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Building a Space for the Human in IoT: Contributions of a design process

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Abstract Technological devices integrate people's lives, actively connecting the Physical and the Digital worlds. Through ubiquitous computing, we can build a network of objects that, in addition to exchanging information, can perceive and act in a certain environment. The network of interconnected objects that is part of Human daily life can and should be called the Internet of Human Things (IoHT) as it involves re-configurations in living environments, in which objects (physical things) start to interact with each other and with people, often without human awareness. For this reason, the design of an IoT environment requires a good understanding of the problem and an evolution of ideas towards a possible solution in which People and other Physical things are linked to the Digital and can be considered as a single (Social, Physical and Digital) System. This article presents a Socially Aware Design process which evolves a solution starting from the understanding of the problem by the interested parties who act as co-designers. The process is illustrated with three workshops held with children, accompanied by their families in a hospital environment, whose objective was the evolution of an IoHT-based (Internet of Human Things) scenario. From the understanding of the design problem to the closing of the third workshop, the maturation of a design process for IoT environments with people is presented and discussed.

Keywords: Design Process, Interaction Design, IoT

1 Introduction

Computational technologies have been incorporated into human activities in such a way that they are unnoticed in use. The intertwining of technology with human activities was glimpsed by Weiser [1991] in the 1990s. We experience the realization of ubiquitous computing, with human things incorporating technologies that turn them into an interaction interface (inbound or outbound or both) and become active elements in a network that is called IoT.

Among the various definitions presented for the Internet of Things (IoT) [IEEE-Internet-Initiative, 2015] we highlight that of the European Research Cluster (IERC): "A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network". Everything in an environment that embodies technology (IoT node) is part of a system, contributing to the realization of the concept of ubiquity proposed by Weiser and Brown [1997] for the physical environment. According to the authors, the computer would be part of people's lives and the use of its resources should be imperceptible.

Technology's "invisibility" means that it will be distributed in environments or coupled with people's bodies without necessarily being perceived. Since its inception, the focus of IoT research and literature has been placed on the technical and technological challenges of IoT systems. Even when it comes to security and privacy, technical IoT challenges are targeting the Industrial Internet, called Industry 4.0 [Lohstroh *et al.*, 2019].

Thinking about an "invisible" technology does not exempt us from thinking about the ways in which that technology can make sense to people. Building connected devices entangled in people's daily lives demands to rethink the processes and design techniques of these systems, especially with regard to aspects of human interaction in these physical environments. Therefore, the investigation of methods and techniques becomes relevant for the design and configuration of an IoT environment in which the technological system is enabled from several distributed computational components, for the ultimate end, which is the human element. In this work, we investigate aspects of ubiquitous and pervasive computer systems in IoT, through the use of Socially Aware Design and Organizational Semiotics (Baranauskas [2014], Baranauskas [2009], Liu [2000], Liu and Weizi [2014]) as theoretical and methodological referential that allow interested parties to co-author the design process through enactive artifacts.

Our proposal is illustrated with a case study conducted with children and professionals of a hospital environment (Hospital SOBRAPAR [SOBRAPAR, 2019]), within the context of the research project "Socioenactive Systems: Investigating New Dimensions in Interaction Design Mediated by Information and Communication Technologies" [Baranauskas, 2015]. The project addresses challenges in the design of technologies in any environment of human coexistence, especially considering the social aspects of the interaction. The project Baranauskas [2015] focuses on the interaction between people in three scenarios of design: museum, school, and hospital environments. In this work, we consider the hospital scenario and its setting. An audience that is one of the parties affected by the system, the patient being treated, in our case children, participates in the process. Together with a team that works to treat this patient, and the child's family. We intend is to positively affect the insertion of technologies in the hospital environment, at the same time as they affect the system being developed.

In the context of caring for children with craniofacial deformities [SOBRAPAR, 2019], we turn our attention to the emotional issues and the affective relationship of the child with the hospital environment. The work involved activities at the hospital, including workshops with groups of children, hospital professionals, and researchers. At each workshop, a new scenario and narrative were proposed, with novel technological features added to the IoT system. The proposed scenarios were built within the hospital environment, enabling the interaction of different stakeholders, including those who were distant. A metaphorical narrative was created that made it possible to create a playful atmosphere for the practice of experimentation in the workshops. Results of the workshops facilitated the evolution of software and hardware systems that promoted the children's activities in the environment. For IoT systems, people must be protagonists; the objects and things that are part of the configuration of the living environment and are commonly used at that location receive computational technologies that make them an interactive node of a network of "things". Thus, the activities developed with people and for people in the design process enabled the system to be created and experimented in the hospital environment. The results of the study contribute to design recommendations for pervasive and ubiquitous technology environments, including IoT environments

During the theoretical development and practical application of the proposed process for creation, development, configuration and testing of the IoT environment [Baranauskas, 2015], we seek to approach the Socioenactive concept that the project has been investigating. Thus, by including the Human in IoHT we intend to address the Social dimension in the environment. By embedding technology in things and enabling their communication in the environment we treat the Physical dimension. The integration of the things in the environment (Physical) with the dynamics of people and their behavior (Social), perceived with algorithms that process data (Digital), enables the interaction to happen.

The paper is organized as follows: Section 2 presents the Background; Section 3 shows same related works; Section 4 presents the Proposed Process; the 5 Section illustrates it with a Case Study; 6 presents the main Results of the Study; and Section 7 Concludes by pointing out new avenues in the theme.

2 Background

IoT devices - networked microcontrollers with sensors and actuators (LEDs, other output components, etc.) - are becoming ubiquitous in the environment, for example in home security systems, public parking lots, physical activity monitoring, etc. Consequently, IoT offers an opportunity to demonstrate the breadth and social relevance of computing in the design of these environments. IoT explores and uses different types of information resources in the physical and social worlds to continually improve information sharing and communication between objects, people, and objects and people. Objects are distributed throughout man-made environments. Crabtree and Tolmie [2016] shows a study on the importance of understanding how we interact with the "stuff" in everyday environments to use this information to support the design of an IoT solution to that place.

IoT can be described as a network of things that exchange information. The things are human creation having some reason to be part of the environment. There could be several people interacting in one place, so the design process must be strengthened with the cooperation of people in an in-depth study of the environment that will receive an IoT System.

According to the authors Cila *et al.* [2017] (Pages 448–459) , the practice of design must achieve a hybrid of technological developments and cultural articulation, "[the technologies] need to be in a format that allows users to invite products into their lives and have a positive impact on their quality of life".

In this context, some authors, such as McEwen and Cassimally [2013] and Rose [2014], argue that a design principle for connecting object-embedded computing technologies involves seeing them as "magic". It means that physical objects incorporate controllers and/or sensors that make them "smart" so that a simple object will do something that it did not do before, *e.g.* air purifiers, which release perfume in an environment when they detect the presence of people. The new acting of the object, incorporated into its basic purpose, must make sense and be relevant to people.

We argue that the design of such environments should be oriented to what these products mean for society and culture. These investigations will help design and create IoT products that go beyond simply incorporating an actuator or sensor into something, but making sense in people's daily lives.

Comparing ubiquitous system design processes Barbosa *et al.* [2016], the authors observed that: the processes followed well-defined steps; most did not consider or do simulations, almost all processes modeled the possibilities of interaction; most interfaces did not anticipate evolution and none allowed adaptation of the user interface and were unanimous in the need for user participation in the process. The authors proposed an approach in which a scenario was presented consisting of a user and a ubiquitous interface to interact with. Depending on the usage scenario, objects were connected devices that searched/scanned according to user-selected preferences in a graphical interface.

Works that suggest IoT design and implementation, such as Ryu *et al.* [2015], do not make the process explicit. The general idea of IoT is to spread sensors that monitor local variables and actuators that act only as a switch to turn things on or off in the environment. According to these definitions, IoT is just a physical layer of network address sensors and actuators.

