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Communication and “smart public space”

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Communication and "smart public space": Opportunities, challenges and supporting IoT Technologies

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Abstract

In this paper we examine communication and IoT technologies as key enablers for the "smart public space", where communication in collaboration with IoT technologies can satisfy business needs and provide applications and services for improving essential aspects of the modern public space such as the levels of safety, accessibility and overall experience of its users. After studying the literature about the concepts of communication and public space, their characteristics and recent evolution, we investigate the concept of the "smart public space" along with the most important components and technologies of Ubiquitous Computing and the IoT ecosystem. Furthermore, we present a case study about the design and development (PoC) of a system of applications for the "smart public space", based on computer vision and IoT technologies, and we demonstrate its features and how it can contribute to crowd management and the safety, accessibility and overall experience of public space users. The "smart public space" brings with it not only opportunities for people and communication, but also challenges, such as the need for availability, quality of service, privacy and new ways to design and manage communication and digital applications for sustainable and useful causes.

Keywords: communication, smart public space, IoT, AI, computer vision, crowd management.

Introduction

The emerging technologies of the Internet of Things (IoT) are transforming the way we perceive and interact with the physical realm. As part of the physical realm, the public space cannot remain unaffected by this evolution. In this paper we examine essential aspects of communication and IoT technologies that are affecting the modern public space, transforming it into an information rich, hospitable and smart environment for human activity, with new digital applications and services for the benefit of its users.

Since the last two decades, the Internet and the virtual world (Cyberspace) have already changed the way people interact, communicate, study or work in the digital sphere, from anywhere and anytime. Especially Social Media, as the virtual vessel for online social interaction, user content generation and digital communication, have led to the promotion of various interactions among users with different backgrounds, resulting in rich social exchange, new kinds of services and professions (digital experts, data analysts, etc.) and new fields for

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data driven research and decision making. Social Media can be defined as a variety of "user-driven platforms that facilitate diffusion of compelling content, dialogue creation, and communication to a broader audience. It is essentially a digital space created by the people and for the people, and provides an environment that is conducive for interactions and networking to occur at different levels (for instance, personal, professional, business, marketing, political and societal)" (Kapoor et al. 2018).

The Internet of Things is regarded as the next big step of the Internet evolution, bringing together the physical and the virtual world, where physical objects are being connected to the Internet at an unprecedented rate. This evolution promises to contribute to the quality of people's lives and to the world's economy in several domains and environments, by having significant consumer and business applications (e.g. in home automation, transportation, healthcare, industrial automation and emergency response to natural and man-made disasters where human decision making is difficult), (Al-Fuqaha et al. 2015). In effect, IoT enables physical objects to sense the environment, measure its features and help perform jobs by collaborating with one another and making decisions. This gives the objects smart new innovative roles to play in people's lives. In order to accomplish this, IoT is exploiting several enabling technologies based on Ubiquitous Computing, embedded devices, communication technologies, sensor networks, cloud storage, big data and machine learning algorithms (McEwen et al. 2014). Following this new paradigm, smart objects present a degree of specialization to support domain specific applications; thus, supporting vertical markets. On the other hand, Ubiquitous Computing and analytical services support domain independent application services, for horizontal markets (Al-Fuqaha et al. 2015).

The physical public space has been seen so far as a vital part of social life, urban vitality, coexistence and inclusivity. The experts in the field of Urban Design have proposed goals and priorities for a modern people centric public space (Jacobs et al. 2011) that emphasize on its llivability, the sense of identity and control over the public space they use, the access to opportunity, freedom to express themselves and extend their experience in the public space, as well as authenticity and meaning. In addition to this, community and public life is very important in order to encourage participation for all and to promote urban self-reliance in public space. Technology, wireless networks and smart mobile devices have already landed on the public space in the hands of their users, and many location-based applications share ratings and content, making public space a place of digital communication and interaction.

The purpose of this study is to demonstrate how IoT technologies and communication can become the next step for the intelligent emancipation of physical public space, transforming it into a smart public environment. This will be achieved by developing integrated, information rich and user-friendly applications that correspond to specific responsible business goals such as public safety, mobility and user experience. In addition to this, our aim is to bring new emphasis to the physical public space as opposed to the digital public space, and make a small contribution to the vision of its empowerment in order to reclaim its position and full potential in the lives of the people. In the context of this study, communication is not treated as a problem that expects a solution or improvement from IoT technologies. Instead, in our perspective, communication serves primarily as one of the contributing factors in order to understand and plan ahead new innovative and useful IoT applications for the smart public space of the future.

The communication context

Communication functions as a necessary component for human interaction in order to convey meanings and create culture, technology and social ties. We can distinguish 3 main communication environments, each revealing discrete behaviors and relationships among humans: a. The private sphere, b. the public sphere and c. the virtual sphere (Figure 1).

