An Approach to Use Comic Strips To Support IoT Systems Requirements Engineering

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***Abstract*—The term Internet of Things (IoT) describes an environment where billions of objects, restricted in resources, use the Internet as an infrastructure for exchanging messages. In the IoT system, a set of heterogeneous devices such as sensors, actuators, energy sources, and processors are fundamental for the interaction between objects. The construction of these systems demands the professionals' knowledge in identifying, analyzing, and specifying the requirements that impact the system quality. However, there are challenges in developing these systems because the different perceptions of stakeholders and the different use of computing resources can cause errors in requirements gathering and lead to ambiguities in developing IoT systems. In addition, its characteristics and its large number of elements tend to increase the complexity of its configuration. Therefore, it is necessary to develop techniques to promote effective communication between the stakeholders, regardless of their areas of knowledge, to establish, define and clarify the requirements. This work proposes comic strips (CS) for defining and gathering requirements for IoT systems. The first set of non-functional requirements for IoT systems was identified in the literature, such as maintainability, security, integration, and performance. We developed a syntax for building comics to assist in the definition and requirements gathering of IoT systems from this set. We conducted a feasibility study using informal, formal, and technical workshops with professionals and users to identify the potential for continuity of this proposal. In addition, this discussion was carried out with undergraduate students who could participate in the process, improving their knowledge in requirements engineering. The students could identify divergence among interests and concepts from stakeholders and propose adequated solutions during requirements elicitation. The results obtained from an established comic were positive and promoted communication between stakeholders. This work's contribution approaches the grammar for defining IoT systems in comics and an effective interaction method.**

***Index Terms*—Internet of Things, Comic Strips, Socially Aware Design, Requirements**

I. Introduction

The production process changed to face dynamic markets. The changes reflect how people live, work and relate to one another, characterized by the intensive use of digital technologies to generate new products quickly and effectively [1]. Internet of Things (IoT), Artificial Intelligence, Big Data, Virtual Realities, and other [2] components stand out as components involving these modifications.

In this scope, IoT gained space beyond productive environments, such as industries and offices, and began to be inserted in all aspects of people's lives, whether in educational institutions, residences and/or leisure, through different devices and forms. access, has expanded its reach around the world [3].

The IoT describes an environment where billions of objects, with constrained resources, use the Internet as an infrastructure for exchanging messages and involves innovative functionality connecting devices and/or objects seamlessly [4]. In the IoT system, heterogeneous devices such as sensors, actuators, energy sources, and processors are fundamental for interacting with objects.

The construction of these systems demands the knowledge of professionals to identify, analyze and specify the requirements that impact the quality and experience of using the [5] system. However, there are challenges in developing these systems, as the different perceptions of stakeholders and the different use of computing resources can cause errors in requirements gathering and lead to ambiguities in the development of IoT systems [6]. Due to the diversity of stakeholders' knowledge in the development of IoT systems, there are different training, terminology, and specific expertise, and the understanding of the system can be conflicting between stakeholders [7]. In addition, the characteristics and many elements of IoT systems tend to increase the complexity of their configuration.

Therefore, it is necessary to develop techniques that promote effective communication between stakeholders, regardless of their areas of knowledge, to establish, define and clarify requirements. Thus, the need for techniques that support the process of defining and gathering requirements in IoT systems is characterized.

In search of solutions, the Socially Conscious Design (SAwD) methodology, through semi-participatory workshops, such as participatory, collaborative, and universal design techniques, can help define requirements that encompass human, organizational, legal, and cultural values. , economic and technical, divided into informal, formal, and technical [8] project levels. Thus, the technical level is based on the information it receives from the formal and informal groups. The elicitation process is iterative, and it goes from casual to technical and technical to informal while checking possible needs to update the model [8].

The first set of requirements for IoT systems was identified

in the literature, such as maintainability, security, integration, and performance [9]. From this set and with the practice of SAwD, we developed a syntax for building comics as an aid in defining and gathering requirements for IoT systems.

This work proposes a constructivist approach of theory and practice [10], the application of SAwD methodology as a feasibility study, to identify the practice of using comics in the requirements gathering process for IoT systems. Software engineering professionals and students participated in the workshop and improved their knowledge of requirements engineering.

The contributions of this work are summarized as follows:

- Use of the SAwD methodology through workshops with stakeholders to support the definition and discussion of IoT system requirements
- Use of comics for visual prototyping and narrative requirements for IoT systems.

