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Design of Service-Oriented Pervasive System for Urban Computing in Cali Zoo (OpenZoo)

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***Abstract*—**The increasing popularity of wireless technologies and mobile computing devices has enabled new application areas and research. One of these new areas is pervasive systems in urban environments, because urban environments are characterized by high concentration of these technologies and devices. In this paper we will show the process of pervasive system design in urban environments, using as use case a local zoo in Cali, Colombia. Based on an ethnographic studio, we present the design of a pervasive system for urban computing based on service oriented architecture to controlled environment of Cali Zoo. In this paper, the reader will find a methodological approach for the design of similar systems, using data collection methods, conceptual frameworks for urban environments and considerations of analysis and design of service oriented systems.

***Keywords*—**Service Oriented Architecture, Urban Computing, Design of pervasive systems for urban environments, PSP Design Framework (Public Social Private), Cali Zoo**.**

I. Introduction

THE vision of ubiquitous computing of Mark Weiser [1] where the computer disappears like it is conceived currently and it is replaced by a distributed computational environment of hundreds or thousands wireless and mobile devices that are cheap and easy to use, has been affecting the future perspective that it is has of home, companies and cities computing [2]. Is in this last scenario, where urban computing focuses, since it is indisputable that in the future cities the ubiquitous computing will change the way of how buildings, objects and people are understood, something similar to the way how electricity has influenced in the cities [3].

It is not possible to determine a priori the effects that will have urban computing on citizens, for some will be technologies that only divide and fragment people from a city, turning them into passive consumers. But moreover we could argue that ubiquitous computing can break the social barriers, enabling citizens to create more effectively interests communities and use technological tools that can improve their capacity of how to interpret a city like a "social creature" and not like a group of buildings and objects. For this reason, it is a challenge to the scientists, engineers, and designers think how to use ubiquitous computing, not only to offer competitive and efficient solutions, but to enable tools that inspire us to be more intelligent, more creative and more curious, to realize that intelligence resides into and among us [3, 4].

These needs are not exclusive of cities in developed countries, citizens from countries with emerging economies like Colombia face similar problems related with environment, poverty, security, education, health, and economy, among others. This is the fundamental reason that has encouraged the research group to develop this work oriented to design of pervasive computational systems for urban environments, expecting that it favors the future implementation of creative ubiquitous systems that can be adaptable in Colombian and Latin-American cities.

Under the consideration the need of start the research from controlled environments and size limited according to the experience of the international scientist community [5], the research group proposed to develop the pervasive system design in Parque Zoologico de Cali [6], a place reserved for the care of wildlife and the Colombian ecosystems, that does not subscribe it is vocation to the recreation and leisure, but that transcends like an ideal scenario to create communities and interactions that promote the responsible education for the environment.

In this paper, the reader first will find the current state of the design notions for pervasive systems in urban environments; later it is describe in detail the method followed to realize the design in Cali Zoo, also logic and physical architecture for the system to deploy in the Zoo. Finally, conclusions and the further work are discussed.

II. State of the Art

A. Definition of the Urban Computing

In [7], it is defined urban computing like a computing that it is developed in a new "third space" between the office and work. This "third space" is complex, as it must include the physical mobility and the social context interpretations. On the other hand in [8], it is define urban computing like the intersection between the mobile computing and social computing, specifying the urban interaction space like "urban atmosphere". A "urban atmosphere" is more than a simply public space that offers connectivity to a computing device

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like it occurs in the Wi-Fi hotspots. About this, Paulos and Jenkins define the concept of "urban atmosphere" as the next four urban subtopics: The place, the community, the infrastructure and the paths.

In [9], it is defined urban computing from the concept of city. For many people a city is a people collection, infrastructure and buildings, but in the other hand the cities can be perceived like historic and culture products that define customs, practices and flows. Thereby, Williams and Dourish define the urban computing research from the vision of a city like a multidimensional culture architecture that it is showed in Fig. 1.

The first dimension takes into account the familiarity degree and access that have the people in a determined urban space. In this case, we can analyze this dimension from two points of view: the public space is dangerous, aligned and full of strangers or it is a set of communities, together socially and joined that support their self in a mutual way. Paulos and Goodman in [10] explored the concept of "familiar stranger" proposed by psychologist Stanley Milgram. The idea of conceive that people interact in an urban space are neither strange nor friendly, but that can be citizens with whom they can interact without losing their anonymity.

