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Towards a Characterisation of Smart Systems: A Systematic Literature Review

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ABSTRACT

Enterprises and governments are focusing their efforts on reducing the gap between the physical and the digital world to address various challenges. This digital transformation is also characterised by a change of paradigm, based on moving from computer-aided technologies to Smart Systems, which are present in several domains such as Smart Cities, Smart Manufacturing, or Smart Services. In this scenario, the exploration of the conceptualisation of Smart Systems has been addressed in the scientific literature with the objective to understand the characteristics of such systems and the implications of their use. However, there is a lack of a generic view of the concept since most studies focus on specific domains. This view is necessary to provide common ground for the development or implementation of Smart Systems within various domains, specially for those that have not been tackled yet. This work aims at addressing this issue through the exploration and analysis of conceptualisations of Smart Systems and Smartness within the scientific literature. For this purpose, a Systematic Literature Review is performed aiming at gathering papers including definitions of Smart Systems, regardless of the application domain. Text mining processing techniques are applied to obtain insights from the definitions extracted from the collected papers. Considering the findings of the literature review and the analysis of the extracted definitions, we enumerate and describe a set of characteristics of Smart Systems. We also provide a diagrammatic view of the elements of a Smart System and their relationships through a meta-model.

1. Introduction

The rise of the new industrial revolution, known as the Industry 4.0 [1], is fostering enterprises and governments to adopt and develop new technologies to allow them to optimise strategies, develop new products, shorten development periods, achieve resource efficiency or provide more personalised products. The change from product to service-oriented enterprises is another factor that plays an important role in this trend [1] as well as the extended use of the Internet of Things (IoT) [2]. A relevant aspect in this new scenario is the especial focus on the reduction of the breach between physical and cyber components, accomplished through the integration of operation systems and Information and Communication Technologies (ICT) with the idea of forming Cyber-Physical Systems (CPS) [3]. Moreover, there is a trend towards moving from the development and application of computer-aided approaches [4, 5, 6] to more digital, networked and intelligent methods and agents [7, 8]. Within this context, the concept of Smartness and Smart Systems have began to be used in different domains. Indeed, the word "smart" has been widely used to name products (Smart Phone, Smart TV, Smart Watch, etc.) as well as methods, applications, frameworks, and techniques proposed in the scientific literature [9, 10, 11, 12, 13, 14]. Recently, concepts such as Smart Cities [15], Smart Manufacturing [16], or Smart Grids [17] have gained attention not only being tackled by industry practitioners but also being widely discussed in the scientific literature. Generally, these concepts are associated with advances within specific fields through the development, implementation and application of ICT [18, 19], the use of intelligent devices [20], Artificial Intelligence (AI) [21], and novel industrial and management technologies [19].

Notwithstanding, this wide adoption of the word "smart" to represent or qualify certain types of systems did not provide a unified specification of the features that make a system smart. The scientific literature shows divergences when describing Smartness or Smart Systems. Some works consider that smartness is possible through the extensive use of ICT or digital capabilities [18, 22, 23, 24, 25, 26, 17], whilst others provide a more holistic view of the concept, considering that smartness is reached through the cooperation of several factors such as policies, economy, governance, education, individuals, technology, sustainability, etc., towards the improvement of a certain environment

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and its inhabitants [27, 28, 29]. In the business and management field, smartness is defined by the business strategy, the background of the stakeholders or behaviours directed towards sales [30, 31, 32]. On the other hand, in the field of social sciences and education, smartness is viewed as a social construct instead of the inherent and interrelated abilities of an individual [33, 34]. In this sense, there is a need for reaching a common understanding of the concepts of Smart Systems and Smartness to guide the development of novel methods and technologies. However, although an understanding may have been reached in some domains and, in some cases, more general concepts are introduced [35, 36], there is a lack of a generic view of the concept of Smart System that integrates different domains into a unified concept.

The exploration of the state of research regarding Smart Systems and the concept of Smartness within certain domains is an open research subject. In general, works addressing this subject aim to obtain definitions to serve as common ground for the development of new applications. Notwithstanding, most papers do not consider a generic view that is independent from the application domain. Moreover, to the best of our knowledge, there is a lack of consensus regarding the conceptualisation of Smart Systems and their characteristics considering common points regarding how they are treated in different domains in the scientific literature. Therefore, this work aims at exploring the state of the art regarding Smartness and Smart Systems. We put special focus on defining the characteristics of a Smart System through the study of explicit definitions of Smartness and Smart Systems presented in scientific papers. This is done by manually extracting those definitions and analysing them through diverse methods.

To this end, we conduct a Systematic Literature Review (SLR) aiming to retrieve papers containing definitions of Smartness or Smart Systems. The search is carried with independence from the domain in which the definitions are presented. The definitions are then manually extracted from the collected papers and a semi-automatic analysis is carried out to obtain the results. The final objective of the work is to identify the characteristics of Smart Systems, driven by similarities between the concepts presented within the extracted definitions. The methodology aims at answering the following research question:

- What are the characteristics of a Smart System?

The contributions of this work can be summarised as: (1) to provide a view on the state of the art regarding of Smartness and Smart Systems considering how they are defined, (2) to identify similarities in the definitions provided in scientific papers regardless of the application domain, (3) to define the characteristics of Smart Systems, (4) to establish an initial common ground towards a unified definition of Smart Systems through a formalisation represented using a meta-model.

This paper is organised as follows. Section 2 introduces concepts that are relevant for the current work and describes attempts of defining different types of smart systems in the literature through reviews of scientific papers. Section 3 describes the methodology followed to perform the SLR and the approaches used to analyse the selected papers. Section 4 describes the results obtained from the analysis. Section 5 presents the characteristics of Smart Systems considering the obtained results. Section 6 enumerates the threats to validity of this work and the manner that those threats are tackled. Finally, Section 7 presents the conclusions and future work perspectives.

2. Research Context

To define the characteristics of Smart Systems, it is worth to first explore the definition and properties of a system from a generic perspective. Therefore, in this section we first introduce some systemic notions defined in the General Systems Theory [37]. After, we provide an introduction of different domains in which the concept of Smartness is used. Finally, we enumerate and describe works that aimed at exploring the state of the art regarding different types of Smart Systems such as Smart Cities, Smart Homes, Smart Industries, among others.

2.1. General Systems Theory

The most accepted definition of a system was introduced by [37]: "*a system is a set of interacting elements*". [38] extended this definition considering that, according to GTS, a system is a set of interconnected parts with properties that are richer than the sum of the properties of those parts. Moreover, a system has boundaries and a set of attributes that make it unique when compared to other systems [38].

There are two fundamental perspectives to view a system [39]: from the *teleological* aspect and from the *ontological* aspect. The *teleological* aspect is focused on the behaviour and functioning of the system, whilst in the *ontological* view the system is analysed from a structural perspective.

The work by [38] based its definition on the *ontological* view by considering a system as a "*bounded set of interconnected elements forming a whole that functions for a specific finality in an environment, from which it is dissociable and with which it exchanges through interfaces*". The authors also defined a list of concepts that characterise a system:

- System Element: a component of a system.
- Relation: a link between two entities.
- Objective: set of actions that the system can execute in its environment in order to achieve its objective.
- Environment: all that is outside the boundaries of the system.
- Interface: element of the system through which a connection between the system and its environment is established.

We consider these as base characteristics and that a smart system has all of those base characteristics and some additional ones that we aim at define in this work.

2.2. The Smartness concept in different domains

The Smartness concept is used in a variety of domains, representing different types of systems. We briefly describe the main concepts behind some common Smart Systems next.

