Pervasive Ambient Intelligence Platforms in the IOT Era based on a Ubiquitous User Model Ontology

An Implementation Account

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Abstract: This paper presents how ambient data integration is obtained in Wi-City, i.e. a project promoted by the Regional Government of Sicily that aims at supporting mobile people activities by means of intelligent applications able to generate personalized recommendations that take into account both personal and context parameters. The paper shows how this is made possible by the decreasing cost of the monitoring systems in the IOT era and by the availability of ontology engineering methods to data integration. In particular, aim of the paper is to illustrate a pervasive platform consisting of environmental sensors readily installable on the city and body sensors easily wearable by people that cooperate by means of an ambient data ontology to better support the user decisions in a smart city. Examples of how embedded consumer electronics products are used to monitor the user ambient and how developing an effective ambient data ontology are illustrated to give an implementation account of the proposed platform.

1 INTRODUCTION

In a smart city, the citizens are able to use the technologies that improve the relevant aspects of their life (Aoun, 2013). A step beyond the smart city is the intelligent city scenario where an open and interoperable city information platform is able to support ubiquitous decision making by using intelligent systems (Berthon, 2011). In this scenario ambient information plays an important role. Indeed, at the basis of an effective decision support system there is the information coming from devices able to recognize the people activities, to measure the parameters of the systems in which the people carries out its activities, including traffic and environment, and to monitor the health conditions.

Today, the various city life aspects are mainly managed by separate decision support systems and consequently the ambient intelligence is partitioned into sub-ambients that don't communicate between them, e.g., car navigators help drivers only to find the best path to the desired destination, whereas specific e-health applications send alarms to rescue the users involved in accidents.

However, the increasing diffusion of mobile devices makes possible, in principle, to inform the users about the most suitable actions using the same terminal device independently on if they are at home, at office or are walking or driving.

Also, the more and more decreasing cost of the monitoring systems in the era of IOT (Internet Of Things) makes possible to support the user activities by means of intelligent applications able to generate recommendations that take into account both personal and context parameters. Indeed, these ambient data may be monitored by means of embedded consumer electronics products provided with network identifiers and cooperating between them under the supervision of an Ambient Intelligence (AmI) software resident on the user mobile and/or in some remote city server.

For example fig.1 shows the pervasive e-health service envisaged in (Acampora, 2013) for an ubiquitous rescue of people. It is based on the interconnection of different AmI technologies involving body sensors, emergency response and hospital equipments.

Although such picture has the merit of envisaging the interconnection of the data collected by different AmI technologies to give rise to a ubiquitous system at urban scale, it underestimates the critical problems to be solved for the real

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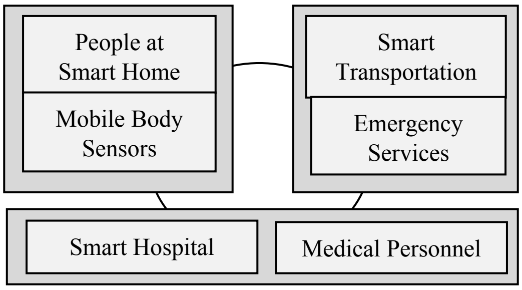

Figure 1: A general perspective of a pervasive e-Health system hiding critical implementation issues.

interoperability of the data collected by the different consumer electronics devices.

An ubiquitous architecture able to manage all the mentioned information sub-systems has been proposed by the authors in previous papers where all the mentioned data are integrated by an ontology based approach and a fuzzy logic based engine is adopted to support the decisions of the users and of the rescuers, e.g., (Costanzo, 2013a).

The original aim of Wi-City was to support mobility and logistics activities of citizens. Then, the monitoring system was mainly dedicated to collect traffic data by in situ technologies, e.g., (Leduc, 2008), (Faro, 2008), (Faro, 2011a). Such data are sent to the main city server where they are stored in XML/RDF format (http://www.w3.org/RDF). Also, personal data giving a general description of the current user status and task are stored on the user mobile so that the Decision Support System (DSS) implemented on the server or in the user's mobile may be able to suggest the best path to destination or the best delivery cycle taking into account the traffic conditions and the general user status. Data of city interest stored on public or private databases may be used by the DSS to identify the service most suitable for the mobile-device-using users.

Aim of the paper is to improve this architecture by taking into account the local and global ambient data collected by an ubiquitous monitoring platform consisting of cooperating sensors readily installable on the city and easily wearable by people to better support the user decisions.

In particular, in sect.2 we show how the functional Wi-City architecture has been extended to include the ambient monitoring functions. In addition, the consumer electronics products and their interconnection to implement the above Wi-City extension are briefly illustrated. Sect.3 discusses the data ontology for ambient data integration at city level taking into account the General User Model Ontology (Heckmann et al., 2005) and its extension (Costanzo, 2013b).

