic knowledge could improve disambiguation tasks.

Table 3 compares the performance of the tools. DBpedia Spotlight achieves perfect precision and accuracy scores, but it has a low recall, indicating that it recognized fewer entities compared to the ground truth. On the other hand, Babelify recognized a high number of entities but suffered from low precision due to overfitting, detecting irrelevant concepts unrelated to the requirements domain. TagMe and Spacy kept a good balance in all their measures: they recognized almost all the expected words with a precision higher than 65%. Wikifier performs well in entity detection but has a lower recall compared to the aforementioned tools. TagMe obtained the higher results for the used data, but Spacy was so close: it has similar values for accuracy and precision, keeping the same recall. So we can say that even if TagMe had a good performance in requirement domain, better results could be obtained using a specific-domain knowledge graph for training Spacy.

5 Conclusions

The domain of requirements is highly ambiguous and complex. In order to enable automatic processing of requirement specifications, techniques such as knowledge graphs can be employed. Linking a concept to a knowledge graph allows for disambiguation of its meaning, and entity extraction tools can be used for this purpose. Evaluation results exhibit considerable variability in accuracy, precision, and recall. While precision and recall are useful metrics, accuracy is critical in determining whether the tool is performing correctly.

It is possible that the combination of different tools can improve results and provide greater accuracy in identifying requirement entities. Moreover, using a KG specific for requirements domain could help to solve the problem about those unrecognized entities due there is not an entry in a general-purpose KG.

This evaluation may be applied to different domains to determine whether the tools have the same ability to recognize entities as they do in the requirements domain. The next step could be to detect relationships between the identified entities in order to build a knowledge graph. A more specific study could be performed using massive datasets of the requirement domain, what it would require techniques for annotating massive data. In addition, automatic techniques should be considered to properly choose the expected entities for each of the knowledge graphs to be evaluated.

Table 2. Core features comparison results

Tool	Language	Disambiguation technique	Knowledge graph
DBpedia Spot-light	Among the supported languages are German, English, Spanish, French, Italian, and Portuguese. The full list can be found at [9]	They modeled DBpedia resource occurrences in a Vector Space Model (VSM) using a variant of the TF-IDF algorithm to weigh words based on their ability to distinguish between candidates for a given surface form. Therefore, they use cosine similarity to compare the similarity between context vectors and the context surrounding the surface form. In an improved version [8], they use a generative model to calculate the probability that a candidate is correct for a mention, which improves disambiguation accuracy, as well as time performance and required space	DBpedia
Wikifier	It supports around 100 languages among which are German, English, Spanish, French, Italian, Portuguese, and Chinese.	They build a bipartite graph where each node on the left represents mentions and each node on the right represents Wikipedia entries for those mentions. The graph is augmented by edges between concepts based on their semantic relatedness. They use the graph to calculate the PageRank score for each vertex, and after some iterations, they obtain the relevant concepts for each mention. A threshold value can be specified by the user to discard all candidates that were scored below that value.	The entities are linked to wikipedia pages, although the service includes information from the Wikidata ID and DBpedia URI in the response.
Babelify	Provides support for 271 languages [1], including English	They build a directed graph which relates mentions in the text with their Babel candidate. They construct a graph that relates mentions in the text to their possible candidates in Babel, also linking those candidates that are semantically similar. In this way, all possible interpretations are obtained for each mention, and the heuristic of the densest subgraph is applied to obtain the best candidate for a mention (based on lexical and semantic coherence), and thus arrive at the most coherent semantic interpretation.	BabelNet
TagMe	English, Italian and German	They apply a voting scheme where the goal is to reach a “collective agreement” on the real meaning of some mentions. To select the best candidate, they tested two algorithms: Disambiguation by Classifier (DC), which computes the probability of correct disambiguation for every candidate of a mention and then selects the best one; and Disambiguation by Threshold (DT), which selects the top n-best candidates. Then other works improved that initial version by topical classification and clustering [22] [20].	Entities are linked to a Wikipedia page, but Wikidata URIs could be inferred from them
Spacy	English, although a model can be trained to recognize other languages	Starting from a defined knowledge graph, candidates for entities can be generated. Then, a machine learning model selects the most suitable candidate. The power of Spacy lies in the fact that each component is customizable, allowing the user to improve accuracy by combining techniques for candidate generation and scoring.	It allows configuring the desired knowledge graph, although in this work, an implementation with Wikidata was used.

Table 3. Performance evaluation results

Tool	Accuracy	Precision	Recall	F1-score
DBpedia Spotlight	1	1	0.27	0.42
Wikifier	0.85	0.66	0.63	0.65
Babelfy	0.9	0.39	0.95	0.55
TagMe	0.75	0.71	0.9	0.80
Spacy	0.68	0.66	0.9	0.76

References

1. (Apr 2015), <http://babelfy.org/javadoc/it/uniroma1/lcl/jlt/util/Language.html>
2. Abdallah, Z.S., Carman, M., Haffari, G.: Multi-domain evaluation framework for named entity recognition tools. *Computer Speech & Language* **43**, 34–55 (May 2017)
3. Al-Moslemi, T., Gallofré Ocaña, M., Opdahl, A., Veres, C.: Named Entity Extraction for Knowledge Graphs: A Literature Overview. *IEEE Access* **8**, 32862–32881 (Feb 2020)
4. Antonelli, L., Delle Ville, J., Dioguardi, F., Fernández, A., Tanevitch, L., Torres, D.: An iterative and collaborative approach to specify scenarios using natural language. In: *Workshop on Requirements Engineering (WER22)*, (Modalidad virtual, 23 al 26 de agosto de 2022) (2022)
5. Brank, J., Leban, G., Grobelnik, M.: Annotating documents with relevant wikipedia concepts. *Proceedings of SiKDD* **472** (2017)
6. Checco, A., Demartini, G., Löser, A., Arous, I., Khayati, M., Dantone, M., Koopmanschap, R., Stalinov, S., Kersten, M., Zhang, Y.: Fashionbrain project: A vision for understanding europe’s fashion data universe. *arXiv preprint arXiv:1710.09788*(2017)
7. Corral, A., Sánchez Crespo, L.E., Antonelli, L.: Building an integrated requirements engineering process based on intelligent systems and semantic reasoning on the basis of a systematic analysis of existing proposals. *JUCS - Journal of Universal Computer Science* **28**, 1136–1168 (11 2022)
8. Daiber, J., Jakob, M., Hokamp, C., Mendes, P.N.: Improving efficiency and accuracy in multilingual entity extraction. In: *Proceedings of the 9th International Conference on Semantic Systems*. pp. 121–124. ACM, Graz Austria (Sep 2013) **7**
9. DBpedia Spotlight - Shedding light on the web of documents: <http://www.dbpedia-spotlight.org/faq> (accessed March 8, 2023)
10. Ferragina, P., Scaiella, U.: TAGME: on-the-fly annotation of short text fragments (by wikipedia entities). In: *Proceedings of the 19th ACM international conference on Information and knowledge management*. pp. 1625–1628. ACM, Toronto ON Canada (Oct 2010)
11. Hogan, A., Blomqvist, E., Cochez, M., d’Amato, C., de Melo, G., Gutierrez, C., Gayo, J.E.L., Kirrane, S., Neumaier, S., Polleres, A., Navigli, R., Ngomo, A.C.N., Rashid, S.M., Rula, A., Schmelzeisen, L., Sequeda, J., Staab, S., Zimmermann, A.: Knowledge Graphs. *ACM Computing Surveys* **54**(4), 1–37 (May 2022), *arXiv:2003.02320* [cs]
12. Hosseini, H., Bagheri, E.: From Explicit to Implicit Entity Linking: A Learn to Rank Framework. In: Goutte, C., Zhu, X. (eds.) *Advances in Artificial Intelligence*, vol. 12109, pp. 283–289. Springer International Publishing, Cham (2020), series Title: *Lecture Notes in Computer Science*
13. Khurana, D., Koli, A., Khatter, K., Singh, S.: Natural language processing: state of the art, current trends and challenges. *Multimedia Tools and Applications* **82**(3), 3713–3744 (Jan 2023)
14. Malik, G., Cevik, M., Bera, S., Yildirim, S., Parikh, D., Basar, A.: Software requirement specific entity extraction using transformer models. *Proceedings of the Canadian Conference on Artificial Intelligence* (May 2022)
15. Malik, G., Cevik, M., Khedr, Y., Parikh, D., Başar, A.: Named Entity Recognition on Software Requirements Specification Documents. *Proceedings of the Canadian Conference on Artificial Intelligence* (Jun 2021)
16. Martinez, A.R.: Natural language processing. *Wiley Interdisciplinary Reviews: Computational Statistics* **2**(3), 352–357 (2010)