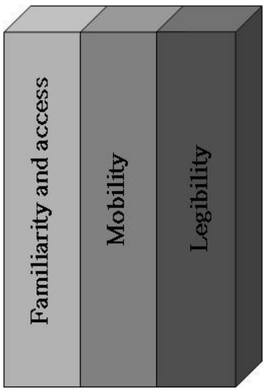

Fig. 1 Multidimensional vision of an urban space [9]

The second dimension is the goods, mobility, capital, information and people inside an urban space. This local mobility is embedded in a more global mobility, currently the firsts social networks like facebook.com, hi5.com or myspace.com are from discretionary mobility as it depends that the user has the leisure time to the network connectivity, in the future the social networks will be "always present".

The third and the last dimension is legibility, which is, the capacity that a citizen has to understand in a determined context what represents a specific urban space. If a person listen the sound of an airplane engine or sees an aircraft that is landing, it is clear that a citizen understands that he is near to an airport, which is called legibility. So, the more degree of legibility has a person of a place, a better availability will have for interact with others inside of that public space.

A more holistic approach of urban computing can be found in Cityware project [11] developed by many British Universities. Cityware has proposed that a city can be interpret it like a system [12] that has three layers: people, the spaces and technologies, that in sum create between them interactions, information and sensitivity to the location, like the ones that are showed in Fig. 2.

Considering the definition of urban computing from different points of view, we can conclude that the term urban computing can be refered to many aspects, that it is possible that in the future can be confuse among a concept cluster related or derivatives that make imperceptible the real reason for this investigative trend, that it is to make cities a better place to live [3].

B. Research Areas of Pervasive Systems in Urban Environments

Fig. 2 shows some of the research areas of major interest to the development of pervasive systems in urban environments by the international scientists' community.

Based on this integral view of urban computing, the research group executed the pervasive system design for the urban environment of Cali Zoo approaching different areas like the human computer interaction, the spatial and transpatial social networks, the mobility, the urban encounters and the localized services.

C. Considerations of the Pervasive System Design in Urban Environment.

Each city is unique by multiple complex factors, this reality analyzed from the systemic point of view, makes necessary regard the pervasive system design for urban environments like a research priority for the develop of future cities. Many researchers have been conducted in an isolated way in the design of the particular components of the pervasive system for an urban environment: People [14], Technology [15] and Spaces [16].

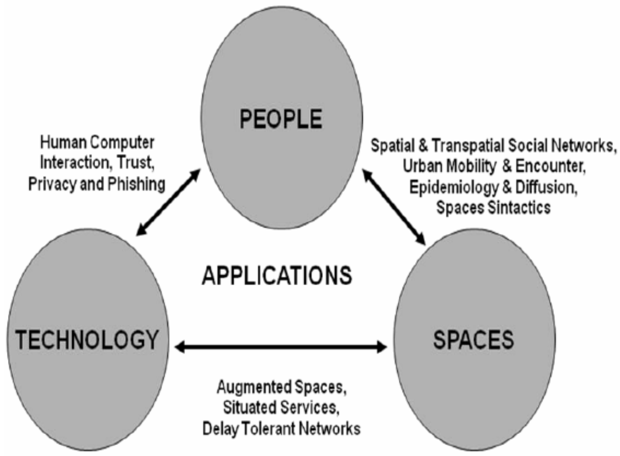

Fig. 2 Research areas of pervasive systems in urban environments [13]

However, in [17] the three components are integrated with the objective of offer a more holistic methodological proposal, this include a collection of characteristics and specific metrics that can be used to evaluate and interpret an urban pervasive system, equally an observation, analysis and simulation method is defined that can be used to study the system.

Most of research about pervasive system design direct to urban environments has been made by experience or tests developed in limited areas during short periods of time [5]. Due to the limited knowledge and the few experience of similar projects in Latin America, the research group proposed to develop a design in the same controlled conditions but with the vision to use this pilot for future investigation in bigger city areas and in longer time periods. For that reason they consider the use of the framework PSP (Public Social Private) proposed by Vassilis Kostakos [18], a conceptual model that was tested on a large scale urban stage in the Cityware project [5,11].

The conceptual architecture of the PSP framework is based in a two dimension matrix: The system privacy degree vs. the three principal aspects of the systems in urban environments (Architectural space related with the physical environment, interaction space related with technology and the Information space related with people). In the Fig.3 it is show the PSP framework matrix which is consistent with the results in [5] and [17].