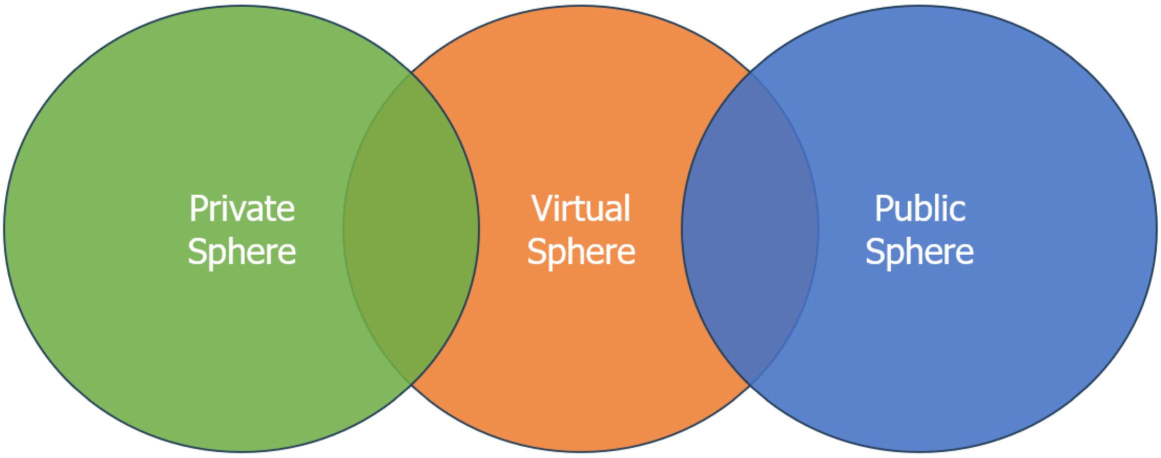

Figure 1: Communication environments

Communication occurs through communication channels that can be physical media (air, sound, paper and writing), electronic media or digital media. Obstacles for communication can be either the noise in the channel that hinders the correct receipt of the messages and the process of encoding or decoding of the messages that can have errors.

The most famous model explaining communication is the Laswell formula for the process of communication, where there are roles for the sender ("Who?"), the message ("Says what?"), the medium ("In what channel?"), the receiver ("To whom?") and the result of the communication ("With what effect?"). In the basic generalized graphic model of communication an event can be perceived by either a man or a machine, so technology is given a place to the communication process, as a destination of a message, or its originator, or both (Gerbner, 1956). Moreover, the development of communication can go along with the development of technology, since it has been suggested that context rich communication situations can arise with the development of technology (Hall, 1989).

Modernity has brought with it the mass communication phenomena following the rise and spread of the mass society and mass media. Aspects of mass communication is the coverage of mass audiences with the proliferation of mass media (newspapers, TV, radio), journalism, advertising, promotion and marketing. In the past few decades, we have witnessed the revolution of digital communication. In the beginning with email services, blogging, forums and groups and then with the burst of the social networking applications where there is a constant need for digital content, new digital formal and informal relations and interaction of the users (Castells, 2014). Technology innovation in smart applications and devices have made it possible for everybody to connect to services and to communicate. The discussion about the use of Internet and social media such as Facebook, WhatsApp, X (Twitter), YouTube, LinkedIn, Pinterest, and Instagram, and the kind of impact that they have on people's lives and on interpersonal communication and social interaction is open for research by several scientific fields that explore their positive and negative effects. Generally, the cost of interpersonal communication, the enriching communication channels and modes as well as Building Wider Social networks are regarded as main positive aspects of internet usage, whereas distracting attention, reducing social skills and increasing negative emotions are the main negative, however, the impact of Internet usage on interpersonal communications is still unclear (Li et al, 2022).

The newest evolution of communication is the rise of the IoT environment with new possibilities and opportunities brought about from the collaboration of the physical and digital worlds.

Public space as a medium

Physical public space can be seen in many ways as a medium of human activities, which can be grouped into two main categories (Carmona et al, 2009): a. Activities for movement and transportation and b. social activities and activities of interpersonal communication. In a similar way, public space activities can be described as flows (movement, traffic) and concentration (Tuan, 2001). Public spaces can be defined as non-domestic places with public accessibility (Humphreys, 2010) and so they can have a variety of uses, like parks, restaurants, cafes, streets. When it comes to their commercial nature, public spaces can be either non-domestic and non-commercial physical places, such as publicly accessible plazas, or semi-public spaces with social and public function for sociality and recreation, such as cafes and restaurants (Figure 2).

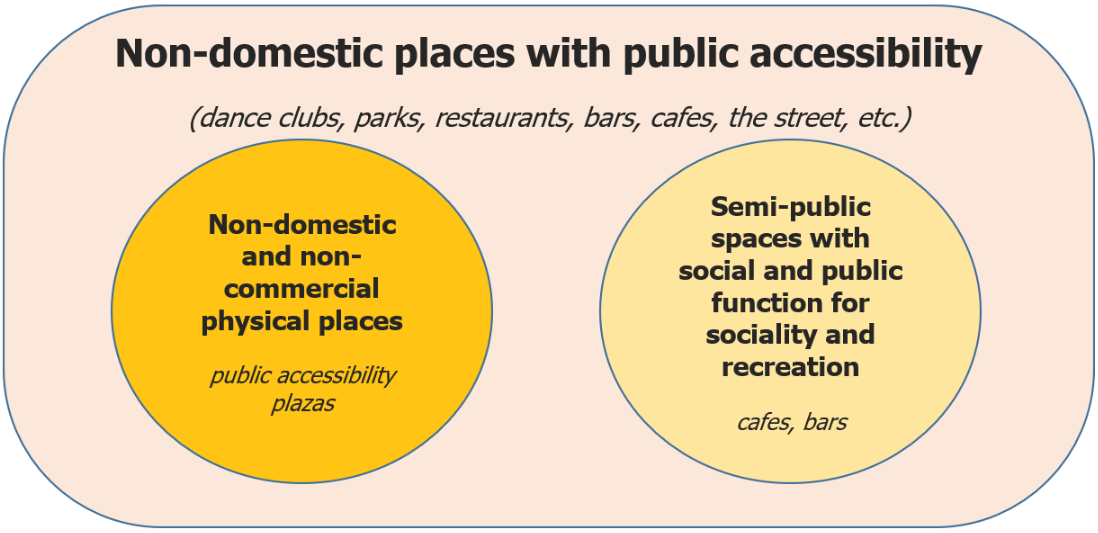

Figure 2: Classification of public spaces (based on Humphreys, 2010)