The work by Radanliev *et al.* [2019] argues that there is growing attention to the proposal of IoT models, and infrastructures in the literature. They point out a lack of processes addressing the design of systems that allow the integration of systems and technologies in constant evolution in a simple and understandable model. The paper contributes to the proposal of a new model of a reference architecture for the integration of these systems and technologies. Internet 4.0 seems to have a central concern in business disregarding the discussion on Human factors in its composition. An architecture in which the person is represented as one more 'thing' connected with other things, while the Human and its social interactions are what drives, transforms, and is transformed by the system.

Initiatives such as that of Hribernik *et al*. [2011] contribute to the discussion of co-design of IoT products, which they call intelligent products, that is, things with sensors and actuators that communicate. The authors believe that the direct involvement of people, such as designers, builders, testers and end-users in the design process of IoT products can guarantee a high degree of compliance with requirements for functionality, ergonomics, sustainability and other factors that directly affect acceptance of the IoT solution. The authors suggest the use of low-cost, easy-to-handle sensor platforms and kit to facilitate the co-designer active role.

Humans are part of the System and their emotions cannot be left out. The article by Tiwari *et al*. [2019] argues the recent relevance of emotion recognition. Physiological signals are a way to detect human emotions with the help of IoT and artificial intelligence techniques. The authors propose a system capable of determining emotional state using physiological parameters, which include: heart rate, galvanic skin response, and skin temperature, among others. The measured physiological parameters fed a neural network that classified the data into several emotional states, mainly: anger, joy, sadness, and joy, using pattern recognition algorithms like Convolutional Neural Networks and similar approaches. Research has shown that changes in physiological parameters can be related to people's emotions. Although the system proposed in the article deals with a human singularity, emotion, it was not clear which method was used for the design of the system and how the human is part of the solution. Facing IoT requires new perspectives, understanding and asking pertinent questions about the ontological nature of smart, connected products and their impact on people's lives. In this work, a design process for the construction of ubiquitous and pervasive interaction scenarios is proposed, based on Socially Aware Design, starting from the understanding of the problem with the involvement of stakeholders to evolve a solution of design. The novel concept of Internet of the Human Things is proposed, which implies the use of the Internet resources that allow the metaphor of magic to happen in order to create a narrative in which information shared between people and objects makes sense to all, positively affecting users through Socioenactive systems.

3 Related Work

In the last years, several efforts have been done in the investigation and construction of artifacts embedding contemporaneous technology (sensors, actuators, microcontrollers, etc.) to compose environments in offices, in quotidian life, in hospitals.

The work of Roalter *et al*. [2010] shows how an office without technology in things has been transformed into an 'intelligent environment' in which sensors and actuators have been incorporated into its things to act with people (present or remotely to it).

In the daily life, robot animals have been suggested to replace real animals, as they can prevent accidents, such as scratches, bites and allergies, but still having a positive impact on people. Most animals with technology are modeled after ordinary animals, such as dogs and cats. However, they may not meet human expectations. The work of Shamsuddin *et al*. [2017] uses PARO, a robot (seal), to successfully increase mood, stimulating the emotional state positively towards human-to-human interaction. Similarly, activities that involve embodiment like hugs can promote socioemotional states in pediatric patients, as in the work of Jeong *et al*. [2018], reinforcing this type of interaction in socioenactive settings. The results in this case go in the same direction as those presented in Section 4, showing an improvement in the patients' mood through the interaction promoted by the built scenarios.

The work of Lim *et al*. [2019], designed with the objective of examining the social and psychological effects of using interactive distraction for the reception of patients in a hospital for children. Its goal was to make the reception area fun and vibrant for all visitors so that it contributed to reducing the anxiety of people waiting for assistance. In this work, with the use of virtual elements inserted in the hospital reception environment, the social interactions that emerged from the scenario contributed to the improvement of the participants' well-being. The results observed by the authors are related to those presented in Section 4, with the difference that our constructed artifacts use tangible and embodied interactions instead of virtual ones.

Regarding our design process, other similar approaches have applied it in different contexts, such as for the design of applications in the interactive digital television context [Buchdid *et al*., 2019], the design of social networks [Pereira and Baranauskas, 2015], to name a some. Our process has iterative and incremental nature, and its structure shares some similarities with other processes and approaches, such as for the Design Thinking [Plattner, 2010]. The literature presents some cases of application of Design Thinking, such as the work of Fauquex *et al*. [2015] to create "People-Aware IoT Applications" that seeks a recognition of the human in the process, although, still in the role of system user. Another highlight is the use of Design Thinking in the so-called Industry 4.0 with a view to the user (employee) to migrate processes [Burresi *et al*., 2020].

However, there are also key differences between our approach and Design Thinking, both in conceptual and methodological aspects. While Design Thinking prioritizes a small set of people, usually approached as a central stakeholder or user, our approach goes beyond direct stakeholders to consider a wider range of interested parties. While Design Thinking starts by empathy and definition from the designers perspective, our approach starts from the identification and involvement of people or entities as interested parties, work-

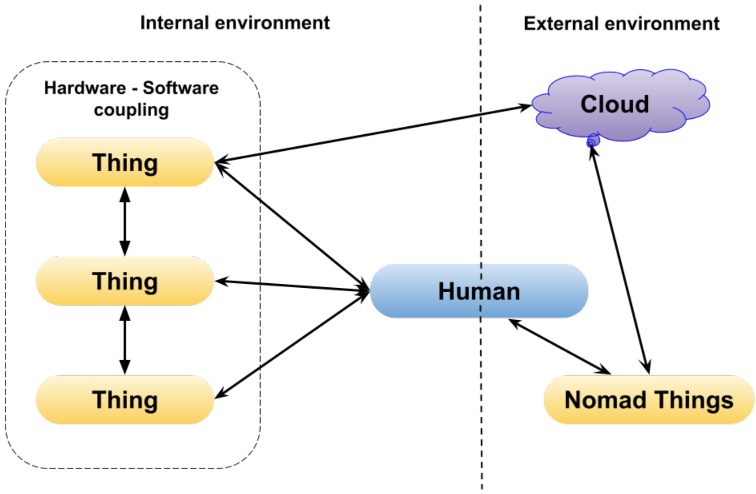

Figure 1. IoT environment (extended from Lee [2016]).

ing with them rather than for them. These interested parties contribute as co-designers to understand the design context, identify and understand the problem, and to articulate a viable design solution (Baranauskas [2009], Baranauskas [2014], Baranauskas *et al*. [2013]).

4 A Process for Building Environments Based on Ubiquitous and Pervasive Technology

The IoT System, as an instance of a pervasive and ubiquitous computational system, is designed and built by incorporating computational technologies to the environment objects. Each element of the scenario is likely to become a node in the object network, with the technological skills of sensing or acting in that environment. Lee [2016] proposes an IoT model consisting of three basic elements: Human, Object, and Service, emphasizing that the maximum potential is achieved with the connections between "people-objects", "objects-objects", "service-objects", and "services-services".

The breadth of computer networks to delimit an IoT environment starts from the definition of Local Area Network (LAN) [Tanenbaum, 2011]. Similarly, a local network of objects is a private network with their own access protocols. The network of addressable objects (IoT) should function as a system offering local services at the network protocol application layer. The system can be configured as an intranet (Private Internet) which, to be accessed via the (public) Internet, requires the implementation of security and privacy standards.

Based on Figure 1, we use two elements (Object and People) of the three suggested by Lee [2016] for the representation of the IoT environment. We consider the Service element (present in Lee's work) as other systems that exchange information with the IoT System and will not be considered at this time for environmental composition.

