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Enhancing information-based spaces using IoT and multimedia visualization - a case study

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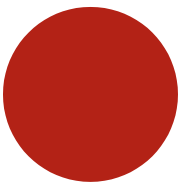

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Resumo

O principal objetivo desta pesquisa é fazer uma exploração em torno dos conceitos e tecnologias vigentes nas áreas da Internet de Coisas (IoT) e da visualização multimédia que possam ser aplicáveis para serviços distribuídos e na criação de espaços aumentados e que contribuam para melhorar a experiência coletiva e participação das pessoas que assistem a conferências profissionais, reuniões de grupo e espaços públicos em geral. Assim, a metodologia será baseada em uma revisão das tecnologias aplicáveis à IoT e para a visualização de informação e no design de uma proposta inicial de um sistema como caso de estudo para a criação do ambiente desejado, assim como a sua comparação com casos documentados de sistemas reais aplicados no contexto de eventos e espaços públicos. O resultado final é um estudo sobre as perspectivas de aplicabilidade destas tecnologias, considerando também problemas e limitações ao projetar eventos de tempo e orçamentos limitados.

Palavras-chave: IoT, Multimédia, Espaços Aumentados.

Abstract

The main objective of this research is to explore the current concepts and technologies in the areas of Internet of Things (IoT) and multimedia visualization that may be applicable to distributed services and for creating augmented spaces and that contribute to improve the collective experience and participation of people attending professional conferences, group meetings and public spaces in general. Thus, the methodology will be based on a review of the technologies applicable to IoT and the visualization of information as well as the design of an initial proposal of a system as a case study to create the desired environment and its comparison with study cases of systems applied in the context of events and public spaces. The end result is a study of the perspectives of applicability of these technologies, considering also problems and limitations when designing for events with limited time and budgets.

Keywords: IoT, Multimedia, Augmented Spaces.

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Pedro José Ayala Casanova

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Abbreviations

AGI	Ambient Geospatial Information
AR	Augmented Reality
AV	Augmented Virtuality
BLE	Bluetooth Low energy
CSS	Cascading Stylesheets
DLP	Digital Light Processing
DSI	Display Serial Interface
E Ink	Electronic Ink
EPC	Electronic Product Code
GPS	Global Positioning System
HDMI	High Definition Multimedia Interface
HTML	HyperText Markup Language
ICT	Information and Communication Technologies
IoMT	Internet of Multimedia Things
IoT	Internet of Things
LCD	Liquid Crystal Display
LCoS	Liquid Crystal on Silicon
LED	Light-Emitting Diode
MIT	Massachusetts Institute of Technology
MPEG	Moving Picture Experts Group
NFC	Near Field Communication
QR Code	Quick Response Code
RSS	Really Simple Syndication
SMS	Short Message Service
UGC	User-Generated Contents
UI	User Interface
USB	Universal Serial Bus
UX	User Experience
VGI	Volunteered Geographic Information
VR	Virtual Reality
WSN	Wireless Sensor Network

Chapter 1

Introduction

The increasing availability of multimedia contents (and devices to access them) have created a new experience of space that is actually beyond our immediate spatial and temporal reality, that is redefining our capacity for managing a multiplicity of connections and data types. Thus, from the last decade, the boundaries between spatial and digital experiences have faded, giving way to new hybrid environments, which besides being full of a broad range of services are also in need of efforts that drive all that technological progress towards experiences that make sense for people (McConnell, 2017).

This *augmentation of the space* implies rich and diverse kinds of interactions, that are yet to be fully discovered and developed. Nevertheless, despite all the novelties that it implies, our daily activities and most basic needs remain almost invariable throughout time; people keep gathering and socializing in environments that are used for a broad diversity of purposes as might be: recreation, education or other forms of collaboration. Thus, irrespectively of whether they are associated to technological means or not, the notion of physical space remains linked to basic principles that are timeless. As part of research done at Apple's Multimedia Labs, Woolsey and Semper (1991) described early ideas for complementing public spaces[1] through multimedia, pointing out that a successful public space has be to be in the first place : 1) open for social interaction, 2) should run under a determined spatial function and 3) must offer possibilities for the user to use it at different moments, so it becomes a reference through time.

As for the Internet of Things (IoT) is regarded; it is necessary to highlight its big relevance in the current technological panorama. According to Ma (2011), developed nations are considering IoT as one of the main points in their strategies for economic growth. Thus, the European Union published fourteen action-plans about IoT development in 2009, aiming to ensure its leadership on this field. Additionally, China's research programs on IoT are being strongly supported by different funds and institutions, as a clear sign of the importance that this field has for that nation's future plans. Finally, McConnell (2017) cites a press release from Gartner Inc. in which forecasts that for 2020, the number of connected *things* will brake the 20-billion units barrier. [2].

[1] For details about *public space* definition check: Gehl and Matan (2009)

[2] On-line source: Gartner Report

1.1 Motivation

The scenario described above represents a great opportunity for research and creativity fields equally. Even though being a matter of study that has been addressed since the beginning of the computer era, the enrichment of the space through computational features is more relevant nowadays than ever before, surpassing the technical research challenges to reach human behavioral dynamics, turning into a highly dynamic and interdisciplinary area that involves contrasting branches, such as: architecture, design, social sciences or technology. This scenario was anticipated by Woolsey and Semper:

> To proceed with our particular projects we need to explore the questions and considerations that arise when the human mind, technology and environment interact with one another. We need to examine projects that have put computers in public spaces and learn from the veterans of the logistical and economic trenches how we might combine design elements effectively. (Woolsey and Semper, 1991)

More specifically, for the case of this study, the application of technologies in the context of conferences and other programmed events proposes specific dynamics that are worth being explored. Namely, the existence of a determined schedule, the specificity of the group of participants, the time-limited duration of these events, or the need of social networking are all characteristics that are important to consider in the design process. Additionally, these events also imply the necessity of good quality information that be available at the moment and place that is required and that still interferes minimally on the flow of the main social dynamic, and multimedia is already being used broadly for this purposes. (Floris and Atzori, 2016)

Nevertheless, interaction of persons and devices can produce counterproductive effects rather than improving experiences in some contexts; this paradoxical effect of the use of portable devices on real-world human interaction is a problem commonly addressed nowadays by researchers [3] and despite these subjects have been widely discussed and known already as a cultural problem, several questions about how will be the future of the common space under all this spectrum of communication possibilities are yet to be answered. About this challenge, Leite gives an optimistic point of perspective by stating:

> The forms of crystallization of our experiences, such as memory, emotions, daily or playful practices find in the current configuration of urban spaces (augmented) a field of elaboration and sharing of a "common vision" of reality within a group. (Leite, 2010)

[3] Information source on the blog entry: The Smartphone Paradox.2015

Thus, the work of creating informational value in an environment that is already evolving and enriching, represents also a great opportunity to explore ways to improve experiences of people involved in collective activities and shared environments.

1.2 Research question and strategy

The main driver of this research is to explore the conceptual framework, state of the art and plausible applications of IoT-based services and multimedia infrastructure for the creation of augmented environments that contribute to the collective experience and participation of people attending conferences and group meetings.

Research question

> *How a design based on IoT and multimedia for creating an augmented environment can positively influence the overall experience of the participants of conferences and events?*

Research strategy

- **Literature review:** Analysis of the available references, potential fields of application and available examples.
- **Initial Concept design:** Elaboration of a proposal for a design, selection of the technologies that would be used.
- **Case study comparison:** Contrast of the proposed case experience with other studied cases.

1.3 Expected results

According to the planning and the current progress of the research. The expected contribution of the overall dissertation can be summarized as follows:

- **Solution design:** A general design with proposed elements for the augmented environment, including the IoT design.
- **Final report:** A document with all the observations and conclusions as final step of the study.

Chapter 2

State of the art

2.1 Augmented space

As individuals living in modern societies, we are used to live in public spaces filled by advertisements, video screens and a large variety of information sources that surrounds us almost everywhere. Thereby, it is very common to see an increasing tendency to develop our activities in environments that mix both multimedia (dynamic) information to urban (fixed) elements in our physical spaces. In many cases, these elements improve the amount and quality of the information we receive but also the way we relate to the space, and to other persons as well. According to Leite (2010), due to the use of these information and communication technologies (ICT) a new interactive dynamic has been created, between the physical terrain and the information that comes through digital networks. Thus, the ways in which relationships are created are being rebuild, in concordance to the spatial context.

This subject had been addressed also by Manovich (2006), who described how the use of electronic means and multimedia information in our surroundings, adds different layers to the actual space and yields to a completely new dynamic that he defined as *augmentation*, in which the capacity of analyzing and exploring the space are expanded to new levels. More specifically:

> Augmented space is the physical space which is '*data dense*', as every point now potentially contains various information which is being delivered to it from elsewhere. (Manovich, 2006)

This new potential of the space is also an expansion for human possibilities that is far from being limited to a scenario where technological solutions are just enhancing architecture or urban space functionalities; In fact, a big variety of gadgets and carry-on elements are now of common use for users in order to enrich their experience of the world thanks to ICTs (mobile devices, GPS, smartwatches, etc.), all of them augmenting our possibilities and making our decisions faster and more accurate. This insight about the importance of technologies for the emergence of new human

behaviors was forecasted several years ago by Engelbart under the concept of *Augmented Intellect*, as in the following quote:

> Increased capability in this respect is taken to mean a mixture of the following: more-rapid comprehension, better comprehension, the possibility of gaining a useful degree of comprehension in a situation that previously was too complex, speedier solutions, better solutions, and the possibility of finding solutions to problems that before seemed insoluble. And by 'complex situations' we include the professional problems of diplomats, executives, social scientists, life scientists, physical scientists, attorneys, designers–whether the problem situation exists for twenty minutes or twenty years. (Engelbart, 1962)

Regarding this augmentation of human capabilities, Manovich (2006) mentions Engelbart's concept as part of his explanation of the new paradigm of space, but updating its scope, by describing the *augmented space* as an environment that is continuously adapting to the needs of the user and that is not confined only to a professional context and its activities. Moreover:

> Today, however, we are gradually moving into the next paradigm, one in which computing and telecommunication capacities are delivered to a mobile user. Thus, augmenting the human also comes to mean augmenting the whole space in which someone lives, or through which someone passes. (Manovich, 2006)

2.1.1 Virtuality and reality

As discussed above, the massification of the Internet access due to the emergence of connected mobile devices is well known as one of the most relevant steps for the establishment of the information society as we know it, not only thanks to the increment of available information for decision-making but also because of the changes on temporal and spatial rules for this data to reach us. Nevertheless, there are some other facets, when talking about *real and virtual*[1] these elements that are summarized in the following paragraphs:

Manovich (2006), described how the idea of *virtuality* is not confined to the *cyberspace* realm anymore, given place to an integration to the physical *reality*. Nevertheless, the possibilities of *augmentation* also comprehend collective experiences of the space, conveying determined kinds of information and feelings to groups, or facilitating a concrete type of interaction, that could be the case of exhibitions, museums, conferences, galleries, etc. This is also explained by Leite:

[1] According to Milgram and Kishino (1994) "real objects are any objects that have an actual objective existence"; whilst virtual objects are "objects that exist in essence or effect, but not formally or actually".

> Thanks to its ability to transcend the "here and now", to combine the *real and the virtual*, the augmented urban space connects different forms of daily interaction and integrates them into a significant whole of spatial and social dimensions. The experience of these spaces constitutes one of the elements that structures our social bonds, reinforces the sense of belonging to a specific group and the space as an expression of rooting, but that also allows us to go beyond the materiality of space. (Leite, 2010)

The analysis about how real and virtual elements link to each other was being under study even before this panorama was near to be as developed as it is nowadays; Thus, Milgram and Kishino (1994) proposed the concept of a "*virtuality continuum* which connects completely real environments to completely virtual ones"(p. 199); this transition is also described as *mixed reality*. See Figure 2.1. The *mixed reality* contains two scenarios: augmented reality (AR) and augmented virtuality (AV), each one depending on the relationship among virtual and real elements displayed.

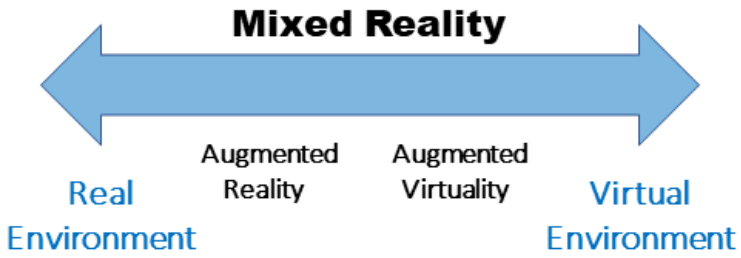

Figure 2.1: Virtuality Continuum. Adapted from: (Milgram and Kishino, 1994)

2.1.2 Immersion and augmentation of the physical space

The concepts of augmentation and immersion are related to the scale and purposes of the experience that is being created. It is very common to see both terms associated to Augmented Reality[2] and Virtual Reality [3].

[2] Augmented Reality for Milgram and Kishino (1994) "refers to all cases in which the display of an otherwise real environment is augmented by means of virtual (computer graphics) objects. The converse case on the virtuality continuum is therefore Augmented Virtuality (AV)

[3] "a Virtual Reality (VR) environment is one in which the participant observer is totally immersed in, and able to interact with, a completely synthetic world. Such a world may mimic the properties of some real-world environments, either existing or fictional; however, it can also exceed the bounds of physical reality by creating a world in which the physical laws ordinarily governing space, time, mechanics, material properties, etc. no longer hold". (Milgram and Kishino, 1994)

Thus, for a determined physical space, the elements displayed on devices that are contained in it will result on an augmentation, in which the user is still aware of the real context around him/her. On the other hand, an immersive experience of the space will get the user out of its reality to a totally simulated space. This is summarized by Manovich as:

> [...]whether we should understand a particular situation in terms of immersion or augmentation depends on how we understand the idea of addition: we may add new information to our experience – or we may add an altogether different experience. (Manovich, 2006)

2.1.3 The shared experience of the augmented space

According to Leite, the new forms of experiencing the public space are contributing to the construction of new types of social bonds and also building the reality of our daily spaces (Berger and Luckmann, 1991) that now has a hybrid nature and gives place to a more *"intersubjective and shared world"*.

The author also explains that there are two main vehicles that mediate for creating these experiences:

- **Visibility:** the capacity of sharing images of the urban space, that has given a new visual dimension to places, as well as it does for the representations of them through interactive maps (as might be Google Earth) that are now full of symbols and pictures of the space;
- **Mobility:** Linked to the new forms of walking through the physical space (GPS and other geo-location services), creating a sense of technological comfort that makes easier to explore, as well as changes the way of finding and being found.

Leite also mentions some relevant methods for collectively sharing these experiences based on this visibility and mobility of the collective space, these are briefly mention below:

- **Memory and traces:** *Memory* refers to the ability to collect and share representations of the *collective memory*, a record of the past experiences lived in the space through images and comments. Closely related to it, *traces* are understood as the signs left by the repetition of patterns and behaviors, that are not necessarily done by an explicit desire of persons.
- **Emotions and games:** The act of socially sharing *emotions* relies on the feelings of empathy and closeness between individuals, the ICTs can contribute to create channels for sharing these emotions (via through sensors or buttons). Linked to this, augmented social environments and collective experiences are likely to be constructed around *playfulness*; games can encourage interaction and facilitate dialogue between people.
- **Collective knowledge:** it means using the sense of the *shared experience* as tool in the experience of the common space. Creating a more creative and participative dynamic based on cooperation and socially generosity, where the shared knowledge about the space can help increase feelings of trust, commitment and participation.

2.1.4 Creation of value in augmented environments

For Sakamoto et al. (2012). The most important aspect during the process of designing augmented reality elements is to define *the meaning of the virtual elements*; the addition of meanings to forms of products is relevant for the design of the user's experience. For them, the forms need to offer value to the user, and recall five principal ways of adding significance to experiences:

- **Empathy:** this is engagement of the user through a feeling of closeness to the empathetic forms. Virtual pets are typical examples used in on-line services for encourage them to change undesirable behaviors.
- **Persuasion:** User's behaviors can be positive or negative influenced depending on the feedback information that is offered by the system. Design of emotional incentives that stimulate the users and reinforces their involvement are key aspects to be considered.
- **Economy:** Always a tangible reward that is valuable for the users is a good incentive, although it doesn't have to be actual money or goods necessarily. Virtual money associated to the system are a good example of this kind of value.
- **Information:** The addition of useful information for the user, helps him/her to make better decisions, this enables the user to decide explicitly and with feeling of security, that is useful to increase intrinsic motivation.
- **Ideology:** It refers to the influence that the experience has on the user for the long term; also called self-efficacy, it is influencing users' behaviors by influencing their attitudes and values; and educate them in a deep enough level for reaching goals on their own.

