Web Squared: Paradigms and Opportunities

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ABSTRACT

In this article, we explore the technical implications related to Web Squared paradigm. Representing an evolution of Web 2.0 that emphasizes the interaction between the cyber world and the real world, Web Squared contemplates the use of sensors to share huge amounts of data and foster the creation of new services. In this context, we analyze the different approaches and opportunities related to the use sensor-equipped smartphones to generate and distribute context related data both automatically and through appealing user applications (e.g., games). We discuss a general methodology to adopt when devising smartphone-based distributed sensing applications and explore both the issues and adopted solutions in this context. Finally, we identify unresolved technical challenges limiting the widespread deployment of Web Squared services, which deserve future research effort.

Categories and Subject Descriptors

A.1 [**Introductory and Survey**]; D.2.10 [**Software Engineering**]: Design—*methodologies*; H.1.2 [**Models and Principles**]: User/Machine Systems—*human factors, human information processing*

General Terms

Design

Keywords

Games, Mobile Sensing, Web Squared

1. INTRODUCTION

Sensor networks consist of autonomous and distributed sensors deployed to monitor context related environmental parameters. A sensor network is comprised of nodes, each of which can have sensing, computation, communication and even motion capabilities. In this context, many research work has been focused at devising reliable and decentralized solutions aimed at supporting services connectivity in such environments; yet, to date, these solutions have been generally limited to research purposes without any large-scale deployment [1, 2, 3].

Instead, the current popularity of smartphones is creating potential for factual market use of sensor networks. Indeed, a smartphone is a ubiquitously present mobile device and it generally embodies a large set of embedded sensors. Off-the-shelf devices have accelerometer, digital compass, gyroscope, GPS, microphone, proximity sensor, light sensor, and camera, which could be exploited to foster the rise of new applications based on sensing. In essence, the smartphone revolution is providing the opportunity to take past research on sensor networks and apply it to real mobile scenarios. Indeed, sensor-equipped smartphones can be used generate and distribute context related data both automatically and through appealing user applications (e.g., games), thus involving a potentially high number of nodes and generated data. This clearly provides both a very challenging context for new research and the opportunity for extremely pervasive services. Moreover, what is more interesting, is that the data generated by this pervasive smartphone network could be used not only to benefit the people possesing such devices, but also the other people in our Society.

The *Web Squared* paradigm is a direct consequence of the spreading of smartphones with embedded sensors and communication capabilities. These devices allow to extend the Web to everything that surrounds us. If previous, traditional applications needed human interaction to perform tasks, new sensing-based applications can perform context related actions, in a user transparent way. In general, in this context, applications based on *augmented reality* could automatically enrich the perceived reality with additional information of the subject object available through other information sources (e.g. Internet). In general, the *information shadow* of any object corresponds to any digital data related to that object available in any database. Nowadays, any object casts an information shadow which, if captured and processed intelligently, could be used to generate new pervasive services [4, 5, 6, 7, 8].

The data produced by sensing applications extends the notion of *collective intelligence*, that it is no longer only crowdsourced information, but it comprises also data automatically generated in real time, fostering new cascading applications and services. If comparing these sensor-enabled smartphone-based networks against the classic Web 2.0 scenario, generated data and services increment exponentially,

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rather than linearly, thus naming the new step in Web evolution “Squared”.

With this article, we aim to provide a technical analysis of Web Squared services based on smartphone networks. We discuss a general architecture to design a smartphone based sensing application and explore development issues and possible solutions. Finally, we identify unresolved technical challenges for the widespread deployment of Web Squared services that deserve future research effort.

The paper is structured as follows. Section 2 explains the common mobile application contexts and sensing paradigms, criteria used to identify pure Web Squared applications. Section 3 presents the design aspects of Web Squared applications, developing issues and few attempts of solutions that, unfortunately, do not completely solve those issues. Finally, Section 4 presents concluding remarks.

