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Introducing Sentient Requirements for Information Systems and Digital Technologies

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Abstract. Traditionally requirements for Information Systems are considered as functional and non-functional. However, with current omnipresent Digital Technologies, we believe that new requirements dealing with individuals' well-being are emerging. We call them sentient requirements using the term from the animal rights protection field. In this paper, we analyze the existing literature to understand better the deep nature of humans' interactions with digital technologies and we introduce sentient requirements. It is based on a literature review including scientific and science-fiction literature. We apply these requirements to improve user experience in museums through a visiting game as a use case. Our proposal could be used by researchers and practitioners to enforce the design of Information Systems in various application fields to provide a better interaction between humans and digital technologies.

Keywords: Sentient Requirement, Well-being, Information System, Digital Technology, Museum, Visiting Game.

1 Introduction

We are dealing with visitors' experience improvements in museums through serious visiting games. Our goal is to find an accurate way to enrich user experience (UX). Personalization is usually the way this goal is processed. Information and Communication Technologies (ICT) devices are generally supporting this approach. An important step during design and engineering of IS is requirement engineering at the early phases of the development life cycle [1]. Thus, the first step was to identify requirements to provide a personalized experience when using UX featured applications and their associated devices.

From our point of view, the personal use of ICT implies a new kind of need dealing with the well-being of people using them. For example, when a visitor tries to use a portable device in a museum and if the screen is not enough responsive because it is too dirty, the device becomes a source of stress, and its initial goal to provide a better experience to visitors cannot be reached. This kind of concern about ICT devices should deal with self-awareness to provide welfare or well-being to users. The same kind of idea can be found in [2]. It evokes digital and social media technologies can take control upon human consciousness and, by this way, they imply dissatisfaction

about these technologies. For example, social networks stimulate depression when “we feel we have to check, but checking does us no good” [2]. The current and future Information Systems (IS) and supporting devices should be designed, developed, and updated in a way to enhance and especially not to damage humans and their well-being.

The requirements are traditionally seen as functional and non-functional. A functional requirement is a “description of a behavior that a software system will exhibit under specific conditions [3], a non-functional requirement (NFR) is a “description of a property or characteristic that a system must exhibit or a constraint that it must respect” [3]. The former type represents the set of functionalities to be provided by ICT devices, and the latter covers additional aspects like security, availability, scalability.

The main research gap addressed in this paper is based on the following statement: the traditional requirements do not cover the need to provide ICT and ICT devices (called globally ICT in the following) dealing with the well-being of their users. This kind of requirement is not functional by nature. Their purpose does not cover the suitable functionalities addressing the application needs. They don't either address non-functional requirements which deal with the operability of the system architecture. This new kind of feature adds an additional dimension to the usual requirements and also impacts a sub-set of traditional functional and non-functional requirements.

In the case of museum visit experience, the literature review did not identify sources expressing this sort of requirements explicitly. To be able to feed our proposal, we took our main inspiration from science-fiction literature and completed it by related literature reviews. As an example, I. Asimov defined the four laws of robotics (the three first ones [4] and later the zeroth law). The Asimov's laws influenced ethic rules for Artificial Intelligence (AI). We have been inspired by the Powers Trilogy of Anne McCaffrey and Elisabeth Ann Scarborough [5][6][7]. This trilogy describes a living planet, Petaaybee, which is also depicted by the authors as a sentient planet. Sentience is defined as an ability “of experiencing an affective state” [8]. This term was especially developed in the field of animals' rights protection [9][10]. The sentience concept matches our approach of the relationship between humans and technologies; thus, we qualified the new family of requirements as “sentient”. This term was first developed in the field of animals' rights protection [9][10] and is already used in the field of Artificial Intelligence [11]. The Sentient Machine is introduced to define the evolution of machines from Artificial Narrow Intelligence to Artificial Generalized Intelligence by A. Husain [11]. The goal of our work is to specify sentient requirements for applications interacting with human through ICT devices. Sentient requirements would add an additional view to the design and development of ICT. In a broader acceptance, our goal is to explore what sentience abilities, or sentientness, imply for ICT.

In Section 2, we present our research approach. Section 3 is dedicated to the presentation of identified sentient requirements that are applied to a use case of ICT in the context of a museum to improve user experience. We discuss results in Section 4. Section 5 concludes the paper and gives future directions of our research work.

