User-oriented System for Smart City approaches

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Abstract: The SMART CITY is an important field for ubiquitous computing (UC), ambient intelligence (AmI), connected vehicles (CV), and the User Interface approach. Data vitalization related to in-city data collection and their appropriate diffusion to city actors (private and professional) and their services (applications) is the main issue. In the context of Hotspot-based Internet, Location-based services and Internet of Things, we study User-oriented systems with four typical variants related to transportation and user’ behavior: a dynamic lane allocation system, a system for urban goods delivery, bus shelter-based communication, and street and store consumer adapted guidance and advertising.

Keywords: ambient intelligence; ubiquitous computing; data vitalization; middleware; location-based services; in-environment HCI; contextual mobile learning; dynamic lane allocation; urban goods delivery.

1. INTRODUCTION

In recent years the concept of “smart cities” has emerged to describe how investments in human and social capital and modern Information and Communication Technologies (ICT) infrastructure and e-services fuel sustainable growth and quality of life, enabled by wise management of natural resources and via participative government.

In Smart City systems there are two extreme approaches: 1) Opportunistic systems allowing access to collected information and its “vitalization” by integration – interaction – aggregation in a non-predetermined way. 2/ Well-defined systems able to solve identified problems. While in our international China-France academic research project we study these two approaches, in this paper we focus on explaining four typical Smart City systems, the goal of which is to solve precise problems:

- More appropriate individual and collective human transportation,
- More appropriate traffic management, avoiding congestion by better allocation of traffic lanes,
- More appropriate goods delivery to professionals (shops and companies) and private individuals, and increased traffic fluidity.
- More adapted information systems allowing different forms of shopping (e-commerce, drive picking, after payment home transportation, and physical shopping) and the associated assistance via street and store profiled guidance and advertising.

Before providing a detailed description of our different systems, the next section gives an overview of related works. We then present the main basic techniques that we use.

Fig. 1. Smart-City system architecture.

According to Z. Xiong (2012), the “Smart City” principle in opportunistic perception is based on the concept of “Data Vitalization” (Figure 1). The idea is to give data life, to combine the separated data by avoiding information islands, to build a combination between each type of data, and to increase utilization of data.
In another extreme perception, based on precise demands to be solved, the system architecture is the same, but diversity and “vitalization” are not the main goals. In this case, direct usability, reliability and performance are more important. In our case, we studied four precise situations characterized by appropriate communication and collaboration between several categories of users (private and professional), their vehicles and corresponding services. These four systems could be integrated into a single system, but for the time being this is not our priority.

2. RELATED WORKS

According to the Smart City definition, “a city can be defined as ‘smart’ when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory approach”. In our four fields (better human transportation, better goods delivery, better fluidity of circulation and better citizen information and assistance in everyday life), multiple projects have emerged. We shall mention only a few of them. In the field of human transportation, the interesting work of MIT (2009) paved the way to proposing digitally equipped bus shelters. As we will show, for us this work was the starting point of our contributions in this field. In the field of goods delivery, several projects at French national level and at European level contributed to improving delivery conditions in relation with traffic implications and customer satisfaction (Citylog, 2013). In the third field, regarding appropriate sharing of limited space for several transportation media (individual cars, buses, trams, trolleys, and priority vehicles), multiple studies have been conducted throughout the world with more or less physical, mechanical and ICT based solutions (Nouvier, 2007). One of these concrete experiences was conducted in Lisbon (Viegas et al., 2004). Culture, tourism, sport and shopping can also be assisted by ICT ubiquitous computing and AmI.

3. MAIN PRINCIPLES

For all our four systems, the main principle is to propose an architecture that can combine all participating users (private and professional, active and passive, producer and consumer) and vehicles involved in the environment, as well as the different objects situated in this environment and the associated services (David et al., 2011c). This architecture complies with the structure explained generically in Fig.2 as well as specific behaviors described later on.