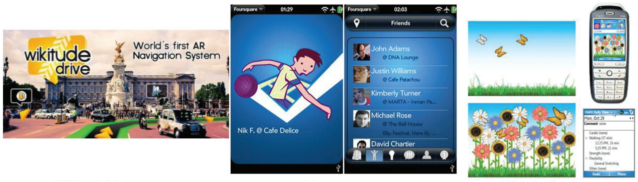
2. CONTEXTS AND PARADIGMS OF SENSING APPLICATIONS

The widespread availability and growing capabilties of mobile sensors-equipped devices such as smartphones have fostered the development of sensing applications in various contexts. Gaming is one of the most successful applications exploiting features such as augmented reality and sensor-generated data. Just to cite a few bu significant examples, *SpecTrek*, is a ghostbusters game that exploits GPS coordinates for geolocalization, *Sky Siege*, is a war game that uses gyroscope and camera to control a virtual helicopter, and *Parrot AR Drone*, which is a flying drone remotely controlled via Wi-Fi through the user smartphone (see Fig. 1).

Other appliances can be found in the transportation context. *Wikitude Drive*, is used to manage trips making use of augmented reality to show routes on display. Social networking applications allow to classify events and activities in which users participate: *Foursquare* permits to geolocate a users position or an event, classify it, and share it with friends part of its social circle. In the environmental context there are many applications which employ a feedback monitoring cycle aimed to prevent or limit environmental pollution such as noise, MSW (Municipal Solid Waste) and carbon monoxide. An interesting research work presented in [9] embodies a participatory urban noise mapping system to render noise maps in urban areas. Finally, another interesting application realm is concerned with health and fitness, in which the scope is to persuade, stimulate users to achieve personal wellness. Examples from this context are: *UbiFit Garden* is a game that stimulates the user to achieve personal health goals by detecting the amount of physical activity performed and linking it with results in a virtual garden (see Fig. 2).


SpecTrek Sky Siege Parrot AR Drone

Figure 1: Examples of gaming applications.



Wikitude Drive Foursquare UbiFit Garden

Figure 2: Examples of social applications.

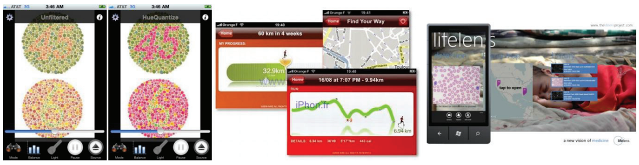

Dankam Nike+ Lifelens Malaria

Figure 3: Taxonomy of sensing applications by scale if sensing.

Several other applications that exploit the Web Squared paradigm can be devised. As an example, let us think of a travel application advising the best route based on real time monitoring of traffic congestion. This could be achieved by quick sharing and collecting speed data through our handheld smartphones. Augmented maps represent yet another example which can be created based on accessibility data transparently generated and shared by users to help people with impairments in finding the best routes for them [10, 11]. Other Web Squared applications could infer our status by sensing some context-related information, successively sharing with it with our buddies, letting them know our actions or publicize a certain event (e.g, a party, a meeting, an accident). Web Squared services could indeed be generated by collecting sensed and crowdsourced data.

Indeed, we can state that applications exploiting sensors and crowd can be classified through two criteria: scale of sensing and users’ involvement. Considering the sensing scale, we can identify three main categories of sensor-based applications: personal, group and community (see Fig. 3). A *personal sensing application* is designed for single individual users and results (often statistical) are displayed only to the subject user without sharing them. An example of personal sensing application is *Dankam* whose goal is using mobile phone camera to help people affected of color blindness in determining colors, or differences in colors, that would otherwise be invisible to them. Instead, a *group sensing application* is designed to collect data from a group of people, typically connected on social networks, successively sharing some kind of inferred information to the others. An example is *Nike+*, an application based on social contest which focuses on user wellness. Finally, a *community sensing application* collects data from a wide range of people and shares crowdsourced or statistical results. An example is *Lifelens Malaria*, an interesting application to analyze blood samples using the camera combined with a magnifying glass; it shares geolocalized points of infection to prevent epidemic spreading of malaria.