2 Research Approach

In this section, we detail our research process depicted in Figure 1.

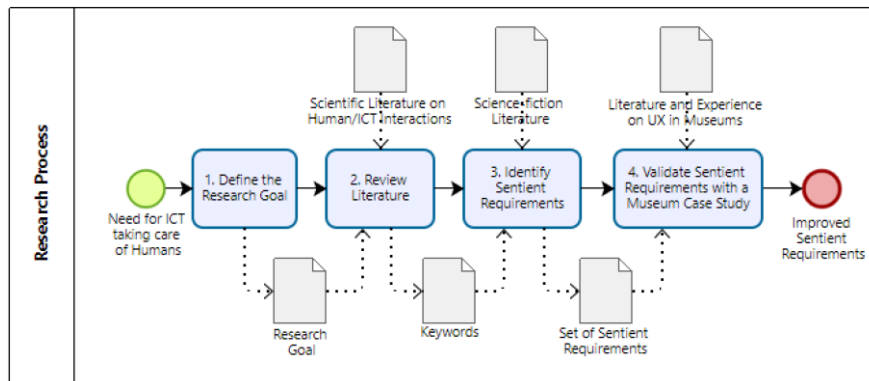


Fig. 1. Research Process.

1. Define the Research Goal. Our initial research goal was to identify requirements for ICT in Museums in order to provide a better, personalized experience to visitors. After a first literature review, we aimed to provide humans with digital technologies and devices that could contribute to their well-being and could help to avoid negative consequences. To reach this goal, theories and practices of design and engineering should be updated to take into account this new dimension which should be integrated very early in the requirements definition step. For the current research, we refined the research goal as: “Is it possible to identify sentient requirements for the well-being of ICT users?”

2. Review Literature. As sentient requirements represent an emerging field, it is difficult to carry out precise research of the literature. Thus, this first step of the literature review was wide. We proceeded by using the following search string: “ICT” AND “Human” on google scholar in January 2021 and we used the backward/forward strategies to complete the study. We have checked the 20 retrieved pages and stopped after 5 pages without relevant results. We included works directly dealing with requirements and those with the associated terms, like “need”, for instance. We excluded several works related to our topic but not specifying any requirements-related information. We classified the gathered literature into the following perspectives: philosophical perspective [2][12][13][14][15][16][17][18]; IT and business perspective [19][20][21][22][23][24][25]; ethical perspective [26][27][28][29]; and societal perspective [30][31]. Then, we carried out the textual analysis of the selected sources and extracted sentences that could be useful to capture the nature of human interactions with ICT with regards to their well-being. In addition, this step allowed us to identify the list of keywords to be used during a more detailed literature review: sentient requirement, well-being requirement, welfare requirement, smart requirement, affective requirement, and synergy requirement.

3. Identify Sentient Requirements. For this step, we used the science-fiction literature to feed the list of sentient requirements. As I. Asimov [4] inspired thoughts on Artificial Intelligence, we have been inspired by the Powers Trilogy of Anne McCaffrey and Elisabeth Ann Scarborough [5][6][7]. This trilogy describes a living planet, Petaybee, which is also depicted by the authors as a sentient planet. We extracted from the first book sentences characterizing the sentient planet abilities and its interactions with humans and other beings. Together with the literature collected from the previous steps, we grouped different ideas depending on their nature.

For instance, to formulate the requirement “Interaction and Involvement”, we generalized the following retrieved sentences and ideas: (i) The synergy requirement studied with application to interactions between human beings: ICT should be designed to support synergy between human beings. The synergy could be understood as interaction and involvement as it also covers the relationship between human beings and ICT [25]; (ii) Human beings and ICT should co-evolve together through time [2][17][32]; (iii) Human-Technology symbiosis “defining how humans will live and work harmoniously together with technology” and Human-Environment Interactions referring to “the interaction of people not only with a single artifact, but with entire technological ecosystems featuring increased interactivity and intelligence” [19]; (iv) “It[planet]’s only courteous to communicate”, “There’s a relationship [between the planet and humans] involved”, “Living here, most of us know that and accept the gifts, the protection, and in return, we offer it companionship”, “I just know that Petaybee works for us, and for itself, in a unique symbiosis...” [5]. We proceeded in the same way for the other requirements. The details cannot be present here due to the lack of space. Based on the analysis we did not include several requirements detailed in different perspectives as we consider them belonging to the two other types of requirements (exclusion criterion). For instance, a requirement “ICT should help to learn on technologies” [33] is a functional requirement as learning objectives are covered by the ICT functionalities. Another example is “ICT should ensure end-to-end encryption” [29] is typically a non-functional requirement as is it related to the security of data usage.