Public space is "where you watch and you are being watched" and they bear meanings shown in uses, activities and functions of urban social life. The human behavior in public spaces can be explained through the concept of situation (Hall, 1989), in a variety of occasions such as celebration, events, demonstration, protest and social involvement, commercialization and promotion of services, products and new trends, free movement, recreation and leisure.

The physical public space has multiple aspects that are studied by many fields and disciplines including architecture and urban planning. Space seems to promote the "illusions of transparency, of natural simplicity, and of giving free reign" and, since it is socially produced (Lefebvre, 1991) can be seen as three different notions: first as spatial practice (how people observe ourselves and others within it), as representations of space (how architects and designers give meaning to it), and as representational space (its symbolic nature people experience).

Amongst the most important issues concerning the discussion about public space in modern cities are the large- scale building projects, the massive transportation systems, poor living environments, poor vision and effectiveness of urban planning policies (Jacobs, 1961), privatization of public space, loss of political importance (in favor of the space of electronic communication and the consequences that may have particularly to oppositional political movements) (Mitchell, 1995), and eventually loss of public life creating what Galbraiths described as "private affluence and public squalor" (Galbraith, 1998).

The most important attributes of the public space is the diversity of the cities in terms of the coexistence of people with very different backgrounds (Humphreys, 2010), such as race, class, religion, sexuality, education, political ideology and temperament. The diversity of the public space brings more social obstacles to interact or have a conversation in public with strangers, without common characteristics (Goffman, 1971). The public realm is a form of social space distinct from the private realm and is essential for the life of the city and it a regio incognita where mostly strangers meet and interact in terms of occupational or other nonpersonal identity categories (for example, bus driver- customer) (Lofland, 1998). In authoritative regimes the public space is under constant surveillance and control in order to suppress freedoms and public expression. Public spaces incline or decline following the overall gentrification of urban landscapes and trends like tourism, and they also face the challenges brought by the privatization of public space.

Technology and public space have a long standing relationship since the public space is used as an environment for outdoor advertising and promotion of messages (e.g. screens, electronic billboards), because it can offer an information rich consumer's experience. The mobile technology has revolutionized the urban life as a "real-time" city (Townsend, 2000) breaking for the first time the limits for omnipresent communication in public space, with social networking promoting the flow of new kinds of information into public spaces and new social and spatial practices. It is argued that "mobile communication increasingly raises the issue of place as an influential factor in communication" (Humphreys, 2011) since mobile applications in smartphones already give access to location-based services and social networking and the users have the opportunity to send contextual information and ratings about the public space they visit in a way that the "communication about place and communication through place both emphasize aspects of the social production of space". In addition to this, it has been suggested that mobile services can be used to facilitate social interaction in public spaces (Humphreys, 2007). Some early examples of how mobile social networks can be used in the city public space has been the case of Dodgeball network ('check-in' messages to meet with friends on local places- Google Maps) and since then a long list of applications has emerged that add value to physical spaces, using geolocation, augmentation, meet ups, messaging and public space gamification (Pokèmon Go), etc..

"Smart cities" and the "smartization" of public space

The "smart public space" is the public space that combines "smart" systems and services for addressing business goals, like mobility, the availability of means and services, facilitate us with suggestions of ways for movement and navigation, warn us to avoid unpleasant or dangerous situations, recommend ways to protect us from threats such as the pandemic or traffic congestion.

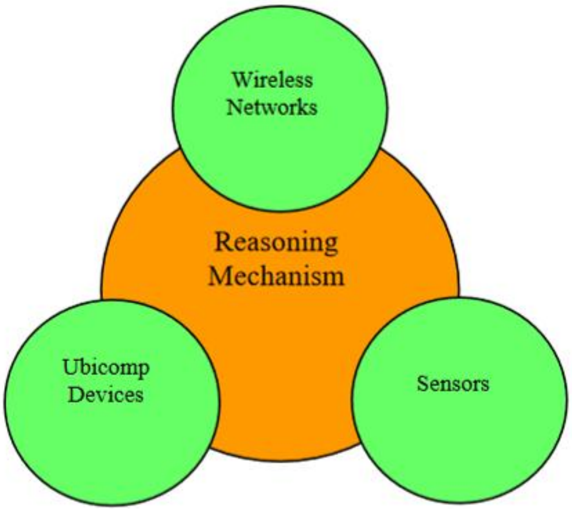

Figure 3: Components of Smart Spaces (Lupiana et al, 2009)

Technology today is even closer to the vision (Weiser, 1991) about a world with countless interconnected computers and technologies that "weave into the fabric of everyday life, to the point where they are no longer distinguishable from it". Smart Spaces can be identified as UbiComp environments (Image 3), comprised of wireless networks, UbiComp devices, sensors and reasoning mechanisms, that can understand and react to human desires (Lupiana et al, 2009).