II. Background

A. Models for IoT System Requirements Elicitation

IoT has become a relevant topic as it enables how people can experience and use the technology in a prototype; however, there are challenges related to identifying the specific requirements of IoT systems [11].

The work [6] highlights that interviews and prototypes are among the most commonly used requirements definition techniques for the development of IoT systems. Due to the variety of stakeholders involved in the project, the interview is used to gather detailed needs and opinions on the expected specifications to ensure minimal conflicts and maximize project interest for all parties [6]. The use of the prototype to assist in the iterative discussion, to identify all the alternative flows, changes, and consistent improvements [6].

The study [12] reports an investigation of how the requirements of different stakeholders can be specified without errors, considering conflicts and influences. They propose [12] a modeling language called IoTRML, which provides means to design requirements models for IoT systems.

The work reported by [13], presents a version of IotReq, a method for eliciting and specifying requirements for an IoT system; other works, [14] and [15], address the topic of requirements for IoT systems, which propose conceptual frameworks to capture and present requirements.

The author [13] indicates that there is no set of best software engineering practices for developing IoT systems. It is known that visual techniques for defining requirements can be used, such as simulation of scenarios, use cases, sequence diagrams, and prototyping [16], however, no proposal associating a visual model for prototyping requirements in IoT systems was identified in the literature.

The work [16], reports the execution of the experimental method applied to identify the use of comic strips in the definition of requirements within a business model. To this end, scenarios were simulated in comic strips to map a business process within a work environment as a result, the use of comic strips had a positive impact, facilitating the identification of requirements and details in business processes [16].

B. Socially Conscious Design and IoT

SAwD directly affects the result. Its contributions focus on promoting a better alignment between demand and those involved and providing greater solution longevity.

SAwD is based on the socio-economic and cultural reality of a group of stakeholders and aims to obtain a broader design vision, involving different stakeholders in the requirements elicitation and design process, emphasizing technical requirements and requirements. informal and formal processes that will favor the construction of a more sustainable system, with lower maintenance costs, fewer requests for changes, and a higher acceptance rate for the final product [17].

In this context, SAwD uses organizational semiotics to discover and model human values, habits, cultures, procedures and rules that involve different types of users of a computer system to link these elements to the technical level of the system [18]. A graphic representation was elaborated by SAwD containing the levels in which it operates, called Onion Semiotics (Fig. 1), presenting the interaction between the informal, formal and technical levels, society and design.

Also, we came across the stakeholder diagram (SD) to map the actors that will be involved and may directly or indirectly impact the [19] project.

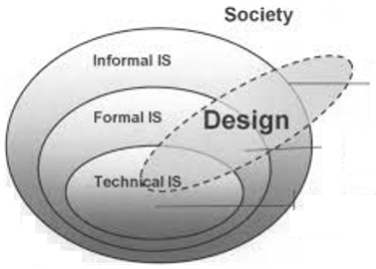

Fig. 1. Semiotic Onion [8]

SAwD proposes participatory and inclusive practices that involve diverse people with different roles, such as developers, designers, sponsors, end-users, or other stakeholders who will be identified appropriately to propose technology solutions [19].

In this scenario, the study [10] highlights the use of SAwD in the early stages of the project to solve the requirements design problem during software development for IoT. In addition, it points out that SAwD activities promote discussions that impact socioeconomic aspects and their implications for people's daily lives.

Other studies, such as [20] and [21], highlight the use of SAwD to support IoT system activities, such as requirements elicitation, construction of real-time interaction scenarios. They reinforce that SAwD helps understand the problem and generate efficiency in the development process of IoT systems.

III. Method

Given the objective presented, the Socially Conscious Design and its artifacts were applied to support the feasibility study of the proposal and the definition of requirements for IoT systems. SAwD presented the concepts and methods that allowed the communication of interactions between stakeholders and the identification of stakeholders in the project.

The period for the design and prototyping of the requirements aims to insert the SAwD artifacts within an estimated period of 3 hours of the execution of the workshop. For the feasibility study, we developed a framework based on [18] to assist in the requirements design process and indicate its applicability.