III. Analysis and Design of the Urban Computing Pervasive System Direct to Services

According to the state of the art of urban computing pervasive system design, the research group decided to conduct an ethnographic study of social research based on the observation of Cali Zoo visitors during 2008 summer to determine the system requirements. Then, based on data collected, the conceptual PSP framework was applied to the urban environment and finally we used the classic cycle of analysis and design oriented to services for sketching the urban pervasive system.

A. Ethnographic Study of Cali Zoo Visitors

The Research Centre of Social Studies (CIES) of Icesi University led the development of an ethnographical study of Cali Zoo visitors, using two methodological techniques. The first research tool that was using it is typical of the ethnographic method, which includes observations inside the Zoo, the application of depth interviews and focus groups with the staff and visitors. The second tool was survey, of quantitative type, under application of survey to visitors.

The study focused on the analysis of three cultural dimensions of the urban space to intervene and:

- Sociodemographic Visitor information: Age, scholarship, origin, socioeconomic stratum and occupation.
- Visitor perceptions about the Zoo: Number of visits, motives or interests that prompted the visit, time of visit, tastes for exhibitions, preferences according to types of animals, habitat, among others.
- Use and possession of technological resources for visitors: cell phones, cameras, VCRs, MP3/MP4 players, internet, social networks, access to broadband networks, and the Zoo TV program.

Overall, the research group found in the visitors wide and open expectations to the integration of the technology in the Zoo's space. On the opposite side, some of the staff said that they are concerned that the urban pervasive system distracts the attention of visitors of enjoying the real experience of the park, by making use of artifacts or technological devices. Thus it was established a set of conceptual requirements that were use for the urban pervasive system.

B. PSP framework use for the urban pervasive system

According to the methodology proposed by Kostakos in [18] we made the following activities:

- A checklist of all the present artifacts in the urban stage to intervene.
- A classification table of all the artifacts according to the framework matrix (Fig. 3) and its relation with the citizens (one to one or one to many).
- We made instance diagrams by each artifact and its interactions.
- The artifacts were organized by subgroups. In the Zoo case was considered that natural grouping is given by the classification of animal species, for example: amphibians, felines and primates.

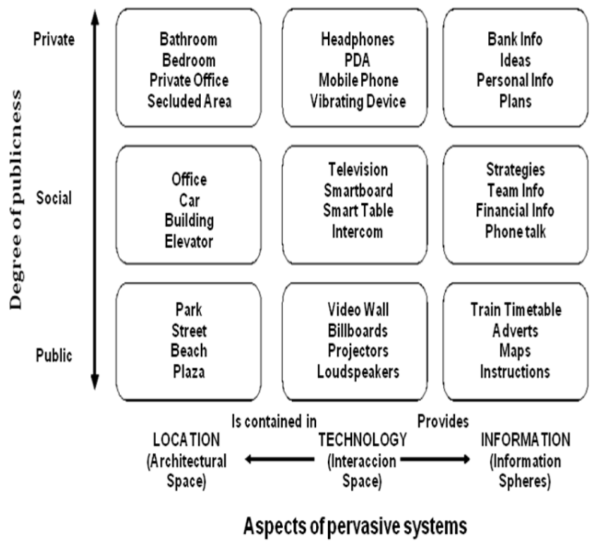

Fig. 3 PSP Matrix framework (Social Public Private) for conceptual design of pervasive systems in urban environments [19]

- Finally, an instance diagram was proposed according to the methodological decision based on the PSP framework, among which one can find: change the used technology, redesigning the physical space, relocate the artifact or reconsider the connection between the artifacts.

C. Designing Considerations for a System Oriented to Services

Service orientation is not a technology, but it is a wide philosophy or paradigm. It includes back-end scenarios like telecommunication services, and high level scenarios like business process and web services [20]. Service-oriented architectures are designed for reuse, providing the possibility of changing parts of a system without re-deploy. For this reason the research group decided to consider the pervasive system from an architectural style oriented to services, as the fundamental objective is that the system's software platform can be used in other different urban environments of Cali Zoo.

Several projects have addressed the use of architectures direct to services for the urban pervasive system design [21 – 24], for example in [21] is showed a service-oriented middleware called MobiSoc that posed an architecture that offers interactions between the people-space urban environments. This revision has revealed that there are three main trends in these service-oriented projects: systems focusing on the location, systems focus in social contexts and systems focusing on sensors.