17. Mendes, P.N., Jakob, M., Garc'ia-Silva, A., Bizer, C.: DBpedia spotlight: shedding light on the web of documents. In: Proceedings of the 7th International Conference on Semantic Systems. pp. 1–8. ACM, Graz Austria (Sep 2011)
18. Navigli, R., Ponzetto, S.P.: Babelnet: Building a very large multilingual semantic network. In: Proceedings of the 48th annual meeting of the association for computational linguistics. pp. 216–225 (2010)
19. Rizzo, G., Troncy, R.: NERD: Evaluating Named Entity Recognition Tools in the Web of Data (2011)
20. Scaiella, U., Ferragina, P., Marino, A., Ciaramita, M.: Topical clustering of search results. In: Proceedings of the fifth ACM international conference on Web search and data mining. pp. 223–232. ACM, Seattle Washington USA (Feb 2012)
21. Tedeschi, S., Conia, S., Cecconi, F., Navigli, R.: Named Entity Recognition for Entity Linking: What Works and What's Next. In: Findings of the Association for Computational Linguistics: EMNLP 2021. pp. 2584–2596. Association for Computational Linguistics, Punta Cana, Dominican Republic (Nov 2021)
22. Vitale, D., Ferragina, P., Scaiella, U.: Classification of Short Texts by Deploying Topical Annotations. In: Baeza-Yates, R., de Vries, A.P., Zaragoza, H., Cambazoglu, B.B., Murdock, V., Lempel, R., Silvestri, F. (eds.) Advances in Information Retrieval. pp. 376–387. Lecture Notes in Computer Science, Springer, Berlin, Heidelberg (2012)
23. Vychezhnanin, S., Kotelnikov, E.: Comparison of Named Entity Recognition Tools Applied to News Articles. In: 2019 Ivannikov Ispras Open Conference (ISPRAS). pp. 72–77 (Dec 2019)

Formulation of a model to determine current and potential areas (*Persea americana* Mill) of Hass variety avocado crops, in the department of Risaralda, based on edaphoclimatic variables and fruit quality.

Gloria Edith Guerrero, Julio César Chavarro, Cesar Manuel Castillo, César Augusto Jaramillo, Juan Pablo Arrubla and Andrés Alfonso Patiño

¹School of Chemistry, Universidad Tecnológica de Pereira, Colombia.

²Faculty of Engineering, Universidad Tecnológica de Pereira, Colombia.

*E-mail(s) Authors: gguerrero@utp.edu.co; jchavar@utp.edu.co; cesar.castillo@utp.edu.co; swokosky@utp.edu.co; juanpablo77@utp.edu.co; andrespatinomartinez@gmail.com;

Abstract

Agriculture is one of the fundamental pillars of any worldwide population, and the proper management of information allows timely decisions to move any company forward. National and departmental government agencies support agricultural sectors that emerge as an excellent opportunity to increase production levels and product commercialization [1], such as the Hass avocado (*Persea americana* Mill) crop. One of the challenges facing this type of crop is to find potential planting and productivity zones to contribute to technological developments in the agricultural sector, benefiting the Hass avocado growers of the department of Risaralda. Therefore, this study proposes the formulation of a model to determine current and potential cultivation areas of Hass avocado (*Persea americana* Mill) in the department, based on edaphoclimatic variables and fruit quality, taking advantage of current trends in precision agriculture, including techniques derived from Machine Learning, such as the use of Supervised Learning algorithms, among which is Random Forest.

Keywords: *Persea americana* Mill, Machine Learning, Random Forest, potential crop areas

1 Introduction

Food security has become a pressing challenge due to rapid population growth, climate change and water scarcity, especially in developing countries [2]. Nowadays, modifications and adaptations are made in agricultural practices to improve soil fertility and the different climatic changes that are currently occurring. Therefore, it is necessary to evaluate the environmental impacts of agriculture in terms of water, nutrients (soil) and atmospheric components [3].

Avocado (*Persea americana* Mill) Hass variety is the most common commercial avocado crop in the world due to the number of essential nutrients and important phytochemicals [4]. This fruit is grown in Colombia, where the Hass avocado production system has recently increased due to the excellent economic opportunities and the high unsatisfied domestic demand [5]. The Hass avocado-producing departments are Tolima, Antioquia, Caldas, Santander, Bolívar, Quindío, Cesar, Valle del Cauca, Risaralda, and Cundinamarca; in Risaralda, avocado is grown in 13 of the 14 municipalities [6]. To address the problems of avocado cultivation, information and communication technology (ICT) approaches are adopted, such as precision agriculture or real-time crop data collection [7]. In this sense, ICT topics for the agricultural sector include procedures for the digital management of geographic information on crops, decision-making systems for mechanizing processes based on georeferencing, and epidemiological early warning information systems, among others [7] [8].

However, difficulties are observed with crop management given the variability in soil and edaphoclimatic conditions of the department. This situation causes effects such as heterogeneity of fruit quality, besides the lack of scientific work to understand the behavior of the crop in the region. This study proposes to formulate a model to determine current and potential zones of Hass avocado (*Persea americana* Mill) cultivation in the department of Risaralda, based on edaphoclimatic variables and fruit quality, using the current trends of precision agriculture and machine learning, to contribute to technological developments in the agricultural sector, benefiting the Hass avocado growers of the department.

2 Bibliographic Review

Machine learning (ML) is an important decision support tool in fields such as crop yield prediction, including supporting decisions on what agricultural products to grow and what to do during the crop growing season; therefore, several machine learning algorithms have been applied to support research aimed at crop yield prediction or suggestion, where the most commonly used characteristics are temperature, precipitation and soil type [9]; In that sense, the different uses of the data obtained from the soil, such as the selection of the dataset for training, as well as the choice of soil environmental covariates, could boost the accuracy of automatic learning techniques [10]. One of the tools used within automatic learning are the crop-oriented recommendation systems where, based on provided variables, a model is created to predict or suggest which crop can be cultivated; to establish this, the models use historical data, such as climatic data (temperature, humidity, pH, rainfall) and fertilizer values (nitrogen, potassium, phosphorus) [11]. Machine learning employs methods such as supporting processes in charge of data analysis [12]. In [13] it is mentioned that different Artificial Intelligence techniques have been proposed and among these techniques that are part of Precision Agriculture, more specifically in the fields of crop recommendation systems, it is observed that algorithms such as k nearest neighbors (KNN), similarity-based models, set-based models, neural networks, among others, are included. These algorithms consider several external characteristics, such as meteorological data, and others, such as the soil profile, to provide the best recommendations, by examining the data, the most important attributes are obtained using techniques such as principal component analysis (PCA) and linear discrimination analysis (LDA). These extracted features are used to train models such as Naïve-Bayes (NBC), Random Forest, KNN; using training data and the performance is evaluated on test data using techniques such as cross-validation, RMSE or accuracy. Reliable predictions of crop yields are difficult for the development of agriculture; crop production varies according to different climatic conditions, having conditions such as dry periods and increasing temperatures; these forces strengthen the need for analysis of crop production in different climatic conditions, in this sense, [14] analyzes the automatic learning method, the Random Forest supervised algorithm can analyze the growth of crops concerning the current climatic conditions and biophysical change. Similarly, in [10], the ability of the Random Forest algorithm to predict soil classes from different training data sets and extrapolate such information to a similar area was evaluated.

Another aspect to consider is the usage of automatic learning models/algorithms and their possible applications to geospatial data, where special attention is given to the models used that are based on artificial neural networks (multilayer perceptron, general regression neural networks, self-organizing maps), statistical learning theory (support vector machines) [15], geo-statistical techniques such as Ordinary Kriging [16], or algorithms such as Random Forest Spatial Interpolation (RFSI) [17].

Obtaining the visualization of different crops and their associated characteristics, high resolution yield maps are used, which are an essential tool in modern agriculture, and these are obtained by spatial interpolation, however, spatial interpolation is generally performed using methods that can be computationally demanding [18]; therefore, some works have been carried out to explicitly take into account the spatial component in machine learning, where observations on the prediction location are included, performed using Random Forest Spatial Interpolation, comparing it with deterministic interpolation methods, such as ordinary kriging, regression kriging, Random Forest and Random Forest for spatial prediction (RFsp) where it is observed that in the case studies of precipitation and temperature, RFSI mostly outperformed regression kriging, inverse distance weighting, Random Forest and RFsp, moreover, RFSI was substantially faster than RFsp, mainly when the training data set was large and high resolution prediction maps were made [17].

3 Methodology

This study aims to formulate a recommendation model based on the Random Forest algorithm complemented with Random Forest Spatial Interpolation (a methodology for spatial interpolation used in Machine Learning) involving three data sources: climatic and edaphic variables and fruit quality. Considering the formulated model, developing an information system that allows establishing current and potential fruit production zones is proposed in the Department of Risaralda, based on edaphoclimatic and fruit quality variables, thanks to the ongoing execution of the project "Development of an information system to determine current and potential zones for avocado (*Persea americana* Mill) Hass variety crops in the Department of Risaralda, based on edaphoclimatic and fruit quality variables (contract 424-201 MinCiencias)"¹.

3.1 Description of the Data Set

Sampling will be conducted for a study of soils, fruit quality and climatic data collection in Hass avocado-producing farms in the municipalities of Pereira, Dosquebradas, Santa Rosa de Cabal, Marsella, Apía, Belén de Umbría, Guática and Quinchía. For the data collection of the first data set (dataset), seven (7) LynkBOX CLIMA PLUS climate stations have been installed in the different farms located in the municipalities selected for the study, allowing the recording of data on climate variables: Temperature (°C), Relative humidity (%), Precipitation (mm), Solar radiation (W/m²), Wind direction and Wind speed, and the building variables: humidity, soil temperature and electrical conductivity, which will be recorded for one year long. The second set of data will be based on a soil fertility analysis, where the parameters, pH, organic matter, elemental analysis (K, Ca, Mg and Na), and phosphorus (P) will be evaluated according to Colombian technical standards NTC 5264, 5403, 5349 and 5350, respectively. Additionally, in the third set of data, variables such as nitrogen content will be calculated based on organic matter content, aluminum using the KCI IM-EAA volumetric technique and texture to the touch Bouyoucos with sodium pyrophosphate - USDA triangular diagram classification - Cl (clayey), L (loamy), S (sandy).