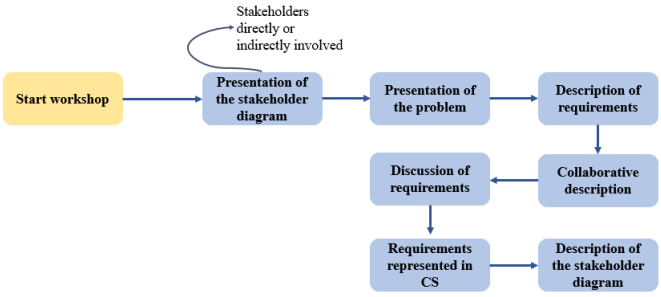

Fig. 2. Work Structure [18]

The development of socially conscious design application was divided into steps to understand the problem. Such a structure (Fig. 2) presents 7 activities: contextualization of the stakeholder diagram, directly or indirectly involved [18]; presentation of the problem that must be solved; followed by the description of the requirements by those involved; the definition of requirements, in a collaborative way; adjustments to the proposed requirements; the discussion of requirements, to generate notes that were not identified in previous activities or improvements; the representation of requirements in a visual form using the comic strip and the identification of stakeholders.

A. Workshop - Planning

The purpose of the workshop is to start the process of defining requirements for IoT systems from the knowledge of the concepts, SAwD techniques, and identification of the stakeholder diagram the following are the workshop artifacts:

- Problem characterization to elicit requirements for IoT systems.
- Contextualization of the stakeholder diagram.
- Description of IoT systems requirements.
- Development of a prototype in comic strips.
- Stakeholder identification diagram.
- Evaluation and dissemination of the proposal.

To run the workshop, we selected four participants, a representative of the software development sector, a professor of computing, and two academics of Software Engineering.

B. Workshop - Execution

The workshop took place on February 20, 2022, lasting 2 hours and 5 minutes, in a University classroom.

In the beginning, a presentation was made on the conceptual bases that underlie the practices for conducting the workshop, such as SAwD, SD identification, requirements for IoT systems, and visual description of the requirements through the comics strips. This initial stage lasted 20 minutes.

After contextualizing, we present the proposal for an IoT system, a parking lot with intelligent elements of the University, an environment known to all participants. In this step, each participant described a requirement according to their understanding of the problem. At each stage, the results and improvement of the requirements described by each participant were presented. The criteria described in the participants are shown in Figure 3, available in [1].

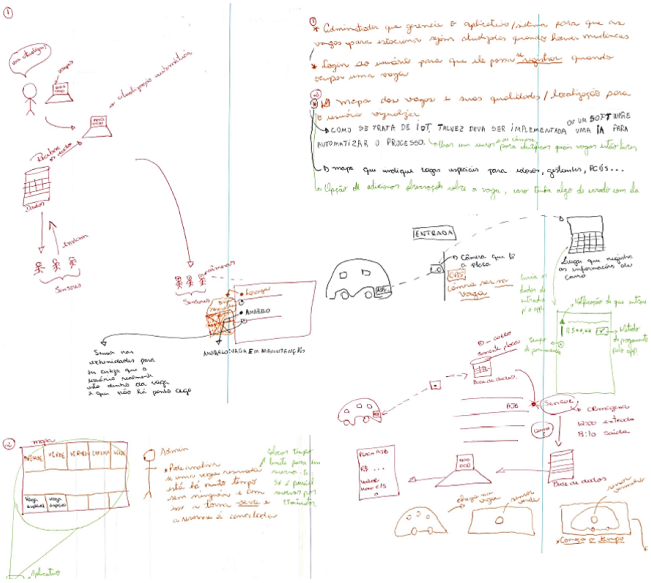

Fig. 3. Requirements described in the workshop

In Figure 3, we identified four requirements: registering vehicle license plates in a mobile application, thus allowing vehicles to enter and exit through the validation of registered plates; the presence of sensors in each parking space; the possibility for the user to choose an area before arriving at the parking lot; identify the number of parking spaces close to trees and check the flow of cars. Such requirements were improved during the collaborative discussions.

With the participants having a clearer view of the IoT requirements for parking, it was proposed to use comic strips to visualize and narrate the described requirements. For the development of comic strips, we use the online tool Storyboardthat [2], which allows the creation of comics strips, has a library of characters, scenarios, objects, which can be adapted according to each project.

[1]https://https://drive.google.com/drive/folders/1yKl1rAfNvqtE7nNiMx7Zi-f8z6j2G9C6?usp=sharing

[2]https://www.storyboardthat.com/pt/

The participants selected only one requirement, due to the execution time of the workshop, to be presented in comic strips, the requirement: the possibility for the user to choose a space before arriving at the parking lot.