The objects form a local area network (IoT) orchestrated by the IoT System (Software) that has the function of processing data and coordinating the exchange of information. The Human present in the environment uses/manipulates objects generating the information flow to the IoT System, which generates information outputs on objects within the environment. Access to the local object network (IoT) can also be done by objects outside the IoT environment. People outside this environment may use computers, smartphones, or other (pervasive or otherwise) Internet-connected communication technology to interact with the IoT System and its components.

In Figure 1, people (Human element) in the environment affect and are affected by the IoHT software system. Therefore, the design of the IoHT environment must begin by understanding the problem with its relevant stakeholders. At this early stage, we have a design problem that will require a recognition of the environment, including the objects in place and the activities performed by people.

By understanding the environment, the design team will be better equipped to think about the transformations of the environment brought about by incorporating an IoHT System, its implications of all kinds (social, ethical, etc.) preferably using some metaphor adding meaning to interactions. Then, the development team can define, specify and implement the physical and logical parts of communication blocks that will be incorporated into the objects, and code a software solution that will orchestrate the communication.

From this, objects will receive technologies as sensors and/or actuators acquiring capabilities such as capturing or displaying information. In short, the problem situation is the gateway to the process, and understanding it is the outlet for a design solution to be built in iterative cycles with stakeholders. Our assumption is that we cannot understand/propose a complete design solution without involving stakeholders in cooperative work as co-designers. The Figure 2 illustrates the proposed process with its theoretical and methodological bases. The activities that run through the design process are based on the artifacts and methods of Organizational Semiotics (SO) ([Stamper and Backhouse, 1988], [Baranauskas and Bonacin, 2008] [Liu, 2000], [Liu and Weizi, 2014]). In addition, the principles for inclusive information system design and a set of semio-participatory [Baranauskas *et al*.,

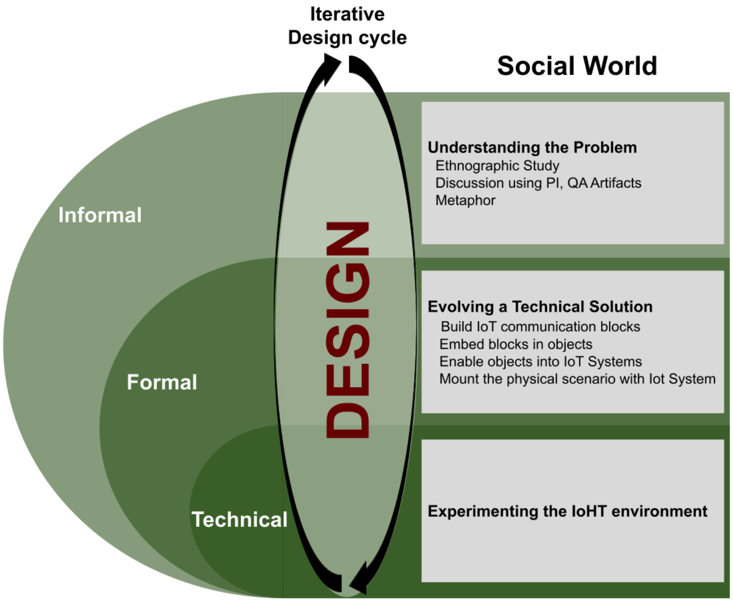

Figure 2. The Socially Aware Design Process for IoHT.

2013] techniques for inclusive design environments are used. The term semio-participatory was coined by Baranauskas (Baranauskas [2009], Baranauskas *et al*. [2013]) to characterize techniques related to interaction design that have SO as their theoretical framework (Liu [2000], Liu and Weizi [2014]) and are adapted to the joint participation of different stakeholders in the domain in question.

Figure 2 shows a framework for understanding system design and technology called 'semiotic onion', composed of three layers: informal, formal, and technical based on Stamper and Backhouse [1988]. In the informal layer, there are ordinary people on a daily basis and interacting with the artifacts produced. In addition to laws and formal models, we need to know about the context, which can be done through an ethnographic study identifying objects that already exist or can be brought into the environment and how the objects are perceived by people. The technical layer deals with technological resources for interactive systems, which mediate actions at the most external levels.

The technical layer refers to development cycles based on the formal layer which, in turn, had the meanings raised from the informal layer. We use the iterative onion as core development cycles to create or evolve communication blocks that will be allocated to objects/things as part of an environment or scenario. By inserting communication blocks into objects they are enabled in the IoHT System and thus arranged in the environment for people's experience.

The evaluation of the objects and the whole environment with different interested parties feed the next iteration. The complete cycle for technology product design covers the three layers of the onion leading to the evolution of the technical level in the iterative development cycle.

4.1 Problem-situation or The Design Problem

The breadth and depth of knowledge about the problem increases with each iterative cycle of the solution-building process and benefits from the participation of the Human element. For an initial understanding of the problem by stakeholders, we suggest the Problem Articulation Method (PAM) [Stamper and Backhouse, 1988], an Organizational Semiotics method that supports the identification of stakeholders who have different types of interests and influences on the design problem or its solution.

For solutions using IoT, we assume that objects (things) in an environment (hospital room, a classroom, a neighborhood, a city, etc.) will be improved with technologies that allow input and output data for the environment of People. For this reason, designers and co-designers can be decisive for a solution that has better acceptance and can be used by everyone circulating there.

4.2 Evolving to a solution (step by step)

After clarifying the problem and understanding who the stakeholders are, a solution using IoHT is proposed. The step by step to evolve the solution is described as follows. For this, some studies were conducted in order to understand the context (*cf.* Section 4.2.1), which allowed to define metaphors and components to be used (*cf.* Section 4.2.2) that could be implemented through an iterative cycle of technical development (*cf.* Section 4.2.3) and that were experienced in the environment (*cf.* Section 4.2.4) contributing to the feedback of the entire process.

4.2.1 Studying and Understanding the Context

The focus of an ethnographic study is to share a culture, in our case, a group restricted to people who share an environment with very clear boundaries of behavior. An ethnographic study describes and interprets the shared and learned patterns of values, behaviors, beliefs, and language [Creswell, 2018]. With this, the project may be enriched with information from ethnography, which can raise knowledge not only about the culture but also about the social (behavior), and information about the things that are arranged in the environment.

4.2.2 Defining metaphors and components

Historically well-accepted computer systems have been built from metaphors: desktop as the working space and spreadsheet as an accounting ledger are classic examples [Rogers *et al.*, 2013]. The magic metaphor suggested for the Internet of Things [McEwen and Cassimally, 2013] may be helpful in working with people on the idea that objects are doing something beyond what they were meant to do, as if they were 'magicians'; they know or do something else.

Matching a good metaphor against the background of the environment can be decisive for making sense of environmental action. For example, a door is designed to be opened and closed by people, however when receiving sensors and actuators, when someone approaches it will open and close automatically. If by itself that fact already seems magical, imagine that this door notifies someone or something of the arrival, which starts working (a TV that turns on, coffee brewing, etc.).

4.2.3 The Iterative Cycle of Technical Development

In the iterative development cycle for an IoHT solution, we work on transforming the understanding of the problem and the solution proposal built cooperatively with stakeholders into a meaningful technical solution. Environment objects will have their roles modified through the technology; for this reason, we categorize objects according to the performance in the IoHT System as follows:

- **Active manageable:** objects capable of capturing some aspects of people's activities through their direct manipulation of them;
- **Passive manageable:** Objects that are in the environment and can be manipulated/touched, but are not IoHT network nodes;
- **Display:** objects that provide noticeable feedback to people considering their senses: sight (light and image), hearing (sounds) and touch (motion);
- **Intermediate:** objects in the environment, and their performance does not depend on the interaction of people with them, but on the direct interaction of other objects with them. They receive information, perform some action and send it to interested parties (Human or not) in the System;
- **Nomad:** objects that are not part of the IoHT environment, however, have permissions to access the System from elsewhere; and
- **Server:** a centralized coordinating object to handle the information. It is responsible for storing data, making complex decisions processing algorithms on the received data.