2.2.1. Smart City

It is based on the idea of creating an urban space characterised by sustainable economic growth and high quality of life of its inhabitants [40]. The core of Smart Cities is the interconnection between all possible elements of the city, including citizen and business, and interfacing them one to another through state-of-the-art technologies [41] such as integrated materials, sensors, computer networks, and decision-making algorithms [42]. Smart Cities include different application areas such as Governance, Energy, Building, Mobility, among others [43], and there are currently various advances associated to the concept such as 5G technologies, sensors, IoT, robotics, virtual and augmented reality, and artificial intelligence [41].

2.2.2. Smart Home

Smart Homes are based on the implementation of a communication network that allows to connect and remotely control or monitor devices and services [44]. The devices used for Smart Homes are various including air conditioning and heating, ventilation, lightning, hardware, and security systems [45]. These devices are often named "gateways", and they are able to interact with tablets, mobile phones, etc [45]. The objective behind the concept is to improve the lives of people through socially and time assistance, guided by automated activities such as sensing, anticipating, and responding to events within a house [46].

2.2.3. Smart Industry

To understand Smart Industry, it is first necessary to define the ideas behind Smart Factories, which are a flexible cyber-physical production factories that provide personalised services or products to customers and their functioning is based on the use of Big Data [47]. In this context, Smart Industry is an evolving network of Smart Factories that fosters and is influenced by the participation of researchers, developers, suppliers, distributors, and end users [47]. Moreover, the Smart Industry is possible through a synergy of IoT devices that allow to enhance the use of computers in the industry [48]. A common term for the Smart Industry is the "Industry 4.0" [49], which was introduced by the German government, and it is based on the IT-driven transformation of manufacturing systems [1] grounded in concepts such as CPS [50], IoT [2], decentralised decision-making, personalised products and services, among others. In this work, the terms "Smart Industry", "Smart Manufacturing" and "Industry 4.0" are used interchangeably [51].

2.2.4. Smart Service System

Service systems are a systems composed of people, information, organisations, and technologies that interact towards the achievement of common objectives [52]. Service systems depend not only on the system elements by themselves but also on the manner that those elements interact [53]. On the other hand, Smart Service Systems are service systems able to learn, perform dynamic adaptation, and make decisions considering data that is received, transmitted or processed in order to improve their capabilities in the future [54]. This type of service system put special emphasis on the human, so that aspects such as knowledge, capabilities, and value are defined by the people of the system [55].

2.3. State of the art

Several works carried out literature reviews during the recent years with the objective to provide a view of the state of the art regarding different Smart Systems such as Smart Cities, Smart Industries, Smart Homes, and Smart Service Systems. This section briefly describes those work, grouping them according to specific application fields for better organisation and to allow the readers to easily highlight how the vision of smartness varies between fields.

Regarding Smart Cities, the work by [56] carried out a literature review with the objective to explore definitions, dimensions, models, and paradigms around the domain. On the other hand, the work by [15] aimed at obtaining the definition of Smart Planning considering its spatial dimension by exploring the use of the word "smart" in the scientific literature. The authors defined the pillars of the procedure of Smart Planning: intelligent location, built environment, smart energy management, and smart mobility for smart people, putting special emphasis on the role of people and their adaptation to smart solutions to tackle the problems within a city. The authors claim that a smart city as a concept involves the urban development in a cohesive strategy through the combination of technology and the knowledge and role of the ICT.

As for Smart Homes, [57] presented a literature review describing the goals of Smart Home Energy Management System and its definitions, applications, and how the components of a Smart Home are manufactured. A literature review is also presented in [58], the work focuses on home automation systems considering their features, benefits and drawbacks. Moreover, [59] analysed 48 papers on smart homes and home health monitoring technologies for older adults. Conclusions drawn from the analysis point out that the technology readiness level for Smart Homes and Home Health Monitoring was still low at the time of the publication. [60] also presented a systematic literature review addressing Smart Home applications related to IoT. The work analysed 229 papers and enumerated the motivations of the use of Smart Home applications based on IoT, the challenges that may emerge, and the recommendations to address those challenges.

Concerning Smart Manufacturing or Smart Industry, despite that this naming is still used in the literature, the Industry 4.0 is often considered as equivalent [51]. In this domain, [16] published a literature review based on an analysis of national strategies and policies addressing Smart Manufacturing from various countries as well as the available scientific literature introducing relevant topics. The work concludes that the most important issues for achieving Smart Manufacturing are the interoperability and development of technologies. [49] also discusses the past, present and future of Industry 4.0 through a Systematic Literature Review (SLR) method that aimed at characterising the state of research for the domain. The work by [61] followed the same method and discussed the current state of research regarding Industry 4.0 including key technologies and applications. Moreover, [51] followed the same path and performed a bibliometric analysis in addition, aiming to describe a detailed overview on the domain including related concepts such as IoT, Industrial Wireless Networks, Cloud Computing, Energy-based Systems, among others.

Some works addressing Smart Service Systems have also focused on the search for a conceptualisation through approaches based on performing literature reviews. The work presented in [43], for instance, aimed at defining Smart Service Systems by applying metrics and machine learning algorithms to perform text mining on a large corpus of scientific papers and news articles. The study puts special focus on Smart Service Systems applied to different aspects of human life such as homes, energy, healthcare, and transportation, and it provides relevant keywords, research topics, technology factors, and application areas regarding the studied subject. The work by [62] also aimed at conceptualising Smart Service Systems through a literature review and in-depth interviews with informants from the industry that have begun introducing smart products into their service systems to improve the capabilities of those systems.

The works presented in this section show a tendency to perform domain-specific studies. Moreover, most works are not focused on obtaining characteristics that make systems smart. This work aims at closing this gap by performing a domain-independent search of definitions of Smartness and Smart Systems in scientific papers. We also perform an analysis of those definitions with the objective to provide a set of characteristics of smart systems and their relationships.

3. Literature Review and Analysis

This section describes the methodology followed in this work. There are two main activities in the methodology, as presented in Figure 1, through a Business Process Model and Notation (BPMN) diagram [63]. The first activity is based on retrieving a set of papers containing definitions of Smartness and Smart Systems in the scientific literature. This activity produces a set of selected papers that are the used as input of the next activity, based on analysing the definitions contained in the papers through text mining methods.

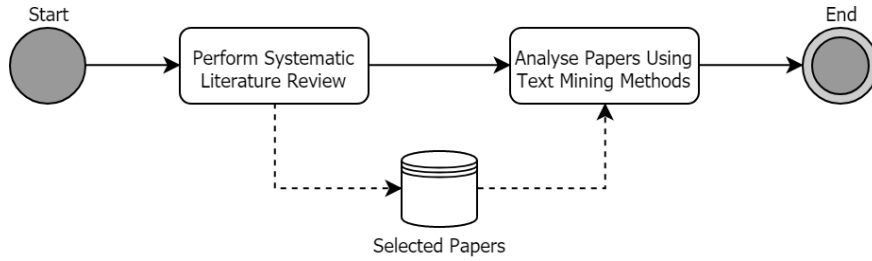


Figure 1: Overview of the methodology followed in this work.

3.1. Systematic Literature Review

This section describes the characteristics of the Systematic Literature Review (SLR). A SLR is based on the application of a systematic process to define the research question, identify relevant studies, evaluate their quality and summarise the findings qualitatively or quantitatively [64]. Moreover, the tools used for selecting the studies must also be identified [65]. The search performed in this work is based on the methodology introduced by [66]. In general, systematic literature reviews are based on carrying out a cycle composed of three main phases: (1) define keywords, (2) search in the literature, (3) analyse the results [67]. The main advantage of performing a SLR is that it follows a predefined strategy that allows to provide concrete evidence regarding the data sources and the criteria to select and analyse papers [68].

The SLR carried out in this work is a process that starts with the definition of the research question and is followed by the definition of the keywords, the search strings and the databases. The search is then performed by querying the databases using the search strings. The filtering sub-process is then carried, and it is based on analysing metadata from each paper to define if it satisfies the first set of criteria F_1 . The full text of a paper that satisfies F_1 is then examined in order to check the second set of inclusion criteria F_2 . The paper is included if F_2 is satisfied. Any other paper is discarded. Details regarding each activity of the methodology are described in the following sections.