2 AMBIENT DATA IN WI-CITY

Fig.2 shows how the Wi-City architecture has been extended to take into account the ambient data. In particular, suitable applications have been developed to measure the indoor environment parameters and the physiological variables so that the DSS resident on the mobile provided with Flash Builder based software version (Corlan, 2009) may take into account the user's health status and regulate the indoor environment, e.g., (Costanzo, 2014). The main weather parameters are collected by a distributed monitoring system supervised by the Wi-City server to inform the user about critical weather conditions that influence the outdoor activities.

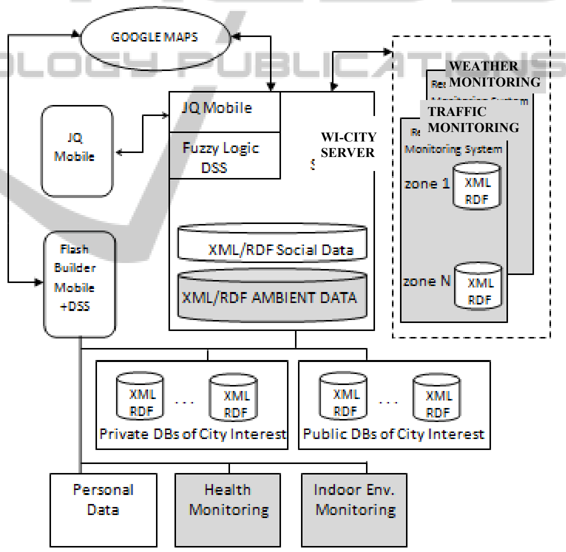

Figure 2: Wi-City architecture including ambient data

Fig.3 shows the implementation structure adopted in Wi-City to monitor the main parameters of the outdoor environment. The interested reader may find the ones dealing with e-health and indoor monitoring in (Costanzo, 2014).

The internal structure of this station allows us to point out that, apart the mechanical devices devoted to measure the rain quantity and wind intensity/direction that have dimensions of about ten centimetres (see fig.4a), the other devices measuring pressure, temperature, humidity and gas emission, may be embedded into a system of very limited dimensions, as shown in fig. 4b.

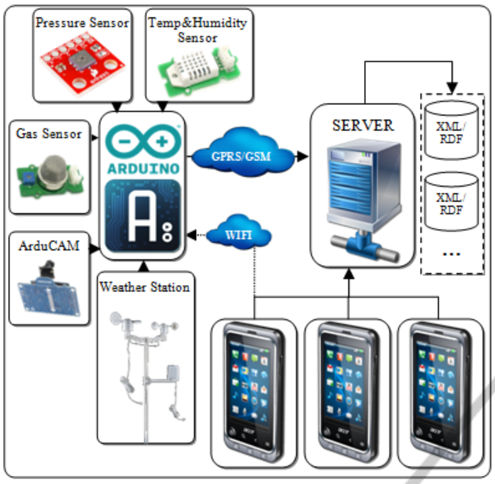

Figure 3: Wi-City environment monitoring station.

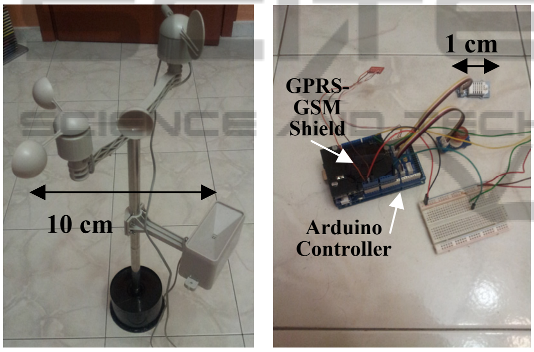

Figure 4: Environment monitoring station: apparatus to measure rain quantity and wind direction/intensity on the left, and Arduino controller on the right.

To transform the sensors of such station into things of internet, they have been supervised by an Arduino board (Banzi, 2009). Fig.5b shows how this board collects all the data coming from the environment sensors and sends them, through a GPRS/GSM shield, to the main Wi-City server where they are available to the users. This station has been provided with a Arducam to make available on internet a picture of the zone involved in bad weather or congested traffic conditions.

The users' mobiles may access directly the data stored on the stations so that the DSS resident on the mobiles may obtain very fast the ambient data without overloading the main server. In other words, the modularity of the system allows the user's mobiles to work cooperatively with the monitoring stations without the server intervention, thus increasing the *time performance* of the system.