If we consider the direct involvement of users on data collection, we can group the applications into two classes: participatory and opportunistic. *Participatory sensing* requires that user actively collects and classifies sensor data. The problem is that these applications depend strongly on users' enthusiasm and willingness to act, meaning that if users do not use the application, no sensing can take place. As a consequence there is a lack of data, the added value necessary to sustain a Web Squared service. An example of this sensing category is represented by the serious game proposed in [12], which shows how a service can be designed to improve crossroad accessibility for blind people. The proposed application generates an augmented map with the position of known accessible traffic lights (i.e., those with audible signals) using users interaction in a Web Squared fashion. In essence, when the smartphone detects the position of a traffic light, it records an audio file and uploads it along with the associated GPS coordinates to a server. The server analyzes the audio file and detects whether an audible signal is present or not; this information is used to automatically update a database about accessible traffic light which has been adopted to generate Web maps as shown in Fig. 4.

Instead, *Opportunistic sensing* collects and classifies sensor data automatically without user interaction. This kind of application is particularly useful for community sensing because it does not need the active participation of users. However, the difficulty stands in devising intelligent algorithms able to autonomously sense and collect context-related information. Clearly, this problem is linked to the ability to efficiently use the smartphone's sensors and correctly interpret the scenarios based on the collected data. An interesting opportunistic application, described in [13, 14], tries to bring the P2P paradigm into mobile networks enabling automatic file sharing based on proximity between mobile users. The application uses network sensors to automatically detect the frequency of users' encounters so as to delegate a particular file search task only to certain mobile devices. In essence, physical encounters among devices, even if short in duration, are detected through smartphone's sensors. This information is then exploited to improve the efficiency of the proximity-based file sharing application.

We define an opportunistic community sensing application as a *pure Web Squared application*, as we consider it compliant to the Web Squared paradigm. Indeed the automatic sensing is exploited to collect data from a wide range of devices so as to generate interesting results and innovative helpful services for community.

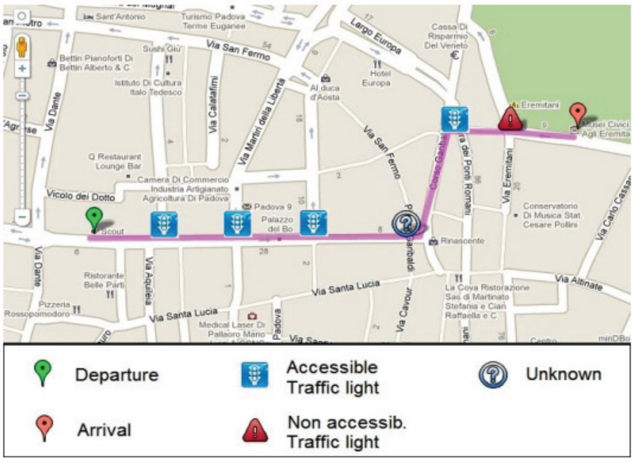


Figure 4: Serious game for crossroad accessibility.

3. DESIGN OF WEB SQUARED APPLICATIONS

Devising an application that performs both sensor data collection and sharing is not trivial. Primarily, it is important that system architecture and application logic are adequately designed in order to achieve the application's expected goal. Clearly, this passes through decomposing the problem into subproblems addressed by specific layers (or modules) in the architecture [15].

These layers can be identified as shown by Fig. 5. First of all, the *sensing layer*, which necessarily lies on the mobile device, is responsible for collecting raw data from sensors. Instead, the *learning layer* processes these data and produces the results. To achieve this aim, this layer can use different solutions ranging from simple algorithms to more complex artificial intelligence techniques. This layer can reside in the smartphone, but its tasks could also be delegated to an external server as in the previously discussed application for detecting accessible traffic lights [10]. The *release layer* is used to display results to the final users; it could also be in charge of persuading the user to perform certain actions when considering participatory applications. In individual sensing applications, results are showed directly on the display and not shared. In group sensing applications, sensor data and even results are shared among the considered group of users, even through social networks. Finally, in community sensing applications, all possible means can ideally be used to spread information to the widest possible audience.