2.2 Internet of Things

In a generalized approach, the Internet of Things (IoT) concept refers to the idea of connecting any device to the Internet; this includes everything: from cell phones, home appliances, light dimmers, wearable devices, etc. (Morgan, 2014).

However, nowadays is also common to associate IoT to devices equipped with sensors and actuators of different types, through which a determined system has the capability of collecting and sharing information on-line. This is a more up-to-date perception, that is aligned with the evolution of communication technologies, in which persons and devices are part of the communication process. This is:

> The IoT is a giant network of connected 'things' (which also includes people). The relationship will be between people-people, people-things, and things-things. (Morgan, 2014)

Along the same line of reasoning, Ma (2011) describes IoT as the next step in networks and interconnection technologies. Thus, given the implication of objects as addition to the traditional Internet (that includes humans and data); the elements and interactions in IoT's communication would be as in the figure 2.2:

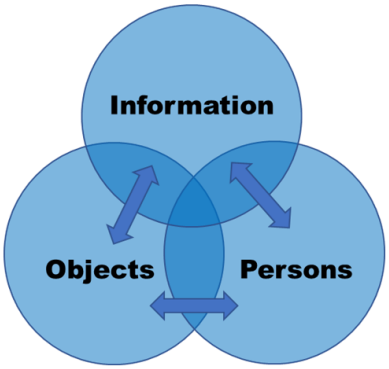

Figure 2.2: Elements of IoT Communication. Adapted from (Carrión et al., 2017).

This upcoming paradigm of an *Internet of Everything*, in which the use of a search engine will offer solutions for questions that exceed the mere necessity for information is depicted by Sterling in the following sentence:

> [...] I no longer hunt anxiously for my missing shoes in the morning. I just Google them. As long as machines can crunch the complexities, their interfaces make my relationship to objects feel much simpler and more immediate.(Sterling, 2005)

Finally, Ma (2011) translates that user experience scenario into a more technical definition of the IoT:

> Based on the traditional information carriers including the Internet, telecommunication network and so on, Internet of Things (IoT) is a network that interconnects ordinary physical objects with the identifiable addresses so that provides intelligent services.

2.2.1 History of the IoT

The term IoT was first used around 1999 by Kevin Ashton, executive director of MIT Auto-ID Labs[4], a project focused on how to create an alternative for RFID for parts and products using the Internet. The initial aim of the concept is described by Ashton (2009) himself in an article of 2009:

> I could be wrong, but I'm fairly sure the phrase "Internet of Things" started life as the title of a presentation I made at Procter and Gamble (P&G) in 1999. Linking the new idea of RFID in P&G's supply chain to the then-red-hot topic of the Internet was more than just a good way to get executive attention. It summed up an important insight which is still often misunderstood.

Besides this being the first known mention of the IoT term, Lee (2012) mentions that ideas about connecting different objects through networks existed even before, as in the case of a coffee pot that was linked to a camera at a Cambridge's Computer Lab, back in 1993. [5]

[4]The Auto-ID Lab at Massachusetts Institute of Technologies (MIT) traces its roots back to 1999 and the founding of the Auto-ID Center, which laid much of the groundwork for the standardization of RFID technology and the introduction of the EPC. Now a member of the global Auto-ID Labs network, the Lab continues research on the evolution and application of RFID systems, as well as other disruptive Internet of Things technologies. Sources: `https://autoid.mit.edu/about-lab`; `https://www.redbite.com/the-origin-of-the-internet-of-things`

[5]This example constitutes probably the fist known antecedent to the web-cam that is commonly used today in almost every web-connected device.

2.2.2 Multimedia and IoT

Floris and Atzori (2016) explain the concept of a *multimedia thing*, as: "objects capable to acquire multimedia contents from the physical world, being equipped with multimedia devices such as cameras and microphones", and defines the *Internet of Multimedia Things*[6] as:

> a network of interconnected objects capable to acquire multimedia contents from the real world and/or present information in a multimedia way. (Floris and Atzori, 2016)

From the information above it is possible to notice that the notion of the IoT has been in evolution through the time, it differs for different professionals and researchers and it has been influenced by the availability of new technologies and social trends. Thus, Floris and Atzori (2016) named three main generations of the IoT, associated to different kind of components:

1. **RFID tags**, commonly used for monitoring purposes, logistical tracking applications.
2. **Sensors and Actuators**, which allowed to send/receive information between digital and the physical worlds, created the Wireless Sensor Networks (WSN).
3. **Virtual objects**, it's the most recent IoT generation, developed based on the creation of a virtual object to every physical object involved, mediated through multimedia means.

2.2.3 Architecture of the IoT

According to Popentiu-Vladicescu et al. (2017), the major components of an IoT system include: sensors/actuators, communication between servers or server platforms (based on cloud computing or FOG computing), middleware platforms, data analytic engines, and applications developed on mobile/wearable devices.

- **Real-world layer:** the physical real-world objects and sensing devices that collect the information for the IoT application.
- **Virtualization layer:** creates the virtual functionalities (virtual Objects) associated to the Real-world layer.
- **Aggregation layer:** combines virtual objects in order to create new composite objects, capable of providing services.
- **Application layer:** manages the services requested by the IoT application, also delivers all of the functionalities of the system to the final user

[6] Based on the original MPEG's definition of: Internet of Media Things and Wearables (IoMT & W): https://mpeg.chiariglione.org/standards/mpeg-iomt/iomt-architecture

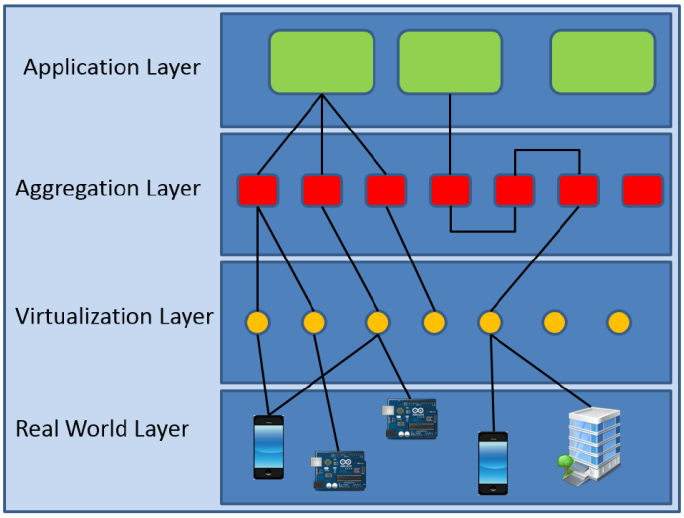

Figure 2.3: IoT Main Layers. Extracted from (Floris and Atzori, 2016).

2.2.4 User-centered IoT

The task of creating real-world valuable experiences by technological means has to be unequivocally linked to real needs on the user side; this idea is reinforced by McEwen and Cassimally (2013), pointing out that besides the emergence of new services, the main feature of technology (IoT in specifically) will always be to connect those "things" that satisfy human timeless demands, this is:

> Technology's great drivers have initially been fundamental needs, such as, food and water, warmth, safety and health[...] (McEwen and Cassimally, 2013)

> [...]The shape and details of these things will change but not the needs they address. As technology has progressed, new categories of objects have been created: in the electronic age, they have included telephones, radios, televisions, computers and smartphones...(McEwen and Cassimally, 2013)

Regarding to this main functionality of the IoT as a provider of solutions centered on user's needs, Rowland (2015) remarks the importance of a subtle integration of products to the user's environments, avoiding interfering on lifestyle dynamics or complicated tasks. These technological products are used in environments where people likes to feel security, quality and predictability in services (home, offices, etc.). When trying to illustrate this subject Rowland talks about IoT products for users with especial needs and states:

> Technocentric solutions which are insensitive to the needs of the occupants will fail. For example, an assisted living product needs to balance the need of vulnerable people for safety and support, while preserving their privacy and autonomy.(Rowland, 2015)

Rowland also explains the importance of a clear value proposition for IoT products. Thus, since many experimental solutions are interesting but don't provide easy-to-use or are connected because in response to technological possibilities instead of needs on the user side and says: "Some things are arguably being connected just because it's possible to do so, not because they need to be"(Rowland, 2015). Thus, for achieving the goals of the UX design the user has to understand three main questions: (see figure 2.4)

1. **What does the system do?**. Value Proposition, what problems does it solve?
2. **How does it work?**. Conceptual Model, understanding of the system's functionalities.
3. **How can I use it?**. Interaction Model, is it easy to use?

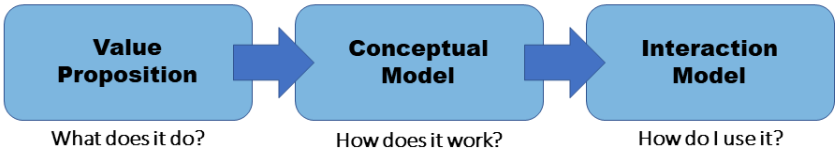

Figure 2.4: Main Aspects IoT UX Design. Adapted from: (Rowland, 2015).

2.2.5 Services in distributed IoT systems

Distribution of functionalities across an IoT system determines whether the experience that the user will have is right or is not. Surpassing the limits of traditional design of UI layer; *service design*[7] requires understanding user's needs along all the different *touchpoints* of a system, trying to ensure the coordination of the different components, and the uniqueness of the experience, regardless these be online or offline. About this subject Rowland says:

> Designers need to consider how best to distribute functionality across devices. They need to design UIs and interactions across the system as a whole -not treating devices as standalone UIs- to ensure that the overall UX is coherent. (Rowland, 2015)

Additionally, Rowland explains that user interfaces and good industrial design are important for the final quality of an IoT product but are not the only factors to consider; warns about the possibility of creating single applications or infrastructures that individually could seem appealing, but that would provide a weak overall user experience because of the lack of consistency. Nevertheless, for the case of a project that has a limited time-frame (as in the kind events that are

[7]The activity of planning and organizing people, infrastructure, communication and material components of a service in order to improve its quality and the interaction between service provider and customers.The purpose of service design methodologies is to design according to the needs of customers or participants, so that the service is user-friendly, competitive and relevant to the customers.Source: http://trydesignlab.com/blog/what-is-service-design/

being studied in this work) solutions need to guarantee a quick assembling, affordable materials, and yet offer a solid aspect and coherence in the overall experience.

The figure 2.5 shows a glance over the disciplines and general steps involved in the design of IoT projects.

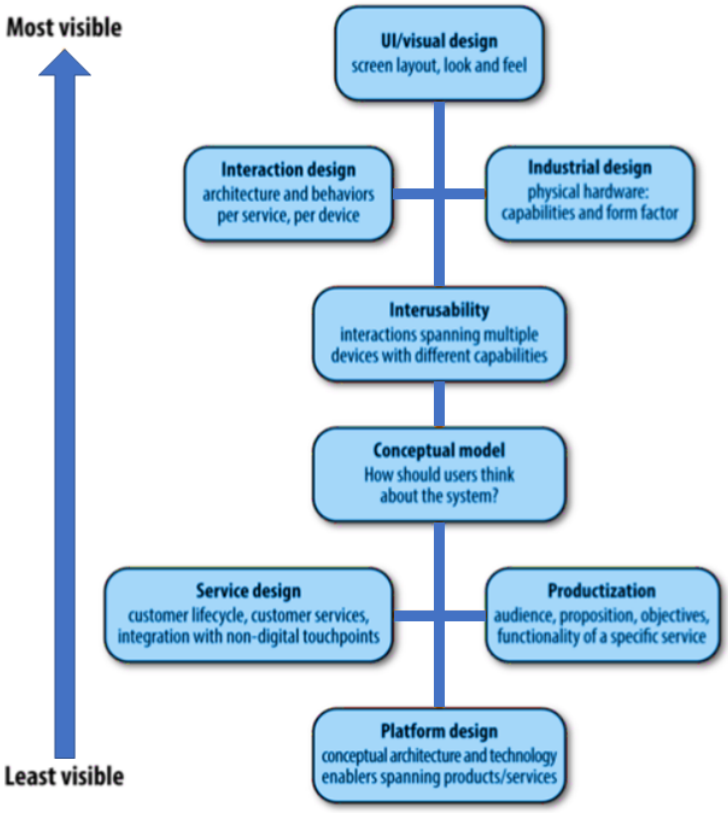

Figure 2.5: Design Facets in IoT. Adapted from: (Rowland, 2015).

2.3 Case studies

2.3.1 Case 1: Blendology

Blendology is British company specialized in the creation of interactive solutions for events. The focus of their products is to improve engaging and performance of organizers, customers and marketing managers during events. The main functionality of the platform is to allow users to make real-world connections through technological mediation, as well as exchanging digital contact details by the use of interactive portable devices that link to each other by tapping. Additionally, the use of their IoT-based platform allow them to deliver measurable results, by tracking activity of the users and effectiveness of branding efforts. Thus, at the end of the event, different stakeholders can receive reports with details about activity data that is registered by the system, according to their specific interests.

The clients initiate the experience when registering on the website of the company, where they can create their profiles and fill in the details that they want to share with the system (and other users). Then, each one of them receive a personalized interactive device that contains their details. This device also includes an e-ink[8] display that shows event-related information for the user. See figure 2.6. [9]

More information on:
https://youtu.be/fYMUdGp7Pzw http://blendology.com/

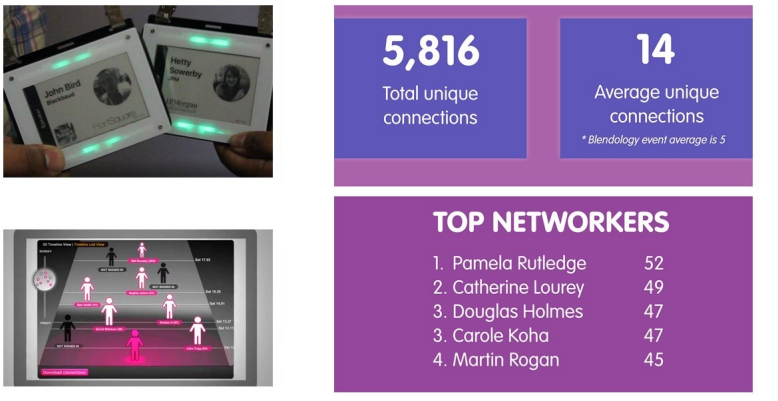

Figure 2.6: Diverse images from Blendology's system.

[8] E Ink (electronic ink) is a popular type of electronic paper display technology, characterized by high visibility and contrast, a wide viewing angle and low power requirements. The technology has been commercialized by the E Ink Corporation, which was co-founded in 1997 by MIT undergraduates J.D. Albert & Barrett Comiskey, MIT Media Lab professor Joseph Jacobson, Jerome Rubin and Russ Wilcox. Source: Wikipedia

[9] Figures adapted from: https://nswmentalhealthcommission.com.au/news/our-news/iimhl-delegates-use-blendology-to-form-international-connections

2.3.2 Case 2: Eventagrate

Eventagrate is a company that offers services in the realm of augmented spaces for different kind of environments and events; their work is focused on the creation of enjoyable experiences through interactive multimedia installations that can go from sensor-based interactive projections, video mapping and augmented reality.

Eventagrate work is strongly oriented to the field of marketing and entertainment, with a very broad spectrum of application settings and potential clients (kids, sports, business, museums, etc.). See figure 2.7. [10]

More information on:
https://youtu.be/_3RFrW4QALo http://www.eventagrate.com/

Figure 2.7: Diverse images form Eventagrate products.

[10] Figures adapted from http://www.eventagrate.com/

Chapter 3

Technological review

The present chapter, covers some general aspects about technological equipment and software tools necessary to work on projects that involve IoT technology and Multimedia for temporary conferences and group events:

3.1 IoT Technology

3.1.1 Mobile applications and technology

A mobile application is a software solution designed and developed according to the capabilities and constraints of modern carry-on computing devices (smartphones, tablets, etc.). Depending on the type of functionalities, mobile apps can be distinguished into three main categories:

Web-based apps

It's the most common type, depends on Internet connection (mainly wireless) to operate; they can be used on several devices, requiring only on browser's compatibility and quality of connection. Web apps, do not require storage in the user's device since they work in browsers (Chrome, Safari, or Firefox).

Pros:

(i) Easy to build and to maintain.

(ii) Development is not expensive.

(iii) Can be developed for all platforms (iOS, Android) as long as it can operate in a browser.