The chosen implementation architecture is *fault tolerant* since the system functions show a graceful degradation in case of a failure of a component. Also, it guarantees high *reliability* and *accuracy* at *low cost* since cheaper electronics components able to work with a satisfactory continuity and precision are widely available on the market.

On the contrary, for what concerns the interoperability, although the data collected by the Arduino controllers are sent in JSON format (http://www.json.org) that can be easily converted into XML/RDF statements, this does not guarantee per se the data interoperability.

Indeed, to this aim, it is required that not only every measured data is stored by a triple (subject, predicate, object), e.g.: (device_id_01, temperature, 25°), but also that the terminology used, i.e., the predicate *temperature* and related properties, should be known by both the Arduino controllers and the DSSs so that they may work cooperatively. A suitable ambient data ontology is sketched in sect.3.

3 AMBIENT DATA ONTOLOGY

Currently, there is no data ontology proposed by the standardization organization, e.g. the World Wide Web Consortium (W3C), to represent the data featuring all the aspects relevant for the citizen activities, e.g., health, environment and preferences.

However, this should not prevent the use of the ontological approach to data integration. Indeed, one may develop a suitable ontology to manage the relevant aspects that a DSS should consider to issue its recommendations to support mobile people in a smart city and publish this ontology using a suitable editor, e.g., Protégé (http://protege. stanford.edu) so that it may be used by any remote processes to extract the XML/RDF data stored in the mobiles or in the main server using JSON queries.

Also, this solution allows the remote DSSs to issue SPARQL queries (http://www.w3.org/TR/ rdf-sparql-query) if the data are formatted by means of the Ontology Web Language (OWL) defined in (http://www.w3.org/2004/OWL).

A suitable ontology mapping should be done when the standard ontology will be available; but, to avoid of organizing the data relevant for user's activity modelling by means of a folk ontology that will require a great mapping effort when the standard ontology will be available, in our implementation we structured these data taking into account the extended General User Model Ontology (GUMO) outlined in fig.5, that is a meaningful step towards a standard user model ontology.

Let us note that the ontology of fig.5 differs from GUMO since it contains further data sections, e.g., the ones related to the car traffic and to the services of city interest. Also, the terminology to represent the data within each section takes into account the one proposed by GUMO, as well as the terminology proposed by a companion GUMO ontology called UbisWorld (Heckmann, 2006). A reconciliation of terms and properties should be done in future works.

Since the paper deals with ambient data, in fig. 6 we point out how they are represented in Wi-City and some differences with UbisWorld. To this aim, on the top of fig.6 we sketch, by means of the OntoGraph option of Protégé, the part of the Wi-City ontology representing **transport facilities** and **urban services**. Circles and rhombi denote respectively classes and individual objects.

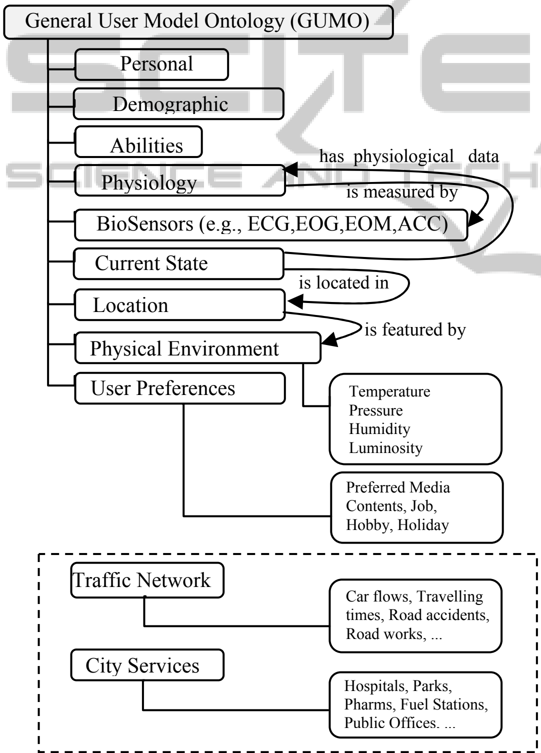

Figure 5: Extending the GUMO structure

Let us note that any ontology may be represented by an object oriented (OO) language, but that an OO program is not necessarily developed according to a standard data ontology since object names and properties may be chosen freely by the programmer.

Also, data ontology refers to the standard terminology to be used in a certain knowledge domain and may be more conveniently represented by markup languages such as XML, RDF or OWL.