3.2 Data Preparation

It will be considered the generated datasets presented in a different format, as observed in the datasets described above; for this reason, it is imperative to clean and normalize the data for subsequent use with the algorithms. Techniques from the Random Forest algorithm [19] will be used for missing data. A data scaling or normalization process is also conducted to convert the dates and times of the different data sources.

3.3 Random Forest Spatial Interpolation

When the data sets are configured, the prediction process will be carried out, which is framed in the use of the Random Forest Spatial Interpolation algorithm, using the local spatial information, it is to say, spatial variables to select the spatial dependencies and the complex spatial patterns that are presented [20]; a first training of the data will be done using the algorithm Random Forest, since being an algorithm based on decision trees, a prediction is made through a series of partitioning rules; the spatial correlation between the data obtained is not included in Random Forest standard, it will be taken into account that the nearby data contain information about a prediction location, for this purpose, additional spatial variables will be incorporated in the Random Forest model.

¹Project supported by MinCiencias, Gobernación de Risaralda, and Alcaldía de Pereira, work executed by the research groups GIA and Oleoquímica of Universidad Tecnológica de Pereira

3.4 Accuracy Evaluation

The following accuracy metrics will be used to verify the predictions: coefficient of determination, Accuracy, mean absolute error (MAE) and root mean square error (RMSE) [17].

4 Final Considerations

The information system proposed in the execution of the project (contract 424-201 MinCiencias) will allow establishing by means of a suggestion if the current production areas of avocado cultivation are the most appropriate and to determine the potential areas of cultivation.

References

1. Perfetti, J.J., Bravo-Ureta, B.E., García, A., Pantoja, J., Delgado, M., Blanco, J., Jara, R., Moraga, C., Paredes, G., Naranjo, J., *et al.*: Adecuación de tierras y el desarrollo de la agricultura colombiana: políticas e instituciones. *Fedesarrollo* **447**, 456 (2019)
2. El-Bendary, N., Elhariri, E., Hazman, M., Saleh, S.M., Hassanien, A.E.: Cultivation-time recommender system based on climatic conditions for newly reclaimed lands in Egypt. *Procedia Computer Science* **96**, 110–119 (2016)
3. Singh, R., Kumari, T., Verma, P., Singh, B.P., Raghubanshi, A.S.: Compatible package-based agriculture systems: an urgent need for agro-ecological balance and climate change adaptation. *Soil Ecology Letters* **4**(3), 187–212 (2022)
4. Dreher, M.L., Davenport, A.J.: Hass avocado composition and potential health effects. *Critical reviews in food science and nutrition* **53**(7), 738–750 (2013)
5. Ramírez-Gil, J.G., Ramelli, E.G., Osorio, J.G.M.: Economic impact of the avocado (cv. hass) wilt disease complex in antioquia, Colombia, crops under different technological management levels. *Crop protection* **101**, 103–115 (2017)
6. MADR, M.d.A.y.D.R.: CADENA DE AGUACATE, Indicadores e instrumentos. *Lect Econ.* 2019;52(52):165–94 (2019)
7. Martínez, D.H.F., Galvis, C.P.U.: Tic para la investigación, desarrollo e innovación del sector agropecuario (2018)
8. Vite Cevallos, H., Carvajal Romero, H., Barrezueta Unda, S.: Aplicación de algoritmos de aprendizaje automático para clasificar la fertilidad de un suelo bananero. *Conrado* **16**(72), 15–19 (2020)
9. Katarya, R., Raturi, A., Mehndiratta, A., Thapper, A.: Impact of machine learning techniques in precision agriculture. In: 2020 3rd International Conference on Emerging Technologies in Computer Engineering: Machine Learning and Internet of Things (ICETCE), pp. 1–6 (2020). IEEE
10. Geetha, V., Punitha, A., Abarna, M., Akshaya, M., Illakiya, S., Janani, A.: An effective crop prediction using random forest algorithm. In: 2020 International Conference on System, Computation, Automation and Networking (ICSCAN), pp. 1–5 (2020). IEEE
11. Pozdnoukhov, A., Kanevski, M.: Machine learning algorithms for analysis and modeling of geospatial data. In: Annual Conference of International Association for Mathematical Geology (IAMG 07), Beijing, China, 25-31 August (2007)
12. Carranza, J.P., Salomón, M.J., Piumetto, M.A., Monzani, F., MONTENEGRO CALVIMONTE, M., Córdoba, M.A.: Random forest como técnica de valuación masiva del valor del suelo urbano: una aplicación para la ciudad de río cuarto, Córdoba, Argentina. In: Congreso Brasileiro de Cadastro Técnico Multifinalitário-COBRAC (2018)
13. Sekulić, A., Kilibarda, M., Heuvelink, G.B., Nikolić, M., Bajat, B.: Random forest spatial interpolation. *Remote Sensing* **12**(10), 1687 (2020)
14. Mariano, C., Monica, B.: A random forest-based algorithm for data-intensive spatial interpolation in crop yield mapping. *Computers and Electronics in Agriculture* **184**, 106094 (2021)
15. Kuhn, M., Johnson, K., Kuhn, M., Johnson, K.: Classification trees and rule-based models. *Applied predictive modeling*, 369–413 (2013)
16. Talebi, H., Peeters, L.J., Otto, A., Tolosana-Delgado, R.: A truly spatial random forests algorithm for geoscience data analysis and modelling. *Mathematical Geosciences* **54**, 1–22 (2022)

Multidimensional Energy Analysis in Agricultural Coffee Production Systems to Assess Sustainability.

Cristian Méndez-Rodríguez^{1,2}, Cristian Camilo Ordoñez Quintero², Claudia Sofia Idrobo³, Luis Freddy Muñoz Sanabria³.

¹Environmental Studies Group (GEA), Environmental Sciences, Department of Biology, University of Cauca, Popayán 190002, Colombia. cristianmendez@unicauca.edu.co.

²Intelligent Management System (IMS), Faculty of Engineering, University Foundation of Popayán, Popayán 190002, Colombia.

³LOGICIEL, Faculty of Engineering, University Foundation of Popayán, Popayán 190002, Colombia.

Abstract.

A coffee farm is sustainable when it uses the system inputs (energy/materials) and transforms them into high quality beans, avoiding the loss of energy in waste and pollutants. The aim of the research is to evaluate sustainability in coffee agricultural production systems, through multidimensional energy analysis (with the emergy tool). This research was conducted in the farm "La Angostura" in Popayán, Colombia, during the years 2018-2020. The results show that the farm achieved its best energy performance and was most sustainable in 2020, producing 8750 kg/ha of cherry coffee, with the lowest Transformity ($1.35E+06$ seJ/J) and the highest Emergy Sustainability Index (0.97), for the three years analyzed. In addition, natural inputs contribute approximately 57% of total emergy, and those coming from the economy 43%. This study provides a precise analysis of the energy flows that interact in the system, the significant uses of energy and the sources of energy at each stage of the production process. This research provides a basis for the management and planning of the territory in relation to its agricultural strengths.

Keywords: *Sustainability, Agricultural coffee production system, Emergy Analysis.*

1 Introduction.

In 2016, Colombia was the third largest coffee producer in the world with approximately 14 million bags (equivalent to 9.23% of world production), followed by Brazil and Vietnam [1]. These data consolidate coffee as the main agricultural product of the country and demonstrate its great contribution to the Colombian rural economy. The Cauca department is a region that stands out for its high-quality coffee and denomination of origin; where the aim is to generate a product recognized as excellent at an international level [2].

Coffee is a common crop in the traditional farms of the department of Cauca. According to the Comité de Cafeteros del Cauca, the department occupies the fourth place nationally in coffee production, with 93,000 families, 31 municipalities of the department of Cauca have 64% of the land for agricultural production to coffee cultivation [1]. A significant part of the department's coffee production is carried out on the "Popayán plateau", which includes the municipalities of Popayán, Piendamó, Morales, Cajibío, El Tambo and Timbío, with traditional and technified production systems. This research will be carried out at the "La Angostura" farm in the village Clarete Bajo of the Popayán city, where there is a traditional coffee plantation (small producers), with approximately 800 coffee trees of the Castillo variety.

In recent years, the agricultural sector of Cauca has focused on the development of strategies for the generation of value chain, with coffee being a key link, focusing on the production of specialty coffee [3], where the improvement of efficiency and sustainability constitutes an innovative and necessary bet for the growth of the productive chain. In addition to the importance of coffee in the region, and the scientific advances in this area, it is necessary to study the use of conceptual and methodological tools that allow the modeling of a productive chain in relation to its multidimensional energy flows (coming from the natural, social and economic systems) in order to have an integral evaluation of the sustainability of coffee production systems [4]–[6].