In the representation shown in Figure 3 we highlight the relationship between interested parties and devices. The IoHT environment includes a number of objects within it that are part of its composition and some of them can be touched/manipulated by people (1) and (2). In Figure 3, a person interacts with or between manipulative active (1) and passive (2) objects. This interaction with manipulative active things (1) generates information that is communicated to the server (3), where data processing occurs and can be communicated to several other objects or manipulative assets that can inform people (1).

A system for environmental control is centralized in the Server and acts as a communication center that receives and sends information to all objects that are part of the network (3) (4) (5) (6). The Server may send (5) data to an intermediary object that processes and returns (5) information to the server as needed. Another path of data arriving at the server is the creation of feedback on a display object (5), which processes and can return the response to the server (5). A Nomad thing/object that is outside the IoHT environment has privileges to send (6) or receive information (6).

Having defined the objects with integrated technology, a team works on the design and construction of the IoHT communication blocks. The blocks enable objects to send and receive information; they can select input or output for people. The communication blocks are incorporated into objects that receive the network address and an initial configuration allowing them to be part of the IoHT System. Afterward, objects can be used and rearranged aesthetically in the physical environment according to the desired scenario and narrative.

4.2.4 Experiencing the Environment and Reviving the Process

When people use and test the technologies, they assist the design team to observe problems, allowing a technical update during the development cycle and serving as feedback for stakeholders to understand the problem. Thus, we can inspect and update the formal layer with new studies and adjustments and, consequently, have a better understanding of the people's context. The technical apparatus undergoes improvements and upgrades during iterative development cycles. However, the development cycle cannot be detached from the social world in which people live and which also evolves in accordance with the parties' participation as codesigners of the solution.

5 The Case Study at SOBRAPAR Hospital

To conduct this study, a partnership with the SOBRAPAR Hospital was established. In what follows, the study Scenario and the Participants are described (*cf.* Section 5.1), presenting a brief summary of the Ethnographic Study (*cf.* Section 5.2) carried out at the institution that contributed to the Understanding of the Situation of the Problem (*cf.* Section 5.3) so that we could propose solutions thinking about the Metaphor of Magic (*cf.* Section 5.3.1). Finally, we present all workshops conducted as instances of the socioenactive system, that make up the Interactive Cycle (*cf.* Section 5.4).

The workshops were held in one of the rooms of the SOBRAPAR hospital. There were three workshops during 2018 and each lasted an average of one hour and thirty minutes. In each workshop, six children between the ages of 7 and 12

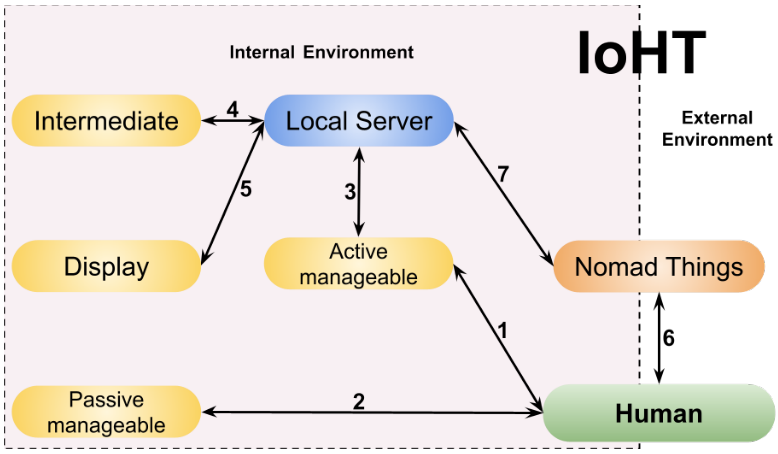

Figure 3. IoHT system connecting external and internal environment.

were chosen by the hospital staff. The activities performed in the workshops were recorded, survey answered and the children drawn at the end of the first workshop as a source of information. The team of associate researchers present observed and take notes of the events.

5.1 Study Scenario and Participants

This research has been conducted in partnership with the SOBRAPAR - Cranium and Face Hospital, located in Campinas (SP), which, since 1979, promotes the surgical treatment and rehabilitation of patients with congenital or acquired facial skull deformities resulting from trauma, tumors or other conditions. SOBRAPAR is a private, philanthropic institution of federal utility whose mission is to rehabilitate people with facial skull deformities, integrating them into society and promoting well-being through quality, ethical and humanized interdisciplinary activities, combined with research activities [SOBRAPAR, 2019].

As part of the iterative design cycle, a total of three workshops were planned and conducted with the participation of 16 children aged 7 to 11 years, all attending the hospital. All activities were approved by the Research Ethics Committee of the University of Campinas, under the number CAAE 72413817.3.0000.5404. A consent form for the child's participation in the study was signed by the respective legal guardian, who was given the option to accompany the child during the workshops. In addition, the children participating in the study also signed an assent form, with text adjusted to their level of literacy, according to the Committee's rules.

5.2 Summary of the Ethnographic Study

To learn about the possibilities of using contemporary technologies (based on IoT) with children who attend SOBRAPAR, we initially conducted an ethnographic study conducted by an anthropologist linked to the [SOBRAPAR, 2019] project and by graduate students. The activities were carried out in early 2018 and consisted of observations from professionals working in the hospital (doctors, psychologists, educators, etc.) and patients, as well as a mapping of the internal spaces used (waiting room, multimedia hall, etc.). The purpose of this ethnography was to understand the dynamics of interaction in the hospital, and to interact with people in this environment.

The treatment process provided by the hospital begins with the registration of the patient with the social service and ends with the annual follow-up performed by a multidisciplinary team after medical discharge. In addition, medic-patient interaction extends beyond the hospital environment into the home through applications available on family and patient smartphones. We realize that some specialties, such as speech therapy, are dependent on technology to perform their work in a more appropriate and effective way to treat the patient.

Thus, in light of the observations, we identified three possible areas for the development of technological solutions for and with SOBRAPAR: psychology, psycho-pedagogy and speech therapy. Such solutions may expand to other areas or sectors of the hospital, such as reception and social service, for example. By looking at how children interact in their real environment, we intend to develop a technology solution that involves patients, family members, and staff working at the hospital to inform the design process of IoHT environments within a hospital environment.

5.3 Understanding the Problem Situation using SAwD and Proposing Solutions

In parallel to ethnography, the problem of using IoT-based technology in SOBRAPAR was first discussed by the researchers of the project [Baranauskas, 2015] to which this study is linked. We began with a preliminary statement of a problem situation that was discussed by the group on the SAwD[1] [da Silva *et al.*, 2016] platform that supports the SAwD Method. For this, we used the artifact named the interested parties diagram, which aims to raise stakeholders impacted by the prospective solution , discussing the problem situation (Figure 4). The interested parties are in the Community (Bystanders, Legislators), Market (Collaborators, Competitors), Source (Clients, providers), Contribution (Actors, Principals) and Operation (Technical, System) layers. The closer to the center (Operation Level), the more influences and contributions to a solution.