Cons:

(i) Needs a browser to run, making poorer user experience and less intuitive usage than in native apps.

(ii) Typically, they are slower than native apps.

(iii) Cannot use device's utilities.

Native apps

For this kind of apps, no connection is needed; a native app can work faster by exploiting the specifications of its host device's processor, as well as using specific embedded hardware units like GPS, gyroscope or sensors.

Pros:

(i) Native apps are fast and responsive, better overall performance.

(ii) They are more interactive and intuitive, smoother input and output from user.

(iii) Internet connection is not always required.

Cons:

(i) More complex development.

(ii) More expensive.

(iii) Not suitable for very simple projects.

Hybrid apps

A hybrid app, is a combination of a native and a web apps; this kind of products can be install in the user's device like a native app but being web app. Hybrid apps can do everything like a web app but they also incorporate native app features. A hybrid app has two parts: 1) a back-end code built using languages such as HTML, CSS, and JavaScript and; 2) a native shell that is downloadable and executes the code using Webview[1]

[1] WebView is an application provided by Android which allows to integrate the browser into a native application; it is very commonly used in Facebook, Twitter, etc. Source: https://elandroidelibre.elespanol.com/2015/06/que-es-webview-y-por-que-tengo-que-actualizarlo.html

Pros:

(i) Built on web technology, which make them easier and faster for development.

(ii) Cheaper than development than for native apps.

(iii) No browser needed as opposed to a web app.

(iv) Have access to the device's internal functionalities (storage, camera, sensors, etc.)

Cons:

(i) Slower operation than in native apps.

(ii) More expensive than standard web apps.

(iii) Less interactive than native apps.

3.1.2 Sensors, transducers and actuators

Some important terminology related to IoT technology is summarized below: [2]

- A *sensor* is a device that detects phenomena from the physical environment (light, heat, motion, moisture, pressure) and translates them into measurable representations (digital or analog signals). Some of the most common types of sensors that can be found in modern devices react to stimuli like: sound, light, pressure, movement, proximity, temperature, acceleration, etc.
- A *transducer* is a device that converts one form of energy into another. Examples of common transducers are those that transform electrical energy into some other form of power: light bulbs (optical), microphones (sound), and electric motors (movement).
- Finally, an *actuator* can be defined as a device that uses energy to generate motion. Thus, an actuator is considered a type of a transducer.

[2] Information summarized from (SCME, 2011)

3.1.3 Development boards

BBC micro:bit

Is an ARM-based system designed by the British Broadcasting Company (BBC) as part of a computer education project in the United Kingdom on 2015.

It consists on a board with an ARM Cortex-M0 processor, accelerometer and magnetometer sensing capabilities, powered via USB or external battery. The inputs and outputs are done through five ring connectors that are part of the 23-pin edge connector. It also has Bluetooth and USB compatibility, and a led display consisting of 25 points, it has two programmable physical buttons. See figure 3.1. [3]

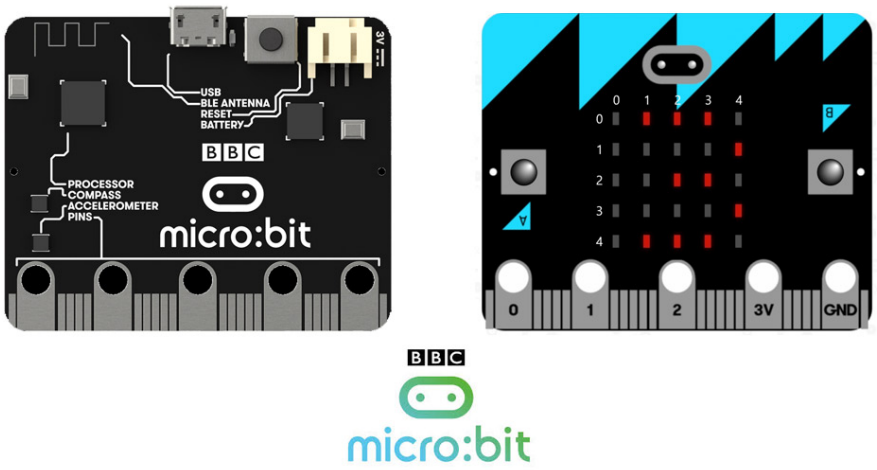

Figure 3.1: BBC micro:bit.

[3] Source: https://en.wikipedia.org/wiki/Micro_Bit; Figure adapted from: http://unthinkabledigital.co.uk/bbc-microbit-digital-teaching-and-learning-in-the-classroom/

Raspberry Pi

The Raspberry Pi is the name of a variety of single-board *general purpose micro-computers* created by the Raspberry Pi Foundation to promote teaching of computer science and development of small projects for the general public.

The Raspberry Pi doesn't include the common peripherals that are seen in traditional portable computing devices (keyboards, mice, etc.); nevertheless, additional kits and connectible adds-on are linkable to the main board, expanding its functionalities.

As for the specific case of multimedia projects is regarded, some of more important features that are commonly seen in the Raspberry Pi include: an integrated Videocore graphics processor, which allows the Raspberry Pi to decode 1080p video streams, OpenGL rendering capacity for graphic computing, full sized HDMI video output, DSI (Display Serial Interface) port and a 3.5mm/4-pole composite video and audio output jack. See figure 3.2. [4]

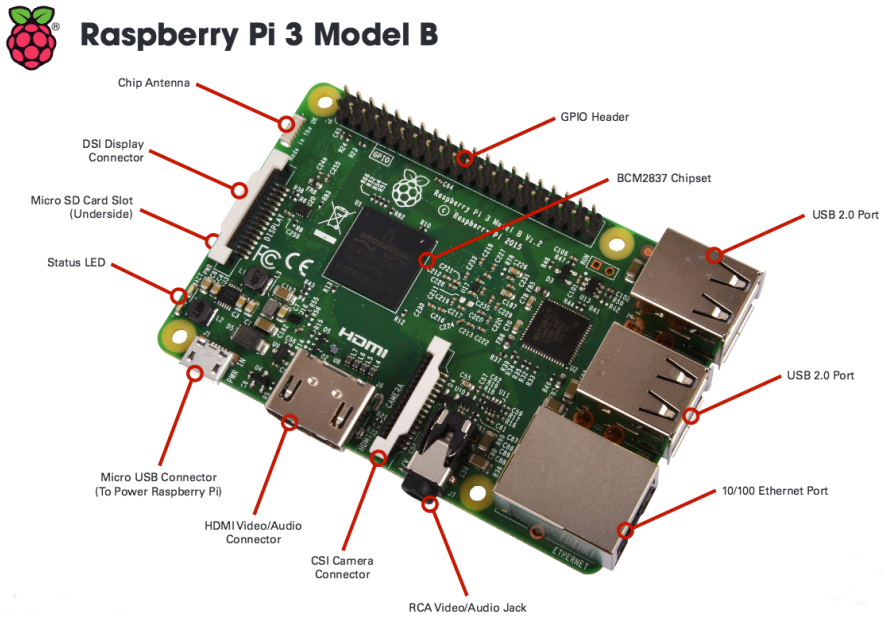

Figure 3.2: Raspberry Pi 3.

[4] Source: https://www.xataka.com/ordenadores/raspberry-pi-3-model-b-analisis-mas-potencia-y-mejor
Figure adapted from: http://auseparts.com.au/index.php?route=product/product&product_id=188/

Bluetooth Beacons

Beacons are small devices that enable location services by transmitting very small sets of data via Bluetooth Low Energy (BLE), covering a distance up to 50 meters. Mobile apps "react" to signals that are periodically sent (300 ms as average interval) by beacons, triggering events and/or information display for the user. Beacons are commonly powered by small batteries with very high efficiency, but in some cases, USB port can provide alternative and steady power supply. Mobile devices and PCs that support BLE can emit and receive beacon signals as well. See Figure 3.3. [5]

The main benefits of using beacons are:

1. **Improved accuracy:** when compared to other services like: GPS, Wi-Fi proximity, or cell tower triangulation.
2. **Affordable:** an average beacon can cost around $ 15-25, but there are some basic models that can be as cheap as $ 5.
3. **Small size:** are adaptable to almost any type of space. Finally, due to their characteristics, beacons are mostly used for indoor services, but they can be used outdoor also. [6]

Figure 3.3: Illustration about how beacons can trigger events on mobile apps.

[5]Figure adapted from: https://kontakt.io/beacon-basics/what-is-a-beacon/
[6]Source: https://kontakt.io/beacon-basics/what-is-a-beacon/

NFC tags

This kind of spatial markers is based on Near-field Communication (NFC) technology, which is a communication protocol that allows communication for short radius (within 4 cm). Tags' functions are activated when microwaves generated by the user's device reach the microprocessor located in the tag, sending the information for the recipient unit for executing a determined function. See illustration on figure 3.4. [7]

The main benefits of using NFC tags are:

1. **Improved control of action:** Due to its operation characteristics, it is easier to control timing and identity of users engaged.
2. **Privacy:** Users' movements can only be registered by those NFC tags that were voluntarily activated by them.
3. **Price:** Prices of Tags units are around $0.10 and $0.60 depending on their characteristics and quality.

Figure 3.4: Illustration of an NFC tag functioning.

[7] More information on: http://webcamsocialshopper.com/wp-content/uploads/2014/02/BLE-vs-NFC-infographic.png; Figure adapted from: https://sc01.alicdn.com

3.1.4 Platforms

Octoblu

Octoblu is an open-source, multi-protocol IoT platform that allows the creation of secure IoT services; it constitutes an interesting example of an adaptable platform that would help to connect smart devices, wearables, physical spaces, objects and web services, requiring little programming skills and intuitive configuration for designing IoT projects. See figure 3.5. [8]

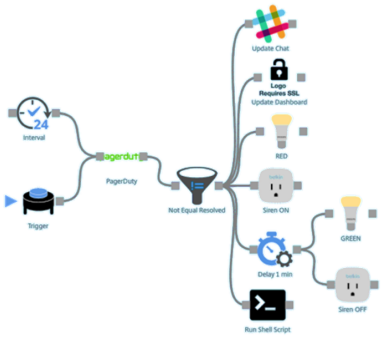

Figure 3.5: Octoblu's Configuration Example.

Android Things

Android Things is an operating system designed by Google for IoT projects. It is based on the mobile operating system for mobile devices called Android and it's aimed to facilitate the integration of low-power and memory constrained devices to the Internet of Things (IoT), which are usually built from different companies and under diverse protocols. Thus, Android Things supports three different kind of boards: the Intel Edison, the NXP Pico i.MX6UL and the Raspberry Pi 3 .

Having been launched on May of 2018, Google states that the main advantages of Android Things will be: high security standards, direct updates and the compatibility with the already existing environments and community for Android developers. See figure 3.6. [9]

Figure 3.6: Key strengths of Android Things.

[8] Information and figure adapted from: https://octoblu.github.io/

[9] Adapted from: https://fossbytes.com/wp-content/uploads/2018/05/Android-Things-1.0-release.png

3.2 Multimedia technology

3.2.1 Video projectors

Video projectors (VP) are commonly used in a big variety of projects and settings where amplified visualization of multimedia contents is required (conference rooms, classrooms, home cinema, concerts, performance stages, video mapping purposes, etc.). VPs receive a video signal input, which is processed according to the correspondent technology (reflective or transmissive) and then send to the projection surface by using an optical system and a light source. According to the projection technology, VPs can be classified as:

- **DLP projectors:** In DLP (Digital Light Processing) systems the light is *reflected* in a small chip that contains a rectangular matrix of up to 2 million pivoting microscopic mirrors (each one the size one fifth of the width of a human hair).

  Pros:

  (i) DLP projectors offer bright, colorful images with high contrast ratio.

  (ii) The resulting image is much sharper due to the small separation between pixels.

  (iii) Light losses are reduced, and light output is higher due to the use of mirrors.

  (iv) Deeper black color.

  (v) Produces a smoother image (as good as a 35mm or 70mm film).

  (vi) Highly accurate and without shadows.

  Cons:

  (i) Its price is higher when compared to LCD projectors.

  (ii) The DLP has a limited number of pixels due to the reflected chip.

  (iii) The DLP is not as bright as LCD technology.

  (iv) It can generate a rainbow effect[10] with brief flashes of color on the screen.

- **LCD projectors:** LCD (Liquid Crystal Display) In this technology, light is divided into the three main light components (red, green, blue) and *transmitted* through three individual liquid crystal panels finally the images are recomposed in one, constituted by pixels, and are projected onto the screen by a lens.

[10] The rainbow effect is perceived as brief stints of sequential light flashes. These disturbances show up, especially when a bright object shows up against a darker background in the projection. While some people do not notice this distortion, it is quite disturbing for those who do. More information on: http://www.theprojectorexpert.com/dlp-rainbow-effect/

Pros:

(i) The LCD projector has a better lighting efficiency.

(ii) They have good color saturation.

(iii) Capable of producing very bright images with the same voltage.

(iv) This type of projectors doesn't produce rainbow effect.

(v) They are generally the quietest projectors because don't require a noisy fan.

(vi) LCD VPs can provide beautiful color even if the image is soft or in a bright room.

(vii) This kind of VP usually has lens shift capacity.

Cons:

(i) Generally are bulky, as they consist of more internal components and making them more difficult to transport.

(ii) Dead pixels cannot be reactivated, causing a permanent damage to the projector.

(iii) Replacing parts in the LCD panel can be expensive.

(iv) Images can look over pixelated due to the *screen door effect*[11]

(v) Color uniformity is lower than in DLP projectors.

(vi) LCD projectors can be subject to loss of overall image quality over time.

- **LCoS projectors:** LCoS (liquid crystal on silicon) is considered a hybrid between LCD and DLP technologies. It uses liquid crystal chips with a mirrored back; thus, they are reflective (like DLP) but also block the light using liquid crystal (like LCD).

  Pros:

  (i) Incorporate the best of DLP and LCD technologies.

  (ii) Outstandingly accurate color reproduction.

  (iii) They don't suffer from screendoor effect

  Cons:

  (i) Usually have a higher price than DLP or LCD technologies.

  (ii) Contrast ratio is not as good as in similar LCD / DLP projectors.

[11] The screen-door effect is a visual artifact of displays, where the fine lines separating pixels (or subpixels) become visible in the displayed image. This can be seen in digital projector images and regular displays under magnification or at close range, but the increases in display resolutions have made this much less significant. More recently, the screen door effect has been an issue with virtual reality headsets and other head-mounted displays, because these stretch a single display across a much wider field of view. Source: https://en.wikipedia.org/wiki/Screen-door_effect

Finally, VPs can be differentiated according to their illumination sources as well, the main options available are: traditional bulbs VP which have high energy consumption, need longer time to start functioning and LED and Laser VPs [12] which offer lower energy consumption, lower heat dissipation and almost instant on/off switching.

The figure 3.7 [13] shows the main types of video projectors:

Figure 3.7: Types of video projectors.

3.2.2 Video processors

In a very simplified way, a video processor can be described as an electronic device that processes a video signal (or a set of them) for being used in another display devices such as LCD screens, VPs , DLP rear projection displays, etc.

New video processors are designed to meet the increasing demands that are associated to technological advances in multimedia field. Thus, large-format displays, 4K resolution, multi-source and multi-display managing are some of the standards that users require in their projects nowadays, and that are reachable with video processors.[14]

[12] More information about Laser VPs can be found here: https://www.lifewire.com/how-laser-based-video-projectors-work-4132351

[13] Information and figure adapted from: http://projectorfocus.com/led-vs-lcd-vs-dlp-projectors

[14] More information on: http://www.pixell.com/what_is_a_VP.htm

3.2.3 LED displays

Despite the existence of a broad variety of physical display options, based on different technological and budgetary possibilities, some of the most frequently used panels for informational and recreational purposes nowadays are the LED displays. A LED display uses an array of light-emitting diodes as pixels for image visualization. Colorful and bright LED panels that are seen in many public spaces and electronic devices were possible to build since the introduction of the first efficient Blue LED technology, which among to the miniaturization of these semiconductors helped to generate panels that display images and video in the full spectrum of colors, as well as with good contrast and high resolution.

Perhaps the LED physical screens are omnipresent nowadays due to the use of devices like smartphones, tablets and computers (all of them elements that constitute a fundamental part of the augmented environment we live in); there are many ways in which these technologies are being applied for augmenting physical shared spaces and as part of existing architecture, giving way to new possibilities in augmented environments, some of these uses are briefly reviewed as follows:[15]

I. **LED screens**: These are the most basic and well-known applications of LED display technologies in classic physical screens, they comprehend a wide number of possible configurations and sizes, that are useful different environments, fixed or transportable. Some of the advantages of LED panels are. See figure 3.8.