A coffee farm is efficient when it uses the energy/materials input to the system and transforms them into high quality beans [7], [8], avoiding the loss of energy in waste and pollutants. The objective of this article is to model the stages of the production process and identify the multidimensional energy flows involved, such as: natural resources (sun, wind, rain, soil, etc.) and resources from the socioeconomic component (fertilizers, equipment and machinery, infrastructure, labor, technical services, etc.), in order to evaluate the sustainability of the farm. This paper uses the methodological tool proposed in [9], where the processes of the production chain are modeled and an Energy evaluation is carried out to estimate the sustainability of the farm. The study's main contribution is to provide baseline information on the sustainability of the coffee farm and the most significant uses of resources (in energy terms).

The article is organized as follows: section 2 presents the methodology (the general context of the research, the first modeling phase, and the Energy tool to evaluate sustainability in agricultural systems); section 3 shows the main results of the research; and finally, the conclusions are presented.

2 Methodology.

2.1 Agricultural coffee production system description – “La Angostura” farm.

The research was carried out taking as a reference the data provided by the Traditional Farm "La Angostura", located in the village Clarete Bajo, north of the city of Popayán, Cauca, Colombia, and has an area of 5.8 Hectares. This farm has a traditional polyculture of Castillo variety coffee, which is characterized for being one of the Colombian coffee varieties resistant to rust, and stands out for its aroma and citric acidity. The crops planted in semi-shade, with bushes such as orange, mandarin, lemon, and “guamos” trees. Currently there are 800 coffee plants, it is a young coffee plantation (6 years old), and has a planting density equivalent to 5000 trees/ha. The geolocation of the farm (average elevation 1800 m.a.s.l), the tropical climate of the region and the biodiversity favor coffee production. Three stages were identified on the farm: planting, harvesting, and processing, where the final product obtained is dry parchment coffee. The analysis of energy flows for the "La Angostura" farm was carried out for the years 2018, 2019 and 2020, due to the unavailability of information from the owners.

2.2 Phase 1: Modeling – ANSI/ISA 88 Standard.

This tool allows modeling industrial processes, by describing equipment and procedures [9]. The ISA-88 committee has published 5 parts of the standard. The Part 1: Models and Terminology, which seeks to model the production process in relation to the chronological procedures and associated resources, is very useful (Figure 1) [10]. Phase 1 is applied at each stage of an agricultural production system. This process modeling using ISA 88 helps to characterize reliably the energy flows (considering convention proposed by Energy Analysis) present in the agricultural production system.

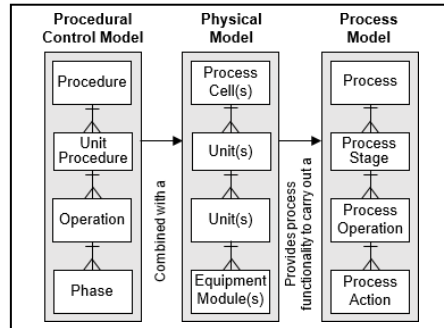


Fig. 1. Process modeling - ANSI/ISA 88 Standard.

2.3 Phase 2: Emergy

The emergy is defined as the available energy previously required, which has been used directly or indirectly in the transformations necessary to manufacture a product or service ($Y = R + N + F$, Figure 2). The unit of measurement of emergy is solar emjoules (seJ). Emergy flows are represented in three categories of resources: (i) R as renewable, (ii) N as non-renewable (R and N flows are provided by the environment) and (iii) F the inputs of the economy (provided by the market and flows coming from the economy) [11]. Emergy is a quantitative tool, based on the law of conservation of energy, thermodynamics, systems theory and systems ecology [12], achieving an integral analysis of the production system [13].

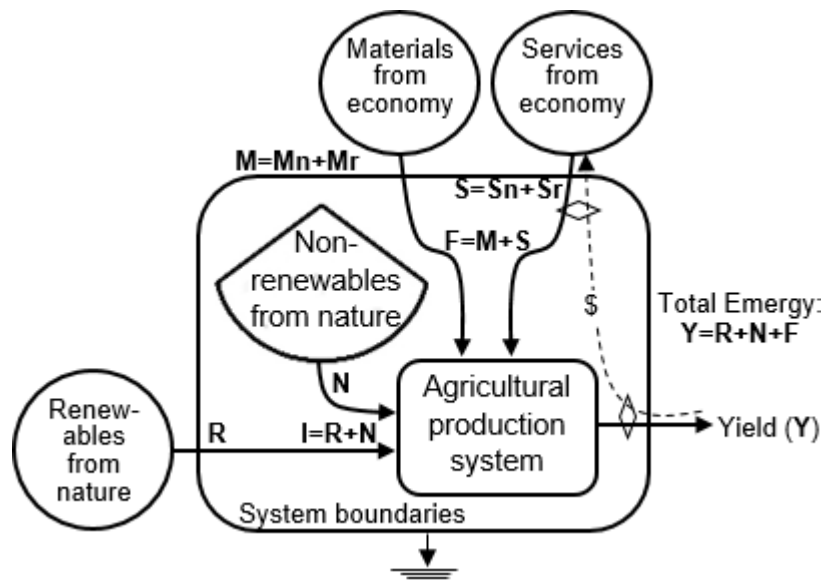


Fig. 2. Agricultural production system model, based on the Emergy analysis [14].

3 Results and Discussion.

3.1. Stages modeling - production process.

The unit procedure, operations, by-products flows, and phases of these stage are pre-sented in Figure 3, and Table 1.

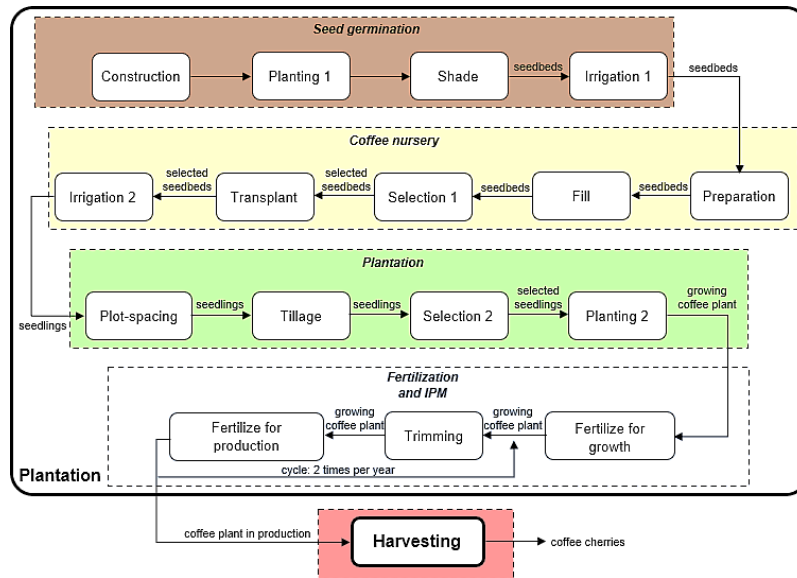


Fig. 3. Operations and flows of plantation and harvesting stages.

Table 1. Description of plantation and harvesting stages.

Unit Procedure	Pro-	Operation	Phase
Seed germination		Construction	Building the germinator
		Planting 1	Sowing seeds in germinator
		Shade	Protecting seeds from sunlight
		Irrigation 1	Keeping the germinator moist
Coffee nursery		Preparation	Preparing substrate organic fertilize
		Fill	Filling coffee bags
		Selection 1	Selecting seedbeds
		Transplant	Transplanting seedbeds to bags
		Irrigation 2	Keeping bag soil moist
Plantation		Plot-spacing	Establish planting density
		Tillage	Digging holes for each seedling
		Selection 2	Select seedlings
		Planting 2	Sowing the seedlings in the pits
Fertilization and Pest/weeds Man-agement		Fertilize growth	Fertilizing coffee in growth
		Trimming	Pruning coffee plants
		Fertilize production	Fertilizing coffee in production
Harvesting		Harvesting	Harvesting coffee beans

3.2. Emery Analysis.

In order to identify the energy flows in a coffee agricultural system, it is necessary to characterize the stages that are carried out in this productive process. In this way, it is possible to detail the energy flows that are contributing to the system in each of these stages. This detailed inventory is shown in Appendix A, where all the energy flows involved in each stage of the production process are presented (for the year 2018). This table is designed according to Emery's methodology.

Figure 4 shows the energy contributions of nature to the farm (green bars) and the contribution of the economy (orange bars) for the year 2018. In general, it can be seen that most of the energy comes from non-renewable resources, mainly from energy provided by the soil (nature) and energy from labor (economy). The data in Table 2 show that the stage that demands the most energy resources is planting, with approximately 84% of total energy use, harvesting contributes 15% and the milling stage only contributes about 1%.