As stated before, the data collection phase is of paramount importance to Web Squared services. Data should not come only from local device sensors, but from all what surrounds us, therefore developers should put particular emphasis to cooperation and data sharing with and from other mobile devices, servers etc.

3.1 Design issues

Despite their attractiveness, sensing applications risk overloading the device and consuming the limited energy resources available. This would jeopardize the smartphones functionality whose primary function is receiving and making calls. Collection and classification of a large amount of sensor data, especially if done locally and in real time, require mobile devices with higher capabilities. Indeed, data sampling and processing make excessive use of computational resources. A critical design choice which has major impact in the energy resources is the sampling frequency. Frequent sampling, signifies constantly using mobile resources while achieving a more correct representation of the sampled activity. On the other side, a less frequent sampling might not be beneficial, as fewer data are collected but at the same time the energy resources are less stressed.

Moreover, if another service requires resources or a user concurrently runs another application, it could interfere with sensing. Frequent sensing requires complete support for multitasking and background processing. Concluding, yet another source of consumption is given by the transmission costs for sending and sharing data through a server or com-

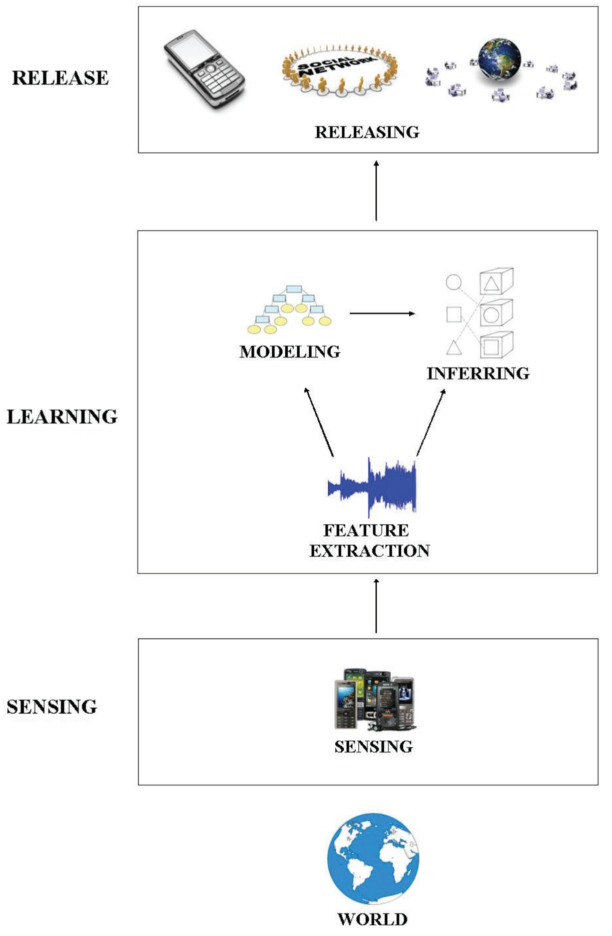


Figure 5: Layers composing a Web Squared oriented architecture.

munication platform in general.

During the development phase an important issue arises from programming into a device-specific platform. Most vendors offer Software Development Kits (SKDs), APIs and software tools, which do not offer low-level sensors control. For example, the Bluetooth API 2.0 in the Android platform allows programmatically instrumenting the device discovery and RFCOMM connections, but it does not provide direct control on pairing routine, service discovery on remote devices. Therefore, developers must use workarounds methods available elsewhere to gain control. Yet, another example is the sampling rate which in some platforms is unpredictable because it varies with CPU load. Third parties would need finer-grain controls to develop more accurate sensing. Programmers must also face the problem of heterogeneity of the development tools. Applications tied to Vendors-specific APIs, require porting into other platforms which is often a tedious and time consuming task.

Typically, Web Squared applications need to collect and share data only if mobile devices are in a certain context and sensing quality is not affected by the environment or users. Therefore, mobile devices should belong to specific user classes or behave in specific ways corresponding to those assumed and modeled by developers. Unexpected changes of the background environment or user's actions could compromise the quality of gathered data while external device interferences could invalidate the accuracy of collected samples. This problem is exacerbated by the continuous context variations even in unexpected ways. However, once these data have been collected, it is important to make use of algorithms that can produce the correct results even in presence of outliers or background noise so that the application proves useful to the users.