The infrastructure capable of accomplishing this vision is the "Internet of Things" which has been defined by International Telecommunication Union (ITU, 2005), as "the global infrastructure for the information society, supporting advanced services through the interconnection of (physical and virtual) things based on existing or emerging interoperability between information and communication technologies" (ITU, 2005).

Figure 4: The vision of Smart Cities

The smart public space can be seen as part of the broader picture of the smart city ecosystem (Figure 4). From the combination of smart things (devices, sensors and actuators) we have smart applications that connect, produce and share information, in broader smart systems that create smart ecosystems. Cloud computing and Artificial Intelligent play a pivotal role in the smart ecosystem. The IoT technologies of the "smart city" infuse information into its physical infrastructure to "improve convenience, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains" (Nam and Pardo, 2011). The programme of Smart Cities includes: Institutional Factors, Public Safety, Government & Agency Administration, City Planning & Operations, Buildings, Technology Infrastructure and applications, Physical Infrastructure, Energy, Water, Transportation, People (Quality of life), Healthcare, Education, Economy, Environment (Harmon et al, 2015). According to Giffinger et al. (2007) the key dimensions of a smart city is economy, mobility, environment, people and governance while Thuzar (2011) finds most important the quality of life, sustainability of economic development, management of natural resources and convergence or economic, social and environmental goals. The key components of a smart city (Nam and Pardo, 2011) are the technology, the people (creativity, diversity and education) and the institutions (governance and policy).

The data drawn from the public space is processed and translated into information and services that enrich the experience of the people in the public space, gain their trust, resulting in the deepening and strengthening of the relationship between the public space and its users. Overall, a smart city provides some level of interoperability and Internet-based government services as basic infrastructure for ubiquitous connectivity (Al-Hader et al., 2009).

The term “smart” and “smartness” in the smart city is realized only when an intelligent system adapts itself to the users’ needs (Albino et al., 2015). In addition, there is a concept of community that has been attributed to the smart city (Nam and Pardo, 2011) and as a result the technological applications aim at inspiring the sense of community among the citizens. In this way the members of the communities and institutions in a smart city should feel the desire to participate and transform their environment (“smart communities”). People who contribute in the smart city share common qualities such as affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism, open-mindedness, and participation in public life (Nam and Pardo, 2011).

Supporting IoT technologies

The technologies that support IoT (Al-Fuqaha et al., 2015) should be capable of interconnecting billions or trillions of heterogeneous objects through the Internet, so there is an increasing number of flexible layered architecture however there are not yet been converged to a reference model. The main proposed architecture consists of five layers: A. The Object layer includes sensors and actuators to perform different functionalities such as querying location, temperature, motion, acceleration, humidity, etc.. B. The Object Abstraction layer transfers data through various technologies (RFID, 3G, GSM, UMTS, WiFi, Bluetooth Low Energy, infrared, ZigBee, etc.) to the Service Management layer through secure channels. C. The Service Management or Middleware (pairing) layer pairs a service with its requester based on addresses and names and enables the IoT application programmers to work with heterogeneous objects without consideration to a specific hardware platform. D. The Application Layer provides the services requested by consumers or businesses and covers numerous vertical markets such as smart home, smart building, transportation, industrial automation and smart healthcare (Khan et al., 2012). Lastly E. the Business (management) layer manages the overall IoT system activities and services with the use of a business model, graphs, flowcharts, etc., makes it possible to monitor and manage all other layers and also supports decision-making processes based on Big Data analysis.

In an effort to form a holistic framework to build diverse Ubiquitous Computing systems for the IoT is the Smart DEI model (Poslad, 2011), which consists of Smart Devices, Environments and Interactions model and can also support different types of smart spaces, with the use of smart mobile devices (Poslad, 2011).

Overall, the core elements of IoT technologies and functionality have been categorized (Al-Fuqaha et al., 2015) into the following groups. First there is A. Identification of objects which uses both object ID and object address to identify objects within a communication network (addressing methods include IPv6 and IPv6). B. Sensing from objects within the network and sending the data to database, bata warehouse or the Cloud. C. Communication between IoT objects with protocols such as WiFi, Bluetooth, IEEE 802.15.4 (LR-WPAN), Z-wave and LTE-Advanced or more specific communication technologies like RFID (RFID tag and reader), NFC (Near Field Communication) used for active readers and passive tags and UWB (ultra-wide bandwidth) designed to support communications within a low range coverage area using low energy and high bandwidth. WiFi communication technology have a maximum range of 100 m and can allow smart devices to exchange information even without using a router. Bluetooth is used to exchange data between devices over short distances with more the energy saving short-wavelength radio (especially Bluetooth 4.1, that provides Bluetooth Low Energy, high-speed and IP connectivity). In addition, IEEE 802.15.4 standard is suitable for reliable and scalable IoT communications and LTE (Long-Term Evolution) standard and provides for high-speed data transfer between mobile phones based on GSM/ UMTS network technologies and LTE-A (advanced) offers higher throughput and lower latencies. D. Computation with all types of processing units (e.g. microcontrollers, SOCs, FPGAs), software applications, and hardware platforms (Arduino, UDOO, Raspberry PI, Beage etc.) and also Cloud Platforms consist an important part of IoT real time computation of data, big data and knowledge retrieved from them. E. Services of IoT can be distinguished in four main categories: Identity-related Services are the most basic services that are used in all other types of services, Information Aggregation Services that summarize raw data, Collaborative- Aware Services that built on top of Aggregation Services to make decisions and Ubiquitous Services used to make services available anytime, anywhere and to anyone who needs them. Last but not least F. The Semantic functionality of IoT is supported by Semantic Web technologies (RDF, OWL, EXI) and offers the extraction of knowledge by detecting, analyzing data, defining needs and sending the right decision to the right resource.