[1] `http://erytheia.nied.unicamp.br:3000/`

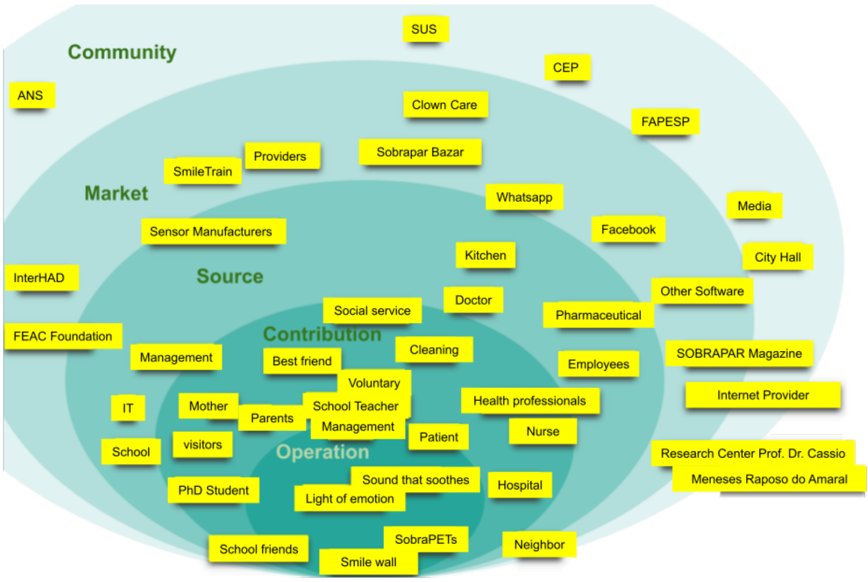

Figure 4. Knowing and listing stakeholders.

Then, some stakeholders were discussed (evaluated) with regard to the issues and/or problems that they would have, as well as possible ideas and possible solutions to those problems. The artifact that supports these discussions is named *the evaluation framework*, its completion, and the results are in the technical report [Hayashi *et al.*, 2018] and a clipping is shown in Figure 5. With the two artifacts filled in a collaborative way, we came up with an idea for building some IoT components to incorporate into objects and then build a scenario for the case study, detailed in the report [Hayashi *et al.*, 2018].

The workshops were held in one of the rooms of the SOBRAPAR hospital. There were three workshops during 2018 and each one lasted an average of one hour and thirty minutes. The activities were filmed, questionnaires were answered and the children drew at the end of the first workshop as a source of information. The team of associate researchers who were present made observations and notes.

5.3.1 Thinking and Proposing the Metaphor of Magic

We formalized the idea of "creating SobraPet", a (physical) place in the hospital, where plush animals could interact with children. With this idea, we could keep this narrative case study and create empathy with the children. Sobrapet inspired the team to bring stuffed animals to life, through ubiquitous computing, to interact with children. Thus, the magic metaphor proposed by [McEwen and Cassimally, 2013] was used in the composition of the scenarios.

5.4 Iterative cycles

The iterative cycles of the workshop design process are described as follows, through the realization of the three workshops. The evolution of the scenarios occurred after the first workshop held in June 2018 (*cf.* Section 5.4.1), so that the second one was improved with more components (*cf.* Section 5.4.2) and the third was also refined (*cf.* Section 5.4.3).

5.4.1 Workshop 1

The creation of an initial scenario as an instance of a socioenactive system, based on a short narrative involving the arrival of Pets in the hospital environment, was the theme of the first workshop. Based on the initial understanding of the problem, the objective of this workshop was to investigate the affective state of children undergoing treatment in the hospital and to verify the potential effects of the system in positively affecting them. Thus, with the idea of "working" the affection through the hug, the initial narrative created involved the arrival of animals (in our scenario, the artifacts represented by plush animals with integrated ubiquitous technology) at SobraPet, allowing them to be hugged by children. So, this experience of pets' responses to hugs could be performed. The scenario also involved the creation of a virtual object to show pictures taken when a child huggs one of the Pets with a certain intensity.

In the physical composition of the IoHT environment, in a hospital room, we used a 50-inch TV (as an actuator), two sensors, a plush actuator (a monkey and an owl, respectively) and a notebook, as system manager responsible for the devices communication. We also used a sensorless pet (bear), a type of passive-manipulative object used for the child's perception of technology in the environment.

In step 1, we created the communication blocks composed of hardware and other components that would be embedded in the objects. To show the mural (virtual object), the hardware (Raspberry Pi 3) enabled r communication on the network with the application that would show the intensity of the embrace received by the Pet and environment pictures on TV. An owl (named as Corujita), was configured to take pictures with a camera, using an embedded Raspberry PI 3, sending them to the server to be displayed on TV. Finally, a communication block was set up to exchange information with sensors (load cells) to know the intensity of a child's hug in the stuffed animal, a monkey (named as Chico).

In step 2, we set up a server responsible for coordination

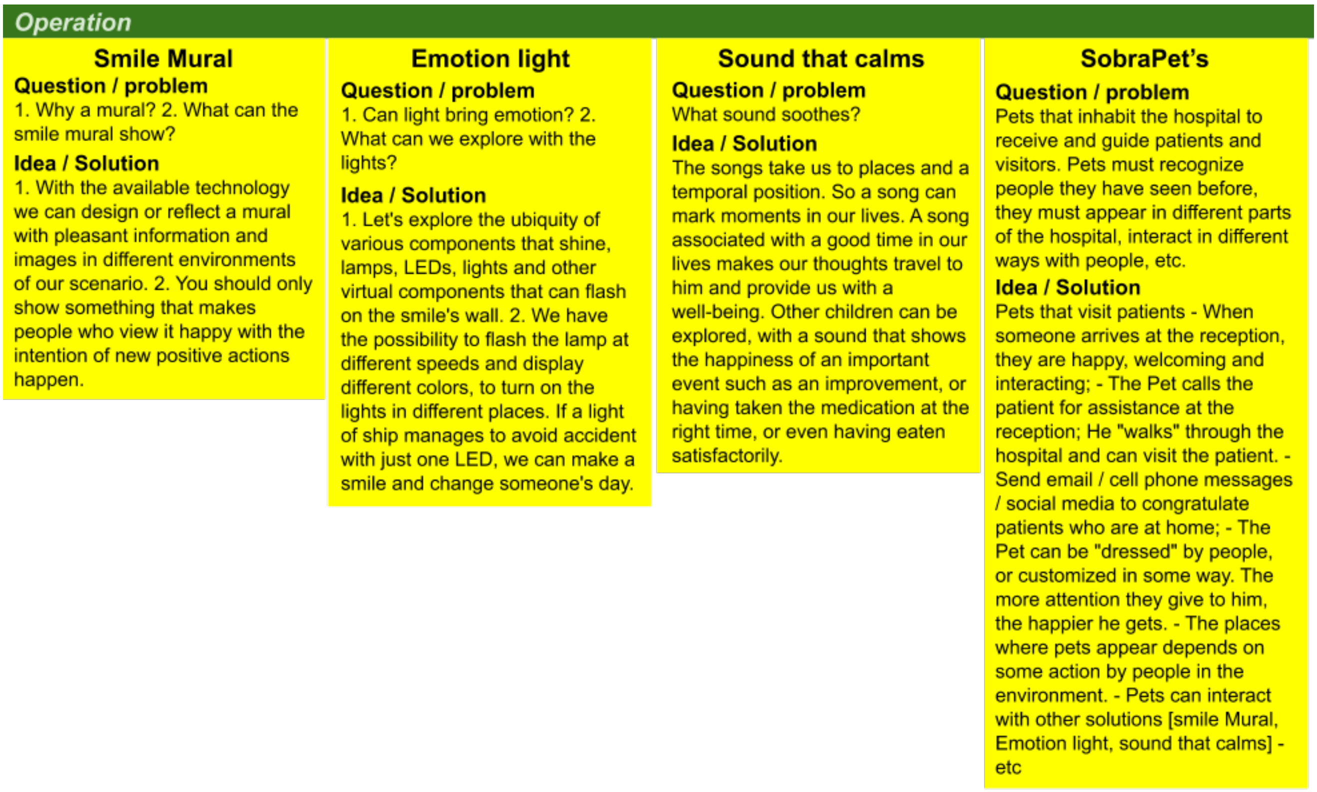

Figure 5. Evaluation frame (Operational level). The discussions were about the Smile Mural, Emotion light, Sound that calms and Sobrapets.

of the communication between the blocks. The logic of the system involved monitoring the intensity of the hug and instantly showing its value on the monitor; if the hug was strong and persistent, this triggered the hardware that took the photos to capture an image to be sent and displayed on the monitor. The server used a sound system (audio) to thank for the hug and request another one.