Even if sharing of data is crucial to the Web Squared paradigm, privacy issues arise. Indeed, a malicious subject that captured this sensible data could produce serious privacy problems using them to infer users' context and/or some personal data. Personal sensing applications are clearly much less exposed to this risk, as data collection and processing are performed locally. Group sensing applications are based on a trust concept in the buddy circle, so a user who shares information assumes that the communication channel is secure. In this case, the security issues regard *social engineering hacking*, in which attackers disguise themselves as friends or acquaintance alluding the victim, collecting social information by spreading malignant codes and phishing sites inside the buddy circle. Community sensing applications, the closest to the pure Web Squared paradigm, are the most exposed to this problem as information is shared with no control and without knowing with whom these sensed data is shared.

Clearly, researchers and developers should focus their efforts to ensure the integrity of data so that users can be encouraged to disseminate information; this way, the community could continue to benefit from Web Squared applications without any concern about security.

3.2 Proposed design solutions

There are different possibilities to address the aforementioned issues. For instance, focusing on resource consumption, the first intuitive approach regards the design of algorithms keeping in mind energy and computational constraints; this involves a wise management of sensor duty cycles as turning off sensors when inactive reduces energy consumption.

Using a minimal set of sensors is another possible solution, this as data processing is reduced even if this forces developers to mediate between accuracy and energy efficiency. An example is represented by [16], which introduces advanced location-based services to provide user context in indoor and outdoor environments. To preserve energy consumption this work proposes an event-driven technique in which only the accelerometer is in active state while other sensors are turned off until the inertial sensor detects user motion. While outdoor context is well defined by using GPS corrections, the indoor context (based also on Wi-Fi signal power) suffers from lack of accuracy.

Cloud infrastructures can help assist in data processing. Collected data can be sent to back-end servers that will take care of the analysis and will return the results. To minimize the energy cost of transmissions, which can be very high if the amount of data to send is considerable, data analysis can be divided in two phases. In the first, coarse grained phase, the features could be extracted from raw data in mobile device. In the second, fine grained phase, a more precise analysis could be made inside the cloud using only extracted features.

Table 1: Summary table of discussed works.

	Opportunistic sensing	Participatory sensing	Continuous sensing	Resource preservation	Adaptive techniques	Privacy
Ear-Phone	V		V	X		
Serious Game		V				
M2M Share	V			X		
LifeMap	V		V		X	X
LittleRock	V		V	V		
CenceMe	V		V	X		
SoundSense	V		V	X	X	X
SocialFusion	V		V			V

The most radical solution is to equip mobile devices with low power hardware. As argued earlier, the continuous sensing consumes a lot of energy because sensors are either in active state or idle state, never in sleep state [17]. Low power hardware can lead to an improvement in consumption up to three orders of magnitude, but it requires a modification endorsed by phone manufacturers to the existing phone platform architecture.

Regarding the classification of users' behavior and context, *Supervised learning techniques* are used to improve efficiency and effectiveness of machine learning algorithms. These algorithms permit to minimize training phase using user's supervision. Supervised learning is used in [18] to infer and share in social networks the presence of individuals using off-the-shelf sensor-enabled mobile phones. The technique is used during the training phase, permitting classification after feature extraction. This process is performed offline on a desktop machine to reduce computational costs, yet, this involves an energetic cost which is related to the transmission of generated behavioral models. Another example is represented by [19], which uses the smartphones microphone to model sound events and infer relative context. The supervised technique is used in this case to model the general sounds (voice, music or ambient sound), whereas an unsupervised adaptive classification is used to discover new sounds specific to the individual user. In particular when the application detects a new sound repeated over time proposes it to the user, who can then decide whether to ignore it or classify it creaing a new behavioral model.