Based on work related the research group proposed to design a pervasive system direct to the urban atmosphere capable of supporting intelligent environments that provide location-based services and interaction with sensors within a social context (direct to the citizen).

This project integrates the potential of a service-oriented architecture with the urban pervasive system development. This requires that you define the services that the software platform will provide, thus like clarify what will be the orchestration of the services that will be integrate and configure. This architectural style will allow that the different services can be reused in multiple applications depending in the context. For the definition of these services it was taken into account the adjustment and the interaction of the citizen with the system.

Using the conceptual results derivative from the ethnographic study and the PSP framework application to the urban environment, we applied the basic cycle of analysis and design of a service-oriented architecture [25].

IV. Logical Architecture

Taking into account design of system described in above section, the group of researchers proposes a logical architecture for this project called OpenZoo, which can be applied to other context to higher scale. Fig.4 shows logical architecture of OpenZoo.

Logical architecture includes five main components:

- **A service component** that is responsible for orchestrating and store services available in the system.
- **A localization component,** which identifies the localization of citizen through of different wireless networks technologies.
- **A multimedia component**, which enable the asynchronous communication and storage of multimedia contents.
- **A social context component**, based on community theory and social networks, enabling identification of different social contexts where citizens will move on.

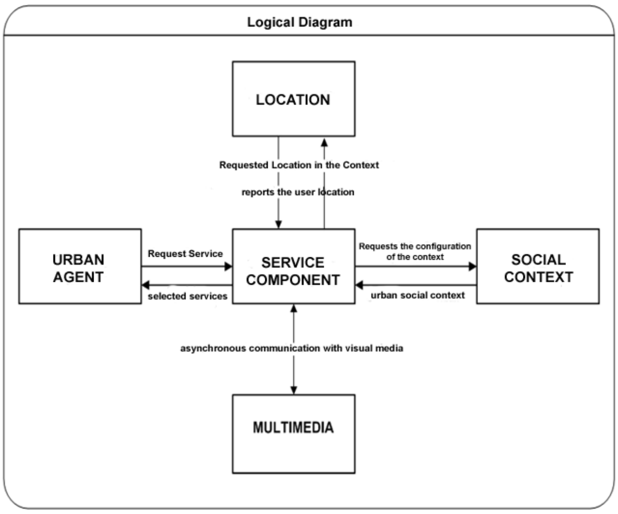

Fig. 4 Logical Architecture of OpenZoo System

- **An urban agent**, who interact with citizen, enabling characterization of individual, trough of register and configuration of user profiles, with them will be able to access to customized preferences.

To complement the logical architecture of system, it was design a diagram representing urban atmosphere [8] like shows in Fig. 5, which generates the social relationships present in the Zoo.

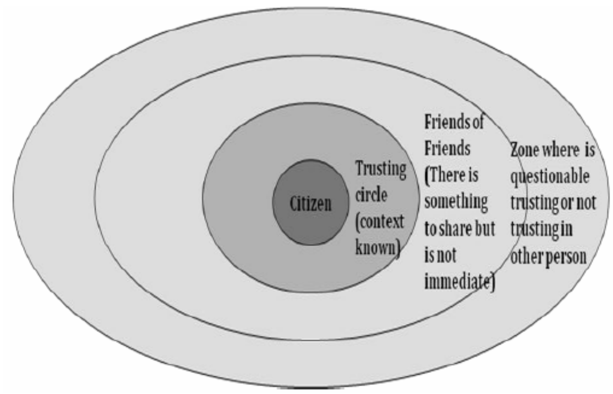

Fig. 5 Urban atmosphere present in OpenZoo system

V. Physical Architecture of System

Taking as reference logical architecture described in section IV, the researcher group has proposed physical architecture of urban pervasive system, which is detailed in Fig. 6. Physical architecture of system includes:

- Back end of system oriented to services, which includes platform Web and mobile server, localization engine and multimedia server.
- Component of social context which offers characteristics of profile, community, contacts and interaction tools.

This component can convert itself in engine of analysis and test of data obtained of citizens.