4. Validate Sentient Requirements with a Museum Case Study. To check the applicability of the sentient requirements, we apply them to a role-playing visiting game in a museum.

3 Emergence of Sentient Requirements

To qualify the new kind of requirements we used the term of sentience. Broom [9] defines: “a sentient being is one that has some ability: to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risk, to have some feelings and to have some degree of awareness”. This author underlines different aspects of sentience [10]: the sentience is related to ethics and moral issues; sentient abilities could be acquired and also be lost; the sentience requires “to act in an acceptable way towards each other person and toward each animal that is used”; and effects should be adapted to a given animal, “some components of sentience being dependent upon cognitive ability”. [8] mentions that sentience

covers all aspects of sensory consciousness; to be sentient means to be “capable of experiencing an affective state”. By [34], the capacity to have pleasant or unpleasant experiences “entails having a quality of life or experiential welfare, from which it follows that sentient beings have interests”.

Based on the identified from the literature needs for a better consideration of humans in ICT, we define the sentient requirements as follows:

- **Interaction and Involvement:** ICT should interact and communicate with human.
- **Awareness:** ICT should be aware of human beings, know and learn about them, and sense/perceive humans.
- **Safety:** ICT should protect from danger and harm and take care of human; the laws of I. Asimov fall in this requirement.
- **Belongingness and Felicity:** ICT should provide a feeling of being comfortable or happy with ICT.
- **Adaptability:** ICT should be adaptable, thus be able to detect distinctive characteristics of each human and to adapt itself to this given individual.
- **Sustainability:** ICT should be able to stand for a long time and to protect the environment and earth ecosystem.
- **Respectfulness:** ICT should be respectful. Respectfulness is very important as it works in both directions: not only ICT should be respectful with humans, but also humans have the responsibility to make ICT ethic, non-dangerous for other beings.
- **Inclusiveness:** ICT should be inclusive and ensure equality between humans, it should be done with regards to different origins, languages, health situation, and more.
- **Self-Reflectiveness:** ICT should learn about itself and contribute to human development by providing additional capabilities and skills.

The sources of sentient requirements are summarized in Table 1.

Table 1. Sources of Sentient Requirements.

| Sentient Requirement | Philosophical Perspective | IT and Business Perspective | Ethical Perspective | Societal Perspective | Science-fiction |
|-----------------------------|---------------------------|-----------------------------|---------------------|----------------------|-----------------|
| Interaction and Involvement | X | X | | | X |
| Awareness | X | X | X | | X |
| Safety | | | | | X |
| Belongingness and Felicity | | | | | X |
| Adaptability | | | | | X |
| Sustainability | | | | X | |
| Respectfulness | | | | | X |
| Inclusiveness | X | X | X | X | |
| Self-Reflectiveness | X | X | | X | |

We applied the sentient requirements to the case of a role-playing visiting game in a museum based on our experience with museums and the related literature [35][36][37][38][39][40][41][42][43], etc.

The purpose of the game is to learn the process of manufacturing an artifact. The visitors can choose between three different roles. The game is provided through touchable tablets to each player. The visitor has a role and follows different steps of the game to build his knowledge. Across the museum, the visitor solves puzzles related to the content encountered corresponding to different resources and manufacturing tasks. In Table 2, we illustrate the sentient requirements expressed for our use case and deduce related functional requirements to show how the sentient requirements could be implemented in practice.