   - Good image resolution and quality.
   - Adaptable to indoor and outdoor conditions.
   - Bright and vivid images.
   - Small size and weight.

Figure 3.8: LED Screens.

[15] Information and figures source: https://www.optokingdom.com/

II. **LED curtain display**: suitable to be installed on high buildings external walls, roof and windows of buildings. They are very popular among customers and are excellent for advertising (See figure 3.9). These video walls modules have as a main features:

- Higher transparency.
- Very good light transmission.
- Lightweight.
- Simple installation.
- Nice appearance.

III. **Transparent LED screens**: they are becoming popular in shopping centers and halls, where their adaptability to different arranges make them fit well in almost every space, especially for glass walls, in which their 70-90% transparency rate allows building of fantastic arrays without obstructing the light transit (See figure 3.10). The main features of these screens are:

- High transparency and light transmission (60% more than a LED display).
- No iron structure needed for installation.
- Modular design and lightweight.
- Individual LEDs are not distinguishable from 5 meters.
- Nice appearance, objects seem to be in the air.

IV. **Flexible LED curtains**: is a recent modality, commercialized since 2016, it is used for decorative purposes in external wall of buildings (shopping centers, stadiums, stores). Their appearance looks appealing both in day and night time (See figure 3.11). Their main features are:

- Lightweight structure.
- They can be rolled to match the shape of the building.
- High transparency rate.
- The color of led and pixel pitch can be customized.

Figure 3.9: LED Curtains.

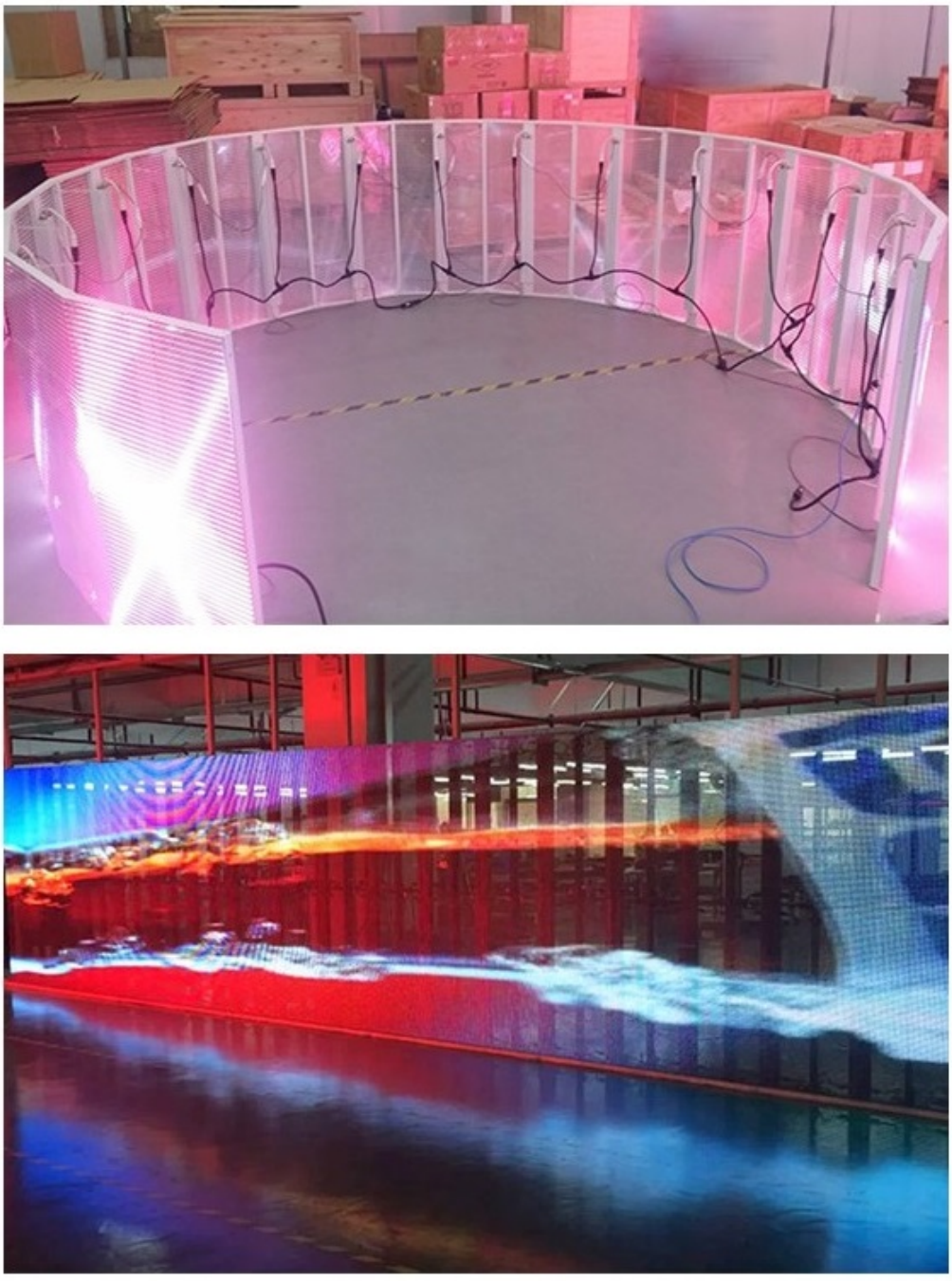

Figure 3.10: Transparent LED Screens.

Figure 3.11: Flexible Led Curtains.

V. **Floor led panels**: are mainly used for staging projects, bar, parties. Allow people to walk, explore or dance on a space the with led screens on the floor thanks to their high resistance design. See figure 3.12.

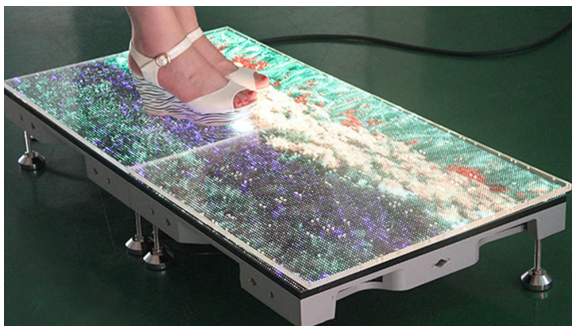

Figure 3.12: Floor led panels.

3.2.4 Microtiles

The company Christie offers the option of building displays in almost any size and configuration by using small display blocks called *MicroTiles*[16]. These devices are based on DLP technology and are offer image high quality in different indoor spaces as well as ambient light environments.

MicroTiles are applicable in a wide range of situations including architectural projects, street advertising, command and control of video walls, and production of events. In addition to it, according to the site of the manufacturer, MicroTiles technology offers bright images and a wide palette of colors when compared to LED panels and plasma displays. See figure 3.13.[17]

Figure 3.13: Microtiles.

[16] More information on: https://www.christiedigital.com/emea/business/products/microtiles

[17] Source:http://www.sixteen-nine.net/2013/05/28/projects-giant-microtiles-wall-launches-kazakh-ra bolashak1/

Chapter 4

Experience design

4.1 General description of the system

4.1.1 Introduction

The main idea for the designing stage would consist on thinking how to create handy and simple scenarios for a customizable IoT platform that would be used for delivering multimedia contents and information to users who participate of technical and professional meetings or even recreational events.

Based on the nature of the conference and the specificities of the attendance background, it would be possible to invite a number of them to participate of specific dynamics, in which interactive/customizable devices and software applications would allow them to explore different aspects of the augmentation of the shared space of a conference, based on the principles described by Leite (2010) *(Traceability, Emotion and Common Knowledge)* and finally use these means for positively influencing the quality of the experience of the participants.

4.1.2 User experience design facts

According to Rowland (2015) is not possible to design significant and valuable experiences for products or services if users don't want to use them or understand how to do it as first step. For this reason, it is crucial to describe briefly some facts that are associated to the desired UX design:

What does the system do?

The system offers information and multimedia contents to users through a diversity of elements that are part of the physical and the on-line space of a determined event. Thus, persons and devices are itinerant recipients and generators of diverse kinds of data that give a dynamic and adaptive character to the system, creating an augmented space that is constantly being fed and can offer amusement, information, logistical or professional networking services.

The scenario described above enables shareholders (users and organization) to improve their experiences in several aspects, some of them are:

1. To know where and when are things occurring during the activity.
2. To meet those persons that have common interests and exchange information.
3. To participate of decisions and leaving feedback about activities.
4. To make a recording of important events and information accessed.
5. To solve common problems through collaboration.
6. To have fun and improve feelings of confidence.

How does the system work?

In very general terms, the system would work based on two main operation blocks which are interrelated:

1. *Multimedia platform:* This is achieved by distributing multimedia contents (video, photos, sounds, text) through different physical channels (displays, projectors, speakers, smartphones, microcomputers, etc) that would be assisted by a IoT platform that connects devices.
2. *IoT platform:* It refers to those elements for connection and communication between devices (routers, beacons, badges, etc) that are distributed through the system and work with interactive I/O devices (keyboard, touch-panels, cameras, microphones, sensors, etc) to allow users to make decisions and adapt tools to their needs during the activities.

How can it be used?

The IoT system's fronts of initial action would be distributed through different *touchpoints*, these constitute the places of access to the overall dynamic for different types of users, they need to be designed for being accessible and functional for every person, regardless the knowledge and level of engagement that the user already has. The main *touchpoints* for any user are:

1. *The user claims of the interactive badge:* Once the user enters to the physical area where the physical experience takes place, it's expected to receive a participant's kit in which is included the device that is going to allow him to interact with the system.
2. *The user installs a proprietary app:* The user can in a previous moment or during the activity time, install a smartphone application related to the proposed dynamic. After informing the user about the permissions that are required to access data and functionalities in the device, they could start to use functionalities of the device like BLE/NFC triggers.

3. *The user reaches an installation on the venue:* This is the case in which the user gets access to a physical touch point located in the space of the event, having the opportunity to use interfaces for interacting with physical objects and start a narrative in the system.

According to Ma (2011), there are three main elements that articulate the communication process of an IoT system, these are: *Objects, Persons and Information*. Since in this work the analysis and design are based on the influence of this communication act in the *Augmented Space* described by Manovich (2006), this element is included as a participant of the dynamic, this is explained as follows:

4.2 Articulation of the system

4.2.1 Space: Fixed parts and physical environment

Designing the space that hosts persons, objects and information is perhaps one of the most important aspects in the creation of an IoT system that manages multimedia information and contents. Based on the theoretical discussion showed on section 2.1, design of services encompasses different disciplines, depending on the complexity of the project and the objectives of it. In a system involving distribution of functionalities in different physical and virtual *touchpoints* it is important to design of the different types of communication between the system and users, signposting and logistics adjusted to the space and the group of participants are all elements to add to the classic UI and UX approach that is required for technological projects that include standalone interactive devices around a physical space.

For the specific case of the system discussed here, the main focus should be to create a distributed platform that receives and sends information based on the necessities of the different stakeholders, including their opinions to favor co-creation and adaptability of the space that not only will receive the real-world interactions but also those that come from the on-line digital world. A summary about some of the main premises about the space is the following:

- Reachability and widely available access to the experience that make things easy and present in the space.
- An overall feel of cohesiveness and general sense that creates security and predictability.
- The necessary stimuli and feedback for establishing curiosity and eagerness in the stakeholders.
- On-line and off-line functionalities that guarantee a stability of the service.
- Correct signalization and education for helping the users make their own decisions without miss out the steps of the ideal costumer journey.

4.2.2 Things: physical and virtual objects as means for participation

The main vehicles for participation in the system; they are those devices and gadgets that allow the users to interact with other users and the space around; these can be carried by the user or be fixed, which make them parts of augmented environment as emitters and/or receivers of information that is created and transmitted either by voluntary or involuntary actions of the users. Thus, the main premises about connected objects for adding value in an IoT experience as the one discussed should be:

- The devices must be ready to use or must easily configurable.
- High quality UI and interactivity design (when applicable).
- Configuration options and co-creation must be adjusted to the background and interests of the attendees.
- In the case of wearables and itinerant things, lightweight and portability must be guaranteed.
- Devices must offer online and offline functionalities for users.
- Appealing appearance and adaptability to the environmental conditions (light, outdoors, physical demanding conditions, etc)

Additionally, it's also relevant to classify and explain some details about the main objects required for an implementation, these are divided in two main categories:

- **Fixed things:** Refers to those devices that are placed in predetermined locations (this include physical or virtual touchpoints), being referential part of the system, they help create channels for communication with (and between) persons as well as linking to other connected objects. Some of these kinds of elements are: visualization devices (projectors, LED displays), fixed beacons, smart-enable multimedia devices (amazon echo, Chromecast audio), touch-enabled devices (panels and tablets), installations based on sensors and computer vision, registration points, etc.
- **Itinerant things:** These are the kind of objects that are associated to specific users or movable devices, they are constantly moving around the space leaving traces of activities and collecting data, they are vehicles to communicate not only with the system but also with other itinerant devices. Some of their main features are: exchange data (networking, communication, enjoyment), to leave traces about activity (emotional maps, statistics of performance, artistic representations), express opinions (polls, feedback), collaborate in diverse kind of activities (professional or recreational dynamics) and recording of situations around the event (save technical details, take pictures and videos, etc).

  Some ideas about itinerant things are discussed as possible applicable solutions below:

Interactive badges: An interactive badge (IB) is a portable device (or set of devices) that is intended to be the key that allow users to access contents, experiences and even knowledge in a specific environment. IBs are a good vehicle to profit functionalities associated to IoT technology synergistically with the methods described by Leite (2010) (See 2.1.3).

There are different kinds of devices and technologies that are potentially employable as IBs, perhaps their applicability depends on the context and needs of the event in which are going to be used, all of them must try to accomplish the premises established for the design premises discussed above.

Beacons based on mobile apps:

In terms of leverage of the possibilities of devices like smartphones and tablets for beacon-activated services; the specific requirements of a project are determined by the spatial scale, frequency, quantity and type of the data that is needed to transmit and register. For example, it's not the same to track movements of users around the area of building with several floors and make it in real time than tracking them around a big park or a city, as well as, receiving data from users only when they decide to refresh their position. Thus, objectives associated the kind of events discussed in this section are achievable through development and use of some specific communication features as: Bluetooth (BLE), WiFi, NFC. More detailed design hints and additional ideas can be found in the discussion about official apps.

4.2.3 Information: communication and data types

The exchange of information during the experience intends to reach different levels of exchange that are not just limited to delivering back-end data for registering specific events and statistics, or appealing hypertext and multimedia contents among devices; it would also be expected to achieve improvements in communication at real-world level by proposing different types of interaction and feedbacks that improve efficiency at personal connections (networking, co-creation of ideas) and the feeling of enjoyment and involvement in the event. Thus, this goal is closely related to the analysis and stimulation of the emotional aspects of the dynamic (mainly through playfulness and empathy) but also by boosting the attainment of common knowledge and the need for collaboration , which serves as a vehicle of integrating individuals with common interests and needs.

Types of information to share, process and store:

- *Multimedia contents:* Generated by users and generated by the organization.
- *Technical Information:* Files, documents, abstracts, extended abstracts.
- *Personal details:* Associated to the badges, electronic business card, skills, cv, games, things generated by the user.
- *Feedback and opinions:* Based on badges/beacons, buttons, etc. They can express opinions (like or dislike), voting in polls, ranking options, etc.
- *Statistics:* register of users' activity in different informational contexts (including the ones mentioned before), keeping it anonymous, it can serve as a report for the users about their individual paths and saved information (cloud or physical storage) and generate emotional or activity maps.

4.2.4 Personas

Description of some representative user profiles are introduced with the aim of making a brief illustration of the diversity of users that could potentially reach an IoT integrated system in the shared spaces of a conference, as much as for describing the different services that these environments can provide to them individually, according to dynamic and specificities of the hosting context.[1]

As discussed by Rowland (2015), distributed IoT services must be considered as a whole experience spread at different touchpoints. Thus, the profiles introduced bellow are going to be useful to describe later some user stories that include interactions in different components of the system, and that are made from different starting situations and points:

1. **User 1.** ***(Foreigner attendee)*** **:** User 1 (22) is a male student, attends to the event from abroad and he is strongly involved in projects related to the subjects of the meeting. He loves technology, is very curious and *up-to-date* in everything regarding to new gadgets, music, video games and social networks. He has not claimed an interactive badge but has already installed the app of the event in his smartphone.