After finishing the construction of the requirement in comic strips, the participants consolidated and evaluated the results, so we made the acknowledgments and closed the workshop.

IV. Results and Discussion

The workshop resulted in three artifacts: description of requirements for IoT systems; development of a prototype in comic strips and; stakeholder diagram identification;

The description of requirements for IoT systems of a parking lot can be identified in Figure 3. Participants described requirements that they consider necessary for an IoT parking lot, highlighting the improvements carried out collaboratively.

The requirement to register vehicle license plates in a mobile application, thus allowing vehicles to enter and exit through the validation of registered plates, underwent adjustments: registration of plates is carried out autonomously by the system, and vehicle entry is made with a user identification tag.

The requirement for presence sensors in each parking space was maintained, adding colors to the free and occupied space. The user's requirement to choose a parking space before arriving at the parking lot has been adjusted, allowing the user to have the parking application installed on their cell phone and then view and reserve the desired space. And the requirement to identify the number of spaces near the trees and to check the flow of cars, was maintained without changes by the participants.

With the improvements made collaboratively, it was possible to build the requirement proposal. For this, the requirement: is the possibility for the user to view, choose and reserve a space, in the parking application, before arriving at the parking lot. So the Storyboardthat tool was the support tool for this comic strips construction.

Figures 4, 5, 6, 7, 8, 9, and 10 present the comic strips of the selected requirement. comic strips presentation can also be found in the shared folder [3].

Figures 4 and 5 present an overview of the IoT parking lot of a University, the connection networks, transmission, communication, and sensors, in addition to showing a character named Danny, specifying his destination and the need for a parking space.

Figure 6 presents the narrative of the search for a parking space. It is necessary to open the application on the cell phone and view the parking lot and its available and unavailable spaces, as illustrated in Figure 7. Figures 8 and 9 report the process of booking a parking space and demonstrating its location.

Finally, Figure 10 illustrates the character's path to the previously selected spot.

[3]encurtador.com.br/eCJSW

Fig. 4. Comic Strips 1

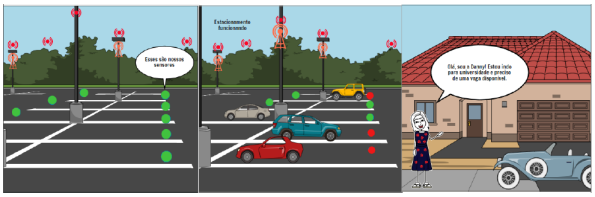

Fig. 5. Comic Strips 12

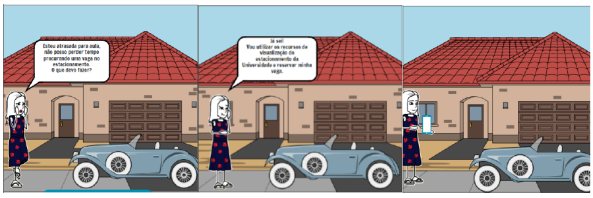

Fig. 6. Comic Strips 3

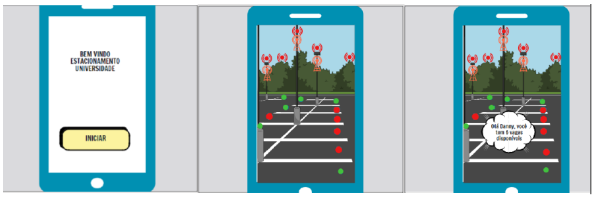

Fig. 7. Comic Strips 4

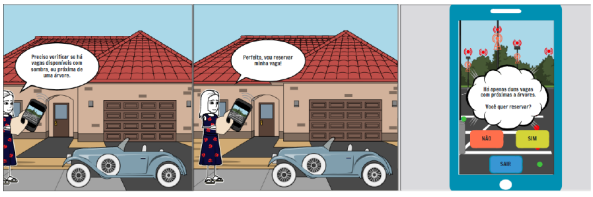

Fig. 8. Comic Strips 5

Fig. 9. Comic Strips 6

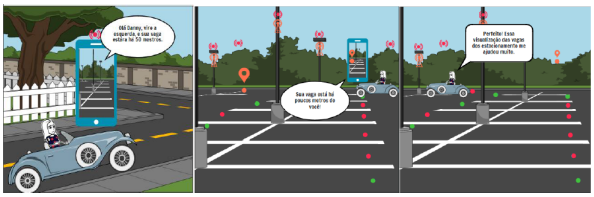

Fig. 10. Comic Strips 7

After completing this step, we can observe that the participants understood the understanding of the concepts and characteristics of IoT systems.