3.1.1. Research question

Initially, the research question is defined. Note that we pursue a characterisation that is independent from the application domain. Hence, the research question that drives the SLR is:

- RQ: What are the characteristics of Smart Systems?

Considering RQ, we derive the following specific questions to serve as guide for the analysis of the papers gathered with the SLR.

- What are the domains of the papers containing definitions?
- What is the time period in which the papers were proposed?
- What are the main keywords used by the authors to propose their definitions?
- Are there any common aspects in the definitions when considering different application domains?
- Considering common points, what are the characteristics of a smart system?

3.1.2. Keywords and search strings definition

The keywords used in the search strings are *smartness* and *smart*. Two search strings are defined, both focused on obtaining explicit definitions, considering that explicit conceptualisations are most likely to include the characteristics of the system that is being defined:

- S_1 : {*smartness is*}, focused on the first keyword *smartness*.
- S_2 : {*we define smart**} OR {*smart* is defined*}, related to the second keyword *smart*.

Note that S_2 is very specific, whilst S_1 is open to diverse string combinations. This structure for S_1 is selected since the concept of Smartness may not be explicitly defined, but described as an attribute of a system instead.

3.1.3. Database Selection

Since two separate search strings are defined (S_1 and S_2), and one is much more specific than the other, two different searches are carried. For S_1 , the following databases are used: ACM, Scopus, IEEE_Xplore, Taylor & Francis Online, and Web of Science. We select five databases taking into account that a minimum of four is sufficient to perform a robust literature search [66]. Since S_2 is much more specific than S_1 , the number of results obtained with this search string is expected to be much lower. Hence, the databases SpringerLink and Wiley are added in addition to those used for S_1 .

It is worth mentioning that we use Scopus and Web of Science, which are extensive abstract and citation databases that gather papers from several peer-reviewed journals. The papers that can be retrieved with these databases come from diverse publishers such as Elsevier, Springer, Taylor & Francis Online, and IEEE. It is expected that this will provide more robustness to the search. Naturally, duplicated papers are expected to appear and they are removed.

Each database has its own syntax to write queries. Hence, the search strings described in Section 3.1.2 are slightly modified for each database to obtain the expected output.

3.1.4. Papers Filtering

After defining the research question and the databases to perform the search, the first filter F_1 consists of basic inclusion criteria comprising: papers in English; papers from journals or conferences proceedings; papers with available full texts, and primary studies. The second filter F_2 consists of the following mechanism: for each retrieved paper we perform an initial exploration to define if it contains definitions for Smartness or Smart Systems. This analysis consists of searching the words "smartness" and "smart" within the text and analyse the context of the paragraph in which the word is present to define if it is a definition. If no definition is found, an overview of the title, abstract, introduction and conclusion is performed in order to identify possible implicit definitions. Papers containing definitions are selected and the proper conceptualisations are extracted, note that there may be more than one definition per paper, hence the number of definitions may not be equal to the number of selected papers. Table 1 summarises the inclusion criteria and presents the exclusion criteria derived from them.

Filter	Inclusion Criteria	Exclusion Criteria
F_1	Papers written in English Paper with full text access Primary studies	Papers not written in English Paper without full text access Literature reviews
F_2	Papers containing definitions Papers with implicit definitions	Papers without definitions Papers without implicit definitions

Table 1: Inclusion and exclusion criteria used to select the papers. The criteria are organised in two filters, F_1 and F_2 , the first is related to metadata analysis whilst the second is based on analysing the full text of the papers.

3.2. Papers Analysis

After extracting the definitions from the selected papers, we apply text mining techniques to perform an analysis. This allows to provide a quantitative, and therefore objective, vision of the set of definitions. The activities that compose the methodology followed in this work are presented in Figure 2 through a BPMN diagram.

Note that we introduce three parallel paths in Figure 2 representing the three main approaches to analyse the gathered definitions. The common activity to all paths is the extraction of definitions from the selected papers obtained after applying the methodology described in Section 3.1.

The first path (bottom path in Figure 2) is based on manually extracting keywords from the definitions and calculating their frequency. The output of the final activity of the path is a set of T tuples $(w, f)_i$ where $i \in T$, and w and f are the i -th word and its frequency, respectively.

The second path is composed of two other parallel paths. For both sub-paths, an activity based on pre-processing the definitions is carried. This pre-processing step consists of removing punctuation signs, such as dots, commas, etc., and removing stop-words. A total of 179 words that are considered as stop-words are removed from the text, some of them are *his*, *any*, *down*, *you*, *can*, *against*, among others. Finally, stemming is also performed in order to convert every word into its root version, e.g. *intelligence* and *intelligent*, are converted to the root word *intellig*. Applying

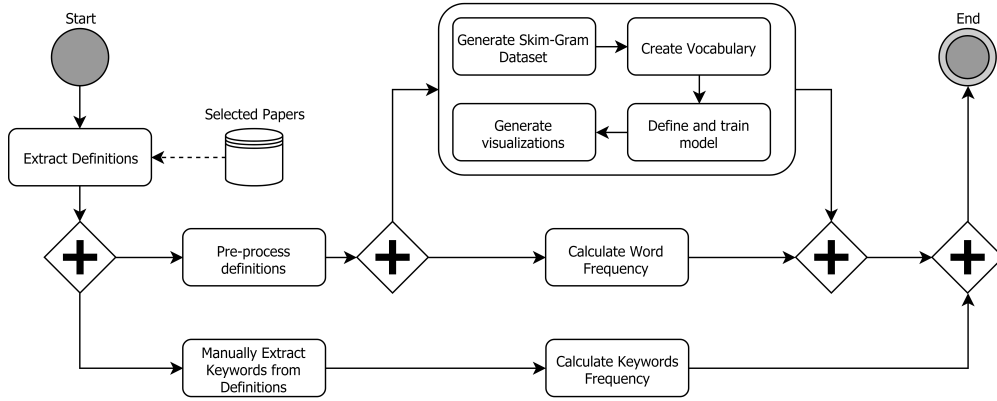


Figure 2: Overview of the methodology to explore the definitions through text mining techniques.

stemming is specially relevant for document retrieval due to that, depending on the chosen stemming method, it may allow to improve Recall without a significant loss of Precision when querying documents [69].

For the first sub-path (middle path in Figure 2), the frequency is calculated as described for the first main path. However, the calculation is applied on the full texts of the definitions and not only on the manually extracted keywords.

The second sub-path is composed of a sub-activity based on the construction and training of a Deep Learning (DL) model [70]. The method used in this work, based on using learned representation of words with vectors, is currently widely used in for Natural Language Processing (NLP) [70]. The core of the method is the Skip-gram model [71], which is a neural network devised to learn vector representations of words within a text corpus. The final idea is to use this vector representation to graphically visualise the relationship between the words within the definitions. For this purpose we use t-Distributed Stochastic Neighbor Embedding (t-SNE) [72] to reduce the dimensionality of the vectors and the K-Means [73, 74, 75, 76] algorithm to organise the vectors into ideally representative groups in order to identify patterns. K-Means was selected due to factors such as ease of implementation, simplicity, efficiency, and proven empirical success [77].