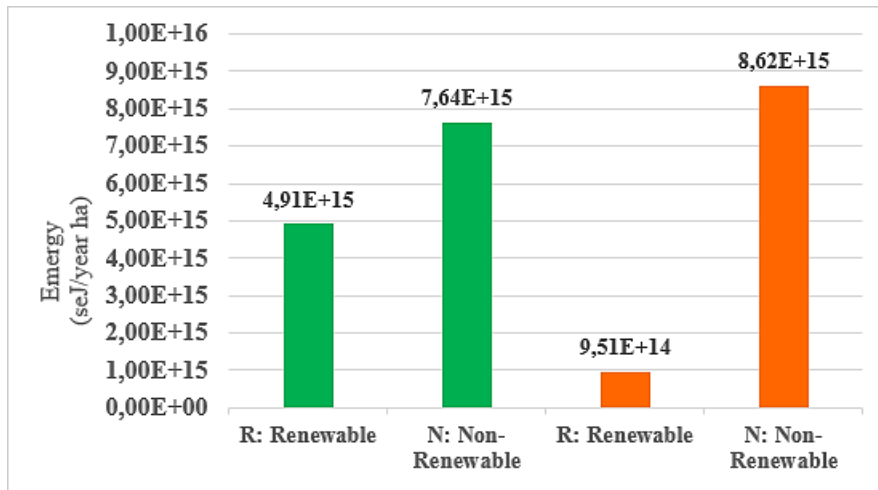


Fig. 4. Energy flows contributed by Nature (green) and the Economy (orange) (Renewable and non-Renewables), 2018.

Table 2. Energy contributions by stages of the production process, 2018-2020.

Year	Plantation	Harvesting	Drying	TOTAL Energy
2018	1.86E+16	3.38E+15	1.75E+14	2.21E+16
2019	1.80E+16	3,02E+15	1,53E+14	2,11E+16
2020	1,74E+16	3,24E+15	1,46E+14	2,08E+16

The energy for 2020 decreased by $0.13E+16$ (SeJ) with respect to 2018, and $0.3 E+16$ (SeJ) with reference to 2019, indicating that less energy was required for the operation of the productive system. In addition, it is important to know the significant energy uses in each stage of the productive process (Figure 5). The plantation is the one that consumes the most resources with 83.9%. The resources that contribute most energy are the soil, renewable natural resources (sun, wind, rain, etc.), and human labor. In the harvest stage, 15.2% of energy is consumed, and the resource that contributes most is human labor. And only 0.78% of energy is used at the milling stage, with human labor contributing the most.

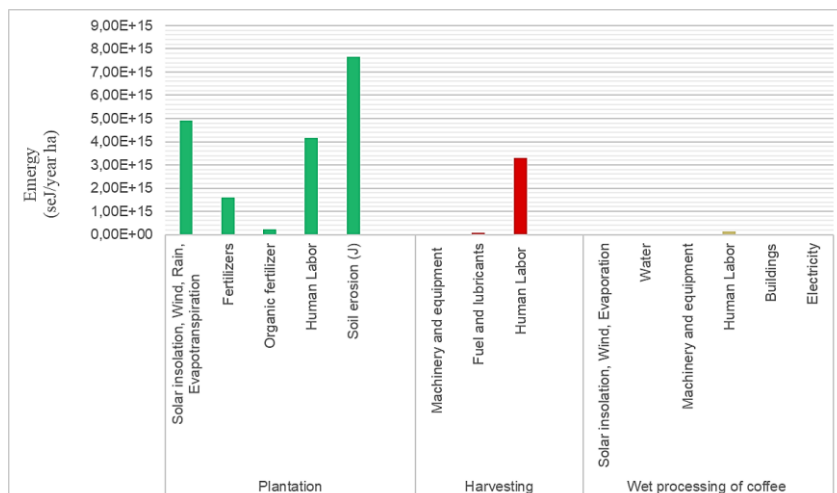


Fig. 4. Significant energy use in each stage of the production process, 2018.

Finally, different indicators were calculated to evaluate the sustainability, efficiency and productivity of the production farm (Table 3).

Table 3. Emery Indices.

Indices	Formula	2018	2019	2020
Total energy [Sej]	$Y_{coffee} = R + N + F$	2.21E+16	2.11E+16	2.08E+16
Transformity [Sej/J]	$T = \frac{Y_{coffee}}{Product\ energy}$	1.79E+06	1.50E+06	1.35E+06
Energy Yield Ratio	$EYR = \frac{Y_{coffee}}{N + F_N}$	2.31	2.46	2.52
Environmental Loading Ratio	$ELR = \frac{R + F_R}{M_R + S_R}$	2.77	2.66	2.61
Energy Investment Ratio	$EIR = \frac{F}{N + R}$	0.76	0.68	0.66
Energy Sustainability Index	$ESI = \frac{EYR}{ELR}$	0.83	0.93	0.97
Productivity - cherry coffee	kg/ha	7500	8200	8750

Comparing the three years analyzed, the “La Angostura” farm had its best environmental and energy performance in 2020, with a production of 8750 kg/ha of cherry coffee, where the Transformity was the lowest, 1.35E+06 seJ/J, and the Emery Sustainability Index (ESI) increased (0,97). This indicates that the decisions taken in recent years have led to a notable improvement in the efficiency and sustainability of the system. The Emery value decreased each year, demonstrating that the system was more energy efficient in 2020 compared to 2018.

4 Conclusions

The sustainable development of the department of Cauca requires the planning of efficient agricultural production systems, where the management of resources and respect for nature are considered. For this purpose, the evaluation of the sustainability of a coffee farm was proposed, considering the energy flows that intervene in the processes of the productive chain. For this purpose, a systemic approach was considered, which would allow for an integral characterization of the components that interact in the system, and the multiple energy flows that intervene, such as: sun, wind, rain, soil, fertilizers, equipment, machinery, labor, etc. This modeling of the production chain was carried out by means of operations and flow modeling, process flow diagrams (PFD), using the ISA 88 standard, thus allowing a broad understanding of the coffee system.

After having the inventory of all the energy flows involved in the system, the Emery method was used, which helps to establish a model that indicates the energy footprint of a product, in this case coffee. Likewise, the tool provides a series of indicators that help to improve the decision-making processes of the coffee producing communities.

The work was carried out in the traditional farm "La Angostura", located in the village of Clarete Bajo, in the city of Popayán, data from the years 2018, 2019, and 2020 were considered. For the three years analyzed, the planting stage is the one that consumes the most resources with approximately 84%. The resources that contribute the most energy are: soil, renewable natural resources (sun, wind, rain, etc.), and human labor; the harvest stage contributes approximately 15% of the energy, here the resource that contributes the most is human labor; and only 1% of the energy is used in the milling stage, with human labor contributing the most.

Approximately 59% of the energy used by the farm comes from nature, of which 23% is from renewable sources and 36% from non-renewable sources. The economy contributes 41% of the energy, of which only 4% is from renewable sources and 37% from non-renewable sources. Energy for 2020 decreased by $0.13E+16$ (SeJ) compared to 2018, and $0.3 E+16$ (SeJ) compared to 2019, indicating that less energy was required for coffee production on the farm.

This work is an important basis that would help coffee growers in the region to make decisions regarding the management of their farms. Similarly, as a perspective it would be interesting to integrate this type of sustainability evaluation work with environmental management issues and the obtaining of green seals. This last option would be interesting to explore, as it would allow the coffee producing communities to have a tool to "demonstrate" that they are carrying out sustainable processes and continuous improvement within their farms, allowing them to have easier access to this type of seals, also achieving a better positioning in the markets.

References

1. Federación Nacional de Cafeteros de Colombia, "ESTADÍSTICAS HISTÓRICAS," *ESTADÍSTICAS HISTÓRICAS - Área cultivada - anual desde 2002*, 2017.
2. Federación Nacional de Cafeteros de Colombia, "Organos gremiales de la Federación de Cafeteros," 2017. https://www.federaciondefcafeteros.org/clientes/es/que_hacemos/representacion_gremial/organos_gremiales_de_la_federacion_de_cafeteros/ (accessed Nov. 17, 2017).
3. Gobernación del Cauca, "Plan Departamental de Desarrollo 2020-2023." 2020.
4. J. F. Martin, S. A. W. Diemont, E. Powell, M. Stanton, and S. Levy-tacher, "Emergy evaluation of the performance and sustainability of three agricultural systems with different scales and management," vol. 115, pp. 128–140, 2006, doi: 10.1016/j.agee.2005.12.016.
5. C. M. Rodríguez, C. F. R. Rodas, J. C. C. Muñoz, and A. F. Casas, "A multi-criteria approach for comparison of environmental assessment methods in the analysis of the energy efficiency in agricultural production systems," *J Clean Prod*, vol. 228, pp. 1464–1471, 2019, doi: <https://doi.org/10.1016/j.jclepro.2019.04.388>.
6. M. Giampietro, G. Pastore, and S. Ulgiati, "Agricultura italiana e conceitos de sustentabilidade," 2016.
7. M. Giampietro, "Economic growth, human disturbance to ecological systems, and sustainability," *ECOSYSTEMS OF THE WORLD*, pp. 723–746, 1999.
8. T. Clayton and N. J. Radcliffe, *Sustainability: a systems approach*. Routledge, 2015.
9. M. Vegetti and G. P. Henning, "ISA-88 Formalization. A Step Towards its Integration with the ISA-95 Standard.," in *FOMI@ FOIS*, 2014.
10. E. Munoz, E. Capon-Garcia, and L. Puigjaner, "ANSI/ISA 88-95 Standards Based-Approach for Improved Integration of Recipes and Operational Tasks Supported by Knowledge Management," in *Computer Aided Chemical Engineering*, Elsevier, 2017, pp. 2335–2340.
11. M. T. Brown and S. Ulgiati, "Energy quality, emergy, and transformity : H . T
i. . Odum ' s contributions to quantifying and understanding systems," *Ecological Modelling*, vol. 178, pp. 201–213, 2004, doi: 10.1016/j.ecolmodel.2004.03.002.
12. H. T. Odum, *Environmental accounting: emergy and environmental decisionmaking*. New York: John Wiley and Sons, 1996.
13. G. C. Rótolo and C. Francis, "Los servicios ecosistémicos en el 'corazón' agrícola de Argentina," *Ediciones INTA*, vol. 44, 2008.
i. B. F. Giannetti, Y. Ogura, S. H. Bonilla, and C. M. V. B. Almeida, "Accounting emergy flows to determine the best production model of a coffee plantation,"
ii. *Energy Policy*, vol. 39, no. 11, pp. 7399–7407, 2011, doi: 10.1016/j.en-pol.2011.09.005.
14. H. T. Odum, *Environmental accounting*. Wiley, 1996.
15. H. T. Odum and E. P. Odum, "The energetic basis for valuation of ecosystem services," *Ecosystems*, vol. 3, no. 1, pp. 21–23, 2000.