Standards to support IoT technologies have been proposed by many institutions and organizations (W3C, IETF, IEEE, EPCglobal, ETSI). Prominent IoT application Protocols are CoAP (Constrained Application Protocol), to enable tiny devices with low power, computation and communication capabilities, MQTT (Message Queue Telemetry Transport), to connect embedded devices and networks with applications and middleware as an IoT and M2M (machine to machine) messaging protocol, XMPP (Extensible Messaging and Presence Protocol), used for multi-party chatting, voice and video calling, AMQP (Advanced Message Queuing Protocol), to support reliable communication in IoT, and DDS (Data Distribution Service), to offer high reliability and quality of service to real-time M2M communications. In addition to Application Protocols, IoT is supported by Service Delivery Protocols (Multicast DNS, DNS service discovery), by Infrastructure Protocols (RPL, 6LowPAN, IEEE 802.15.4 etc.) and other protocols and features to support other important aspects of IoT like security and interoperability (IEEE 1905.1) (Al-Fuqaha et al., 2015).

The systems of Ubiquitous Computing operate in three types of environments: ICT, physical and human environment (Poslad, 2011). Their core properties are their (1) distributed and networked nature, (2) the discrete or hidden way for human- computer interaction, (3) the high level of context awareness, (4) the ability to operate autonomously and be self-governed up to an extent, (5) and the ability to handle multiple dynamic actions and interactions applying intelligent decision – making, with some form of artificial intelligence (AI) (Poslad, 2011). Ubiquitous Computing systems can operate in additional environments than distributed ICT systems mostly because they can work in human-centric personalized environments (personal, social and economic environments) interacting less directly with their users, and secondly that they can handle physical environments of living things (ecologies) and can sense more of the physical world. Artificial Inteligence in Ubiquitous Computing is used to handle incomplete and non-deterministic interactions, collaboration and richer interaction through the sharing of context, semantics and goals.

Machine Learning (ML) and Artificial Intelligent (AI) are part of the computational technologies used in IoT and have proven themselves to offer efficiency and scale and to serve in many application scenarios, especially in real time applications such as Computer Vision. As a data mining technique, ML aims to discover hidden information in data in order to train systems in many fields. Traditional Machine Learning approaches based on linear SVMs and Artificial Neural Networks (ANNs) are now giving way to the evolution of Artificial Intelligence and the development of Deep Learning strategies. Deep Learning (DL) is used in applications for automatic object detection, segmentation and classification. The most widespread Deep Learning architectures are Convolutional Neural Networks (CNN), which are able to classify images into multiple categories, learning their features automatically through convolutional layers that combine multiple non-linear processes. Critical to the success of a CNN is its training process which requires a large volume of samples to enter the system, large computing resources and a long time to complete, ensuring a significant prediction success rate.

Computer Vision is particularly flourishing today as one of the most dynamic precursors of the emerging era of Artificial Intelligence (AI). Computer vision is an interdisciplinary field of study of how computers can be trained to collect data, detect, process, "understand" and describe the visible world, track objects, and automate tasks that human vision system could not process. Computer vision extracts high-dimensional data from the real world for decision support (Huang, 1996) in real time and as a result it can support a lot of use cases in the smart public spaces. More specifically Computer Vision supports applications in the following fields (Xiao et al., 2019):

1. Recognition of objects contained in an image.
2. Object detection, to identify occurrences of semantic objects of a given class. Object detection can be either dedicated or generic object detection (Xiao et al., 2020).
3. Understanding a scene, through the search for the important parts of an image and their further analysis.

A driving force in the development of Computer Vision is the development of Deep Learning technologies, large-scale datasets as well as hardware acceleration that provides powerful parallel computing architectures that allow efficient training and extraction large-scale inference in complex and multi-layered neural networks.

Case study: Smart mobility, safety and experience in Public Space

The case study that we present demonstrates as thoroughly as possible many of the advanced IoT technologies that can support communication and "smart public spaces" in addressing business requirements. It involves the design and development (PoC) of a system of applications for the "smart public place" [26] which collects and processed in real time data about the crowding conditions of a given public space, triggering notifications when necessary in smart phones or smart screens placed on location.

The business objectives that the author tried to achieve is to improve conditions for mobility, to increase the level of safety and to facilitate the overall experience of the users in the public space. In order to succeed these goals, the author searched the literature about crowd management and respective technologies and found that computer vision is the most suitable direction we should implement. The general idea has been to use object detection and object tracking from a computer vision system in order to identify the number of people within a given public space and then to calculate the level of crowding of this public space. As the main use case, if there are more people than the accepted level, then there should be suitable notifications send to the smartphones and also to the smart screens placed on the walls of the public space preventing more crowding. So, the data that is collected is the number of people present at a given time in given public space and also the author decided that speed can play a role in the crowding level so it has been included in the calculation the average speed of people present which can, under certain circumstances, contribute in its crowding. The method that has been chosen amongst the available location systems (Krumm, 2010) as most suitable to collect the data is a camera, following the paradigm of computer vision. Alternative methods like calculating the number of people from smartphones present or using other sensors on the field proved to be much less cost effective.