From the transportation Smart City view on a larger scale then the city (town, country or continent), information models for bus and truck communicating vehicles are:

- the actual truck: its technical state (incidents, accidents, overhaul, maintenance);
- the truck on the road: dynamic behavior, communication with the infrastructure, etc.;
- the truck and its crew: driving time, driver management, hotels;
- the truck and its load: optimization of journeys, cargo management and all logistics

Fig. 2. Our context-aware communicating vehicle system.

In the context of road transport of the future, as the ongoing work shows, a truck benefits or will be able to benefit from different connections allowing it to communicate with:

- the transport infrastructure, providing it with varied information about the road that can be either static (curving, turning) or dynamic (due to ice, traffic jams, diversions or accidents);
- the satellite, allowing drivers to remotely monitor their driving (speed, fuel consumption and stops), know their itinerary and geographic location, communicate with their logistical base, collect information concerning the state of the vehicle for maintenance or in the case of breakdown;
- vehicles in the vicinity going in the same direction (in front or behind) with a view to synchronizing driving (speed adaptation, communication of changes in trajectory and braking), which can ultimately lead to implementation of a “virtual train of vehicles” in which only the first driver will be active, the others maintaining a passive watchfulness. In this case other drivers can intervene to take control of the vehicle only in the event of a problem (Chauffeur2, 2009).

Exchanges can be characterized in the following way:

- commercial exchanges between the customer, the transport company and the driver;
- company management exchanges between the transport company, the driver and his truck;
- exchanges of truck management information between the maintenance services and the truck, with the participation of the driver;
- driving exchanges between the driver, his truck and the services that enable him to organize and manage his trips while respecting safety, efficiency and profitability guidelines.
Fig. 3. Truck information system.

For us the Smart City is a real augmented environment allowing ubiquitous computing in which mobile users can access mobile web and location-based services. Ubiquitous computing (UC) and pervasive systems are major evolutions of information and communication technologies (ICT) allowing new applications in everyday life. As Mark Weiser (1991) predicted, UC focuses on the integration of technologies into daily life with the aim of binding the user, environment and technologies as one. The goal of UC is to eliminate the utilization restriction obliging users to access the IT system only with fixed or portable computers and their classical graphical interfaces (GUIs), with WIMP style and devices (e.g., screen, keyboard and mouse). On the contrary, the wearable computer allows users to act in mobility and in the context related to the real environment. This real environment can be augmented consciously to support the relationship between real and virtual (digital) worlds. The works of Wellner et al. (1993) and Milgram et al. (1995) are pioneer works in the field of augmented reality environment. We characterize our work by three acronyms (David et al., 2010): MOCOCO (MObility, CONTEXTualization, and COOperation), IOD (Internet Of Data) and IMERA (French acronym for Mobile Interaction with Real Augmented Environment).

Real environment augmentation can be more or less conscious. Recognition by the IT system of objects, actors or situations of interest can occur without markers known as passive and unconscious augmentation or with the use of passive or active markers. Recent years have witnessed a large number and variety of marker-based interactions: CyberCode, QR codes, RFID, AR-Toolkit, to name but a few. In this context of mobility we need innovative wearable interfaces allowing users to interact in an appropriate way. Our goal is to study a new approach to mobile web and location-based services (LBS) for communication / collaboration. Classical web communication is worldwide: a user can communicate (access, consult, update, etc.) information that is located worldwide. Conversely, Location-Based Behaviors function on the basis of geographical proximity of actors. Our approach is based on a physical hot spot serving as an accumulation point; a hub for thematic and social collaboration. Different actors can consult, publish or exchange information in relation with the location materialized by the hot spot.

4. MAIN TECHNIQUES

In our approach to the Smart City, we identified 6 main techniques required to implement it. The first technique is a context-aware middleware for ambient intelligence. The second is an appropriate user interface in relation with users’ situations (mobile, nomadic or static) and the relationship with privacy of information explained on large public screens. The third is Web 2.0 use, i.e., collaborative (wiki-based) surfing. The fourth is the internet of things, allowing object to object communication without human implication. The fifth is location-based services with multiple exchange configurations related to environment context. The sixth and last technique is contextual mobile learning as support of just in time mastering of these services and possibilities. In the next section of this paper we summarize these techniques, before briefly presenting four concrete applications.