16. M. Cuadra and T. Rydberg, "Emergy evaluation on the production, processing and export of coffee in Nicaragua," *Ecol Modell*, vol. 6, no. 96, pp. 421–433, 2006, doi: 10.1016/j.ecolmodel.2006.02.010.
17. C. M. V. B. A. B.F. Giannetti, Y. Ogura, S.H. Bonilla, "Accounting emergy flows to determine the best production model of a coffee plantation," *Energy Policy*, vol. 39, pp. 7399–7407, 2011, doi: 10.1016/j.enpol.2011.09.005.
18. M. Jafari, M. Reza, M. Ramroudi, M. Galavi, and G. Hadarbadi, "Sustainability assessment of date and pistachio agricultural systems using energy, emergy and economic approaches," *J Clean Prod*, vol. 193, pp. 642–651, 2018, doi:10.1016/j.jclepro.2018.05.089.
19. J. Björklund, U. Geber, and T. Rydberg, "Emergy analysis of municipal wastewater treatment and generation of electricity by digestion of sewage sludge," *Resour Conserv Recycl*, vol. 31, no. 4, pp. 293–316, 2001.
20. M. Panzieri, N. Marchettini, and T. G. Hallam, "Importance of the Bradyrhizobium japonicum symbiosis for the sustainability of a soybean cultivation," *EcolModell*, vol. 135, no. 2–3, pp. 301–310, 2000.
21. A. A. Buenfil, *Emergy evaluation of water*. University of Florida, 2001.

Appendix A. Emergy “La Angostura” farm, Popayán, Cauca, 2018.

Item	Description	Class	Annual flow (unit/year ha)			Emergy per Unit (seJ/unit)	Emergy (seJ/year ha)	Refs.
			2 first years/30 years	Year of 2018	Total			
Plantation*			2 first years/30 years	Year of 2018	Total			
1	Solar insolation (J)	R	2,72E+12	4,07E+13	4,34E+13	1,00E+00	4,34E+13	[15]
2	Wind, kinetic energy (J)	R	3,54E+06	5,31E+07	5,67E+07	2,52E+03	1,43E+11	[15]
3	Rain, chemical energy (J)	R	4,01E+09	6,01E+10	6,41E+10	3,06E+04	1,96E+15	[15]
4	Rain, geopotential energy (J)	R	8,65E+07	1,30E+09	1,38E+09	1,76E+04	2,44E+13	[15]
5	Evapotranspiration (J)	R	4,52E+09	6,78E+10	7,23E+10	3,98E+04	2,88E+15	[16]
6	Soil erosion (J)	N	6,46E+09	9,68E+10	1,03E+11	7,40E+04	7,64E+15	[15]
7	Nitrogen (g)	F	3,33E+03	5,00E+04	5,33E+04	6,62E+09	3,53E+14	[17]
8	Phosphate (g)	F	6,67E+02	1,00E+04	1,07E+04	9,35E+09	9,97E+13	[17]
9	Potassium (g)	F	4,67E+03	7,00E+04	7,47E+04	9,32E+08	6,96E+13	[17]
10	Urea (g)	F	1,00E+04	1,50E+05	1,60E+05	6,62E+09	1,06E+15	[17]
11	Cal (g)	F	6,67E+02	1,00E+04	1,07E+04	1,68E+09	1,79E+13	[18]
12	Organic fertilizer (J)	80% R	2,00E+03	6,00E+04	6,20E+04	3,87E+09	2,40E+14	[19]

12

13	Seeds (J)	<i>F</i>	3,77E+05	0,00E+00	3,77E+05	5,85E+04	2,20E+10	[17]
14	Machinery and equipment (g)	<i>F</i>	7,33E+01	1,10E+03	1,17E+03	6,70E+09	7,86E+12	[20]
15	Human Labor (USD)	<i>10% FR</i>	1,97E+01	1,66E+02	1,85E+02	2,25E+13	4,17E+15	[19]
16	Pesticides and fungicides (g)	<i>F</i>	6,67E+00	1,00E+02	1,07E+02	1,48E+10	1,58E+12	[21]
Total for plantation							1,86E+16	
<hr/>								
Harvesting			Annual flow (unit/year ha) - 2018					
17	Machinery and equipment (J)	<i>F</i>			1,00E+02	6,70E+09	6,70E+11	[20]
18	Fuel and lubricants (J)	<i>F</i>			7,90E+08	1,11E+05	8,78E+13	[18]
19	Human Labor (USD)	<i>10% FR</i>			1,46E+02	2,25E+13	3,29E+15	[19]
Total for Harvesting							3,38E+15	
<hr/>								
Drying								
20	Solar insolation (J)	<i>R</i>			2,23E+12	1,00E+00	2,23E+12	[15]
21	Wind, kinetic energy (J)	<i>R</i>			5,31E+07	2,52E+03	1,34E+11	[15]

22	Evaporation (g)	<i>R</i>	3,72E+06	1,45E+05	5,39E+11	[22]
23	Water (J)	<i>R</i>	1,78E+07	8,60E+04	1,53E+12	[15]
24	Drying yard or “paseras” (g)	<i>F</i>	7,06E-01	2,65E+13	1,87E+13	[17]
25	Machinery and equipment (USD)	<i>F</i>	2,23E+12	1,00E+00	2,23E+12	[17]
26	Human Labor (USD)	<i>10% FR</i>	5,66E+00	2,25E+13	1,27E+14	[19]
27	Buildings (USD)	<i>F</i>	5,08E-01	2,65E+13	1,35E+13	[18]
28	Electricity (USD)	<i>F</i>	3,44E-01	2,65E+13	9,12E+12	[17]
29	Sacos Jute (USD)	<i>F</i>	1,00E+02	2,31E+10	2,31E+12	[17]
Total for Drying					1,75E+14	
(Y) Total Energy					2,21E+16	Calculated in this study

*The planting stage was carried out in 2013, where the energy flows are applied (items 1-16), however, this is an investment that is being made in the long term, in this study, and according to the indications of experts in coffee production, it is estimated that the crop can have a productive life of 30 years (Arcila et al., 2007b). For this reason, it is necessary to divide the energy applied in the first 2 years (where the crop had no production), between the 30 years of useful life. Similarly, each year (year analyzed in the 2018 table), it is necessary to perform the maintenance of the crop where energy flows must be added (items 1-16, except 13 seeds). This energy applied during the first 2 years, which is a long-term investment, is only done for the plantation stage.

Un sistema de recomendación para la reutilización de fármacos utilizando embeddings sobre Grafos de Conocimiento

Diego López Yse¹ and Diego Torres^{1,2,3}

¹ Universidad Austral, Buenos Aires, Argentina

² LIFIA, CIBPBA-Facultad de Informática, UNLP, La Plata, Argentina

³ Depto. CyT., Universidad Nacional de Quilmes, Bernal, Argentina

Abstract. El proceso de desarrollo tradicional de nuevos fármacos es un camino largo, ineficiente y costoso. Afortunadamente, la reutilización de fármacos representa una muy buena alternativa para superar las limitaciones de los métodos de desarrollo tradicionales. En este sentido, los métodos computacionales de Grafos de Conocimiento y su representación vectorial (embeddings) se han utilizado en el campo biomédico para la reutilización de fármacos con gran efectividad, mejorando los resultados producidos por otras técnicas tradicionales de Machine Learning. El presente trabajo propone un esquema para desarrollar un sistema de recomendación para la reutilización de fármacos utilizando embeddings sobre Grafos de Conocimiento, con la flexibilidad suficiente para centrarse en múltiples enfermedades e incorporar otros tipos de modelos predictivos para identificar a los mejores.

Keywords: *Machine Learning · Grafos de Conocimiento · Biotecnología*

1 Introducción

El proceso de desarrollo tradicional de nuevos fármacos es un camino largo y costoso, que se estima toma en promedio 14 años y cuesta aproximadamente USD 1.8 mil millones para desarrollar un medicamento [7]. Afortunadamente existen otros métodos más ágiles para enfrentar la velocidad que nos plantea la biología sobre las enfermedades. La reutilización de fármacos es el proceso de identificación de indicaciones novedosas para fármacos existentes, y representa una muy buena alternativa para superar las limitaciones de los métodos de desarrollo tradicionales, reduciendo drásticamente los plazos, las tasas de fracaso y los costos de desarrollo.