2. **User 2.** ***(Guru speaker)*****:** User 2 (37) is a female researcher, due to her different occupations in research and assessment of new businesses, she will have a short and intense passage for the event to participate of diverse conferences, group discussions and networking sessions. Given that she is becoming very well known in the sector, she has a lot of connections

[1] "Personas provide a powerful tool for communicating about different types of users and their needs, then deciding which users are the most important to target in the design of form and behavior".(Cooper et al., 2007)

and people interested in spending time with her; for that reason, she has the necessity of organizing her formal and informal activities. Perhaps knowing how to deal with some technological gadgets, User 2 is not particularly prone to use devices that imply complex configuration, she received an interactive badge and installed the official app in her smartphone already.

3. **User 3.** ***(Casual user)*:** User3 (45) is a male officer who works for the venue's services, he is not related to the conference directly, nor particularly familiarized to the subjects of the event but has some interest about technologies and always is dipping his nose in the installations that are brought to the different events, he is very active in social networks and has read a little bit about multimedia services that work with IoT in sites like Amazon. He doesn't have badge nor app because is not registered to the event.

4. **User 4.** ***(Organizer)*:** User 4 (40) is a female professor, she is president of a renowned professional association and volunteers for activities that help integration between professional colleagues, entrepreneurs and students during the event; she is part of the committee that organizes the conference, also has already obtained a badge and installed the app in his smartphone. Additionally, User 4 needs to see more information than the average user, since she wants to track activities and performance of the attendance for reviewing purposes or even for adjustments whilst the event goes on.

4.3 Components of the system

Given that in the past section were described the elements that participate and articulate the interaction and communication act, it is now possible to describe which products could be created in order to build an integrated platform that encompasses all the elements that participate and offers quality services:

4.3.1 Interactive IoT agenda

Introduction

The existence of resources that enhance physical spaces to provide up-to-date information about events taking place at locations where groups gather for enjoyment, professional or academic reasons is a matter that is already broadly applied by organizers and also accepted by users. In fact, it could be said that nowadays offering digitally-enhanced information with details about schedules and social programs is almost mandatory in any space, and is done basically through two main type of channels: a) physical displays placed at the spaces of the convention center, b) information loud on web or mobile applications, this last category to be carried and operated by the users in their portable devices. See case studies in 2.3.

Given this context, the design of an interactive agenda that includes some level of innovation and experimentation in the realm of IoT technology constitutes a big motivation and a major challenge, not only because the existing solutions have been used successfully by users before, but also because adding elements to the experience should guarantee access to new visual and informational elements without implying complicated UX for the users, this it would fit also to the goal of creating an adaptable spatial context, that doesn't require browsing in personal devices that pull out attention from the physical surroundings or incite them to use complicated and poorly responsive installations.

Application areas

Perhaps the first application area for this product would be associated to the space of professional and academical meetings; some other promising scenarios can be considered. Thus, the IoT Agenda, could not just be a movable solution but also be a fixed part of a space frequently used for events from different kind of potential users.

An IoT Agenda can be useful for spaces in which there are offered diversity of activities with parallel timelines and in different spaces, as might be the case of spaces of recreational and cultural interest (thematic parks, festivals, fairs) as well as in university campuses, museums, etc.

Product strategy

For drafting the design of an agenda like the one described above, the strategy considered as the most proper option was to design it as an "upgrade" on the existent solutions, that is to say: try to reimagine some of the aspects of devices for delivering information that are already known by users in this context.

The concept would be to create an interactive agenda that be different scenarios depending on the number, profiles and capabilities of the users that are close to the installation. Depending on the nature of the event and the specific design, the display could show different kinds of information about the general schedules, suggestions, tips about the city, sponsors, etc. Thus, the main functionality to explore for this agenda is an IoT service based on a beacons placed near to a device/installation in specific places of the venue; the proximity of an identified badge or device, would help to filter the information that someone will receive according to her/his profile in the system (area of specialization, available time, friends, mandatory activities, acquired products, etc) which is associated to the correspondent Bluetooth-connected device.

Thus, for the design of the solution it is important to remark some basic principles:

- **User Friendliness:** It should be easily understood by users, which helps creating feelings of security and involvement.
- **Adaptability:** It should be adapted to the necessities of different kinds of users or groups of users (which have different profiles, access and interests).
- **Different methods of access:** Combination in-place physical information delivery to real-time updates being sent to mobile devices or interactive badges.
- **Omnipresence and coherency:** It is related to achieving some sensation of presence and organization around the physical space, but also automation and ubiquity around that help the user without resulting invasive.

In terms of the creation of value as described by Sakamoto et al. (2012); during the experience, the features of the system will benefit users according to the following principles:

1. **Empathy:** The invitation of the system when recognizes the user (and personalizes contents) through the beacon implies a way of creating empathy and security in the user.
2. **Persuasion:** The feedback and information obtained by the user lead them to keep using the system and to be interested in the experience and the event.
3. **Information:** The information is the main focus in this part of the system, helping the users to go around places and improving their experiences.

User stories

User 1: Landing on the event [2]

As a foreigner attendee to the conference, User 1 wants to reach the reception counter of the conference to claim the kit assigned to his category. He reaches the interactive agenda located at one of the main entrances of the event.

1. User 1 has turned on the Bluetooth of his smartphone and when reaches the screen that displays the agenda contents from the whole program are filtered according his interests; a part of the menu offers the option of navigating without using the filter associated to the beacon.

2. User 1 needs to see the map of the event, and taps over the map of the icon, thus, he will be able to go to the information counter easily.

3. User 1 gets to the information counter of the event to claim his kit.

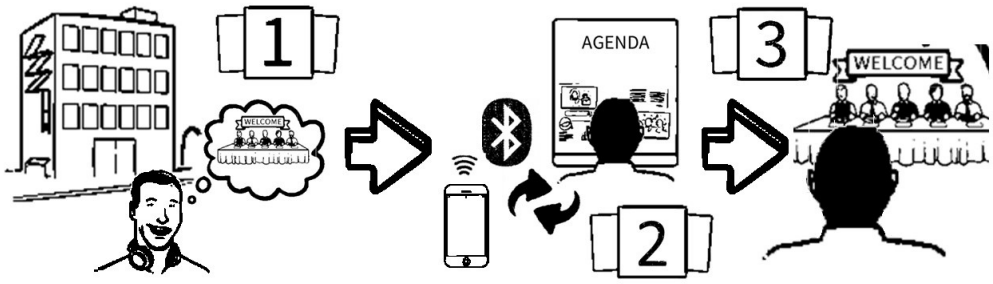

Figure 4.1: User Story: Landing on the event.

[2] Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

User 2: A rushed day [3]

As part of her duties as a reputed speaker in the conference, User 2 had a long session of questions with people who attended to her talk. She will use the version of the event's interactive agenda included in the official app installed her smartphone.

1. Now User 2 needs to get brief and clear information about how to get quickly from the room of her talk to another interesting session in some point of the venue.

2. User 2 has the app on her smartphone, thus, the screen displays the agenda contents; she taps on the button of the menu that shows: 1) the name of the talk she wants to attend, 2) the remaining time for the beginning of the session and 3) the map of how to get to the room are shown in the screen; she can also tap a button turn-on a reminder and guidance map to the place in the app installed in her smartphone.

3. User 2 Arrives to the auditorium of the session on time.

Figure 4.2: User Story: A rushed day.

[3] Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

4.3.2 Social media visualizer

Introduction

The visualization of social media activity is another common resource that is already being used for improving the engagement and monitoring of the activities around group events.[4] It helps displaying reactions, messages and multimedia contents that are generated by the organizers or the participants of the event, and encourages participants for creating a record of the space and dynamics that take place during the event.

Application domain

The domain in which the social media visualizer finds plausible applications is very diverse and it's already widely known; there are several kinds of events that deploy visual solutions for showing the social network and media activities associated to a proposed dynamic (official hashtags, viral challenges, etc.); since the most basic implementations of social media visualizer are indeed based on the idea of updating data and information from devices connected to the Internet (mostly by wireless and remotely), the application of an IoT approach to the idea would contemplate interacting with the virtual environment of social networks by pre-established channels associated to physical controls or objects (which wouldn't be connected otherwise); that would allow users to create innovative ways of sharing emotions and recordings of moments in a friendly and non-invasive way; exploring through these mechanisms new hypothesis for interaction with people that is interested on what happens in the *augmented space* (Manovich, 2006) of the event by sending/receiving information from other geographical places.

Product strategy

An adequate strategy for creating a social media visualizer system that makes sense in the environment of a conference requires some basic elements to consider; thus, the first step is to make an analysis about the different options that are available from commercial providers of software for this purpose (see footnote below), studying its applicability according to the nature and scope of the project and the pros and cons of its technical implementation for the event.

The second step is to analyze the multimedia infrastructure that is needed to use this software for the targeted situation, this is, type and specifications of the screens, speakers, interaction methods (touchscreens, beacons), etc. In fact, this analysis is closely related to the contents that are desired to be shown and the nature of the information to be displayed. Thus, the broad diversity of contents, social media platforms and messages that is possible to show through this means require a strategical design in order to achieve success in different categories (timing organization, overall

[4] Some examples about social media visualizers: https://socialwall.me/en/; http://www.livewall.co/

coherence of messages, and visual appearance) when these tools are being used.

Another matter of analysis is related to possibility of this visualizer to be effectively involved in the IoT dynamic that is proposed for the overall experience, in other words, achieving a way of linking it to a general system that simplifies or automatizes some steps for users, or even promotes the participation of the them on the experience through friendly and playful suggestions. This is better exemplified in 4.3.3.

User stories

User 4: Capturing moments [5]

1. User 4 is capturing some unforgettable moments around the event and posting them to the social media channels of the event.

2. As User 4 is very popular among people from attendance and keeps uploading posts with her smartphone with the aim of helping others to get information about the activities and be engaged to the overall dynamic.

3. When these contents are shown in the social media visualizer (that is placed at the free coffee points and at the entrance of the venue) people is invited to participate uploading their contents by using their mobile devices or the one-touch social buttons (see more details in 4.3.3) distributed around the space.

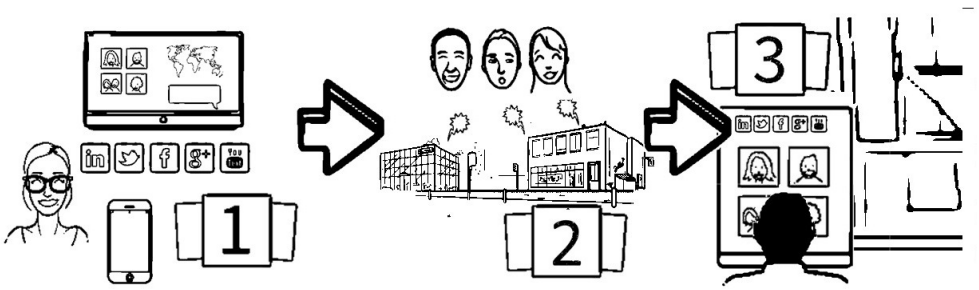

Figure 4.3: User Story: Capturing moments.

[5] Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

User3: The curious user[6]

User3 is not involved directly in the event as a participant, but despite of this, the system offers options for interaction; he wants to see his pictures displayed on the social media visualizer and uploads a picture with the official hashtag in his Instagram app. Thus, he not just gets some intangible value for the interactions that are accessible for his level of participation but also helps to spread information about the event.

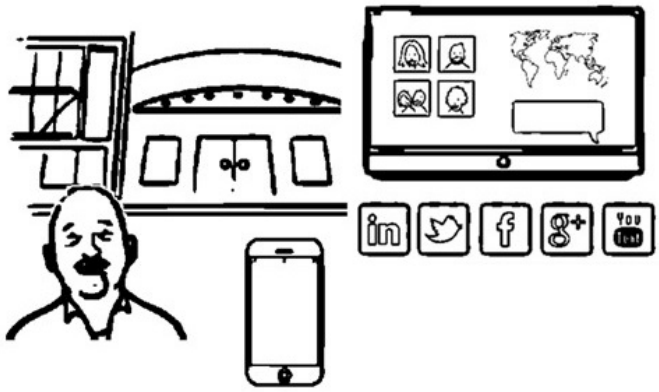

Figure 4.4: User Story: The curious user.

4.3.3 Interactive badges system

Introduction

Since the system that is being proposed has several components that are interconnected and interdependent upon each other, it is necessary to include a discussion about how would be conceived the core of the design; which is based on the idea of using beacons and badges for offering diverse services to itinerant devices that are linked to the integrated to the IoT system; this is a feature that was partially introduced in the subsection above (particularly for mobile phones). Nevertheless, the overall experience design intends to explore the use of alternative elements (things) that don't imply excessive complexity in configuration and usability, and that enhance the collective experience and quality of information for the attendees of events and public spaces.

Product strategy

The main proposed idea would be to use a device (or a set of devices) that could be offered in the format of a compact and portable tool, which besides being an add value as part of the welcome kit that is delivered to participants, would also come to work as a potential tool of interconnectivity for the users; depending on their needs, levels of participation on the event, available technological environment and scope of the project. In it also crucial to stick to the idea that perhaps these

[6]Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

options could be individual coexisting products, their roles should be complementary as they are part of an integrated and distributed platform of services.

Once the context described above is depicted, the first task to do would be to define which devices would be convenient for the project, considering variables like: 1) in which types of tasks each one is more suitable, 2) how each of them adjust better to the background of the attendees and what's the real value they offer to their expectations. This must be defined according to the general goals of the UX design and bounded by the pros and cons of each option.

Adapting the principles discussed by Sakamoto et al., mentioned in 2.1.4, creation of value for users of the interactive badges could be summarized as follows:

1. **Empathy:** The use of the interactive badge offers a friendly environment that invites to have fun while doing some other activities and creates a personalized feeling of the experience.
2. **Information:** The interaction through the badge implies the opportunity of exchanging information with other users, but also learning how to work with the device and the system for the participants.
3. **Ideology:** The user can change his/her perception and knowledge about social dynamics on events, use of technology and specific subjects of interest for the long term by profiting the access to more information.

The use of an interactive badges system in the project can lead to different applications and dynamics, some of them will be proposed above:

1. The devices can be used to be paired with others around the event, allowing different kinds of interactions between holders (exchange of information, proposing themes for discussion, have fun through games, send and receive suggestions, etc.)
2. The devices can be paired with some others located in fixed places of the space, that allow them to obtain information, leave feedback about their experiences and collect details about something interesting that was found.
3. Allow customized and programmed for the users, allowing them to propose new rules for interaction, improve the experience and create their own stories around the event.

User stories

User 4: Connecting with colleagues

User4 is enthusiastic about the conference program in both technical and social levels. Thus, during the breaks and social events she is encouraging people to integrate and socialize using their badges as a booster of the social dynamic. Some examples are listed below:

- *Games and social interaction:* [7] During the social breaks, User4 will volunteer to educate her colleagues assisting to the event on how to create ephemeral and alternating mini-groups of participants by the use of some of the communication features of their badges (like Bluetooth or radiofrequency). The main aim is to achieve a more fluid exchange of information about different topics related to the conference and that they can get to know each other's in the process. Additionally, they will be encouraged to participate for some material and non-material rewards that will be offered when they participate of these dynamics. See the games section in the appendix A for a more detailed description of different ideas that can be purposed as part of these type of experience.

  1. User 4 reach an installation of the event in which is being displayed a game connected to a beacon that is able to send invitations and create mini-groups of selected users, according to their details filled in the system. Thus, she and the other participant are invited by system to have quick match of the accelerometer ping-pong game.
  2. They have a quick and funny match that is displayed in the space for the rest of the attendance.
  3. After the match, the users exchange their contact details that are loaded in the interactive badges.

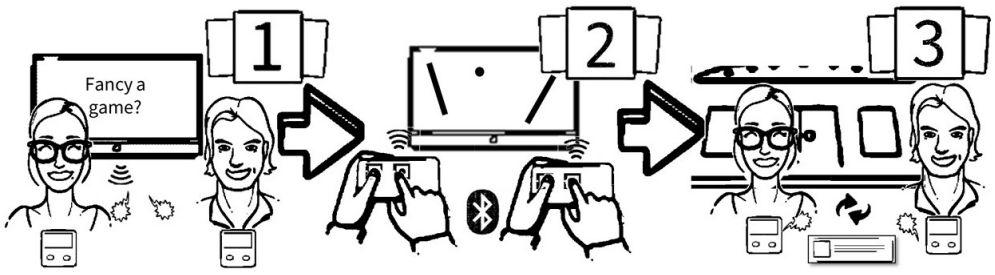

Figure 4.5: User Story: Games and interaction.