Table 2. Illustration of Sentient Requirements with a Visiting Game in a Museum.

| Sentient Requirement | Sentient Requirement Expression | Corresponding Functional Requirement(s) |
|-----------------------------|--|--|
| Interaction and Involvement | The tablet should be able to guess visitor's unforeseen needs and provide answers/guidelines. | Include a chatbot service. |
| Awareness | The tablet should be able to identify satisfying conditions to be used by a visitor (clean, enough power, functional). | Alarm if it is dirty, compute the amount of available power, detect any misbehavior. |
| Safety | The tablet should alarm in case of any kind of danger. | Display/broadcast an alarm and personalized instructions to avoid danger in time. |
| Belongingness and Felicity | Users should feel proud of their accomplishment through the game. | Monitor game achievements, stimulate users, and provide incentives during the game. |
| Adaptability | The tablet should sense emotions and adapt the game to the mood of the user. | Have sensors, compute emotional states, adapt puzzles. |
| Sustainability | The tablet should optimize network communications to lower radio waves emission. | Compute and adapt radio communication intensity to the appropriate level. |
| Respectfulness | The tablet should react to inappropriate usage. | Have sensors to detect unexpected movements, bumps, and drops, display/broadcast warnings. |
| Inclusiveness | The tablet should detect disabilities and adapt the interaction with the visitor (for instance, switch to speech). | Have sensors, detect how the interaction is going on, and provide accurate help. |
| Self-Reflectiveness | The tablet should help to improve the user experience. | Gather game data, analyze player behavior, enhance gameplay. |

Based on this example, we have obtained the following results: (i) We have succeeded to express the identified sentient requirements applied to the visiting game in a museum, and (ii) We have shown that sentient requirements could be translated as a set of functional requirements.

Therefore, our proposal about sentient requirements could be applied to a real case and it provides useful insights to improve user experience design.

4 Discussion

To illustrate the role of sentient requirements in the ICT field, we suggest to model requirements hierarchy as a pyramid (Figure 2.). This pyramid is built by analogy with the Maslow pyramid of needs [44]. It shows the importance of sentient requirements and allows to position them in accordance with the existing requirements typology. As in the Maslow's five levels allow to satisfy human needs, we believe that all three levels of sentient requirements should be achieved in order to provide mindful ICT.

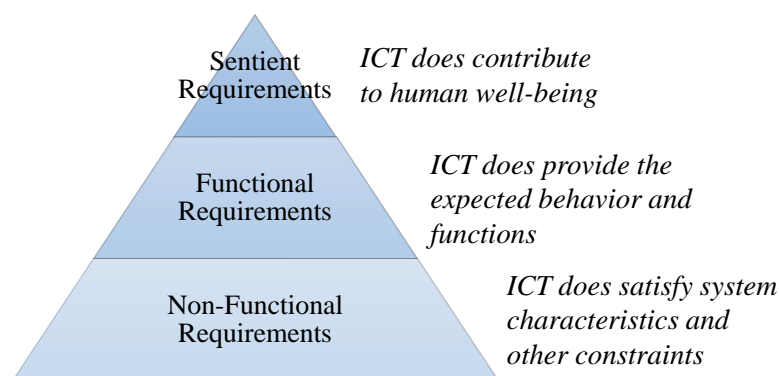


Fig. 2. Requirements Hierarchy Pyramid.

With regards to the Human-Computer Interaction challenges [19], four sentient requirements (interaction and involvement, awareness, inclusiveness, and self-reflectiveness) could contribute to develop the five challenges, namely: Human-Technology symbiosis, Human-Environment Interactions, Well-being, Health and Eudaimonia, Accessibility and Universal Access, and Learning and Creativity.

Considering current trends in ICT, a set of concepts arose recently: digital humanities, Life 3.0, Health 3.0, Welfare Society 2.0 etc. Digital humanities refer to “the intersection of digital technology and humanities: arts, literature, music, dance, theater, architecture, philosophy, and other expressions of human culture” [45]. Tegmark [46] presents the role of Artificial Intelligence can play for human. He defines three stages of Life: Life 1.0 (biological evolution), Life 2.0 (cultural evolution), and Life 3.0 (technological evolution). The last stage (not yet reached) refers to design not only “software” (meaning knowledge used to process the information issued from senses to decide about action, a kind of living “biological software”), but also “hardware”, that

is to say, the ability of organisms to change their physical components. To attain this future Life 3.0, Artificial Intelligence (AI) will play a particular role and should be friendly. One of the main requirements to the friendly AI is to align goals, thus, to better accomplish human goals using superintelligence. The goals alignment could be done by resolving three problems: “making AI learn our goals, making AI adopt our goals, making AI retain our goals”. Within a visionary editorial, Nash [47] defines Health 3.0 as using social networking technologies to exchange about symptoms, medication, and providing medical care. Misuraca [26] foresees different socio-technical trends as, for instance, “Care 3.0 – Robotics for personalized care solutions” and calls it Welfare Society 2.0. These trends underline the necessity to go forward with the definition and application of sentient requirements and make us consider the necessity to take into account the goal-oriented dimension into process-relational philosophy underlying our research.