As far as the technology of computer vision is concerned, YOLOR (You Only Look One Representation) (Wang et al., 2021) has met with all of the authors criteria, because it is among the fastest and most efficient technologies, it works in real time, it is compatible with existing equipment and, last but not least, it is available and relatively easy to learn and implement (repository Wang, 2021). YOLOR brings together implicit and explicit knowledge and constitutes a unified network with the goal of multitasking (Figure 5). Explicit knowledge refers to normal learning, which stems directly from the information which is being observed. Implicit knowledge refers to subconscious knowledge that utilizes prior knowledge or experience to recognize things and situations.

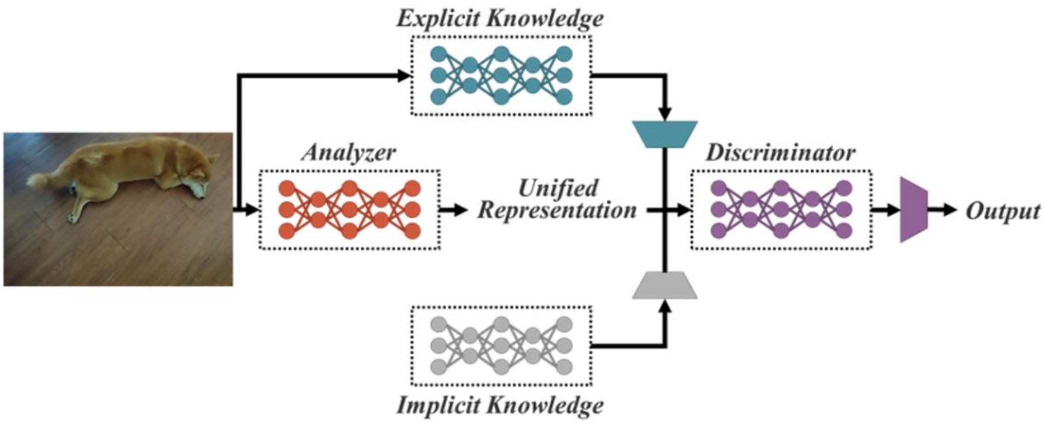

Figure 5: YOLOR use of Explicit and Implicit Knowledge

According to its creators, the introduction of Implicit knowledge into the model increases the efficiency of the methodology (AP: Average Precision) and makes YOLOR as efficient as any other modern object detection methodology (Figure 6).

Method	pre.	seg.	add.	AP^{test}	AP_{50}^{test}	AP_{75}^{test}	FPS^{V100}
YOLOR (ours)				55.4%	73.3%	60.6%	30
ScaledYOLOv4 [15]				55.5%	73.4%	60.8%	16
EfficientDet [13]	✓			55.1%	74.3%	59.9%	6.5
SwinTransformer [10]	✓	✓		57.7%	–	–	–
CenterNet2 [26]	✓		✓	56.4%	74.0%	61.6%	–
CopyPaste [6]	✓	✓	✓	57.3%	–	–	–

* pre. : large dataset image classification pre-training.
* seg. : training with segmentation ground truth.
* add. : training with additional images.

Figure 6: YOLOR performance in comparison to others (Wang et al., 2021)

The researchers demonstrate that incorporating Implicit knowledge does not incur additional overhead by adding additional training data or additional annotation. The YOLOR has been trained with the MS COCO dataset, because it can be efficient with many different tasks including object detection, instance segmentation and multi-label image classification.

Finally, after examining several different categories of public spaces, the author concluded that the one that covers all our requirements and serves business needs of crowd management is the public space of a mall, where people walk freely in all directions and there are mixed uses for shopping, recreation, entertainment, events etc..

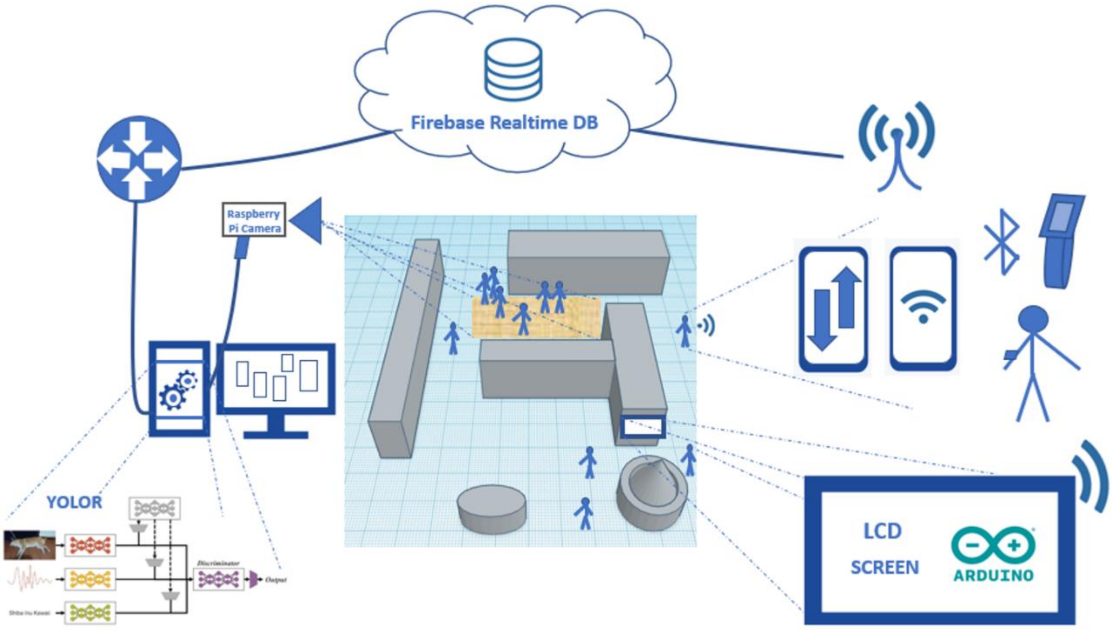

Figure 7: Design of the system of applications

Following the business objectives, the author has designed a system of applications that consists of four subsystems (Figure 7). First of all, there is the subsystem of data collection, where there is a camera or CCTV that captures frames from the public space in real time and send it to the subsystem for data processing.