Los enfoques principales para la reutilización de fármacos se clasifican en métodos experimentales y computacionales [4], y el éxito de la reutilización está sujeto a cómo se combinan estos dos enfoques en colaboración.

En particular, los Grafos de Conocimiento se han utilizado en el campo biomédico para la reutilización de fármacos y otras actividades como la priorización de genes relevantes en enfermedades [5]. La combinación de Grafos de Conocimiento y su representación vectorial (embeddings) propone una visión novedosa para enfrentar el desafío de reutilización de fármacos al establecer nodos y relaciones entre los datos en contraposición a las clásicas bases de información estructuradas, y análisis en espacios vectorizados en lugar de clásicos modelos multidimensionales.

2 Trabajos Relacionados

Los enfoques computacionales para la reutilización de fármacos han ganado popularidad debido a la disponibilidad de grandes datos biológicos. Un gran número de trabajos basados en métodos de Machine Learning aprovechan descriptores construidos manualmente para realizar predicciones (ej., propiedades moleculares), con el fin de identificar posibles fármacos candidatos para ensayos clínicos posteriores [6].

Pero existen métodos más efectivos para representar información biomédica, y trabajos actuales se han centrado en utilizar técnicas de embeddings sobre Grafos de Conocimiento [2], mapeando la información a un espacio vectorial continuo, y preservando la estructura de proximidad del gráfico de conocimiento para ejecutar algoritmos de Machine Learning.

3 Problemática

El proceso de desarrollo de nuevos fármacos es una tarea compleja que requiere el conocimiento de numerosos dominios biológicos y químicos. Posiblemente el mayor obstáculo en este proceso se relaciona con la toxicidad, dando como resultado numerosos compuestos que fallan en las últimas etapas de los ensayos clínicos o que se retiran del mercado [1]. De esta forma, la reutilización de fármacos es una posible alternativa a este problema, acelerando el descubrimiento de nuevas aplicaciones cuando los perfiles de seguridad de los medicamentos que se reutilizan se han evaluado en el contexto del desarrollo de medicamentos para otra enfermedad [3].

La reutilización de fármacos no solo conduce a menores gastos y acelera el desarrollo, sino que también agrega conocimiento sobre los efectos secundarios, la farmacocinética y las interacciones farmacológicas de los fármacos en cuestión [4].

4 Contexto

Para enfrentar el desafío de reutilización de fármacos es posible utilizar distintas técnicas y representaciones de datos biológicos. En este sentido, las técnicas de Machine Learning que utilizan descriptores moleculares son populares y suelen alcanzar niveles aceptables de performance. Pero es posible expandir el espacio de exploración de soluciones utilizando técnicas de embeddings sobre Grafos de Conocimiento que vinculen el amplio universo de datos biológicos disponibles (ej., genes o efectos secundarios relacionados a fármacos).

Por esta razón, el presente trabajo propone un esquema para desarrollar un sistema de recomendación para la reutilización de fármacos, integrando datos biológicos y distintos modelos predictivos basados en embeddings sobre Grafos de Conocimiento para lograr resultados con mayores probabilidades de éxito.

5 Propuesta

Para desarrollar un sistema de recomendación para la reutilización de fármacos centrado en Grafos de Conocimiento, se proponen las siguientes etapas:

5.1 Configuración

La primera fase se basa en definir y estructurar los datos y modelos para analizar y construir los modelos predictivos de embeddings.

- Selección de Grafo de Conocimiento con datos significativos para el desafío relacionado. Si la reutilización de fármacos se orienta a una enfermedad determinada, se debe seleccionar un set de datos con un volumen adecuado de tripletas para esa enfermedad.
- Visualización de grafo integral y subgrafos seleccionados por el usuario para el análisis de la información y la comprensión de las relaciones establecidas.
- Entrenar y testear múltiples modelos de embeddings sobre el Grafo de Conocimiento, asignando la información del grafo a distintas representaciones de baja dimensionalidad, preservando la estructura de proximidad de los datos para explotarla en aplicaciones como la predicción de vértices.
- Realizar predicción de vértices para inferir relaciones entre nodos no conectados dentro del Grafos de Conocimiento (e.j., predecir un fármaco dada una query "X, trata, dengue").

5.2 Evaluación

Para evaluar los modelos de embeddings sobre la enfermedad objetivo, cada modelo debe medirse: (a) intrínsecamente, utilizando métricas como Adjusted Mean Rank (AMR) y hits@k, y (b) externamente contra una fuente de validación externa para comprender su poder predictivo sobre la información del mundo real. De esta forma, un modelo de embeddings que acierta todos los compuestos existentes en la fuente de validación para una enfermedad determinada utilizando menos predicciones se considera mejor que otro modelo que necesita más predicciones para alcanzar la misma cantidad de aciertos.

5.3 Recomendación

Finalmente, en base a la ponderación que asigne al usuario a los métodos de evaluación y la posibilidad de filtrar resultados por variables tales como tamaño molecular y grupo orgánico, el sistema definirá el ranking final de fármacos sugeridos para reutilizar en la enfermedad target.

6 Conclusión

Este trabajo propone un esquema para desarrollar un sistema de recomendación para la reutilización de fármacos utilizando Grafos de Conocimiento, con la flexibilidad suficiente para centrarse en múltiples enfermedades. Además, el enfoque propuesto permite incorporar otros tipos de modelos predictivos (e.j., basados en similitud química) que pueden competir contra los modelos de embeddings sobre Grafos de Conocimiento para identificar a los mejores. En una etapa posterior a este trabajo, los fármacos más prometedores deben ser testeados *in vitro/vivo*, retroalimentando los resultados a las bases de datos para continuar mejorando la performance de recomendación posteriores.

References

1. Barratt, M.J., Frail, D. (eds.): Drug repositioning: bringing new life to shelved assets and existing drugs. John Wiley & Sons, Hoboken, N. J (2012)
2. Florin Ratajczak, et al.: Task-driven knowledge graph filtering improves prioritizing drugs for repurposing. *BMC Bioinformatics* **23**(84) (2022).
<https://doi.org/https://doi.org/10.1186/s12859-022-04608-y>,
<https://bmcbioinformatics.biomedcentral.com/articles/10.1186/s12859-022-04608-y>
3. Li, X., Yu, J., Zhang, Z., Ren, J., Peluffo, A.E., Zhang, W., Zhao, Y., Wu, J., Yan, K., Cohen, D., Wang, W.: Network bioinformatics analysis provides insight into drug repurposing for COVID-19. *Medicine in Drug Discovery* **10**, 100090 (Jun 2021). [elsevier.com/retrieve/pii/S2590098621000117](https://www.elsevier.com/retrieve/pii/S2590098621000117)
4. Malik, J.A., Ahmed, S., Jan, B., Bender, O., Al Hagbani, T., Alqarni, A., An-war, S.: Drugs repurposed: An advanced step towards the treatment of breast cancer and associated challenges. *Biomedicine & Pharmacotherapy* **145**, 112375 <https://linkinghub.elsevier.com/retrieve/pii/S0753332221011598>, <https://doi.org/10.1016/j.biopha.2021.112375>, <https://linkinghub.elsevier.com/retrieve/pii/S0753332221011598>
5. Nicholson, D.N., Greene, C.S.: Constructing knowledge graphs and their biomedical applications. *Computational and Structural Biotechnology Journal* **18**, 1414–1428 (2020). <https://doi.org/10.1016/j.csbj.2020.05.017>, <https://linkinghub.elsevier.com/retrieve/pii/S2001037020302804>
6. Pan, X., Lin, X., Cao, D., Zeng, X., Yu, P.S., He, L., Nussinov, R., Cheng, F.: Deep learning for drug repurposing: methods, databases, and applications (2022)..
7. Sang, S., Yang, Z., Liu, X., Wang, L., Lin, H., Wang, J., Dumontier, M.: GrEDeL: A Knowledge Graph Embedding Based Method for Drug Discovery From Biomedical Literatures. *IEEE Access* **7**, 8404–8415 (2019).
<https://doi.org/10.1109/ACCESS.2018.2886311>, <https://ieeexplore.ieee.org/document/8574025/>

Collaborative Framework for the Implementation of Digital Transformation Processes in Higher Education Institutions: Case Study Unicomfauca

Alex Armando Torres Bermúdez¹

¹ Corporación Universitaria Comfauca-Unicomfauca, Popayán, Colombia atorres@unicomfauca.edu.co

Abstract. The purpose of this Doctoral Research Project is to present a collaborative work framework to support the implementation of digital transformation processes in higher education institutions in order to improve the efficiency of mission processes; the case study is the Corporación Universitaria Comfauca for the implementation of digital transformation processes and the validation of the proposed framework in the mission research process. Through a systematic review of the literature, it became evident that there are few frameworks validated in higher education scenarios to implement Digital Transformation processes, mediated by a collaborative work environment to contribute to the continuous improvement of the mission processes. The proposal focuses on a projective analytical research methodology, the method of quantitative action research type planned, makes it possible to analyze the data of a population in 7 institutions of higher education in the city of Popayan, department of Cauca (Colombia).