Last but not least, the privacy issue is a crucial challenge as the Web Squared paradigm relies on wide data dissemination to produce services; this is possible only if providing an adequate level of security. Privacy-preserving data mining approaches are not sufficient to safeguard the security of the user data because there are several examples of reverse engineering, i.e., attacks that use portions of data (apparently safe and innocuous) to reconstruct the original pieces of information. In [20], the authors propose a system that exploits different data streams to gain knowledge about location and preferences, so as to perform the most appropriate action given the context when certain users are in proximity. To support the privacy of their system and data accuracy, the authors propose to use k-anonymity algorithms. This approach demonstrated to be effective, yet it does not protect a user against the possibility that data regarding her/him, generated by unprotected sensors nearby (managed by other users) cannot be intercepted.

4. CONCLUDING REMARKS

Web Squared applications offer new ways to use smartphones through innovative services based on participation. The possibility to exploit the local data and data of other users can enrich our experience and knowledge. Through a world-wide network of interconnected sensor-endowed smartphones, a huge amount of data can be automatically generated, redirected, combined, and processed to generate innovative pervasive services. The data required to make these services effective cannot be generated through traditional approaches; yet, challenging technical issues in this context require specific attention.

Indeed, design solutions proposed by researchers do not put an end to technical issues discussed in this article. Table 1 summarizes the above mentioned issues addressed by researchers. A black V represents a quite successful solution, whereas a red X represents a partial solution.

We can state that opportunistic sensing, the less invasive sensing technique for users, often requires continuous sensing to identify the right context to retrieve data. In some studies there is an attempt to preserve resources, but this implies to mediate with the application accuracy and often this is a critical point because the quality of results depends directly on the amount of data. Adaptive techniques are still used only in small-scale applications due to costs introduced by further necessary processing. Several works try to solve privacy issues simply managing data stored in the device without sharing, whereas advanced techniques (e.g., exploiting k-anonymity algorithm) could be used to preserve privacy even if at higher computational costs.

Designing energy preserving algorithms is not always a trivial task as low level sensor control is often not offered to developers by device manufacturer. Therefore, the tradeoff solution between accuracy and energy efficiency is not always acceptable. Adaptive techniques augment the range of obtainable results, but also introduce higher computational costs in classification improvement. Using user interaction like in supervising techniques is not always a wise choice as these techniques could be too intrusive and bothering for users. Using cloud computing to offload the processing burden of the mobile devices is paid with increased transmission costs that negatively affect energy consumption and user privacy. The idea of using low power hardware is surely the most effective, but it requires the support of manufacturers.

Finally, the various application markets offer thousands of applications; to stand out and take hold in community preferences, Web Squared applications need both to preserve privacy and to have minimally invasive sensing features in terms of energy consumption and user involvement. Furthermore, they also need to be easily usable and perceived as useful or fun by users, as demonstrated also by the several example of games we had to include in our examples. Indeed, the market success of Web Squared applications is crucial for their functioning as the quality of generated services can depend on the massive availability of gathered data even from other users.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] I. F. Akyildiz, S. Weilian, Y. Sankarasubramaniam, and E. Cayirci. A survey on sensor networks. *IEEE Communications Magazine*, 40(8), August 2002.

[2] N. Aitsaadi, N. Achir, K. Boussetta, and G. Pujolle. A tabu search approach for differentiated sensor network deployment. In *Proc. of 5th IEEE Consumer Communications and Networking Conference (CCNC 2008)*, Las Vegas, Nevada, USA, January 2008.

[3] U. Lee, E. Magistretti, M. Gerla, P. Bellavista, and A. Corradi. Dissemination and harvesting of urban data using vehicular sensor platforms. *IEEE Transaction on Vehicular Technology*, 58(2), February 2009.

[4] T. O'Reilly and J. Battelle. Web squared: Web 2.0 five years on. In *Web 2.0 Summit*, San Francisco, CA, USA, October 2009.

[5] C. E. Palazzi. Buddy-Finder: A proposal for a novel entertainment application for GSM. In *Proc. of the 1st IEEE International Workshop on Networking Issues in Multimedia Entertainment (NIME'04), GLOBECOM 2004*, Dallas, TX, USA, November 2004.