Figure 8: Testing YOLOR in laboratory environment

The subsystem for data processing processes the data with the computer vision algorithm (YOLOR) and calculates the crowding levels of the public space (Figure 9).

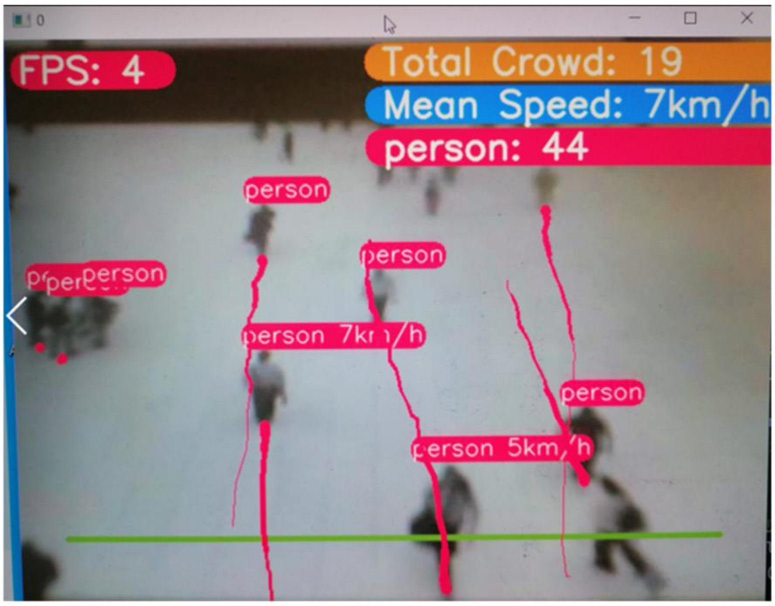

Figure 9: Processing of images in real time

The values of the crowding levels are then sent to the cloud realtime database (DB) and update it. Finally, there is the subsystem for the smart feedback, which is connected to the realtime DB and gets notifications when there is a change in the values of the crowding level. The smart feedback is implemented in two different forms. The first implementation is a smartphone application (Android) that connects to the realtime DB and fires notifications (changing colors, sounds and vibration) according to the levels of crowding in the public space.

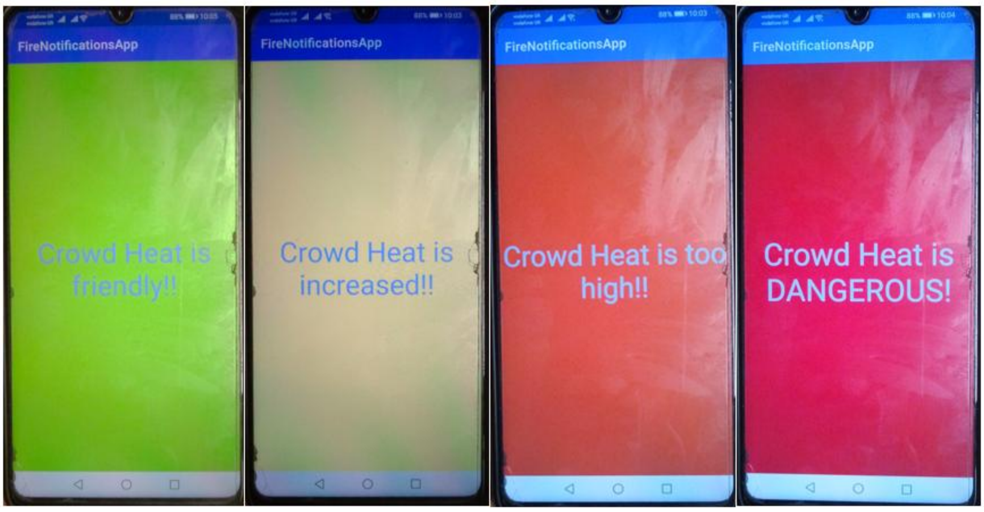

Figure 10: Smart feedback in smartphone

The second implementation is a prototype of a smart screen (LCD I2C, 20X4) connected to the realtime DB through WiFi (NodeMCU, Node MicroController Unit) that shows messages according to the different levels of crowding in the public space. In real life this smart screen could be a video wall inside the mall that would inform the visitors with suitable messages about the mobility and safety conditions in the spaces of the building.

Figure 11: Smart feedback in the smart screen

At this point it is best to mention the main assumptions for the project. First of all, some of technologies and tools used in object detection and tracking (Figure 12) are not mature enough and as a result are not suitable as enterprise solutions.

Figure 12: Logos of tools and libraries used

Moreover, the precision of prediction (coincidence) in the specific implementation was set at a low rate (possibility less than 50%) in order to have more detections. The tests were made in a laboratory set, taking video over video and it has not been tested in the real setting of a public space in a mall.