Key words: *Digital Transformation, Digitalization, Framework.*

1 Introduction

Digital transformation is emerging as a topic of interest not only in scientific communities, but also as an increasingly recurrent practice in organizational dynamics, which are subject to the pressures imposed by digital technologies, new business models that are manifested throughout the value chain, and the personalized demands of users in an environment of hyper-connectivity [1]. More than a few authors have tried to explore the concept of digital transformation through three main areas of change: consumer behavior, business processes and business models [2], [3], [4]. From the literature review, the concept of digital transformation is defined as an evolutionary process of change in the organizational culture that is governed in an environment of hyper-connectivity with collaborative principles for the digitization of processes in all activities of the value chain, which is enabled by the adoption of digital technologies and impact on management processes, business models, value creation, efficiency and operational performance; feasible to implement from frameworks and can be evaluated through maturity models and key performance indicators. In addition to this, research agrees that the education sector is one of the last industries that has initiated changes in a digital culture because it is adhering to old methods and practices, the education sector is no exception [5].

2 State of the art

Regarding models and frameworks for digital transformation, the systematic literature review [6] showed that there are hardly any contributions of systematic methods as a research methodology on Digital Transformation, while it is more frequent to find conceptual models, frameworks and strategies; and much more frequent to find case studies focused on very specific areas. In addition, as a result of academic interest, numerous digital transformation frameworks have been published to address different sectors and their needs [7]. Despite the identified frameworks, however, there are few validated frameworks in higher education scenarios to implement Digital Transformation processes, mediated by a collaborative work environment to contribute to the improvement of mission processes, as mentioned by [8], there is a shortage of practical, implementable and simple digital transformation models that combine technologies, systems and educational phenomena. This theoretical gap is therefore evidence that it remains unclear what type of sustainable digital transformation model(s) could be adopted [8]. According to the literature, it can be established that there are digital transformation frameworks or models for different sectors or areas of industry from a conceptual point of view, with very little evidence of practical, implementable frameworks with achieved results, which indicates a knowledge gap as a state of solution in the education sector.

3 Problem statement and contributions

At present, there is little evidence of validated frameworks in higher education scenarios to implement digital transformation processes in higher education institutions that contribute to the efficiency of mission processes mediated by a collaborative environment [4] [8]. Similarly, [9] recognize that digital transformation is part of this change faced by all types of organizations. In this context, customer demands have changed [10], demanding customized requirements [10]. For this, organizations will have to respond quickly, with the support of collaborative work [11]. This indicates that another factor of Digital Transformation is Collaborative Work. For [1], end-to-end collaboration throughout the value chain is one of the key principles of digital transformation. Considering the aforementioned knowledge problems, the research question oriented to the development of this project arises: How to implement a collaborative work framework of digital transformation to improve the efficiency of the missional processes in a higher education institution?

4 Methodology and research approach

In order to carry out the systematic literature review, the procedure defined by Petersen et al. [12] [13] was followed; however, it is complemented by the research procedures proposed by Hoyos Botero [14]. For the development of the proposal, it focuses on a projective analytical research methodology [15], the quantitative action research method proposed [16], makes it possible to analyze the data of a population in 7 institutions of higher education in the city of Popayán, department of Cauca (Colombia). A sample of one (1) HEI (UNICOMFACAUCA) is extracted where a pre- and post-test will be conducted to know the level of adoption of the digital transformation processes and then the implementation of the process mediated by the technological tool "MCTD"- Collaborative Framework for the Implementation of Digital Transformation Processes, the above conformed from the quantitative research approaches.

5 Evaluation plan

The proposed framework will be assessed by validating its efficiency in relation to the contribution that will be provided in the research mission process at the Corporación Universitaria Comfacauca - UNICOMFACACUA, specifically the research process, allowing it to be a reference framework for higher education institutions in everything related to the current state, maturity level and implementation of digital transformation processes. For this, the evaluation plan will carry out: a) evaluation of collaborative work framework components, b) design of metrics and heuristic evaluation instruments for measuring the usability and interaction of the tool, c) validation of framework usability through framework design experts and software developers, d) verification of the impact of the proposed framework design and refinement of elaborated models, e) elaboration of general document and technical support documents for the project.

6 Preliminary or intermediate results

There is a characterization of the different models and/or frameworks of digital transformation obtained from the respective literature review, 41 digital transformation frameworks for different industry sectors [7], which supports the knowledge gaps described in section 2.

7 Conclusions and Lessons Learned

There is a lot of literature related to the topic of digital transformation for organizations, facing this topic, there are conceptual, maturity and some exclusive models or frameworks with the name of digital transformation models or frameworks, however, there is no evidence of results of implementation of digital transformation processes in the higher education sector in a specific area. A framework is understood as a standardized set of concepts, practices, guidelines and criteria to approach a particular type of problem, which serves as a reference in a specific domain and can be used to address or solve new problems of a similar nature, which may serve as a basis for the implementation of transformation processes in the education sector.

8 Doctor. Stage: Early.

References

1. T. Delgado Fernández, “Taxonomía de transformación digital,” 2020. [Online]. Available: <https://orcid.org/0000-0002-4323-9674>
2. K. Schwertner, “Digital transformation of business,” *Trakia J. Sci.*, vol. 15, no. Suppl.1, pp. 388–393, 2017, doi: 10.15547/tjs.2017.s.01.065.
3. A. Bockshecker, S. Hackstein, and U. Baumöl, “Systematization of the term digital transformation and its phenomena from a socio-technical perspective – A literature review,” 2018.
4. M. H. Ismail, M. Khater, and M. Zaki, “Digital Business Transformation and Strategy: What Do We Know So Far? University of Cambridge,” *J. Univ. Cambridge*, no. November 2017, 2018, [Online]. Available: www.cambridgeservicealliance.org
5. K. Kerroum, A. Khiat, A. Bahnasse, E. S. Aoula, and Y. Khiat, “The proposal of an agile model for the digital transformation of the University Hassan II of Casablanca 4.0,” *Procedia Comput. Sci.*, vol. 175, pp. 403–410, 2020, doi: 10.1016/j.procs.2020.07.057.
6. C. Gebayew, I. R. Hardini, G. H. A. Panjaitan, N. B. Kurniawan, and Suhardi, “A Systematic Literature Review on Digital Transformation,” *2018 Int. Conf. Inf. Technol. Syst. Innov. ICITSI 2018 - Proc.*, pp. 260–265, 2018, doi: 10.1109/ICITSI.2018.8695912.
7. Z. Van Veldhoven and J. Vanthienen, “Digital transformation as an interaction-driven perspective between business, society, and technology,” *Electron. Mark.*, 2021, doi: 10.1007/s12525-021-00464-5.
8. M. A. Mohamed Hashim, I. Tlemsani, and R. Duncan Matthews, “A sustainable University: Digital Transformation and Beyond,” *Educ. Inf. Technol.*, 2022, doi: 10.1007/s10639-022-10968-y.
9. “Taxonomía de Transformación Digital | Revista Cubana de Transformación Digital.” <https://rctd.uic.cu/rctd/article/view/62> (accessed Jun. 20, 2021).
10. R. Morakanyane, A. Grace, and P. O’Reilly, “Conceptualizing digital transformation in business organizations: A systematic review of literature,” *30th Bled eConference Digit. Transform. - From Connect. Things to Transform. our Lives, BLED 2017*, pp. 427–444, 2017, doi: 10.18690/978-961-286-043-1.30.
11. C. P. Lopez, J. Aguilar, and M. Santorum, “Autonomous VOs management based on industry 4.0: a systematic literature review,” *J. Intell. Manuf.*, 2021, doi: 10.1007/s10845-021-01850-8.
12. K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson, “Systematic mapping studies in software engineering,” *12th Int. Conf. Eval. Assess. Softw. Eng. EASE 2008*, pp. 1–10, 2008, doi: 10.14236/ewic/ease2008.8.
13. K. Petersen, S. Vakkalanka, and L. Kuzniarz, “Guidelines for conducting systematic mapping studies in software engineering: An update,” *Inf. Softw. Technol.*, vol. 64, pp. 1–18, 2015, doi: 10.1016/j.infsof.2015.03.007.
14. C. H. Botero, *Un modelo para investigacion documental: guia teorico-practica sobre construccion de estados del arte con importantes reflexiones sobre la investigacion*. Señal Editora, 2000. [Online]. Available: <https://books.google.com.co/books?id=Wa3PAQAACAAJ>
15. M. N. Córdoba and C. Monsalve, “Tipos de investigación, predictiva, interactiva, confirmatoria y evaluativa,”
 - i. *Fund. Sygal*, pp. 139–140, 2008.
16. R. Hernández Sampieri, C. Fernández Collado, and M. del P. Baptista Lucio, *Metodología de la Investigación*. Mexico: McGRAW-HILL / INTERAMERICANA EDITORES, S.A. DE C.V, 2005.



FUNDACIÓN
UNIVERSITARIA
DE POPAYÁN



UNIVERSITÉ
DE LORRAINE



Lifia

Facultad de Informática - Universidad Nacional de La Plata



Universidad Tecnológica
de Pereira



Universidad
del Cauca



FUNDACIÓN
UNIVERSITARIA
DE POPAYÁN



Corporación
Universitaria
Comfacauca
Unicomfacauca

REGISTRADA VENEZUELA