4.1. Context-aware middleware for ambient intelligence

Our goal is to develop a context-aware middleware for ambient intelligence. This middleware is able to collect contextual information from a variety of interaction devices (data gloves, Wii Mote, etc.), techniques (gesture recognition, markers or object recognition, etc.) and sensors (RFID, QR codes, Kinect, etc.) and to use these contexts to provide the user with relevant information and/or services in relation to his/her tasks. 

The goal of this context-aware middleware (CMID) is to support building and rapid prototyping of context-aware services in ambient intelligence, which consists of various computational entities (Smartphone, computer and tablet) with appropriate UI devices and various sensor-based devices (RFID, camera, and marker).

Fig. 4. The architecture of CMID (Context-aware Middleware for Interaction Devices management).
CMID adopts an ontology-based approach for context modeling, and leverages Enterprise Service Bus (ESB) to deliver and manage user-centric context sensitive services. CMID is made up of four parts: Context Aggregator, Inference Engine, Context Knowledge Base, and Query Engine (Fig. 4). Its main services are:

- Sensor and actuator data circulation in a standard format (ESB based);
- Sensor data fusion: collect and convert information from sensors to OWL (we use ontology (OWL) for context description);
- Reasoning Engine and Context KB: check context consistency and deduce high-level context from low-level context;
- Context database: store context data;
- Context query engine: handle the query from the application.

4.2. In-Environment User Interfaces: A taxonomy

As we all know, in the late 80s and early 90s, Mark Weiser (1991) published a vision for the next generation of computers, which he termed as ubiquitous computing. In this context we propose three types of interface (Zhou et al., 2011) on the basis of the relationship with the environment: in-environment interface, environment dependent interface and environment independent interface.

1/ We define the **in-environment interface** (IEI) as an interface that is fixed in the environment. The nomadic user, i.e. the user without his/ her UI devices, can interact with the application (Figure 5).

![Fig. 5. In-Environment Interface (IEI).](image)

2/ We define the **environment dependent interface** (EDI) as an interface that is closely connected with in-environment information and markers (on a corridor wall, on a door, on the surface of an appliance or any other surface). This interface has the ability to provide intuitive interaction techniques, enabling it to recognize and understand the situation of the user and the real environment around him/ her.

![Fig. 6. Environment Dependent Interaction (EDI).](image)

3/ We define the **environment independent interface** (EII) as an interface without any contact with the environment. The user is the sole source of contextualization, i.e. he/ she can acquire information at any time and any place. What this means is that contextualization is carried out by the actual user by showing appropriate contextualizing markers to the webcam. These markers can be grouped on a grid and selected by finger, mask or by turning over the pages of a notebook. In addition, on his/ her own initiative, the user can project the menus, schedules, websites, videos and other information on a flat surface (the wall) in the environment or on a personal surface (a blank sheet of paper, or part of the human body). The user can move freely in his/ her working environment and obtain contextual information independently from the environment (Figure 7).

![Fig. 7. Environment Independent Interface (EII).](image)

We have designed and implemented a series of innovative interface prototypes, allowing the user to interact while moving with at least one hand free. These prototypes can be used in our systems: for in-environment interface in the case of bus shelter interaction, while others can be used in mobility by transportation professionals. Other actors and actuators can be added to take into account contextualization and LBS. In previous implementations we also used another device as a data glove. However it now appears that this device is obsolete. More classical user interfaces based mainly on the Smartphone would appear appropriate for basic users.

4.3. Web 2.0 - collaborative surfing

In the context of the Smart City, collaborative surfing allows different users to exchange information in real time on what is happening in the city from a social, cultural, sports, etc. point of view. Social networks are thus supported and allow groups to use them as they please.

4.4. Internet of things

The Internet of things allows static and dynamic environmental objects to communicate and update real situations. In environment interactive communication, user’s devices can inform the shelter on special needs as baby
carriage or wheelchair and the shelter can propagate this information to the concerned bus.

Fig. 8. Proxemic interaction (Greenberg et al., 2011) and information migration.