Opportunities

Communication and IoT technologies as we have presented so far can become the key drivers for change, transforming the physical public space it into a smart ecosystem. One way to accomplish this is to exploit the data derived from the physical public space itself and to return it to its users in the form of a new generation of information rich services and applications. These applications, apart from achieving different kinds of business objectives, can enrich the experience that each individual gets from the public space (Kapenekakis, 2017) in a way that the smart public space can win back the trust of its users and create new stronger ties with them. Even among the users of the public space new innovative applications and services can empower the feeling of belonging and participation and to strengthen the motivation they share for communication and interaction. If the public sphere and the public space have in essence the same meaning (Sennet, 1999) provided that there is a minimal degree of social connection and cohesion within them, the "smartization" of public space with IoT technologies can contribute to achieving this social cohesion and re-activating people's interest in public space with the help of data, application and service, which can attract the user's engagement. In this context, new opportunities are emerging not only for the public sphere, which in recent years has experienced degradation due to social distancing and the parallel development of the digital public sphere of social media, but for the overall upgrading of the role of public space.

Apart from a new relationship between the public space and its users, the business objectives for mobility, safety, quality of life, social services, education, entertainment poise new opportunities for the application and UX designers, human computer interaction specialists and software developers in order to produce new pervasive services and applications. Interoperability between applications of similar business function is a major component of the new pervasive ecosystem that offers user friendly and seamless services to the individual.

Context- aware computing (Schilit & Theimer, 1994) consist another field of opportunity for the smart public space applications because it includes the exploitation of location information in order to adapt and make decisions according to location of use, the collection of nearby people and objects, as well as the changes to those objects over time. Overall, the environment context- awareness in Ubiquitous Computing comprises 3 main types: the physical environment context (based on physical world dimension or phenomena, such as weather), the human context (social context, activities, user experience etc) and the ICT context of virtual environment context (based on services available in the distributed system, locally or remotely), (Posland, 2011).

Challenges

The "smart public space" as we have described it in this paper faces the challenges of the IoT technologies that enable it. The general IoT Challenges that consist are improving Availability, Reliability, Mobility, Performance, Management (manage the Fault, Configuration, Accounting, Performance and Security (FCAPS) of these devices), Scalability, Interoperability (Al-Fuqaha et al, 2015). In terms of information security, the main challenges fall into the following categories: a) access control, b) privacy, c) policing, d) trust, e) mobile device security, f) middleware assurance, g) confidentiality and h) authentication. From the challenges above, we should especially emphasize on the ubiquitous nature of IoT that should always be met with a high quality of service which is critical for both service availability and user trust.

Additionally, the heterogeneity of the IoT environment, with the coexistence of too many smart objects and applications with different characteristics is another challenge which makes it very difficult to implement good practices to comply with adequate Privacy, Integrity and Availability in relation to the security of user data. Especially personal data protection in the public space is a very sensitive mater and should always be a first priority for the application designers, developers and administrators. Public Spaces differ from one another and one smart application designed for one public space can have unwanted effects if it is used to another Public Space without suitable adaptation (Business/ Feasibility study, Risk assessment, Data Protection Impact Assessment- DPIA, etc.).

The implementation of AI into many applications of the “smart public space” brings new challenges about the limits for its responsible use. The new AI regulation of the EU, the group of 20 Artificial Intelligence Guidelines (G20) of the Organization for Economic Cooperation and Development and its General Principles «Human G20» should be taken into account to draw the levels of risk in every new application that uses AI and to protect the interests of the users. In particular, sustainable development and prosperity, transparency and clarity, reliability, subject protection and security and accountability are the core principles to follow for AI. These principles empower the IoT which, in order to succeed in its role, requires international cooperation between companies, mobile telephony and internet providers, governments and also the users themselves to provide uninterrupted services with quality and secure features. The trend that is forming even among technological giants is the corporate responsibility of the technological organization to meet social responsibility and the sustainability of technological applications, positively activating the reflexes of society, leaving a positive imprint on the progress of people and societies.

Building context- aware applications (Schilit et al., 1994) has to deal with a significant aspect of this emerging mode of computing that is the constantly changing execution environment. This naturally consists a big challenge for IoT application designers and developers since the user location instance is mobile and is changing together with the user. In addition, many elements and factors can be regarded as relevant to the context, such as lighting, noise level, network connectivity, communication costs, communication bandwidth, and even social situations as well as context can also include the identities of the people around the user, the time of day, the season, the temperature (Brown et al., 1997) or even the user’s emotional state and focus of attention (Dey, 1998).

Conclusions

The present paper researched the ways that communication and IoT technologies can collaborate in making feasible the vision of "smart public space". More specifically, one main result of the paper has been to demonstrate how IoT technologies can be designed, configured and applied to a public space with certain characteristics and potentially transform it into an information richer and safer to use social and communication environment. We examined the literature and we demonstrated a case study of a system of applications, which is specially designed for the "smart public space" and combines in real time object detection methodologies and AI, wireless and mobile technologies, as a proof of concept that business needs such as mobility, safety and experience can be met by implementing suitable IoT technologies and communication.

Furthermore, another result of the paper has been to contribute in a better understanding of the opportunities and challenges for communication within the domain of "smart public space" as one of its enabling forces. Finally, since communication and IoT technologies are two main drivers of transformation for the "smart public space", this paper conveys the expectations and aspiration for a physical public space that is friendly, inviting and worth living, has self-confidence and offers engaging and potentially life-saving applications and services for its users.

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