[7] Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

- *Social media things at one touch:*[8]

    1. In the noon of the second day, an alert in the badge User4 carries on, reminds that she is in the same area with two her two colleagues from her institute which are carrying similar devices and registered details in the system.

    2. Their badges suggest a group photo that can be taken and uploaded into the official Twitter account of the event by just pressing a physical button that is part of the space, the predefined format includes the official hashtag of the conference and accounts of the participants that filled the required details in the system previously.

    3. The resulting photo is shown in the social media visualizer installations around the space. See A.2 for further description of this feature of the system.

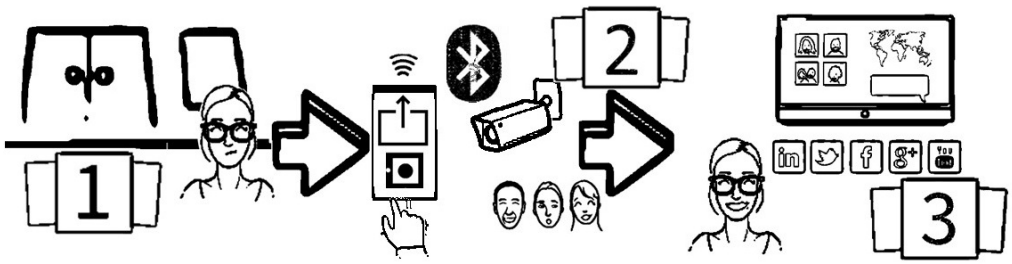

Figure 4.6: User Story: Social media things at one touch.

[8] Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

- *Leaving a feedback:* [9] By the use of the interactive badge, User4 is enabled to leave spatial/temporal traces of her opinions about different experiences that are found around the space (talks, interactive installations, technology demos, services, etc).

  1. A beacon located at the referred location in the event, detects the presence of the user (by its badge) and sends an invitation to give a positive or negative feedback.

  2. User4 can push the button right for positive feedback (happy face), left for a negative one (sad face).

  3. Real-time statistics about the overall advance of different events and reactions from people about them are displayed around the spaces of the venue and in the official app.

     See A.2 for further description about the feature of the system used in this user story.

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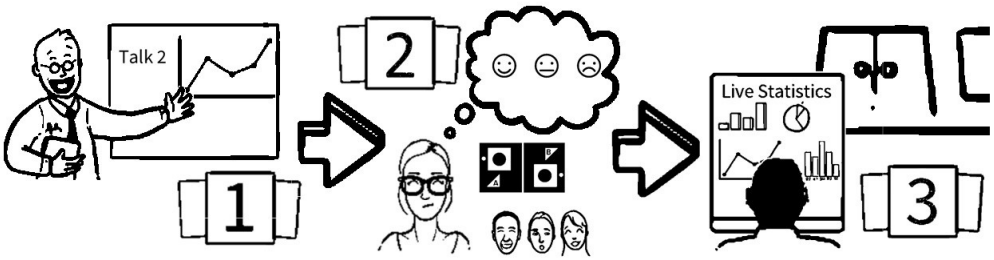

Figure 4.7: User Story: Leaving a Feedback.

[9] Illustrations from Julian Burford: https://dribbble.com/shots/1083617-430-FREE-storyboard-illustrations

Chapter 5

Analysis and discussion

The analysis of the IOT distributed system (and its individual components) that has been described in the previous chapter is going to be divided into two main blocks: the first one is related with the *technological discussion* and the second block is related to the *usability discussion*.

It is important to emphasize that the main sources from which the insights to the discussion have been obtained are:

1. Literature review.
2. Informal technical feedback obtained from specialists in the involved areas.
3. Analysis and comparison with documented case study examples.

5.1 Interactive IoT agenda

The analysis of the IoT Agenda was based on comparison to existing examples, analysis of the technological issues involved in a potential implementation scenario and analysis of its applicability and functionality as part of the social dynamic of the event.

Technological discussion

Multimedia Equipment

1. **LED panels:** As discussed in the technological review; some of the LED panels available in the market allow to show the contents in indoor and outdoor conditions, they are ideal for scenarios in which several installations, around different spaces are needed, they can be adapted to different scales and diverse light conditions. One of the setbacks could be space and additional requirements that some of them could need if the room is small or doesn't allow the intervention for installing additional elements for placement.

   Depending on the technology of the LED panel, there are some equipment that offer the touchscreen capability as a very effective input/output method that allows interaction and

doesn't require additional configuration. This kind of display could be used as a complement of a main visualization method as might be a projection or a bigger LED panel.

2. **Projectors:** As for projectors is concerned, many of the options discussed before are applicable to the idea of the IoT agenda since the basic requirements of high resolution, bright image and vivid colors is achievable with several kinds of projectors, in this specific scenario, dependence on an additional device for interaction and Internet connection could be a limitation to be assumed. The next item discusses the applicable interaction methods that can be used in combination with the projectors.

Methods for interaction

As the solution would be based in a cost-effective and easily-to-implement IoT system, different interaction methods are covered, they can coexist or be individual solutions depending on the scenario; thus, they can be adapted to different kinds of users and places around the space:

1. **Beacon-activated trigger:** this modality can be applied associated to the user's smartphone or to an interactive badge based on programmable boards, which can be recognized by the fixed device that is close to the visualizer of the agenda. Given this specific case, BLE-based beacons are reliable devices for notifying users about the availability of the service from a longer distance (20mts max); on the other hand, the use of NFC tags (based on RFID technology) work at short distances, which is ideal for guaranteeing that the contents required for the visualization device are adapted to a single interactive badge or smartphone in a specific moment.

2. **Touch-screen enabled devices:** As anticipated in the section of LED panels, touch-screens enabled devices can operate as controls for the agenda if they are programmed to offer an interface that allows to control what is shown in the main display of the agenda, or even controlling it as a main display device. Additionally, devices like tablets can be suitable for these purposes, they besides having powerful screens have very good processing capabilities, storage, 3-pin jack port for sound, HDMI connection, etc. These technologies give place to scenarios in which the required software can be directly installed on the device, for easier and simpler implementations.

3. **Proximity sensors:** A diverse kind of sensing technologies can be applied to detect users as alternative methods; the most common alternatives would be to use an infrared-based sensors or computer-vision software packages that allow webcams to detect the presence of users that not necessarily have an application installed on their mobile devices or an interactive badge with them.

Usability Discussion

Some interesting challenges emerge to consideration when analyzing diverse of user experiences for the IoT agenda:

1. **Service for more than one users:** It is necessary to consider the situation in which several users are near one installation that has one or several operation methods; in this case, one of the best options would be to have a big-scale projection or screen that could adapt or divide for offering personalized contents for each one and yet have a congruent service in the overall interface offered by the device.

2. **Priority among interaction methods:** for the case of an installation that can be controlled by two alternative methods; the system should block the option that is not being used at the moment for avoiding contradictory commands and poor usability.

3. **Personalized contents:** The display (or section of the display) that is being used by the user needs to be adapted to the category and personal interest of the user that is in using the device. In other words, one user that doesn't have an identifier (because it's not already registered or has not claimed or installed any kind of mean of interaction) should still receive general information as base case of the system. On the other hand, once the user has some mean for interaction and has completed a profile, adjusted information can be displayed when the correspondent ID is recognized.

4. **Location-adapted information:** For the case of several installations with the agendas, located in several places, the information could be adapted according to the actual location where the user reaches the physical touchpoint. Meaning, that indoor navigation information in the space of the event could be adapted to the specific location of the display (map, route to the desired place, estimated walking time, etc)

5. **Notifications and updates:** Once that a user installs an app, or carries a badge with the required software built-in, a service that could be associated to the agenda is receiving notifications about the events that are already added to schedule, this service could also let know the user about special events (give-away products, shows, special offers, talks, meals)

6. **Beacons for agenda update:** A billboard or poster announcing an event, with a beacon or QR code could be a way of updating an user's individual program; this is to say, an event can be add to the personal schedule associated to the carry-on device (which its individual identifier) and then this information can be checked at the physical places of the IoT agenda or in a personal device (depending on the available options).

5.2 Social media visualizer

In the social media visualizer, many of the technological and usability variables are similar to those discussed in the item above for the IoT agenda, given that they're similar solutions in term of implementation, in some cases could share equipment, if an adequate timing is coordinated according to the premises of the UX design. Thus, as introduced in the design section, the general implementation would require also some basic multimedia infrastructure for displaying of audio-visual contents in conjunction with Internet communication platform (mainly for social networks) and an additional IoT component for creating new innovative channels for the activation of events and displaying of activity.

Most of the technological facts related to visualization equipment and IoT technology that would be applicable in potential implementations scenarios has been discussed as part of the discussion of the IoT Agenda in 5.1; for that reason, in the following items are going to be discussed some other topics that are related to alternative scenarios for social media visualization:

1. **Alternative physical display methods:** Beyond traditional display systems that could be applied in social media visualization tools (led panels, projections); some alternative methods for displaying social media activity (mainly in the form of multimedia and microblogging contents) can be applied as complementary and innovative elements for the social media display system. This would not only would result in eye-catching solutions for engaging user, but also in interesting applications that are related to the thematic of an IoT environment, in which objects that are not commonly connected to the conversation can help create possibilities for the interaction and multimedia realms:

    - *Thermal printers:* This kind of printers represent a very compact and affordable option for printing a variety of data; social media textual activity and pictures are printable in a fast way, also could include personalized content from a local database.[1]
    - *Pen plotters:* These devices can offer an alternative for printing pictures, text and more complex data as might be statistics, a physical map with places where determined activities occur.[2]
    - *Nipkow disc text visualizer:* Based on a mechanical-rotating disc with holes that create light patterns when interfere with a LED source; it would require basic circuitry, a small engine and a microcomputer (as might be the case of a Raspberry Pi). The disc can be programmed to show text and small patterns in the form of moving strip.[3]

    As mentioned in past sections, one of the main idealizations about IoT is the idea of connecting all kind of devices to the Internet, not just because its technically possible or because

[1] Inspiration source:https://youtu.be/PWym4M7Dv7I
[2] Inspiration source:https://youtu.be/WRY-yuHExqo
[3] Inspiration source: https://youtu.be/gTvPC_hkeGs

ideas connected to the realm of industrial control, but as participants of the communication act. Thus, the principal limitation of some of these methods is that the visualization method requires attention in the correct timing from the user, but they could still be good options if applied as a dynamic machinery and non-stop displayer of activity, and if they have back-up cases for disconnection from the Internet or low social activity.

2. **Social dash buttons:** The implementation would be based on physical buttons (switchers or pressure sensors) linked to a microcomputer and image-capturing device (camera module for raspberry pi or a Bluetooth device activated from the distance), allowing users to post individual or collective pictures; with pre-established text for making the social post in one single action and without requiring many. These devices can be easily understood by the user if they are escort by a correct signalization, and the adequate placing in the space, where they could be not only reachable but also uncompromisingly used by the user, with confidence and joy (as in the user story in 4.3.3)

5.3 Interactive badges

Technological discussion

The main technological discussion around interactive badges lies on the analysis of the kind of equipment available and how to implement it in a system of badges and beacons as the one described in the chapter 4. However, regardless the specific technical details that this could imply, it is important to discuss some general facts about the considered scenarios, in order to choose among those which are easily implementable and leave open possibilities to imagine diverse functionalities and services that are not established in the first approach (since the tools are better known after working on them); thus, the kind of device selected could result on variations among different kinds and levels of interactivity and offer completely different user experiences; discussion about scenarios for each type of technology are summarized below:

1. **Based on programmable boards:** There are many options already available in the field of programmable microcomputers, since they allow to develop a big variety of projects related to fields like education, robotics, and digital media; they seem to be a good choice to achieve interesting results, with possibility of reconfiguring the devices according to the requirements of diverse environments, testing of new ideas adding of improvements because of their easy customization and cheap price.

   Additionally, in the case of carefully experience design, an attendance which had some knowledge or interest about this kind of devices could find an open door to scenarios of co-creation and innovative ways of participation by programming certain scenarios; thus, they would create their own experiences and alternatives paths, always based on a basic dynamic initially proposed.

In this scenario, there are two products that could be applied for different kind of implementations:

- *BBC micro:bit:* is the option that is first considered for interactive badges due to its appealing and simple display panel, user friendly programming interface, multiple communication options, portability and compact presentation; making the badge as a shortcut or alternative channel to interact with other users as much as with the augmented environment around them.

  The BBC micro:bit allows communication with other similar devices via radio frequency or vi Bluetooth; it is not possible to activate the two modes of communication at the same time, which can limit the kind of interaction and user experience.

- *Raspberry Pi 3:* This is a more advanced and powerful microcomputer, that besides being portable and compact, would be more adequate for fixed uses as for sending BLE messages to other itinerant devices. Additionally, as discussed in the technological review, it's possible to connect the raspberry pi to different kind of peripheral devices and to the Internet (Wifi or Ethernet), which implies several possibilities for communication, ease in the installation of software, etc. Thus, a series of Raspberry Pi 3 can be used as radiators of information around the space, working with different modes and specific environments, without being noticed by the users.

  The possibility of using additional adds-on to connect different kind of sensors, displays, projectors and mechanical parts gives place to many kind of applications beyond communication and beaconing; the raspberry pi 3 can be also a very attractive option for multimedia artistic projects for enjoyment of the attendance, as well as for integrating different elements of the system information system without needing additional and more complex devices (as expected in an advanced computing device).

2. **User's smartphone:** Many of the goals that could defined when thinking about design interactivity and communication for IoT are achievable using devices like smartphones or tables given the power of computing offered by their processors as well as the variety ports and sensors that they include. Through very simple implementation, smartphones can recognize or be recognizable for beacons that are tracking a determined space. On the other hand, the fact of having a fully functional touch-enabled LED panel, integrated sound and camera are advantages to be considered in multimedia projects. Furthermore, they are equipment that almost everyone already has and can give place for more advanced configurations that leverage their capabilities in dedicated applications. Nevertheless, complexity of customization, persuasion and education of users are matters to be considered, since dealing with them in a short period for organization can result inconvenient the project. On the other hand,

the use of smartphones could promote engagement to dynamics that are already attention-consuming from daily life habits and that could result counterproductive for the distribution of high-quality information and engagement.

3. **BLE/NFC badges:** This is an alternative scenario, in which simple devices are tracked and contacted in a mostly unidirectional way; they are partially interactive since they receive information and notifications from beacons that can be based on BLE or NFC technologies, triggering events in some other devices that can have a very wide range of methods for communicating with the user through feedback and persuasive methods which are being used already in several implementations linked mainly to the marketing field (visual, VR/AR, sounds, haptic or even olfactive transductors). Thus, despite being grouped here as a single category; the expected user experience of each of the options differ since variables as the coverage ranges, methods for access and communication processes are different for each one and are possible to associate to a wide range of events.

   The following steps once the kind of devices to be used are defined, are related to code, install and test the software for the devices. Finally, they would be offered to real users for evaluation based on real utilization data.

Usability discussion

In the usability analysis of the interactive badges there are many ideas that were introduced in the technological discussion and that are inexorably linked to user experience design, some of them are summarized here:

1. **One-to-one vs One-to-many service in beacons:** When devices with several connection methods (like smartphones) are used as means of interaction with the fixed elements that are part of the augmented environment, emerges the question about what kind of service is more adequate:

   - *One-to-many messages:(Based on BLE technology)*, this option allow many users to receive the messages emitted by a single beacon and react to its notifications, their positions can be tracked by using several devices in triangulation; as well as the proximity to one of the emitters can be detected if the itinerant device is in the coverage area. This gives place to diversity of services like that don't demand too many actions from the users and that imply that the message could have more than one potential recipient in an estimated area (notifications, payments, statistics).

   - *One-to-one messages:(Based on NFC technology)*, in this kind of experience, the interaction between user and the space is more private; if one user wants to engage to a determined experience, it will be necessary to approach very close to the beacon (around 4 centimeters or less); this generates constraints to the interaction, which can't

be achieved while walking or by several devices at the same time. It is very effective when important transactions need to be made (payments, gate access, event triggers, digital business cards exchange, etc)

2. **Boosted interaction among users:** As introduced in past sections, there are ways of encouraging interactions among users by proposing ways of communication between holders of a determined device; the success and enjoyment in those activities doesn't rely exclusively in quality of the designed products or how innovative they could be as offers. Some of the most important aspects to considered are summarized here:

   - *Effortless knowledge:* Generally, users need to be guided and persuaded to enter into the mood of the proposed experience without compromising time and attention that should be focused to actual tasks that are part of their goals (Rowland, 2015). Thus, organizers need to facilitate the required tools and instructions about how to begin the experience in the most friendly and simple way (Chaturvedi, 2016).