4.5. Location-based services

While Web 2.0 allows cooperation between actors located anywhere, hotspot-based communication / cooperation allows the addressing of a common reference point called hotspot or hub, which plays a particular role in their communication / cooperation (C/C). This approach creates a new behavior in C/C, by structuring and organizing the activities between actors in relation with this physical hotspot (Figure 9). The role of the hub (hotspot) can be either an important point of interest, i.e. physical location for a particular activity such as transportation, or a meeting point for a rendezvous or an intermediate point for a message destination. Communication can be established between a particular actor and the information panel on the hotspot, for effective advertising or a personal message in the form of a post-it, etc. (Figure 8). Such communication can also be destined for a generically addressed person, who is identified by his role but not personally, like the bus driver of the bus which the actor is boarding. In all these situations the hotspot plays an important role. We identified 8 basic communication / cooperation situations (David et al., 2011b):

1. Global interaction between initiator actor and www server.
2. Local interaction between initiator actor and hub server.
3. Local interaction between initiator actor and hub server with propagation to the final actor.
4. Local interaction between initiator actor and hub server with explicit consultation by the final actor.
5. Local public advertising sent by the servers or initiator actor to the Hub Public Screen, with possible propagation to final actors.
6. Local public advertising sent by the servers or initiator actor to the Hub Public Screen, with possible collection by final actors.
7. Local semi-public information sent by the servers or initiator actor to the Hub Public Screen, with possible collection by final actors.
8. Local private information sent by the servers or the initiator actor to the Hub Public Screen, with collection by final actors permitted by a received access code.

![Diagram](image.png)

Fig. 9. Hotspot based location-based services.

As we explain later on in this paper, bus shelters can form an appropriate hotspot for contextual location-based city services.

4.6. Contextual mobile learning

In a user centered environment, assistance with mastering of proposed services by new or occasional users is mandatory. We propose contextual just in time mobile learning services allowing newcomers to discover and progressively master these services. This service can address travelers, visitors and inhabitants, but also professionals in charge of repairing or maintaining city equipment (furniture, appliances) In this last case, appropriate UIs for professionals are based on EDI & EII (Fig. 6 & 7).

5. CASE STUDIES

We now present four concrete Smart City case studies, related to traffic management, goods distribution and pickup, public and individual transportation, and location-based services related to a public shelter and consumers in the street and store assistance.

5.1. Dynamic circulation lane allocation

“Dynamic circulation lane allocation” aims at providing a system designed to share circulation lanes dynamically between public and rescue service transportation (buses, firefighters and ambulances) and personal vehicle transportation in order to share traffic lanes appropriately in the context of traffic jams and lack of space (impossibility or inadequacy of static allocation of circulation lanes). When there are no buses, all lanes are allocated to the general public. When a bus approaches and on the bus driver’s request, the right-
hand lane is reserved for it. Once the bus has passed, the reserved lane is returned to the general public (Figure 10).

Fig. 10. Dynamic circulation lane allocation.

The system architecture for this application is explained in figure 11. Its goal is to collect in-environment information, communicate with active and passive users (and their vehicles), and take into account authorities’ decisions. In the street, sensors collecting traffic evaluation and specific demands from authorized drivers (buses, emergency vehicles, etc.) are able to transmit to the system observed situations. The system decides on the appropriate action, commands dynamically the position of vertical and horizontal signaling, and propagates the new system state to all users by appropriate media (radio, GPS, etc.) in order to inform them of expected behavior (use of reserved lanes for a bus, leave a lane which is now reserved for non-priority drivers, etc.).

Fig. 11. Dynamic circulation lane system architecture.

5.2. Loading Zone Management for goods delivery and picking

The goal of our goods delivery and picking system is mainly oriented towards ICT-based “Loading Zone Management” (David et al., 2011a). Our aim is to provide a system contributing to fluidity of circulation in downtowns by ICT-based loading zone planning. Just as for lecture and meeting room bookings, we propose to reserve loading and picking areas. Static provisional booking of loading areas is carried out by delivery company logisticians in order to create appropriate distribution trips (Figure 12). A corresponding goods delivery system architecture is explained in Fig. 13. A trip can or could be dynamically and in real time adjusted by the driver-deliverer (Figure 14) in order to take into account specific circulation problems (traffic jams, accidents, late arrivals, etc.). Communication between different drivers-deliverers (and their vehicles), as well as between the Delivery Area Booking Management system and driver-deliverer companies is mandatory.