In step 3, the data input parameters were coded and the system processed, allowing sound outputs on the local device or TV monitor. When the child hugged Chico, a value was captured and sent to the server for evaluation generating three levels of feedback; in all of them there was a speech of thanks for the hug with a sound in the environment generated by the server. The three levels of response involved: (a) for weak hugs- requested a stronger hug; (b) intermediate - the pet said the hug was nice, but he wanted it to be stronger; and (c) strong - the pet said that a photo would be taken. Then, the server fired a message to the owl that captured that moment and uploaded the photo to the server, which immediately informed the display about a newly captured image. The children's interaction with the pet showed that the system worked properly to measure the intensity of hugs and was able to interact with each of the children by voice.

At the end of this Workshop, a meeting was held with the research group, in which the observed results of the activities and proposed changes of scenario and narrative for the next Workshop were discussed. The decisions involved: (i) Improving the Mural interface (virtual object) and bringing another visual element that represented the collective hugs; (ii) The sound of Pet's speech must be internal to him; (iii) Create another communication block to feel the intensity of the embrace that would be incorporated into the bear; (iv) Create more pet phrases and randomize them; and (v) Allow a Pet to react to another hug (iteration shown in Figure 6). These improvements were defined following the direction of evolving the scenarios by adding more interaction elements through ubiquitous technologies promoting more social interaction and input data.

5.4.2 Workshop 2

For the second workshop, the narrative was based on the dynamics of the "hot potato" game, reinvented with "Move on the Pet". We set the stage with a rug on the floor for the children to sit, organized in a circle. In the narrative, the Teddy bear would initially be trapped (hidden in the scenario). As the children hugged Chico, he thanked them for the hug, but after receiving a number of hugs, he would say a number and ask the child with the number to do a little activity (for example, picking up the honey jar on the table), fetch a box, hug the mother, etc.) and Chico would be passed to the next child. After all the kids having performed activities, Teddy would be released from the box.

The IoHT system was reconfigured and programmed to work based on the proposed narrative. The bear and the monkey pets were embedded with a small speaker, internal to their heads, that allowed the voice commands to be heard from their bodies. Corujita also received a speaker to indicate that a photo had been taken and sent to the Mural. Figure 6 shows the first iteration for Workshops 1 to 2 design evolution. Iteration means going back to the design cycle and working in the development cycle to implement the technical part in the physical environment.

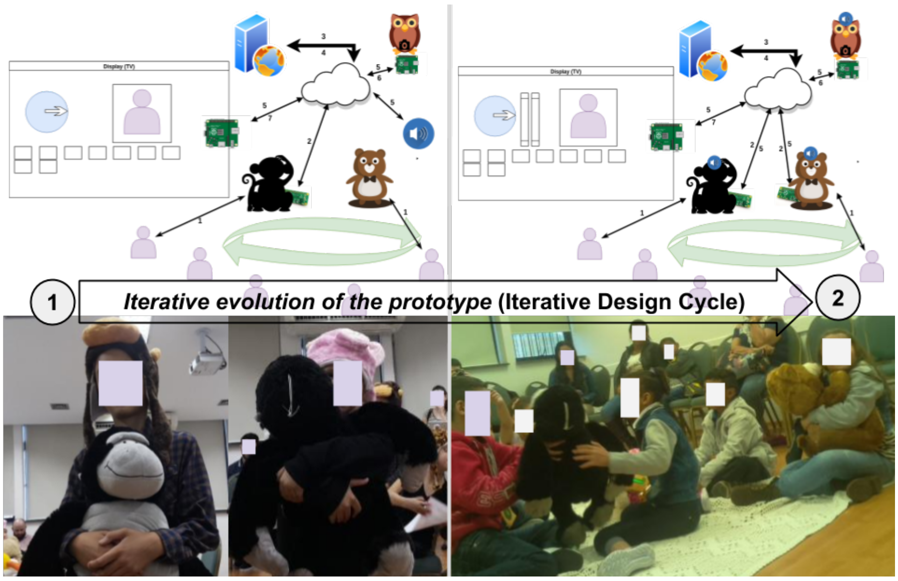

Figure 6. Initial Prototyping - Pets Arrival (1) Evolving to - Pet Pass (2): Development Cycle.

5.4.3 Workshop 3

The narrative of this instance of the system was based on the Christmas mood, and for that, a Christmas tree was incorporated into the environment, with the LEDs responding to the hugs in the Pets (Figure 1). The tree had light levels that could flash when Teddy was hugged, and a tree level could be lit with a number of hugs received by Chico, moving on to the next level until the tree was fully lit. When all the lights on the Christmas tree came on, the mural showed a picture of a Christmas tree with the inputs taken during the workshop and a Christmas sound played in the background.

In this cycle we created a communication block to make the lights flash or turn on depending on the message received. The block was embedded in a Christmas tree, receiving a speaker to give audible feedback to the events (flashing or turning on the lights) and playing Christmas music when it was fully lit. On system reconfiguration, the Mural object was modified to show the hugs given in Chico beyond the hug intensity value, also showing an emoji, happy for a strong hug or sad for a weak hug. When a number of happy emojis (2 for the first and second levels, 3 for the third and fourth, and 4 for the last two) had been reached and Teddy had already received two hugs, one level of the tree was lit.

Figure 7 illustrates the architecture of the IoHT computational system used in the third workshop. Global processing, centralized on a local server, ensures the systemic view. Each unit in the network, introduced in the Physical objects (Pets and Christmas tree), has local processing to guarantee autonomy of local actions; for this reason, a Raspberry was used in each one of them to receive information from sensors attached to them.

6 Discussion

Brennand, et al. 2019 Brennand *et al.* [2019] evaluated the children's user experience (UX) was assessed after participating in two workshops. With the results, the authors showed that the adapted methods were able to capture essential aspects of the children's experience, such as emotions. As the children made drawings at the end of the service, they were useful for evaluation, as the drawings represent greater spontaneity on the part of the children, bringing a look at the emotional responses given by the children through an interview with Emoti-SAM and Laddering, quoted in the article.

An evaluation of Universal Access through the observation of seven Universal Design Principles (DU) and 13 Heuristics for Natural User Interfaces (NUIs), was carried out in the third Workshop held with children in the hospital, reported in dos Santos *et al.* [2019]. The artifacts for interaction, the projected environment, the interaction between children and the artifact were evaluated. Based on the observation made, the authors proposed a checklist that combines the two instruments (DU principles and the NUI Heuristics) and points out recommendations on how to use it in the context of Socioenative Systems.

Some aspects of the experience of using the process proposed in this work, relevant to the design of ubiquitous and pervasive scenarios of technology use, are summarized as follows:

- **Impermanence:** When dealing with ubiquitous and pervasive environments, as proposed in this paper from their IoHT perspective, one problem will never be the same as another; People are different, they can act differently about things in the environment which, in turn, also act and make the environment different. Thinking about the design of interaction in such environments certainly involves the challenge of dealing with impermanence.
- **Affect and Be Affected:** As the team began to understand the problem, it became clear that the solution should (positively) affect the hospital's children, which in turn would affect the system's design. Thus, all stakeholders were involved to evolve the solution presented in Section 5, affecting and being affected by the experience.