The ICT device is a kind of blurred border between the real world, and the virtual universe. Sensors from the real-world feed actuators in the virtual world and vice versa [48]. The device also supplied by the computing resources behind, is the place to get control from the application and where to instantiate the sentient properties. In some way, this concern dives into the research field of Machine Consciousness [49]. But machine consciousness is different. It is more a concern of bringing some intelligence to machines including artificial sentience. Instead, we focus on interaction and sentient properties provided by technology to enhance user experience in the digitalized emerging world of everyday life.

Michel Serres, the French philosopher, states that along his history, Humankind lost abilities, but each time it occurred, it was for a greater benefit [50]. For example, Human “lost” the head with the invention of the computer. But at the same time, the computer raised new opportunities that we now experience through the digital era and the new tools emerging from it. It extended our minds. Michel Serres also states that Humans have completely changed since the mid 20th century. Humankind lost its connection to earth and nature. We do not feel life the same way anymore. Over the world, most people live in cities and this phenomenon seems far from being stopped [51]. Our creed is that this statement shows a missing link in mankind approach to the digital era. As we are losing the connection with nature, we need to reinforce the way we sense our environment.

We believe that the introduction of sentient requirements could contribute to the maintenance of the human sovereignty by aligning properties of technologies to the human needs, by creating this kind of harmony between human beings and technologies. For instance, the application of sentient requirements to social medias inducing the FOMO (Fear Of Missing Out) syndrome (discussed in [2]) could decrease the risk of becoming depressive. Based on infomateriality of [16][32] and close to the relational synergy of [17], our point of view is that human beings and ICT should co-evolve together through time. In line with these works, we claim that symbiosis between human beings and ICT is often foreseen as two opposite sides. This leads us to sentience that we define as a new kind of harmonious co-existence of human beings and ICT through time.

In our view, the specification of sentient requirements would allow to overcome this gap. According to [52] detailing a five-point assessment of contributions (with regards to theory, method, framing, phenomenon, and composition), we position our contribution mainly on the phenomenon axis as we deal with a new emerging concept (sentient requirements) applied to ICT. Sentience becomes a topic in scientific Information Technology-related publications. We believe that this term reflects well the concept of requirements contributing to building an emotional link between human beings and ICT. Our proposal will contribute also to the method axis, as the sentient requirements will impact the existing methods of requirements engineering and the whole cycle of IS engineering.

However, the introduction of sentient requirements will produce many additional, often new, questions to be solved, as, for example, can ICT and devices be designed to be sentient, especially when we think about robots and smart Internet of Things? Can we expect a smarter and more sustainable life with the digital surroundings we are providing? The way we embrace the future and the relationship with artificial intelligence-based technology is different from transhumanism [53] where human beings are extended or augmented with ICT parts.

5 Conclusion and Future Works

We believe that, using the sentient requirements, we can design a peaceful and sustainable digital technology that will help human beings to reach some kind of bliss in the future. IS and digital technologies are not only a tool that serves the consumer economy; there are tools that should gracefully help humans, and their environment including animals and nature to sustain and to enhance. The applications are numerous, we can cite smart healthcare, smart personal devices, smart home applications, drones, entertainment, cultural heritage, industry 4.0, and all fields covered by augmented, mixed, or, in general, extended reality (XR), and so on. We believe that researchers and practitioners who are interested in the design and engineering of IS should take into account the sentient requirements to design more suitable devices. Sentience is a powerful metaphor that deconstructs the way IS are designed and used nowadays.

In our short-term research, we will study how sentient requirements could be implemented to provide personalized usage of digital technologies based on machine learning techniques. In our further research, we intend to experiment sentient requirements with academics and practitioners working on topics around smart life and robotics.

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