This sub-activity starts by concatenating all pre-processed definitions into a single string s , which do not have punctuation and stop-words, and it composed only of root words. In the following phase, a vocabulary used to numerically represent the words of s is created. This consists in assigning an integer value to each word of s . Next, a dataset containing M tuples $(l, t)_j$ composed of indices from the vocabulary is generated, where $j \in M$, and each tuple j consists of an input word l_j and a target word t_j that appears close to l_j in s within a certain window size C . Hence, M ultimately depends on the size of C , the largest the window size, the more tuples are generated. The following step is based on defining and training a Skip-gram model using the dataset of tuples. Skip-gram is a neural network [78] that receives as input \vec{x} encoded as a one-hot vector. The output of the network is a vector \vec{y} , with the same size as \vec{x} , that contains at each of its positions the probability of the word l_j to be close to one word of the vocabulary. In other words, the model is trained to output highest probabilities for words that are more likely to appear next to the input word. For this purpose, the tuples $(l, y)_j$, previously encoded as one-hot vectors, are used as input and target output of the network respectively during training.

The idea of training Skip-gram is to obtain vectors, which are the weights of the network and also known as word embeddings, that represent each word considering the specific context of the word within the text that was used to train the model. This may allow to perform different tasks such as sentiment analysis, text querying, and word visualisation, which is the reason why we apply the method in this work. More details regarding the model can be found in the original paper [71].

4. Results

The method described in Section 3.1 led us to obtain a total of 123 papers containing definitions with a total of 177 definitions. The number of papers obtained for each database is presented in Table 2 joining the results for S_1 and S_2 .

The definitions were various and most of them were introduced in their respective papers targeting specific application domains. Table 3 shows some examples of the papers, including the manually extracted definitions, keywords,

	Retrieved	With Definitions	Definitions
ACM	16	5	9
Scopus	33	14	17
IEEE_Xplore	167	58	86
Taylor & Francis	74	17	22
Web of Science	19	5	8
SpringerLink	40	21	29
Wiley	8	3	6
Total	357	123	177

Table 2: Number of papers retrieved from each database, papers containing definitions, and definitions extracted from the papers.

and domain. Note that, for some cases, more than one definition is introduced in a paper. We provide an example of this in the table with the work by [79], which provides four definitions of Smartness.

4.1. Application domains

The retrieved papers were part of various domains since we did not restrict the search string for specific applications. Figure 3 presents the domains addressed by the papers. The domains were manually defined after analysing the content of each publication. The papers were organised so as to be part of exclusively one domain. The domain "Theory" comprises theoretical works and papers proposing conceptual models.

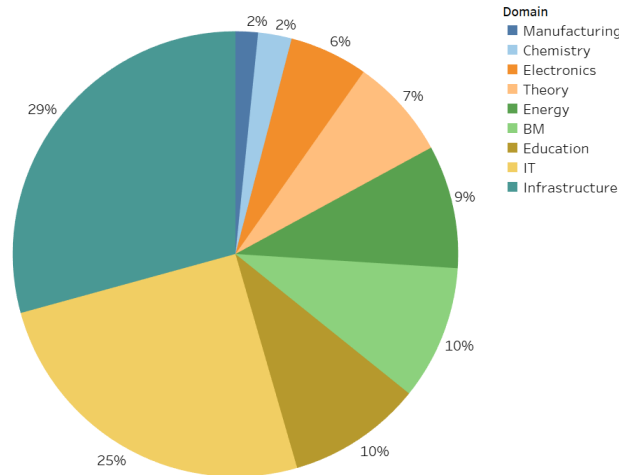


Figure 3: Domains of the papers that presented definitions of Smartness or Smart Systems.

As presented in Figure 3, the concept of Smartness is addressed in various domains, such as energy, manufacturing, education, among others. The most addressed domain is *Infrastructure*, with almost 30% of the papers. The domain includes papers regarding smart buildings, cities and infrastructure. This result is expected due to the spread of the use of the term "smart" within this domain for different purposes. On the other hand, the *Information Technology (IT)* domain groups 25% of the papers. It includes all sub-fields related to the treatment of information such as Information Architecture, Information Retrieval, Communication Technologies, among others. We also included papers related to Computer Science within this domain. Together, these two domains (IT and Infrastructure) comprise more than half of the papers, showing that there is a strong tendency of scientific publications of these domains to introduce definitions.

It is worth mentioning that the domain of each paper was considered when extracting the keywords presented in Section 3.2. The purpose was to separate aspects that were domain-specific so as to obtain keywords that could be applicable for Smart Systems from a generic perspective. However, this was not always possible since some characteristics mentioned in the definitions were too specific for the domain. In such cases, the keywords were discarded.

Paper	Definition	Keywords	Domain
[80]	Smartness is attributed to the development and utilisation of knowledge, skills and behaviors to resist educational hegemony in a way that is beneficial to self and the larger community.	Development, knowledge, skills, behaviors, benefit, self, community	Education
[81]	We define smart cities, which are intelligent large-scale environments, with large amounts of data that are used to improve the quality of life for its citizens.	Intelligence, large-scale environment, big data, improve, quality of life	Infrastructure
[82]	We define smart to mean embedded actuation, sensing, and control logic in a tightly coupled feedback loop.	Embedded, actuator, sensor, control, feedback	Business and management
[29]	"Smart" is defined by the deployment of innovative and commercially available state-of-the-art technology.	Innovate, commerce, technology	Manufacturing
[83]	We define smartness as the number of nodes that have been connected to the information network. Therefore, smartness conceptually represents the degree to which a particular smart grid technology and its external links has been integrated into the utility's power network.	Node, connected, information, network, grid, integration	Energy
[84]	The smartness is coming from the algorithms that extract unique features and recognise the patterns in the features.	Algorithm, features, pattern recognition	Chemistry
[85]	Smartness is associated to the system capability of self-adapting when the operating conditions change and usually it resorts to the action of the control system.	Self-adaptation, action, control	Electronics
[86]	We define smart spaces as environments in which objects have associated with them: (1) a CPU (or brain) allowing some minimal level of intelligence to exist in the object, and (2) sensors that detect the presence of other objects within the environment or the state of the object itself.	Environment, CPU, brain, intelligence, sensor, detect	Theory
[79]	Smartness is being connected and able to act with partial autonomy based on own decision making while cooperating and coordinating with others. This "smartness" typically stems from highly cooperative behavior, self-awareness, self-adaptation, and self-optimisation. Smartness allows the system to introspect and reason about its environment (including potential security threats), the system can protect itself. For a Smart Cyber-Physical System smartness is the system's ability to learn and respond intelligently in new contexts.	Connected, act, autonomy, decision-making, cooperation, coordination Cooperate, self-awareness, self-adaptation, self-optimisation Introspect, reason, environment, self-protection Learn, respond, intelligent, context	Information Technology

Table 3: Examples of gathered papers with the extracted definitions, keywords and domain.

As shown in Figure 3, the concept of Smartness is not employed for a particular domain, but they have spread to different applications. In some cases, the definitions considerably differ one from another, but there are interception points that are common for most applications.

The common aspect for most of the definitions found within these domains is that technology is used to provide smart capabilities to some system. However, the literature review also revealed some definitions that are not directly related to the use of technology to develop Smart Systems. Nevertheless, they provide relevant insights towards the achievement of a generic understanding of Smartness. For instance, considering the domain of *Business and Management*, [30] define smart capital as the flow of information from a company to the financier, in which there is consultation and support that flow in the opposite direction. The authors also state that the degree of smartness depends on the financial product used, the institutional background and business strategy of the financiers, expected time-horizon of the investment, and the stage of development of the firm that is being financed. In the same domain, the concept of working smart is also present in the literature, the works by [31] and [87] present definitions initially introduced by [88]. The former presents the explicit definition introduced in the original paper which states that working smart comprises "behaviors directed toward developing knowledge about sales situations and utilising this knowledge in sales situations", whilst the later also relates the concept with the optimal behavior in sales situations that is based on making situation-appropriate decisions. These concepts are directed towards the use of data or knowledge to make decisions for business purposes.