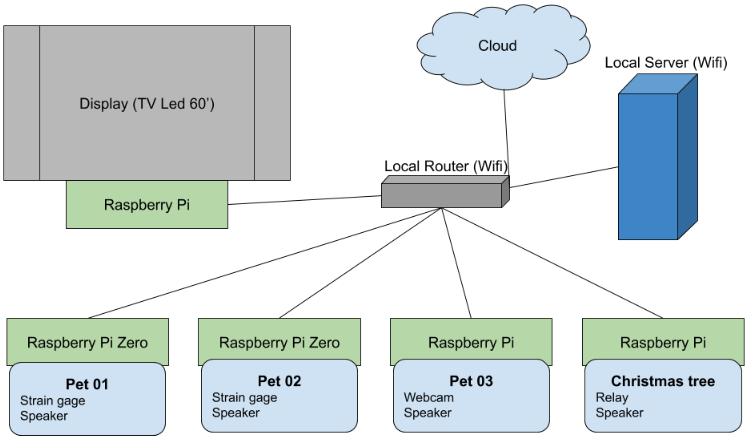

Figure 7. Computer system architecture that supported the workshops.

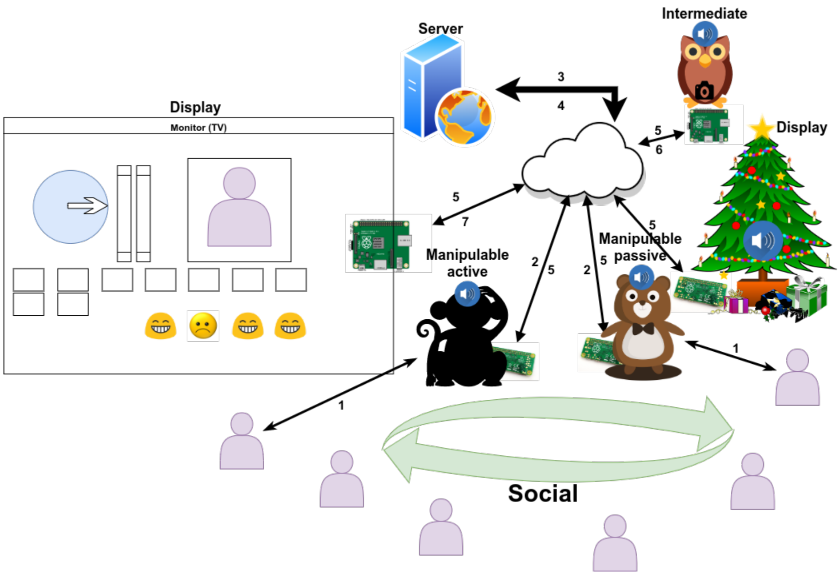

Figure 8. IoT environment diagram created for Workshop 3 (Christmas 2018) with categorization of objects.

- **Metaphor:** the "magic" metaphor was important to the creation of Pets on SobraPet so that the design solution had a directional narrative. The use of animals arose initially with the purpose of working on the affective issue and the relationship of children with the hospital environment, where the Pets would have a place to live. There is also a very large diversity of animals with different characteristics that could coexist showing the importance of differences and acceptance. In addition, they captivate children and allow their emotional expression. Embedded with technology, the animals received communication blocks and acted as IoT objects; when manipulated by children in the hospital setting, they could sense a hug and talk. We can exploit the Pets as messengers, who would visit children; as motivators in a teaching environment for children staying in hospital; and as protagonists of physical or virtual games, etc. Pets as metaphors were accepted and naturally incorporated by children in the act of hugging them , sharing the narrative with their peers, and expressing their affection.

In Workshop 3, the IoT System evolved into a Christmas setting in a hospital room; we found that the process used was effective in creating an environment in which participants made sense of the narrative and actions on the environment [da Silva *et al.*, 2019]. Combining efforts with stakeholders to evolve the IoT-based technology solution was essential to the effectiveness of the proposal. The children had fun hugging the animals and making up disputes about which of the pets would receive the most hugs. They were happy and played naturally in the IoT scenario. This can be seen in Figure 9, where little fingers (1) are pointing at the tree as it lit a level and tinkled Christmas bells. We can see one of the children hugging Teddy (2) and one of the companions (3) of one of the children looking closely at the pictures and other information displayed on the display (mural on TV).

- **The broad meaning for stakeholders:** IoHT systems include in addition to people, other elements (things) that can now act on the system because they have received technologies that make them active. These elements are also discussed as entities that present issues/problems and need solutions/ideas. Changes made in the scenario meet the assumption that an object receiving any information must act on it. Information is

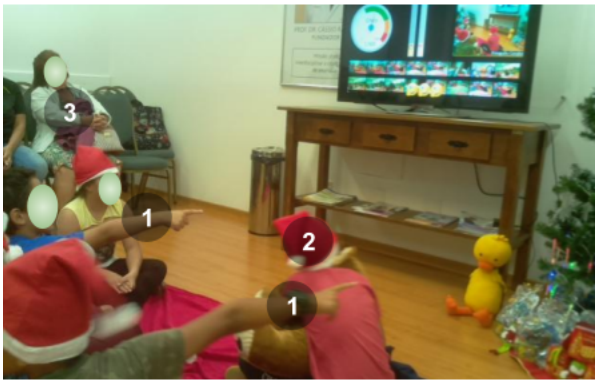

Figure 9. Photo illustrating a moment in Workshop 3.

either captured directly from people or received from other objects that are available in the environment.

- **Evolutionary element:** The system must be able to evolve into the creation of other scenarios in the hospital environment, allowing new experiences for children. With each new iteration of the process, other elements (things) shall be incorporated into the IoHT system in order to enrich children's repertoire of actions, support more complex narratives, with new objects in the environment, allowing their use to become more transparent to them.
- **Social element:** In addition to making the IoT System better with each iteration, discussions with stakeholders should also inform studies so that intersubjective relations and interactions among people, can be addressed in such environments.
- **Enactive element:** New components must be designed and developed for stronger coupling among children and the system objects as a whole. For example, the system may capture physiological signals that may feedback the system by aggregating other information related to the affective aspects of children. The goal is to create enactive cycles enabling perceptually guided actions of human elements in the environment. In addition, computationally captured and perceived social actions may affect technology, and processing these actions will lead to computational outputs in the environment that may affect the social context, creating a socioenactive cycle.

6.1 Social + Physical + Digital: the Socioenactive System

Figure 10 resumes the three scenarios that were taken to the SOBRAPAR hospital. The scenarios were shaped to promote interaction among children (Social) within the environment through the narratives constructed in each scenario. The dispositions and insertions of interactive Pets in the environment reveal the importance of the Physical, and change according to the narrative. Finally, the structures that support the Digital, that is, the capture, exchange of information and the manipulation of data also evolved to generate viable responses to the Physical and Social dimensions. The narratives introduced in each scenario were aimed at promoting the coupling in the Social, Physical and Digital dimensions, evolving naturally due to the demands of the workshop's narrative dynamics.

The ubiquity built in the hospital scenario, through the configuration of an IoHT Environment, allowed to visualize the three dimensions of socioenactive systems: Physical, Digital and Social. The Social dimension (interaction between all those present in the workshops mediated by the technological and social environment), Physics (Physical manipulation of things in the environment) and Digital (coding implemented so that the Physical-Digital environment enabled Social interaction and behavior). Figure 11 illustrates, in a diagram, the dimensions and their relations, which are necessary for the design and implementation of a Socioenactive system. The Physical, Social and Digital dimensions influence each other as shown by the arrows in Figure 11. The Social dimension changes through interactions between people or each one of them with the objects present in the IoHT environment. The Physical dimension, on the other hand, is influenced by people, that is, the social surrounding it and also the Digital that emerges from computational technology embedded in the Physical and that is distributed in the environment. The Digital dimension built on the Physical carries a Virtual environment with the characteristics of everything that is in the environment and assesses the changes that occur at each moment if it modifies itself or responds to the System.