   - *Portable device as mediator:* As discussed before, authors like Sakamoto et al. (2012) think that users need to obtain some added value for using a determined technology as mediator in their relationships with the space and with other persons. This can be critical in professional environments or specific group meetings, where the rules for real-world interactions are previously established from reiterative past experiences; Menezes and Smaniotto (2017) also explain that users tend to privatize their spaces reducing the likelihood of serendipitous encounters but also remarks the importance of the use of ICTs for achieving more people-centred experiences and for breaking barriers in real world interaction, which in the case studied here would translate into benefits for all the stakeholders in a determined event.

     Fortunately, many of the encounters that occur nowadays in the physical space are already mediated by some kind of technological device[4] and connections are associated to knowledge-acquisition opportunities that can result in attractive tangible data as might keeping someone's personal details or initiating a specific task in common.

     Another interesting option for boosting communication through devices is the gamification of certain dynamics, which can result in a nice ice breaker among individuals according to Leite (2010), but this must be administered depending on the context that is proposed for and the type of audience. For example, in professional or academic events would be more suitable to offer a simple (and quick) experience that allows people get to know each other and, shortly afterwards, be able to switch to subjects of common interest, keeping contact details at the end of the contact and details about the interaction. On the other hand, informal environments or specific moments can give place to more elaborated games and dynamics, that can stimulate the creation of

[4] https://thefrailestthing.com/2017/11/18/the-ethics-of-technological-mediation/

confidence and the achievement of more ambitious goals related to the entertainment of users without causing disturbance (see Appendix A).

- *The space as mediator:* The space of the proposed system is the place that hosts the different elements involved in the IoT dynamic, but also is an element that contributes to the organization of activities (since individuals can be invited to create connections and participate of group activities (see Appendix A); this moderation role of the space gives the pace that is required for activities that take place during the event and which has as a main goal to engage the participants to the event's dynamics and create confidence towards the organization and unknown colleagues. Thus, the augmented environment contributes to spread information among users in order to make their own decisions in a more confident way and generates a feeling of appropriation of the space (Sakamoto et al., 2012).

  Nevertheless, according to Menezes and Smaniotto (2017) ICTs should still be viewed as a tool and cannot be thought to replace actual space and its activities. Thus, the use of fixed things that are part of the space can result into mediators between persons, but no more effectively that what one person of the organization can motivate persons to participate of a specific activity (Chaturvedi, 2016). As shown in A.1, games that involve the space and participants can be useful for starting new conversations and creating links between people that not necessarily would be prone to interact in a first moment.

  Finally, Chaturvedi describes the importance of the augmented space as a propagator of knowledge and information as follows:

  > Augmented spaces lead to enhanced learning environment where a room is not just made of static walls and objects are redundant, but, where the walls speak and objects move around to form a narration, helping to distribute knowledge.(Chaturvedi, 2016)

- *Tools vs products:* One of the core discussions around the use of interactive badges is to set the frontier between a product (a ready-to-use device) and a tool (which needs configuration and understanding how to use it). According to according to Rowland (2015), when someone acquires a determined service, wants to invest the minimum effort in configuration and understanding how to use the device. Nevertheless, spaces for participation of users and incorporation of their ideas can be created, mostly in scenarios of co-creation[5] as a vehicle for dynamic improvement of services and for creating experiences that provide ease and knowledge for users. For Chaturvedi (2016), connected devices are supposed to increasingly help us accomplishing time-consuming tasks in the future (because their associated computational power) but remarks that they will require active human participation to be able to understand our requests

[5]More information on: http://www.uxbooth.com/articles/co-creation-designing-with-the-user-for-the-us

anyway, which in many cases require to find the easiest ways for configuration and adaptation to spaces that we habit.

5.4 Overall analysis of the system

As a closure to the discussion, it is important to analyze the main facts related to the overall idea of the IoT multimedia platform as a whole product; establishing a point of view from which is possible to assess the platform of services as integrated as it intends to be; with the benefits and problems that are intrinsic to its hypothetical implementation scenarios. Thus, it is also possible to review variables that were mentioned for the individual components (in the sections above) and relate them to the study of a real scenario for implementation.

5.4.1 Technological discussion

Integration of devices

One of the most important concerns about designing services from IoT systems from a single platform that includes real and virtual objects based on non-compatible software and hardware components is how to achieve an integration of them, reducing the number of complex tasks. Thus, it is important to analyze some existing platforms and how could them be applied in order to contribute to achieve specific goals associated to design of improved user experiences:

- *Android things and Octoblu:* as anticipated in the technological review, these platform could help to achieve the integration diverse kind of physical devices with connecting capabilities, In the case of Android Things, could be specifically useful if there's an android application as mediator for some functions (as might be the case of if there's an official app for the event), many devices beyond wearables or smartphones are linkable to this system (Google Chromecast and Google Home, in the multimedia realm)[6].Thus, despite some of the features that are offered in Android Things are suitable for developers of Android apps for mobiles; its use could also imply an advantage also for people using developing boards, connection-ready devices (specifically in the multimedia area) and interest on creating new services. This is illustrated in the following example extracted from the web Android Things (2018):

  > Making a Toyota car that's able to "talk" to your phone and a service center is hard. Making it talk to everything and doing it efficiently and safely is even harder. Now imagine making a third-party accessory like an alarm system or a remote starter that can talk to your Toyota and your phone and you'll understand why it might not be able to talk to the service center. Android Things can run on the Toyota, the remote starter, the alarm system, your phone and the hardware in the service center.

[6]More information on: https://www.androidcentral.com/how-use-google-home-chromecast

Regarding to Octoblu, this system could offer solutions for triggering of events, connection of different kind of sensors (that could be applied for identifying users, number of attendees in one place, etc.), whose measurements could be communicated through the system for being processed or displayed for users. Visual programming of events by drag-and-drop icons could be useful for designers and non-professional developers.

Multimedia technology

When designing for augmented environments there are a big variety of multimedia equipment for developing infinity ideas; in the technological discussion of the individual components there were mentioned many of them in ideal scenarios of implementation. Nevertheless, many times limitations to the application of determined technologies not necessarily come only from design-related variables or technical decisions. Thus, some other elements need to be incorporated for evaluating the pertinence of certain technologies or not, a process that leads to compare options according to the additional value that they offer in relation to: their price, logistical requirements and environmental adequacy.

In the realm of visualization technologies, selecting among options as the use of video projectors and led displays can be more complex than expected given that they solve different kind of problems and have different constraints. As stated before, LED panels tend to be more adequate when ambient light is a factor to consider and offer additional functionalities as input-output interfaces for users when are touch-enabled; on the other hand, projected images tend to create a variety of possibilities that are beyond information display at large scales; its uses for augmented reality and interactive video mapping installations can find interesting applications in the kind environments described in this work (see 2.3.2). Nevertheless, excessive uses of visual appealing options and complex interactive experiences might result too flamboyant for information services, especially during moments where focus in important activities is needed.

Other facts to consider are related to the operation and space; the convenience of one or another option depends of the characteristics of the venue and available resources. Thus, installation of projectors and reflective surfaces could consume working time for installation, would need more space and higher energy consumption than LED panels. LED screens on their side, could require higher initial investment, offer less versatility in terms of integration of the image to the surrounding space (since they are generally rectangular) whilst projected images can adapt to different shapes. Finally, there are still some constraints regarding the quality of image in LED screens with interactive functions.[7]

[7] Sources: https://foxguardsolutions.com/2015/03/09/top-5-touch-screen-interfaces/ http://www.pdsttechnologyineducation.ie/en/Technology/Advice-Sheets/Interactive-Flat-Screens-vs-Projectors.pdf

5.4.2 Usability discussion

To reach a level of product development that allows to create a fairly functional IoT system for distribution of multimedia contents to high technology devices, enhancing the quality of the shared spaces and adding value to the experiences that occur in them; is a task that despite being interesting and promising can be demanding at many different levels since it implies adaptation to the social dynamics and pre-established rules of the environment and needs to offer bonuses for being accepted as a mediator in situations that could still be simpler and straightforward without technology; Menezes and Smaniotto (2017) pose some key questions that should be considered for assuring understanding of social dynamics related to shared spaces:

- Who are the users?: Some basic information like gender and age (in groups), also interviews helps to collect socio-demographic attributes (education, marital status, occupation, place of residence and work).
- How they use the space?: crossing, standing, sitting.
- What users do?: meeting, working, visiting, using ICT devices, carrying shopping bags, etc.
- When they use the space?: time of observation, periods of the day (morning, noon, afternoon, evening), weekends and frequency of use (daily, many times, sporadically, etc.).
- Where?: which place they use conference center, green space, street, room.

Chaturvedi (2016) explains that even in the case of centrally controlled systems for administering complicated tasks effectively; design cannot be done without paying attention to individual users necessities and adapted to specificities of the environment, and remarks that these spaces are part of a bigger of digital ecology in which relationship between digital and physical elements is more diffused each day, and influences the ways in which interpersonal interaction is done within a community.

For Menezes and Smaniotto (2017) it is important to understand the space and social practices as a set of actions that establish the liaison between several contrasting parameters inherent to human environments that are beyond physical and digital relationship; thus, the masculine and feminine, young and old, building and street, indoor and outdoor, private and public, local and global, sacred and profane, time and space, every day and extraordinary situations, work and leisure are all part of the complexity of designing for groups of users in shared spaces.

5.4.3 Comparison to study cases

By the contrast and comparison of the proposed system against study cases that were introduced in 2.3, it is possible to analyze different aspects about the quality of the service from the perspective of the user experience. For the analysis were selected to different examples: Blendology and Eventagrate; these two cases represent different approaching in the realm of digitally-enhanced experiences for events and public spaces. Blendology, is more centered in the creation and tracking of human connections (with IoT technology as an intermediary) during events, as well as a strong component of data analysis oriented to achieve marketing and networking efficiency. On the other hand, Eventagrate focus is more centered in creating eye-catching experiences that are closer to entertainment and marketing realms.

Despite their differences, both companies have products that improve feeling of enhancement of the experience of space's possibilities for their users, offering diverse methods for interaction. Nevertheless, the goals of these interactions methods are substantially different; in the first case, interaction among users is the focus, leaving the user in an interaction environment based on a more passive approach, leaving activity traces and receiving information. In the second case, the user's experience of the space is more dynamical, visual feedbacks and stimuli help users to engage to the environment, but interaction among users might be limited or not important in terms of system design.

Thus, the idea of experience that is proposed in this work could be considered as a common ground between these cases since it is intended to distribute multimedia contents by different kind of interaction methods and for diverse purposes; and at the same time making feasible that this design of the augmented space can be also a vehicle for people to achieve better channels for communication in the physical and virtual worlds.

The use of devices like interactive badges appears to be promising since it is a modality that has been very well implemented in the case of Blendology's system, but the kind of device used implies different possibilities and limitations; in the mentioned study case, the interactive badges are based on an e-ink display (which can show identification details, map of the venue and agenda), it also have LED illumination for giving visual feedback and haptic capabilities, as well as being an enclosed product with controlled customization possibilities (basically input personal details). This contrasts with the idea of the interactive badge based on a programming board like the BBC micro:bit, which despite enabling different kind of communication methods and being adaptable to many type of dynamics could have limitations in terms of final product presentation (which is very important for business environments) and the needed simplicity for unexperienced users. Nevertheless, the fact of having physical buttons and capability for sound and visual feedbacks by using a simple add-ons kits could take the interaction to different levels and more creative implementations, that could be suitable for younger or more informal environments (as technological

and educational events).

Blendology delivers data of performance as well as a personalized timeline for the users, this is available on the website and the official application for different kind of devices. This is an interesting outcome that is complementary to information about the overall activity from all the people around the space. Thus, for a project like the one suggested here, the focus would be to use these self-generated contents for creating multimedia appealing contents that can be shown around the space, and that are not only based about activity statistics but also about happiness and enjoyment of the overall audience (this is further discussed in 5.4.4).

As for Eventagrate is regarded, one of the most important characteristics of their products is that they are based in remarkable multimedia technology for creating interactive environments. Thus, some of the most used elements that can be seen in this company's catalog are based on innovative forms projections: as interactive video mappings according to the user's preferences, interactive projections for tables that are also reactive to sensors; interactive videos in LED panels (activated by sensors or by touching); and many other kinds of augmented reality products. Even though many of these technologies are always appealing and inspiring, selection of them is done carefully and according to marketing objectives, budget constrains and communication goals of specific environments and groups. As stated in the technological analysis, high-end multimedia technology implies elevated costs and infrastructure, which is always important for the planning and development of any kind of project. Thus, in the specific case of this work, the main objective is to build appealing installation that can imply some level of enjoyment and informational value, for this reason the interaction has to be considered according to the environment of application (for avoiding disturbances to attendees and unnecessary overload of elements in the space that could be counterproductive for information delivery process). Thus, one scenario based in wise use of LED technology for outdoor and highly illuminated spaces in conjunction to interactive projections could be highly suitable to the goals of the project described here.

5.4.4 Data visualization and emotional mapping

For a system that is distributed through different locations around a physical space and that mediates interactions and communication among several users and objects, it is foreseeable that many data will generated during its operating time; this data is irrevocably linked to the environment in which it is generated, and from its analysis is possible to extract valuable information about the experience and reactions of people involved in the event.

In this context, positioning technologies have allowed precise tracking of individuals and geotagging[8] of multimedia contents, from which is possible to collect many data and map spatial users' behaviors. Thus, according to Menezes and Smaniotto (2017) digital technologies enhance potential for multidisciplinary research in the area of users-space relationships and how this kind of information creates additional possibilities for new types of datasets (with calculated features like velocity and timing), finding application in several fields like urban planning, monitoring of recreational activities in outdoor environments, surveying systems and planning of public spaces.

Hauthal (2015) mentions different methods for extracting emotional information (enjoyment, disgust, fear, etc.) from data related activities related to digital technologies and social networks, namely: biometric parameters, empirical surveys and geo-referenced user-generated contents; this last one refers to traces and records of different actions generated by users during when using different interaction methods that can additionally be associated to the geographic space and the time in which they happened; Hauthal also mentions that this kind of information can be denominated as: User-Generated Content (UGC), which is classified into two main categories:

- Volunteered Geographic Information (VGI): This term refers to geographically referenced contents that is voluntarily shared by people without any expectation of material reward.
- Ambient Geospatial Information (AGI): This is called a geographic footprint of activities done by users, data it is recorded and geographically referenced a side effect of another act.

Even though the mentioned research is focused in studying information generated in urban areas of cities and thousands of participants and during long periods of time; the mentioned principles could be also applicable for the study and display of data generated by the services of an IoT platform in a convention center or another type of venue. As discussed in the comparison with the study cases, the use of temporal and spatial information generated by users is an additional product that could add value to the experience and data generated by the system, not only for the clients and the organization of the event, but also for the individual users who attend to it and for people that can participate in the distance, in the characteristic flow of information of an augmented environment as described by Manovich (2006).

[8] According to Djukic et al. (2017) Geotagging is the process of adding geographical identification metadata to various media such as photographs or videos, websites, SMS messages, QR Codes or RSS feeds and is a form of geospatial metadata.

Another important aspect to be considered when talking about UGCs is regarded to the resolution of the analysis of location data generated by the users; generally, data obtained from the activity in a social network like Twitter [9] can lead to analysis of behaviors in the scale of a city; nevertheless, this does not necessarily describe the detail of activity that occurs in the smaller environments.

As commented before, data generated by beacons-activated experiences can register and characterize events with better precision for semi-public environments like the ones discussed here[10]. Thus, mixed scenarios can be contemplated, in which the use of different levels of sources (social networks, beacons, local apps., sensors) can be combined for generating interesting datasets for both analysis and visualizing purposes, allowing to infer emotions (Hauthal, 2015) and even to make semantic analysis from location data (Breser et al., 2017). These are options that could come to boost the integration from individual components of the system like the social media visualizer and the interactive badges systems, not only as connected devices for electronic interaction purposes, but also for generating data that contains meaning and significance for different stakeholders of a project.

[9] Twitter search engine is a Web-based application that is used to collect, process and analyze data from Twitter activity. It allows to collect tweets within a defined geographic space of a given radius. See (Djukic et al., 2017) for more details of its applications for visualization and research purposes

[10] A quick comparison among different location methods can be found on: https://clearbridgemobile.com/location-based-technology-for-mobile-apps-beacons-vs-gps-vs-wifi/

Chapter 6

Conclusion

This dissertation work has been centered around the task of exploring some of the available options in the field of IoT and multimedia technologies as well as their implementation in interactive projects that can create valuable experiences for users in events and public spaces. Through this exploration, it has been possible to gather information about the recent (and always continued) advances in these areas, with special focus on its applications for creating collective experiences and new uses of the space, not just as host of the human activities but also as an active participant in the communication dynamic of the modern society.