As for the definitions that consider social aspects, the work by [34] refers to smartness as a socially constructed concept that divides people into two groups (the smart ones and the ones that are not). The idea that smartness is a concept created by the society is also mentioned by [33], who states that it is a cultural practice rather than an inherent biological property of an individual, criticising the tendency of schools to overlook the knowledge that comes from personal experiences of the students. Other authors present smartness as a relationship between an individual and its community. [80] states that smartness implies the development and use of knowledge, skills and behaviours in order to obtain benefits for the individual and its community by resisting the educational hegemony, and [89] relates smartness to the balance between knowledge and wisdom with strong commitment to the community and work ethic. Some authors relate smartness with the possession of certain abilities that allow smart individuals to be labelled as such. [90], for instance, defines smartness as an understanding of the world with the ability to act with a purpose, think rationally, and effectively dealing with the environment. The definition of [91] also mentions the ability to interact with the world with low effort to produce some outcome. A similar concept is presented by [92], who defines smartness as being capable to respond to some feedback with a quick mind. [93] makes the distinction between book smartness and street smartness, presenting the former as explicit knowledge and the later as the tacit understanding capability of an individual. Finally, [94] defines smartness in the context of smart power as the deliberation, self-knowledge, self-control, creative imagination, and knowledge about the world used in combination to foresee possible consequences; this ability allows to take strategies that are specifically designed and adapted to a particular context even when there are already available some pre-defined "standard procedures".

Other definitions include smart data, defined by [95] as significant and semantically explicit data that is useful to fulfil objectives; smart office, defined as aspects of business processes that coordinate the operations in the office within the context of projects and tasks that are performed by employees on a regular basis [96]; smart service systems, which are systems that rely on smart products as objects that interface service consumers with service providers to coordinate their resources and activities [97]; smart packaging, which employs systems to perform automatic and autonomous modulations in micro/nanostructures in order to adapt to dynamic changes in the environment [98].

4.2. Publication period

Considering the time of publication, Figure 4 shows that there is a tendency to provide or explore definitions of Smartness or Smart Systems during the recent years. This may be due to a possible augmentation of the use of the concepts recently. However, note that this does not imply that the same trend is true for papers addressing the subject, since we consider only papers with definitions for the analysis.

Figure 5 presents the number of papers per year considering the application domain. Results show that there are papers presenting definitions since the late 90s until the recent years for the domains: *Information Technology*, *Theory*, and *Business and Management*. There seems to be an interest of exposing the concept of Smartness, specially in the *Information Technology* domain, which is the domain in which the number of papers is the most distributed throughout the years. Although *Infrastructure* is the domain with the largest number of papers, the discussion of the Smartness concept has been addressed the most during the last years starting from 2015. However, the number of

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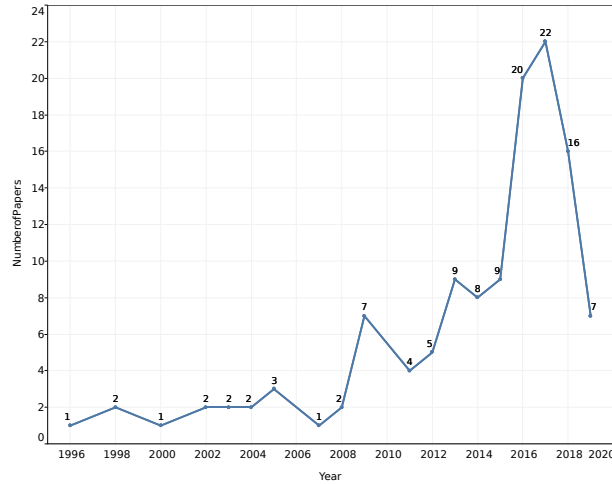


Figure 4: Number of papers containing definitions per year.

papers introducing the concept of Smartness within the *Manufacturing* domain is very low, this may be caused by the tendency to use and explore the term Industry 4.0 instead of Smart Manufacturing or Smart Factory.

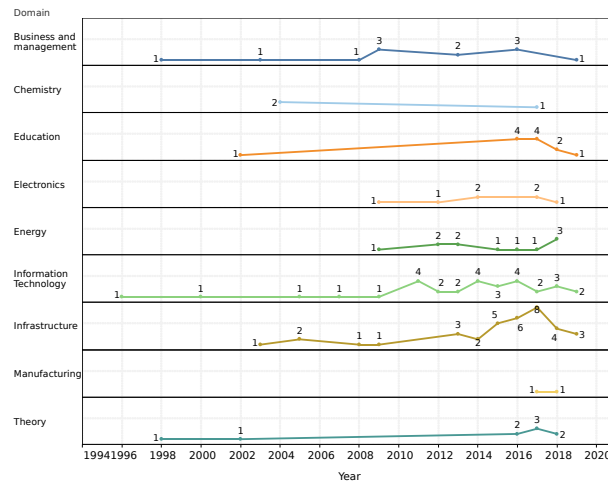


Figure 5: Number of the papers that presented definitions of Smartness or some Smart System per year considering the domain.

4.3. Text mining results

This section presents the results of the methodology described in Section 3.2. First, the results of the word frequency method considering the full definitions and the extracted keywords are presented and discussed. Next, details on the implementation of the Skip-gram model to analyse the full definitions are described, and the visualisation of the most frequent words using the word embedding vectors is shown and analysed. After, we describe the different views found in the literature regarding the relationship between smartness and intelligence. Finally, we present the final analysis of the common and aspects of the conceptualisations of Smartness and Smart Systems considering the different domains.

4.3.1. Word frequency analysis

We applied word frequency counting to the full definitions of the papers. The frequencies of the top-25 most frequent words are presented in Figure 6. Some considerations regarding the figure are worth mentioning. We consider only the root of the words (stemming). The word "smart" is by far the most frequent one with 128 appearances so it was not included for the analysis. We also removed "defin" (root of words such as "define", "defined", "definition", etc.) and "use". The first one is very frequent due to the search string S_2 and it does not add much information regarding the investigated subject. As for the word "use", it is too generic to provide relevant insights.

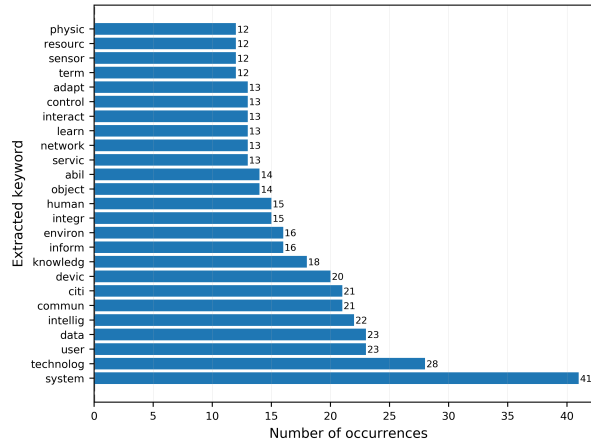


Figure 6: Number of occurrences of the top-25 most repeated words considering the full text of the definitions.

The most frequent word in the definitions is "system" with 41 appearances. The fact that "technology" is in the second place complies with the idea presented by some authors who state that smartness is possible through the use of ICT. Moreover, other frequent words such as "sensor", "devic", "physic", "object", "control", "environ" and "interact" could imply a tendency to use technology considering the following scenario: devices that sense, control and act on objects that are present in an environment in the physical world.

It is also relevant to point out the frequency of the words "user" and "human", implying that Smart Systems ultimately aim at serving users. The treatment of data ("data" and "inform") and its use for learning ("knowledg", "learn") seems relevant as well in the definitions along with the communication capability ("commun", "interact", "integr", "network"). On the other hand, the word "intellig" is very frequent. Therefore, there seems to be a connection between smartness and intelligence. In fact, this relationship is explored in detail in Section 4.4.