The children invited to participate in the workshops were brought to the IoHT environment set up inside the SOBRAPAR Hospital with an adult companion (family member). As soon as they were put together within the technological scenario, they began to interact with the artifacts and with each other (often) changing the existing social rules. Children who had already participated in other workshops entered the room and soon felt comfortable talking to each other and talking about the pets (Chico, Teddy and Corujita) who were present and, with this behavior they started to involve the others (Those who were shy or inhibited with different people in a different space, even inside the hospital they attend.

The children were invited to sit on a circle on the floor and then the dynamics of the workshop were explained. When touching the pets, they felt comfortable, hugging or asking something about them. With this, the social was once again undergoing changes due to the insertion of Physical elements in the environment. The dynamics of the workshop began when the computer system was booted. The codes structured to create the digital environment led to the dynamics in which the perception of hugs (affection with pets in the Physical world) were captured and sent to the Digital that processed, responded to the environment creating a digital mural with photos of the workshop, turning on lamps (Christmas light in the third workshop), playing sounds (Christmas and voices on Chico and Teddy pets). All the systemic dynamics involving the Workshops (1, 2 and 3) allowed us to visualize a single system in which the human was present in the IoHT environment (being part of it), and acting upon the Physical aspects of the scenario. The Digital responded by making changes in the Physical elements and causing behavioral changes in the Social level 11. These dimensions are considered the basis for socioenaction.

The existence of the dimensions alone does not characterize a socioenactive system. The cycles established between

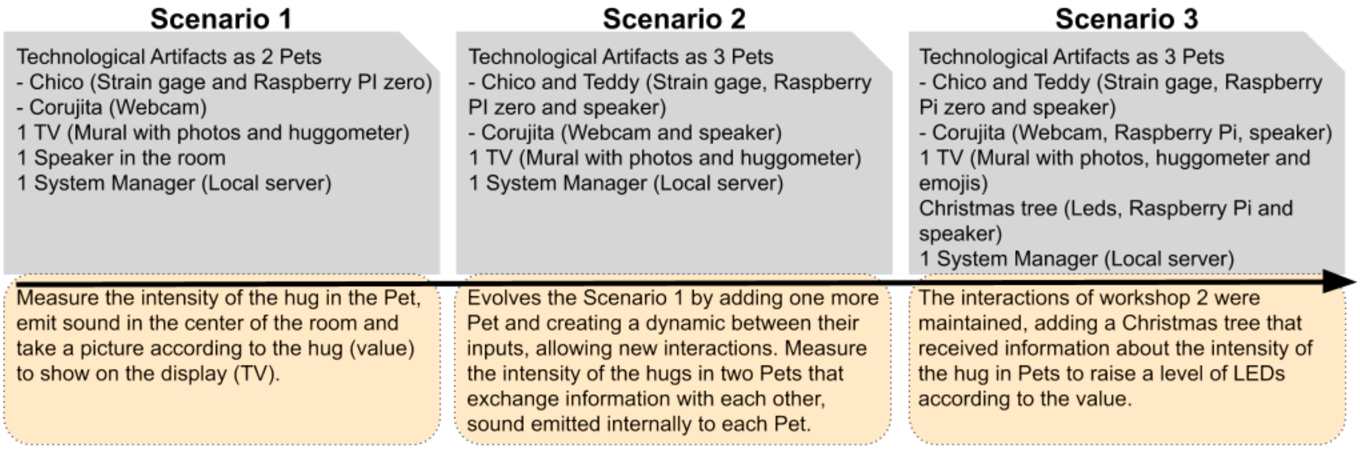

Figure 10. Evolution of the scenarios for the workshops.

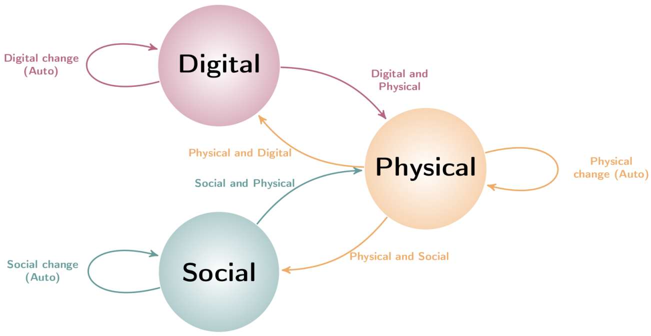

Figure 11. Dimensions of a Socioenactive System.

the dimensions coexist so that any change occurring in one dimension, causes changes in the others, this is the principle of socioenaction.

Enactive systems must also be able to respond to unintentional input, extracted from physiological sensors [Fortenbacher *et al.*, 2017]. These inputs can be included through Galvanic signal, Heartbeat readers, or behavioral analysis extracted from pressure sensors, for example Huynh *et al.* [2016], Costadopoulos *et al.* [2019]. The process of analyzing these signals uses pattern recognition methods such as Support Vector Machines, Convolutional Neural Networks and Machine Learning [Brady *et al.*, 2016].

The gain in the inclusion of these resources can be the construction of dynamic responses of the system extracted directly from the social behavior of stakeholders physiological data. Still, emotional patterns can be extracted from this data and compared with established methods like SAM (Self Assessment Manikin) [Bradley and Lang, 1994], reinforcing the results obtained.

As future work, the system will be evolved for socioenaction, being designed as part of the hospital environment so that people, especially children, can interact naturally without a structured guide from a workshop and researchers. Moreover, sensors that take biological readings (*e.g.*, heartbeat) must be used to capture data that will serve as inputs for the Digital to give more accurate responses to the Physical and the Social dimensions of the system.

Next steps aim to support the fluid interaction between technology and people through feedback loops, where the effect of technology on the human agent is fedback by human action in technology, based on the use of computational intelligence. In this aspect, the inclusion of Artificil Intteligence techniques can assist in dynamic interactions where the system's behavior changes based on new interactions, which emphasize social aspects, with the use of intelligent pervasive artifacts that can identify new patterns emerging from the experience.

7 Conclusions

Designing solutions for a system that connects objects (IoT) to work together with people (IoHT) is challenging, as the environment is plural in both people and objects and their processes of interaction and communication. In this work, we argued that learning about the local context for which an IoT solution should be thought of and bringing people involved to cooperate with the design is one of the key factors in achieving solutions from the perspective of the Human element in the environment. Using the concepts of Socioenactive systems and their influences in practical experiments, through artifacts and tangible and social interactions, we had the opportunity to study the environment, learn about people and bring them together in order to evolve a design solution for a hospital scenario.

For the evolution of the solution in a living and dynamic environment such as the hospital, the team will continue with cycles of change and incorporation of new elements in the solution, so that the Human remains the central element.

Because IoT keeps the characteristics of ubiquitous systems, these environments allow the embodiment of devices and artifacts in a natural way, adding to the narrative and social experience of participants in the codesign process. This challenge was launched in the cited project [Baranauskas, 2015] that will keep us active in several other iterations following the proposed process, seeking to understand the incorporation of the human with things in the environment, as well as the coupling between enhanced technology things in the environment and the digital and social world of humans.

During the execution of the design process, the Social, Physical and Digital dimensions were intertwined, reinforcing the connection between these dimensions and the influence they have on each other besides the importance of considering the Human element as part of the System. New iterations in the system must still be investigated in the IoT environment to have it as a Socioenactive system, established under the three dimensions, Social, Physical and Digital, such as the inclusion of physiological inputs, system responses to social behavior, among others. Universal design techniques need to be worked on, and instruments to investigate participants' emotional responses need to be developed in order to raise the feelings evoked by the system. Such affective aspects are even more relevant in certain domains, such as those of a hospital.

Declarations

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Authors' Contributions

The authors Silva, Baranauskas and Santos worked on the proposal, organization and realization of the workshops at the SOBRAPAR hospital. They also acted in the writing and revision of the paper. The author Gonçalves worked on writing and correcting the text for the final version of paper section.

Competing interests

The authors declare that they have no competing interests.

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