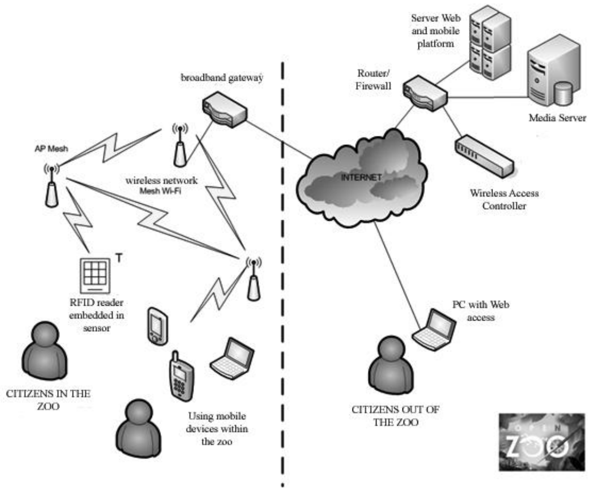

Fig. 6 Physical architecture of OpenZoo System

- The urban agent has three interfaces with citizens. First one is trough of a Web 2.0 platform. Second one is trough of social mobile software for Smartphones with Wi-Fi connectivity. Third one trough urban sensors that includes RFID (Radio Frequency Identification) readers and artifacts for citizens who has RFID tags embedded. Fig. 7 shows an example of one of urban sensors designed to primates section of Zoo.
- From the results of ethnographic study, we found that a better way to reach most of the visitors was to use a simple device based on RFID reader and a device hidden on a urban sensor. The selected "sensor" was a monkey located in monkey's area.
- A Wi-Fi network infrastructure, based on mesh topology which offers flexibility and more coverage into Zoo Park, and coverage to the mentioned urban sensor.

VI. Conclusion and Furter Work

Perhaps the most important result for the project was the ethnographic study, that show the develop team that the use of mobile technologies like Smartphones was not appropriate for the target of the project. From this premise we redesign most of the system, with the results shown.

The execution of pervasive system design for urban environment in Cali Zoo has been important for research team to involve it in a new domain or scope of application of ubiquitous computing and we hope that it has a great impact in citizens and cities of future.

Active participation during the project, of researchers and professionals in different fields of knowledge; such as sociologists, anthropologists, biologists, social communicators, designers and engineers discovers need of advances in dynamic methodologies, multidisciplinary with social responsibility to design of urban computing pervasive systems.

During the research work related to designing pervasive systems for urban areas, we found that although there are several methodological proposals and design frameworks, most of these are conceptual and are not easily applicable to the analysis and design of software components services oriented. This makes the design work is wasteful and expensive for any urban pervasive system to be developed.

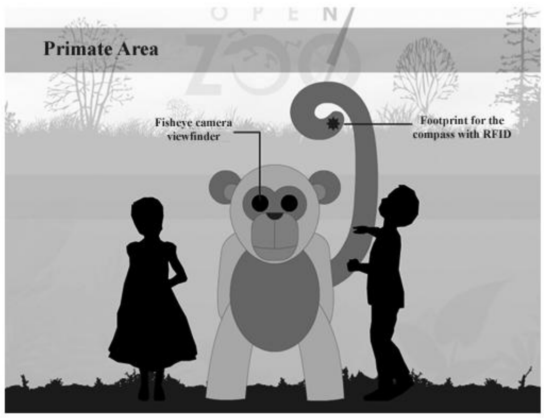

Fig. 7 Physical architecture of OpenZoo

Moreover, for data collecting and requirements of citizens in the intervention area were used classic techniques, associated with ethnographic social studies.

These tools allow determining important requirements, such as the need of a pervasive system including for citizens of different economic conditions and ages. From this requirement and its implementation framework in the PSP, were designed urban sensors, and artifacts with which it, people will interact with RFID technology. This design is considered more useful and inclusive than other alternative systems based on Bluetooth and Smartphones.

However, taking in account what was mentioned recently in [17], it is clear that these studies are expensive, static and don't represent accurately the metrics required for a pervasive system of an urban environment. This has motivated to research group for propose projects to apply techniques for collecting and validating social settings with a high degree of observation in multiple scenarios and emerging as the Living Labs that have generated great interest in Europe and USA [26-28].

Taking in account similar projects, it is remarkable to find that pervasive system OpenZoo contains a holistic view of the urban environment, which includes three components: people, places and technologies. Also, we addressed a design that includes the three trends in this type of project as OpenZoo is a location-oriented system, sensors, and social contexts. Thus the research team hopes that the pilot proposed in Cali Zoo, will enable to have new projects and experiences on a larger scale in less controlled areas in cities in Colombia or Latin America.

At time of write this paper, we are beginning pilot test in the zoo, and expect to have feedback from users.

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