We also applied word frequency counting on the keywords that were manually extracted from the definitions only. Figure 7 shows the occurrences of the top-25 most frequent keywords that were manually extracted from the definitions. Results show that most of the manually extracted keywords presented in this section coincide with the words that have the highest frequency within the full definitions. Aspects such as data, knowledge, environment, communication, sensing, controlling, learn, the presence of an user, and intelligence seem to be relevant within the definitions considering not only in terms of quantity but also considering the qualitative value that we gave to those words at the moment of their extraction. Moreover, there are some concepts that are not present in the results obtained using the full text of the definitions, which have some frequency within the set of extracted keywords such as integration, ICT, development, autonomy, optimisation, infrastructure, and context.

4.3.2. Word clustering

For the Skip-gram model described in Section 3.2, the vocabulary size was equal to 100, the embedding vector size was equal to 100, the number of iterations during the training was equal to 50000 with a batch size equal to 100, and we used a skip window size equal to 5. These hyper-parameters were defined initially considering the literature [99, 100] and empirically fine-tuned afterwards.

Since the word vectors obtained after training the model were high-dimensional, we applied the t-Distributed Stochastic Neighbor Embedding (t-SNE) to aid at performing a visual analysis of the results, which is a technique that allows to visualise high-dimensional data by giving each data point a location in a two or three dimensional map [72].

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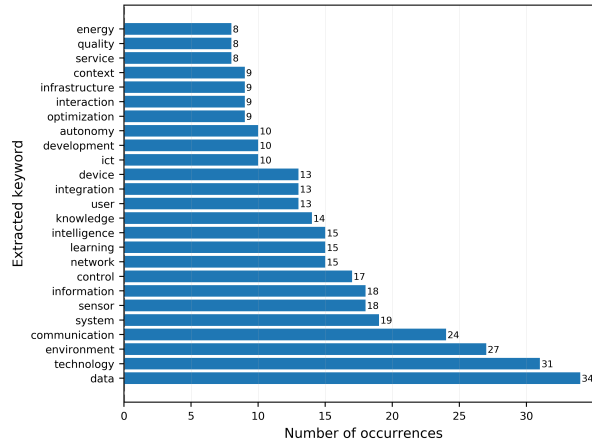


Figure 7: Number of occurrences of the top-25 most repeated keywords that were manually extracted from the definitions.

The learning rate used for t-SNE was equal to 10, with 10000 iterations, and perplexity equal to 3. These values were empirically defined. We also applied the K-Means algorithm to automatically organise the data into representative groups or clusters, using an empirically defined value of $k = 5$, which is the number of clusters to be assigned by the algorithm. K-means presents a number of advantages such as its ease of implementation, simplicity, efficiency, and proven empirical success [77].

Figure 8 presents the word embeddings using the first 25 words of the dictionary, which are the most frequent words within the definitions. It is worth mentioning that, same as in Section 4.3.1, the words "smart", "defin" and "use" were removed considering the same reasons.

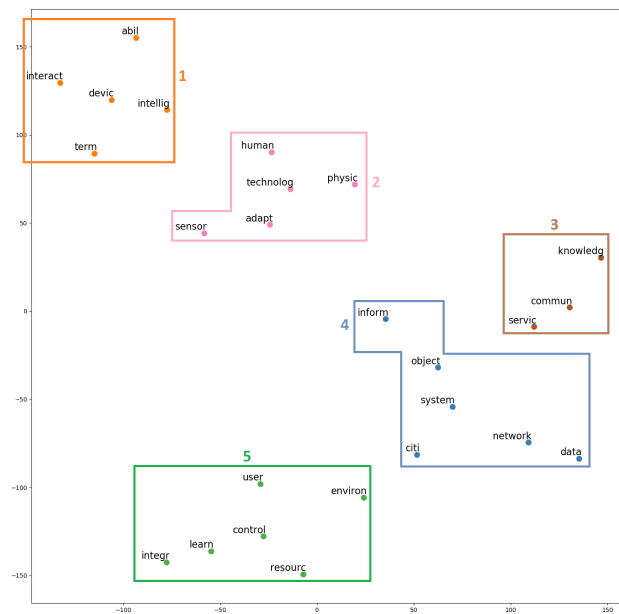


Figure 8: Visualisation of the embedding vectors using the 25 most words in the definitions.

Results show five differentiated clusters. Cluster 1 may be related to the ability of devices to interact and behave in an intelligent manner. Cluster 2 is likely to reflect the use of the word "sensor" with the ability to adapt and to be connected to physical environments. Moreover, humans appear close to these words, which may imply a tendency to

use sensors and technological means to sense human actions or data. Cluster 3 does not provide much information since it is the cluster with the less quantity of words. However, it seems to represent the relationship between services and communication, the later is one of the most frequent words as presented in Sections 4.3.1 and 4.5. Cluster 4 has the word "system" in its centre and "object" very close to it, which may seem natural if we see a system as a collection of interacting objects or elements. In fact, this interaction (a "network" composed of objects) with the main objective to perform data or information exchange may be reflected by the appearance of the root of both words within the cluster. On the other hand, the root word of "city" is also within the cluster, possibly reflecting a wide use of the term system to describe smart cities. We consider that clusters 3 and 4 could be merged, since they appear relatively close and both tend to represent communication capabilities to exchange data or information within a system. Finally, cluster 5 is specifically related to some capabilities of Smart Systems with respect to their environment, such as "integration", "learning", and "controlling".

Note that the results provided by the Skip-gram model are the output of a fully unsupervised learning approach. Thus, no human direction towards a specific or correct result was provided to the model during training (supervised learning). Therefore, they are often open to different levels of interpretation. However, we consider that the patterns discussed in this section reflect some specific aspects described within most definitions of Smartness or Smart Systems.

4.4. Smartness and Intelligence

The definitions of *intelligent* and *smart* found in the papers are diverse. Some works treat them as synonym, for instance, [101] considers that a smart system is also intelligent, stating that "*smart is intelligence – the ability to learn or understand or to deal with new or trying situations. The ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria (as tests)*". Note that this definition is focused on the behaviour. The work by [102] follows the same tendency, stating that "*an intelligent system is in which different structures are able to co-operate with each other in a coherent way. A smart system is an intelligent system in which services can be exploited by users to their maximum*". However, in this case, the definition is more related to the structure than the behaviour.

Other works consider them as different or complementary concepts. In the work by [35], for instance, it is stated that "*Smart Systems meet to some extent unexpectedly the expectations of their users when they provide comfort or do some daily magic; they sense and act*", whilst "*intelligent systems solve problems in a rational way like humans do and are able to reflect and explain their threads of inference; they solve and justify*". The definition refers to the behaviour of the systems, stating that smartness includes only the capability to sense and act, whilst intelligence allows to reason and explain the why the system performs actions. [103] presents intelligence as an evolution of smartness, stating that "*the future of Intelligent Manufacturing will not stop at the level of smart, but to truly realise the intelligent. Intelligent Manufacturing system achieves autonomous learning, autonomous decision-making and continuous optimisation*".

Finally, some papers refer to intelligence as a component that must be embedded into systems in order to make them smart. For instance, [104] consider that "*sensors, machines, equipment, products, etc., are equipped with embedded local intelligence – which makes them smart objects –and are invisibly (over the cloud) interwoven in order to cooperate and negotiate with each other, thus becoming capable to reconfigure automatically themselves (through actuators) for flexible production of multiple types of products*". Moreover, [105] describe smart objects within the IoT from the same point of view: "*objects in IoT are made smart through embedding intelligence using some innovational technologies*". However, we consider that the authors are describing the concept of *knowledge* when they refer to *intelligence* in their definitions.

4.5. Similarities within definitions

The final analysis of the definitions was focused on describing the most frequent words for each domain and their relationships. With this approach we aim at extracting aspects from Smart Systems that could be considered common to all domains. Table 4 presents the words that were present in the top-25 most frequent words (within the extracted definitions) for at least three different domains. It is worth mentioning that the words are counted after the pre-processing phase described in Section 3.2.