Regarding to the potential for creating these individual and collective experiences through technological means, the project included the conceptualization of dynamics and services in which the space (and the connected objects contained in it) had a participation as mediators for the interaction among users. Thus, in the design description chapter, were described initial stages of UX design for these experiences, identifying potential users and depicting some usability challenges associated to them.

Additionally to the design stage, through this research it has been also possible to identify potential opportunities for contribution by the comparison with some existing examples of systems in the area (addressed in the study cases discussion), allowing to reinforce ideas and re-imagine services that already exist. Nevertheless, it is also important to say the field of augmented informational spaces for marketing and recreation in events has already changed by the lowering in costs of technology (LED panels, projectors, etc.) and by the incursion of the smartphone as a fundamental tool in our activities, creating environments that are already very familiar for users, this imply that detailed planning and design is going to be needed in order to create valuable solutions that make a difference in the future. However, many of these experiences are yet to be adapted and transformed by the integration of new objects to the IoT communication dynamic and all of them require user-centered approaches and ideas that favor the social integration of individuals, incorporating them to human dynamics without seizing of the user's attention and compromising their privacy.

As for the potential future scenarios of testing of these ideas for research purposes is regarded, the study contributed to identify those technological solutions that could be useful in the creation of quality services; the use of programmable boards seemed specially convenient since it could contribute to manage sensors and multimedia devices in easy and affordable prototypes; this can help create promising projects involving different areas, from design and artistic realms to computation and information technologies, given its simple configuration. The tool that were mostly studied in this work was the BBC micro:bit, which shows several interesting features for communication and interaction without needing advanced skills for its use; the use of more powerful boards as Raspberry pi 3 implies the possibility of developing more complex projects and parallel tasks, diversity of connections and communication possibilities, but with limited portability and a less friendly environment and enclosed product mood.

In parallel to the emergence of these new technologies, the presence of the Internet of Things is also becoming more evident with new smart-enabled products that are already working at home, recreational and working places where collective dynamics take place. Thus, during the exploration of available products and platforms in this field, it was possible to note how giant companies like Google are already working on creating environments that deliver comfort, security and compatibility for the next generation of services that are going to appear in the coming years, which guarantees its relevance for the future. Although many of the products that will be included in this development are not going to be necessarily related to the multimedia field (since the IoT is expected to cover diverse important fields like health, security, transportation, etc.); many of them will need to be part of elaborated plans for development of services, in which the UX design principles and co-creation scenarios will play important roles, as well as the mediation of multimedia interfaces visualization methods for management of those connected devices and associated systems.

6.1 Limitations

As discussed in past sections, the kind of project described in this work implies different levels of organization that must mesh into a holistic approach for taking the initial idea to a productization stage, for this endeavor it's required participation of contrasting professional areas as design, technology or communication. Thus, the principal limitation that was found for the development of the project is related to achieve an effective implementation of the components of the proposal and the testing them with real users during the time stipulated for the research. Another important constraint to consider is related to the available literature related to specific research about augmented spaces applied for events and meetings, since much of the information related to formal research is focused in the study of urban open spaces, whilst found information in the realm of

events corresponds to corporate brochures and promotional information about commercial products.

6.2 Future work

For future development scenarios, it would be adequate to work on specific details about interaction design and design of interfaces for the parts of the system that require it; a very important example of this case is the interactive IoT Agenda, which is a product that implies an interesting challenge, since it would require to integrate visual interfaces to some other interaction methods based on sensors or beacons. Another matter of future work is related to the testing of an IoT platform with interactive beacons, based on a development board like the BBC micro:bit and with real users. This would require some additional elements of the system to be integrated into the platform for collecting and displaying data about users' experiences and emotions about the experience of interacting with the multimedia elements of the environment and with other users as well.

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Appendix A

Proposed Features of the system

A.1 Games based on interactive badges

1. **Accelerometer Ping-Pong:** A game based on the idea of the traditional ping-pong is shown in the screen for people walking around the space. The participants should find out how to use their interactive badges to hit the virtual ball by giving a specific orientation to the built-in accelerometer in their devices.

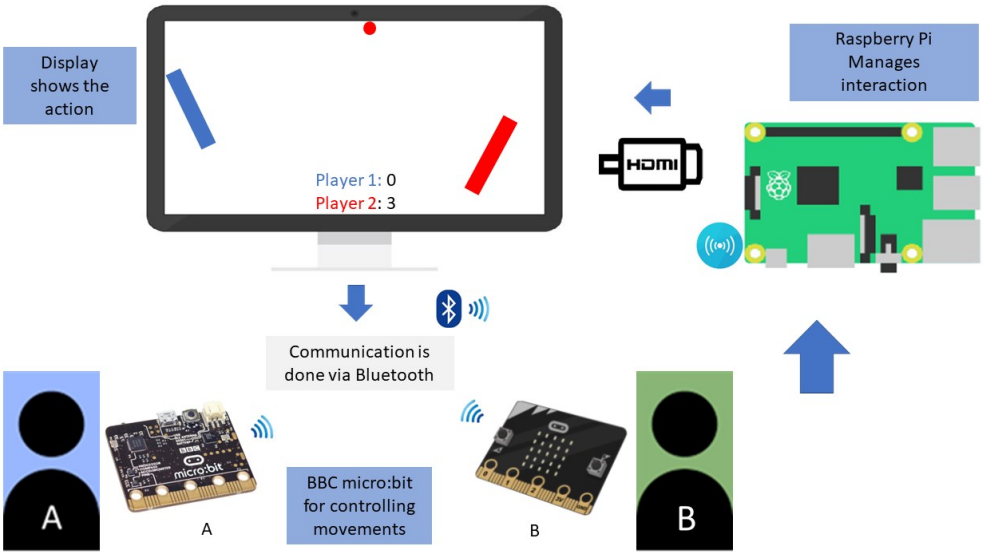

Figure A.1: Accelerometer ping-pong.

2. **Conference Trivia:** A game based on questions and answers that can snatch the attention of the attendees in specific moments and about determined subjects; it can host up to four devices linked to a programmable board that manages the timing and main processes of the game, a led screen is used to send and receive questions to the group of contestants, the buttons in the frontal part of the interactive badge are used to answer the questions (yes/no). Buzzing and visual notifications are allowed in the interactive badges for individual participants.

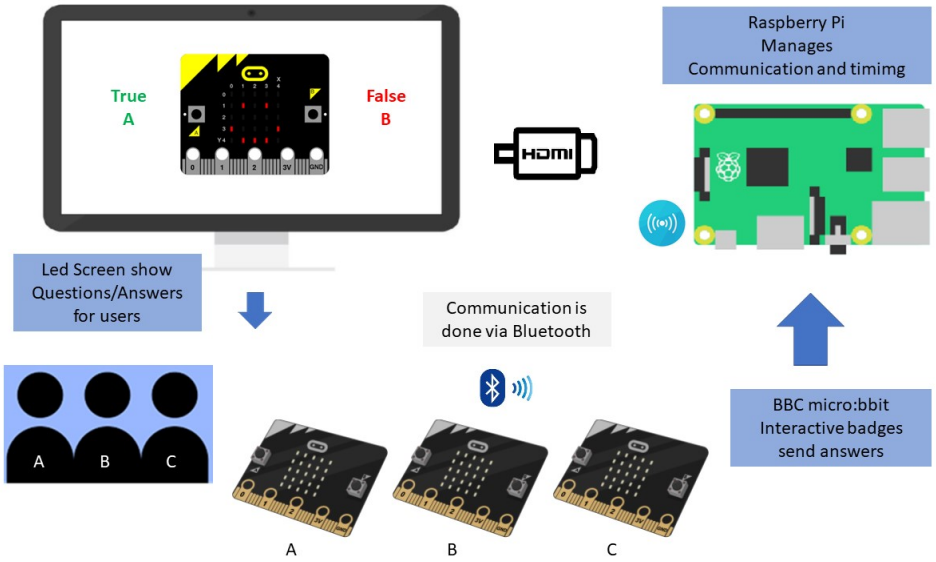

Figure A.2: Conference trivia.

3. **Slot Machine:** Several interactive badges run a collective slot machine when they're together and linked to one beacon. Depending of what figure they obtain in their displays, they could participate of some challenge and get a small prize if they find a solution to it. Thus, the slot machine will determine challenges based on common interesting subjects for the mini group. Buzzing and visual notifications are received in the individual badges and continuity of the dynamic can be followed in the screen.

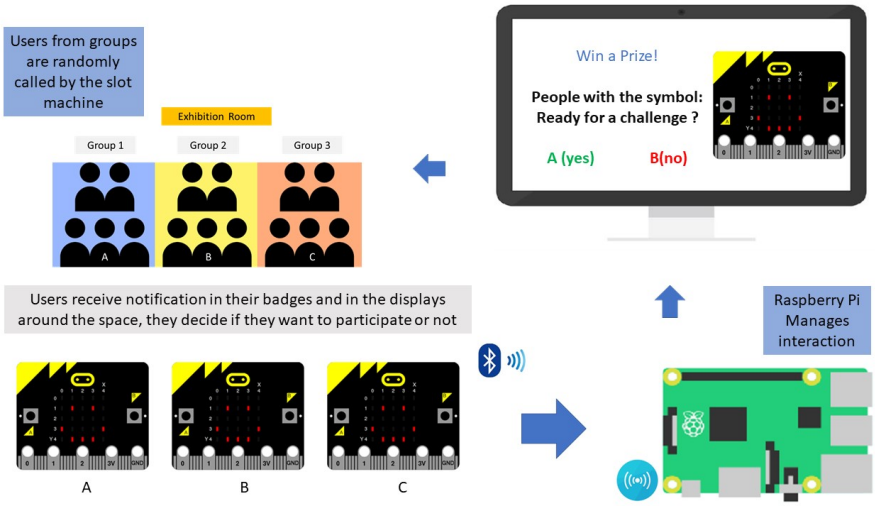

Figure A.3: Slot machine.

4. **Treasure Land:** Use of the interactive badges to find some other devices (working as beacons) that are distributed around the space, each participant can follow a different road to reach his/her treasure, the main objective is to create curiosity in many of the participants to explore the space of the event and help each other by exchanging information in a collaborative way.

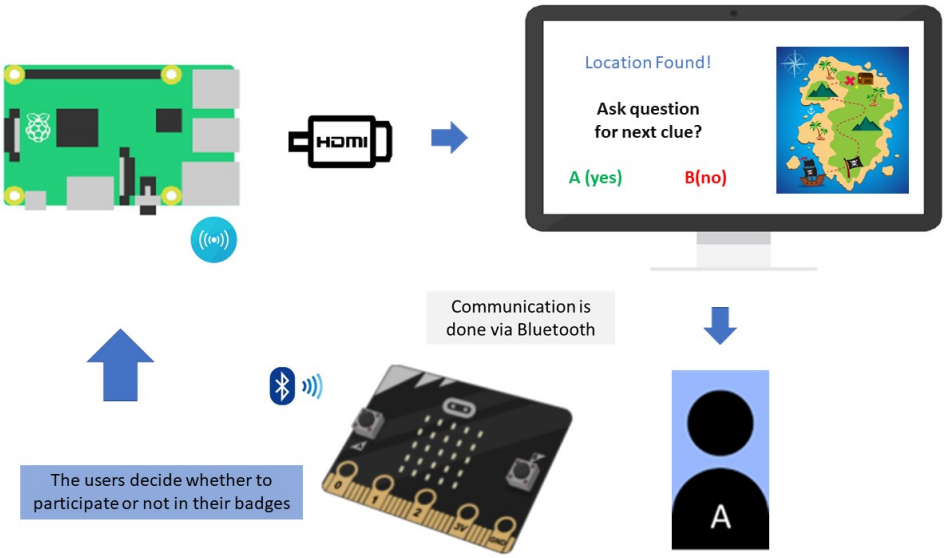

Figure A.4: Treasure land game.

A.2 Interactive badges around a conference space

1. **Leaving a feedback:** Would be a feedback and polling system in which an user that just watched some specific feature around the space of the event (talk, poster, show, booth, etc.) can leave an opinion of (approval, disapproval, neutrality). The use of the interactive badge allows users to choose between different levels of approval, as well as to leave spatial traces about individual experiences at specific moments. The system sends the information of the different reactions collected to a computing device for processing and calculations, then, statistics about different events and users are calculated and displayed in the screens around the space.

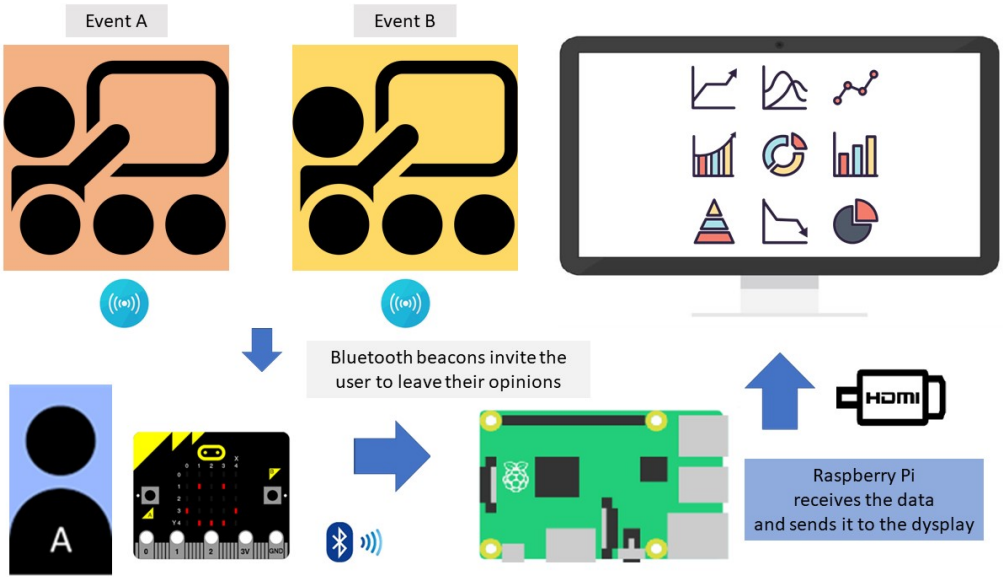

Figure A.5: Feedback system.

2. **Record a moment:** Using an one-touch button device connected via Bluetooth to a microcomputer with a camera, the button works as a trigger that sends a message for taking a picture when pressed. The system will upload the photo and a predetermined text to the official Twitter account of the event. Additionally, when a group of interactive badges are together and close to the dash button, they receive a group alert to take a picture by the method described. The IDs and personal details of the interactive badge holders could be associated to tags in the post and additional features that make the posting process quick and personalized.

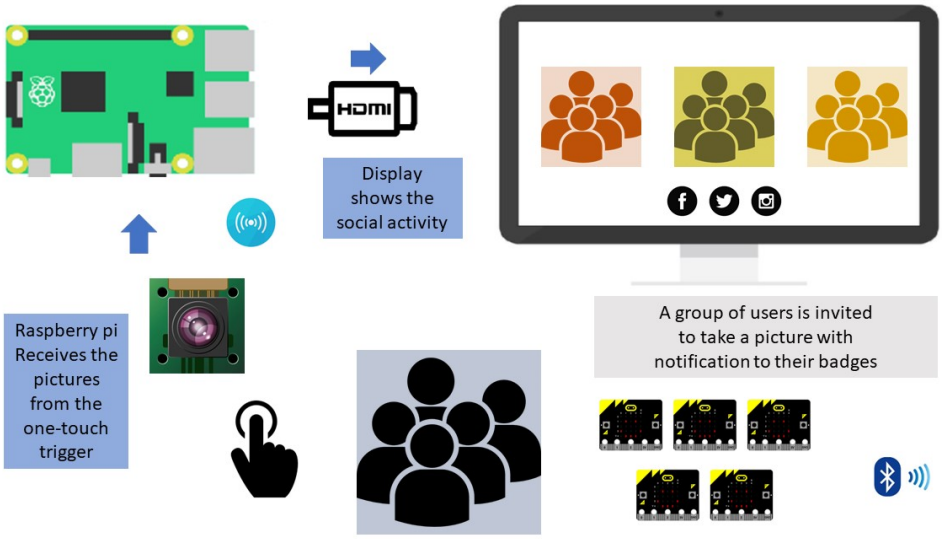

Figure A.6: Social networks dash button.