With a frame-by-frame reading (Figs. 4 to 10), there is no complete scenario: the presentation of the virtual parking lot, a character who needs to check availability and reserve a space in the university parking lot, use the application to verify, the choice of the vacancy, and completion of the service.

The SAwD methodology can collaboratively support participants in understanding the problem, identifying the particularities of IoT systems, and defining requirements. In this way, through CS, it is possible to visualize the complete requirement, from a user's request to completing the desired service.

In this context, the use of comic strips provides the inclusion of the story's narrative, allowing a better understanding of the details of the system's characteristics from the user's perspective.

After the construction of the comic strips, we proceeded to fill in the stakeholder diagram, 17 stakeholders that influenced or could influence the project were identified. Figure 11 presents the stakeholders divided into five categories. It is possible for a stakeholder to belong to more than one category at the same time, for example, the Requirements Engineer belongs to both the operation category and the contribution.

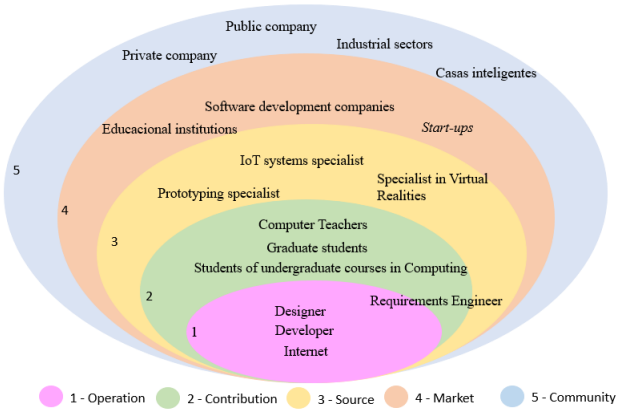

Fig. 11. Stakeholder diagram

The categories can be described in:

1) operation: referring to the technical and systemic part.
2) contribution: those that directly contribute to the problem. item: those that provide data and/or are a source of information for the problem or its solution, or use them.
3) market: market aspects related to the problem.
4) community: community representatives who influence and are influenced by the problem in the social context.

Given the number of identified stakeholders, it is possible to notice the dimension that the diagram has in understanding the problem and how the artifacts of the SAwD methodology can impact the definition of requirements.

V. Final Considerations

The IoT represents a challenging context for building systems, demanding new ways of thinking. In this article, we propose and discuss a constructivist approach [10], based on methods and techniques to assist in defining and gathering requirements for IoT systems.

We conducted a feasibility study using a SAwD workshop with professionals, users, and students from the technology area, which inserts the SAwD experience as part of the process of identifying requirements for IoT systems, where the common understanding of those involved is an action that generates positive results; and building a visual model with comic strips.

In this way, from a set of requirements, it was possible to establish a comic strips. The results obtained were positive and promoted communication between stakeholders, generating a contribution focused on the definition of grammar for defining requirements for IoT systems in comic books and, an effective method of interaction.

A. Future works

Given the results generated, we highlight that new SAwD workshops will be conducted in order to develop visual [22] models, using other models such as UML (Unified Modeling Language) to help define requirements for IoT systems.

For this, an application guide is expected, as exemplified in Figure 12. initially, semi-participatory SAwD workshops must be conducted, involving the stakeholders of the IoT project, in this activity-specific information and requirements are generated, which will be visualized through visual models such as UML and/or comic strips. In addition, we hope that the visualization of IoT system prototypes can happen in virtual environments in real-time, as it can attract stakeholders with countless opportunities to create innovative and unique [22] experiences.

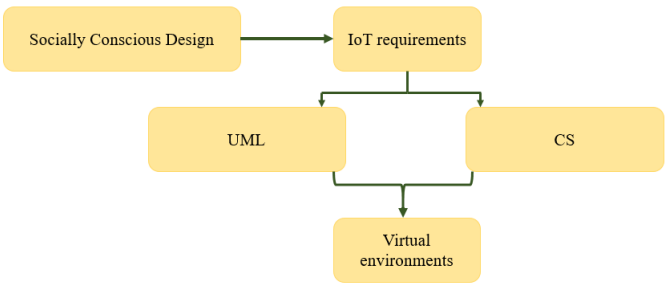

Fig. 12. Application Guide

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