Word	Domain									Total
	BM	Chemistry	Education	Electronics	Energy	IT	Infrastructure	Manufacturing	Theory	
technolog	X		X		X	X	X	X	X	7
environ	X	X	X			X	X	X		6
system				X	X	X	X	X	X	6
inform	X		X		X			X	X	5
commun			X	X	X	X	X			5
intellig				X		X	X	X	X	5
data	X		X		X	X				4
network	X				X	X	X			4
sensor	X		X	X		X				4
adapt			X	X	X				X	4
user						X	X	X	X	4
servic	X					X			X	3
object	X						X		X	3
self	X			X		X				3
devic	X				X	X				3
knowledg			X			X			X	3
interact			X			X		X		3
control				X	X				X	3
technic				X	X			X		3

Table 4: Words in the definitions that are present in the top-25 most frequent words for at least 3 domains. BM: Business and Management. IT: Information Technology.

Results show that 21 root-words appear within the most frequent root-words of the full definitions of at least three domains. Words related to technology (root "technolog") are the most frequent, appearing within the top-25 most frequent words in seven out of nine domains. This may reflect the relevance of the use or application of technology to achieve smartness. Words related to environment and system are in the second place, appearing in six domains, possibly implying the relevance of a system and its behaviour within a certain environment. Communication, information, data and network are also other frequent words that are related to the interaction between elements, which is a concept that is commonly addressed in works describing Smartness or Smart Systems.

Besides the raw calculation of root-word appearances, we also applied a weighting mechanism aiming at giving more relevance to frequent words that appear in domains with more definitions. Our reasoning behind this is that a word that is the most frequent within a very large text corpus will likely be more relevant and descriptive than one that is the most frequent in a much smaller text corpus. Naturally, we exclude very simple words and also stop-words to apply this reasoning. Hence, we gave weights to each domain reflecting the number of unique words within the full set of definitions for that domain.

Therefore, the relevance θ_i of the word i is defined by $\sum_{j=1}^N \lambda_j(i)$ for a set of N domains. The function λ_j is defined considering the number of unique words within the definitions for the domain j , and it is proportional to the domain with the highest number of unique words. Moreover, it considers if the word i is present within its top-25 most frequent words for the domain j , if it is not present, the value of λ_j is equal to zero. The formulation is presented next:

$$\lambda_j(i) = \begin{cases} u_j/u_{max}, & \text{if word } i \text{ is in the top-25 of domain } j \\ 0, & \text{otherwise} \end{cases}$$

Where u_j is the number of unique words within the definitions of the domain j and u_{max} is the number of unique words of the domain with the maximum number of unique words. For instance, the domain *Infrastructure* ($j = 7$) has the highest number of unique words within its definitions ($u_7 = 478$) so $\lambda_7 = 1$, whilst $\lambda_3 = 0.36$ for the domain *Education*, which has a total of 173 unique words. Figure 9 shows the results of this analysis.

The results of the weighted frequency calculation are similar to the raw results presented in Table 4 since "technolog" is in the first place and "technic" is still the least relevant word. However, the order of some words is different, which may be relevant to select specific attributes to formalise the characteristics of Smart Systems. For instance, with the weighting method, the word "user" is more relevant than only considering its raw appearance in top-25 for each

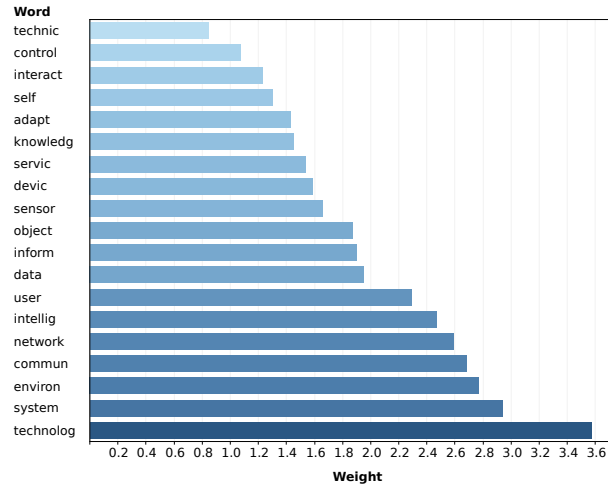


Figure 9: Weights of the most frequent words in the definitions considering their appearance in definitions of each domain.

domain. This could reflect the importance of the interaction between Smart Systems and the users. Moreover, some definitions are already based on systems that are user-centred [106, 107, 108].

5. Characteristics of Smart Systems

Considering the results presented previously, we extracted a set of characteristics of Smart Systems. The wide use of the word "system" within the definitions found in the literature shows a tendency to consider a systemic view to provide definitions. This systemic view allows to take into account some pre-defined properties or elements of Smart Systems derived from the GST [37], characterised by the presence of system elements, relations between elements, the objective of the system, an external environment and the interface. However, specific attributes that make systems smart do exist, making Smart Systems a specific type of system. These characteristics are presented next:

- **Communication Capability:** the elements must be able to interact to exchange data, communicate their capabilities, and inform about the state of their surroundings [109, 110, 111, 112, 113, 114, 115]. Communication is essential for interoperability between the system elements. Note that the words "data", "information", "interaction", and "communication" are widely used in the definitions, reflecting the value of the interoperability between the elements of Smart Systems, or between the system elements and their environment.
- **Embedded Knowledge:** human experience and expertise must be captured by the system [116] as well as information about the environment. In the context of Smart Systems, knowledge can be viewed in different ways depending on the needs of the system. For instance, it can be a knowledge base devised by human experts, common in Knowledge-based Systems (KBS) [117], used by an inference engine to make decisions (model-driven resource). On the other hand, it could be a Machine Learning (ML) [118] model used by an element when it is necessary to process some input data or to retrain the model with novel training samples (data-driven resource). Independently of how it is represented within the system, all of the decisions of the system must be based on knowledge [119].
- **Learning Capability:** learning comprises the application of diverse methods and algorithms that allow to modify the knowledge of the system [120, 121, 122]. This capability enables an adaptive behaviour, allowing to satisfactorily handle new contexts or situations [123]. Learning is accomplished by the system in an autonomous manner, updating its knowledge with minimal or any external intervention.
- **Reasoning Capability:** Smart Systems must be able to reason using their knowledge to make decisions [123, 124]. A range of techniques, such as neural networks, fuzzy logic, evolutionary algorithms, expert systems, etc.,

can be used by the system to provide strategic decision-making and flexible data processing [125]. Reasoning also allows the system to predict future states of the environment in order to act before the changes are manifested [126].

- **Perception Capability:** The systemic view described earlier implies the presence of an environment that Smart Systems interact with. To be able to perform this interaction, sensors (perception) are used to perceive the state of the environment, and actuators (control) are used to take actions to modify that state. According to the quantitative results obtained in this work, both "sensor" and "control" are words with high level of relevance for describing Smart Systems. Smart Systems must continuously sense or perceive the environment and themselves [35, 32, 114]. This would not be possible without sensors able to monitor and detect changes in their surroundings [105]. Smart Systems are able to describe and analyse the environment using data acquired by the sensors [127].
- **Control Capability:** Smart Systems are ultimately devised to serve humans or to provide the necessary tools and mechanisms to improve aspects of human life. Although this may seem implicit for any human creation, the definitions in the literature explicitly address this aspect. Moreover, they introduce two paths regarding the relationship between users and Smart Systems. The first one refers to the Perception Capability, due to that they are often devised to collect data from users through the use of sensors. The second one is based on a high automation level that allows to avoid the need of user intervention to perform certain tasks or to make some decisions. The control capability is available through actuators that execute decisions made by the system, using the available resources, on the environment in order to modify its state [101]. Smart Systems must have actuators that perform independently without the intervention of elements that are not within its boundaries.