[6] C. Bettini, D. Maggiorini, and D. Riboni. Distributed context monitoring for continuous mobile services. In *Proc. Working Conference on Mobile Information Systems (MOBIS 2005)*, Leeds, UK, December 2005.

[7] F. Corradini, R. Gorrieri, and M. Roccetti. Performance preorder: Ordering processes with respect to speed. In *Proc. of the 20th International Symposium on Mathematical Foundations of Computer Science (MFCS 1995)*, Prague, Czech Rep., September 2005.

[8] G. Marfia, G. Pau, and M. Roccetti. On Developing smart applications for VANETs: Where are we now? Some insights on technical issues and open problems. In *Proc. of IEEE International Workshop on Ubiquitous Multimedia Systems and Applications (UMSA'09)- International Conference on Ultramodern Telecommunications (ICUMT 2009)*, St Petersburg, Russia, October 2009.

[9] R. K. Rana, C. T. Chou, S. S. Kanhere, N. Bulusu, and W. Hu. Ear-phone: An end-to-end participatory urban noise mapping. In *Proc. 9th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN 2010)*, Stockholm, Sweden, April 2010.

[10] A. Bujari, B. Licar, and C. E. Palazzi. Movement pattern recognition through smartphones accelerometer. In *Proc. IEEE DENVECT/CCNC 2012*, Las Vegas, NV, USA, January 2012.

[11] C. E. Palazzi, L. Teodori, and M. Roccetti. PATH 2.0: A participatory system for the generation of accessible routes. In *Proc. of the IEEE International Conference on Multimedia and Expo (ICME'10)*, Singapore, July 2010.

[12] C. E. Palazzi, G. Marfia, and M. Roccetti. Combining web squared and serious games for crossroad accessibility. In *Proc. 1st IEEE International Conference on Serious Games and Applications for Health (SeGAH 2011)*, Braga, Portugal, November 2011.

[13] C. E. Palazzi and A. Bujari. Social-aware delay tolerant networking for mobile-to-mobile file sharing. *Wiley International Journal of Communication Systems (IJCS)*, August 2011.

[14] C. E. Palazzi and A. Bujari. A delay/disruption tolerant solution for mobile-to-mobile file sharing. In *Proc. of IFIP/IEEE Wireless Days 2010*, Venice, Italy, Oct 2010.

[15] N. D. Lane, E. Miluzzo, H. Lu, D. Peebles, T. Choudhury, and A. T. Campbell. A survey of mobile phone sensing. *IEEE Communications Magazine*, 48(9), September 2010.

[16] J. Chon and H. Cha. Lifemap: A smartphone-based context provider for location-based services. *IEEE Pervasive Computing*, 10(2), February 2011.

[17] B. Priyantha, D. Lymberopoulos, and J. Liu. Littlerock: Enabling energy efficient continuous sensing on mobile phones. In *Proc. 9th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN 2010)*, Stockholm, Sweden, April 2010.

[18] E. Miluzzo, N. D. Lane, K. Fodor, R. Peterson, H. Lu, M. Musolesi, S. B. Eisenman, X. Zheng, and A. T. Campbell. Sensing meets mobile social networks: The design, implementation and evaluation of the cenceme application. In *Proc. 6th ACM Conference on Embedded Network Sensor Systems (SenSys'08)*, Raleigh, NC, USA, November 2008.

[19] H. Lu, W. Pan, N. D. Lane, T. Choudhury, and A. T. Campbell. Soundsense: Scalable sound sensing for people-centric applications on mobile phones. In *Proc. 7th Annual International Conference on Mobile Systems, Applications and Services (MobiSys 2009)*, Krakow, Poland, June 2009.

[20] A. Beach, M. Gartrell, X. Xing, R. Han, Q. Lv, S. Mishra, and K. Seada. Fusing mobile, sensor, and social data to fully enable context-aware computing. In *Proc. 11th Workshop on Mobile Computing Systems and Applications (HotMobile 2010)*, Annapolis, MD, USA, February 2010.