Fig. 12. Goods delivery in the city problem modeling.

Fig. 13. Goods delivery system architecture.

5.3 Communicating bus stop

The “communicating bus stop” aims at providing a sophisticated form of communication between the transportation system and its users (David et al., 2011c). Users’ implication in the social life of the city is also taken into account. Mobile internet, location-based services (LBS) and Internet of Things (IoT) are the main concepts of this approach, and the bus stop is considered as an explicit hotspot supporting communication. Eight communication / collaboration situations can be used to create general or specific communication / collaboration in the context of social networks or individual / private communication.
This makes it possible to create different types of communication between the users (transported persons) and transport professionals (such as bus drivers) to communicate in advance special needs to the driver; and exchange information between the vehicle and the bus shelter (by IoT).

We studied these possibilities in-depth in (David et al., 2010). The bus shelter is not only used for public transport information, in which we propose individual exchange and information between the traveler and the bus driver in order to indicate special transportation conditions (diseases, bicycles, stroller transportation, etc.) but also for individual transportation such as hitch-hiking support (Figure 15) based on EDB (Electronic Display Board). Additional services can also be supported by the bus shelter (Figure 16), in order to support neighboring communication (shopping advertising, cultural and sports information, etc.).

5.4 Street and store consumer adaptive help and advertising

Up-to-date ubiquitous computing with in-environment distributed sensors, actuators and user interface devices are able to create an Ambient Intelligence environment in a shopping area. The main goal is to detect potential shoppers and propose them appropriate goods, i.e. goods in relation with their shopping profiles and identified present needs. To allow this, we need first to capture potential consumer presence by appropriate sensor(s), and then to study his/her profile and determine what kind of information it would be appropriate to present him/her with in order to intercept his/her attention. The first stage in this capture process occurs in the street. Data collected by the sensors provide the system with information about the potential consumer, data that can be more or less precise: a young man or woman at least, or a regular customer to the store, etc. In relation with this profile, the system could then display in the shop window an appropriate advertisement. In this shop window display, it seems important to display advertising information not only for one passer-by and potential client, but for several. The display strategy can be organized by applying the proxemic user interface policy, i.e. give more information to shop windows near located customer(s) and less to distant ones. It may prove interesting to take two additional behaviors into account: in-shop continuation of consumer tracking, in order to provide more precise information in relation to his/her movement in the store, and in-the-street movement, in-the-street walking and shop window watching. In the first case, increasingly detailed information can be given to the potential consumer in relation with his/her location in the store (suit, shirt, pants department, or kitchen furniture department) with detailed knowledge of his/her situation (just married, etc.). The system can collect, store and use the information collected from previous purchases in the store or elsewhere (his/her Facebook profile). In the second situation (in-the-street walking) it could be interesting to propagate the discovered profile of the potential consumer to other stores to allow them to use this information to provide him/her with increasingly detailed and appropriate advertising.
6. CONCLUSIONS

In this paper we briefly explained our view of the Smart City in the context of transportation and citizens’ everyday life. We gave the main principles and techniques used and presented four case studies. Our goal is to obtain a generic approach based on a reference architecture and services, allowing us to more easily take into account new applications permitting implementation of the data vitalization concept. A common background for this system is a MDA (Model-Driven Architecture) approach based on a design and implementation process and associated formalisms. We are not directly responsible for wireless network characteristics and performances for which we are not only users but also experienced consumers. We are, however, responsible for integration of the cloud computing approach to our problem in order to take it into account, mainly from the software architecture point of view. We are currently studying the impact of MANET (Mobile ad hoc networks) in this context leading to VANET (Vehicle Mobile ad hoc network) and to “Vehicle mobile cloud”, facilitating the exchange of information between vehicles driving around other vehicles.

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