Note that the interaction between the elements of a Smart System produces new characteristics or properties to emerge. Emergence is based on the idea that a system has one or more properties that are not possessed by its elements individually [128]. Hence, novel characteristics are derived from the interaction between the system elements, including the environment [129]. Emergence derives into unexpected properties that can be positive or negative [130]. For Smart Systems, unexpected behaviours produced by emergent properties must be always positive [35]. Some of those emerging properties are:

- **Self-Organisation:** the actions performed by Smart Systems are not limited to the environment, since they can also be used to act on the system elements in case that self-organisation is necessary [104]. Hence, the system is able to modify and manage its structure while keeping its original objective [131]. In this context, self-organisation implies the capability to independently adapt since there is no need of any external influence to organise the system elements.
- **Context-Awareness:** the context comprises information that characterises the current state of an environment [132, 133, 134]. A system is self-aware if it considers the context in which it operates when performing its activities [134]. In order to be context-aware, a system requires to sense the environment and to have embedded knowledge that allows it to interpret the state of that environment.

This set of characteristics provides insight regarding the nature of Smart Systems, which can be considered as systems that are able to update their internal knowledge used for reasoning to make optimum decisions. For this purpose, Smart Systems must have the capability to continuously perceive the environment and to control it, and to allow communication between their elements.

On the other hand, concerning the concept of intelligence in Smart Systems, there are several views of the relationship between smartness and intelligence, as discussed in Section 4.4. From our perspective, intelligence is represents the combination of the following smart capabilities: Learning, Reasoning, and Embedded Knowledge. We consider that intelligence comprises the ability to create or update knowledge (learning) considering the data exchanged between the system elements and the different states that the environment assumes. It also allows the system to adapt to new objectives and states of the environment through the reasoning capability possible using the knowledge.

We provide a graphical representation of a Smart System taking into account the characteristics described earlier. Figure 10 shows a meta-model of a system extended with elements able to provide smart capabilities. The model was devised using a Unified Modelling Language (UML) Class Diagram [135]. We extend the language through dotted lines and boxes representing properties that emerge from relationships between some elements.

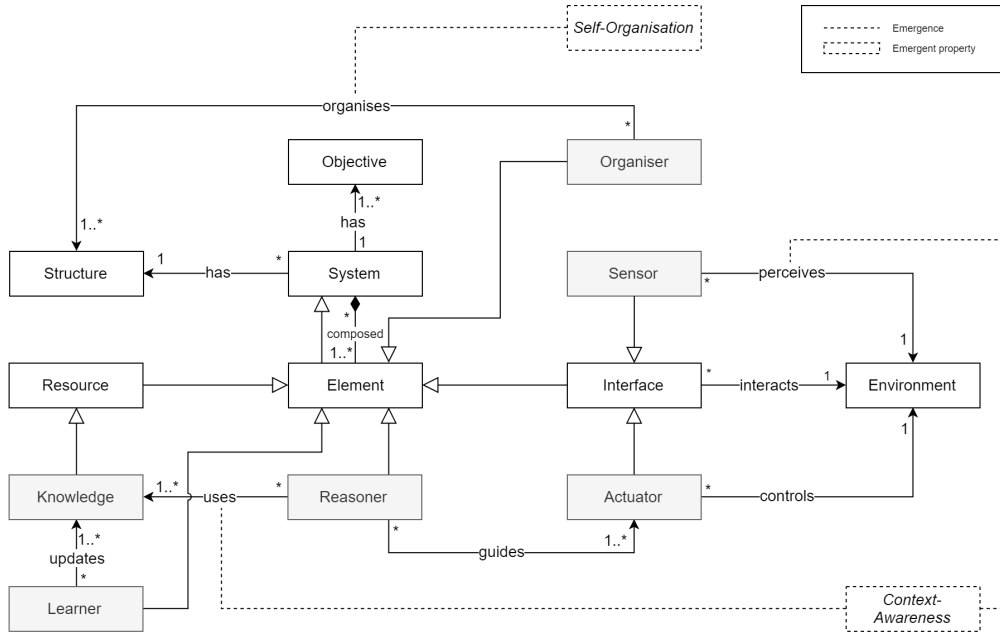


Figure 10: Meta-model of Smart Systems.

The model includes basic elements from the GST introduced in Section 2.1: the System has an Objective, a Structure, and it is composed of a set of Elements. These Elements could be Resources or Interfaces that are connected with the Environment. We also consider the Structure of the System, which defines the form of the system. It is a schema of the organisation of the elements of the system and their relationships. To provide smart capabilities, the model is extended through the Organiser, which is a system element able to organise the Structure of the System. Among the resources, we introduce the Knowledge, which can be updated by a Learner element and it is used by the Reasoner. These elements provide the Learning and Reasoning capabilities, respectively. On the other hand, there are two types of Interfaces in Smart Systems: the Sensor and the Actuator. The first one provides the Perception capability whilst the second one allows the system to be able to control the environment (Control capability). Note that there are emerging properties that are present within this setup: Self-organisation, through the interaction between the Organiser and the Structure; and Context-awareness, through the interaction between the Sensor, the Environment, the Reasoner and the Knowledge elements.

6. Threats to validity

In the scope of the development of this work, some threats to validity were identified. One of these threats is the fact that the papers obtained by applying the SLR are directly dependent on the search strings used to perform the search in the databases. Hence, a number of relevant papers containing explicit definitions of some Smart System may not have been obtained due to the structure the original search strings. This was due to that we focused on collecting definitions from different domains.

Another threat to validity is the fact that we discarded domain-specific characteristics that could actually provide relevant information for systems within a specific context. Since we aimed at a generic definition of the characteristics of Smart Systems based on the definitions presented in the scientific literature, we do not consider this a gap, since it is not within the scope of this work. However, future research may address the inclusion of more domain-specific definitions in order to instantiate the generic characteristics defined in this work for more specific purposes. Indeed, new search strings should be defined to perform the literature searches.

Finally, the manual selection of keywords within the definitions could represent another drawback. Although a qualitative analysis to obtain relevant keywords from each definition is the core of the methodology, and despite the fact that some relevant characteristics were gathered through this technique, having a human analysing several documents containing a large amount of text could lead to subjective errors. However, we consider that the use of the quantitative

techniques allowed to attenuate this specific issue.

7. Conclusion

This work presented a Systematic Literature Review aiming at gathering papers containing definitions of Smartness and Smart Systems considering different domains. The objective of the work was to draw common aspects that could serve as base for a characterisation of Smart Systems from a generic perspective. A semi-automated analysis of the definitions was carried using Text Mining methods in order to obtain quantitative insights from the extracted definitions. Finally, the characteristics of Smart System were presented and described. We also provided a qualitative analysis of relevant elements that were identified during the review of the collected papers.

Results showed that definitions often rely on a systemic view to define Smart Systems. Moreover, aspects such as technology and communication are bounded to the description of this type of systems as well as other capabilities such as knowledge, learning, adaptation, sensing and actuation. These aspects were gathered and organised so as to develop a characterisation of Smart Systems that can be considered independent from the application domain. Considering the results, Smart Systems, besides some base characteristics that are common to any system, are able to self-organise and be aware of the context, to provide communication between their elements. Moreover, they are able to learn, reason, perceive themselves and their surroundings, control their environment, and have embedded knowledge to be used for making decisions.

Future work will aim at exploring a higher quantity of papers addressing Smart Systems from different domains. A final conceptualisation of Smart Systems, able to cover most domains, should also be derived. Moreover, concepts regarding Smart Systems should be formally represented, for instance, using meta-models or ontologies. The authors will develop proper implementations of prototypes of Smart Systems for different purposes based on the characteristics presented in this paper. Finally, the characteristics described in this work were obtained in a fully data-driven manner and they were devised to be purely atomic; hence, further qualitative analysis of the gathered papers could be performed in order to isolate more complex or emergent characteristics.

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