Therefore, differences between ontology representations deal with the terms used and their

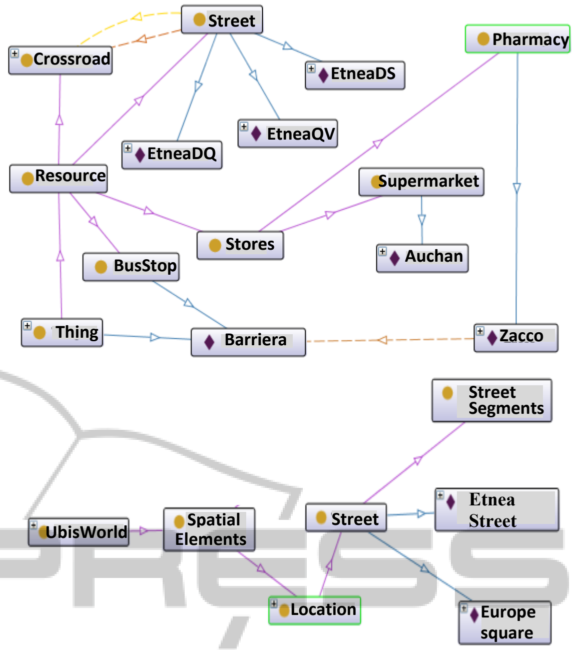

Figure 6: Some transport concepts used in Wi-City (on the top) versus UbisWorld (on the bottom).

interrelations. Fig. 6 points out that in Wi-City the name of a street (service) is an *individual object* rather than one of the data fields of a street (service) as suggested by UbisWorld (see the bottom of fig.6). Also, in Wi-City the urban graph is defined as a set of *street traits* delimited by *crossroads*, whereas this aspect is not handled by UbisWorld.

The **physiological conditions** are well represented in GUMO by the data collected by the *Biometrical Sensors*, as pointed out in fig.5, e.g., EOG, EOM, and ACC sensors. But, in GUMO it is not present a section dealing with the *Environmental Sensors*, although such sensors should be foreseen explicitly in the ontology to represent the *things of internet* used to measure the **indoor and outdoor environment conditions**.

Indeed, in GUMO the environment data are described generically by variables referred to either indoor or outdoor locations and collected under the section *Physical environment* in fig.5.

Moreover, both in GUMO and UbisWorld the properties of the ambient ontological entities, i.e., the ones linking the main subjects to the objects of the ambient domain, are not defined explicitly. Therefore, how linking the subjects to relevant ambient objects by agreed properties (also named predicates) is still an open problem.

A simple way to solve this problem is the one of linking any subject of our domain, e.g., a person or a car, to the *location* by the predicate *IsLocatedIn* and the location to the environment by predicates such as *ItsTemperatureIs* or *ItsHumidityIs*. The values of a variable should not be represented as individual objects unless such values refer to a stable entity, e.g., the name of a street may be seen as an individual object whose temperature is given by a data measured by a thermometer and the current temperature value is a field of such data.

Following such conceptualization, the main environmental data featuring the location of the person named "Annalisa" may be represented by the simple ontology shown in fig. 7 that should be read as follows: Annalisa (subject/individual object) is located in (predicate) Etnea Street (subject/ individual object) where there is the thermometer T01 (subject/ individual object). The street temperature is the data measured by T01, whose current value is the current street temperature.

Analogously, the user heartbeats are not an individual object but are data associated to the ECG sensor worn by the user. This is represented in the ontology of fig.8 where we take into account both physiological and environmental ambient data.

Such ontology may be described as follows: Annalisa is located in the Etnea Street and wears an ECG, i.e., one of the wearable biometrical sensors. In the street there is a temperature sensor that is one of the sensors of a weather station. Her heartbeats and the street temperature are given by the values associated to the data *heartbeats* and *temperature* of the ECG identified by ECG01 and by the thermometer identified by T01.

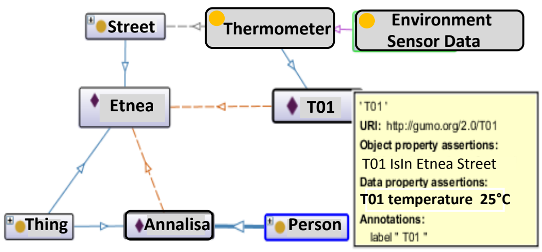

Figure 7: Ontology describing some environment data

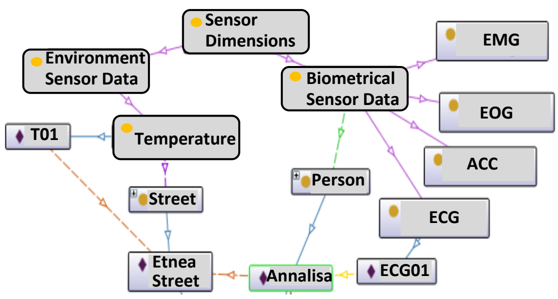

Figure 8: Ontology describing some ambient data at different abstraction levels.

Although we have discussed only some aspects of how building a suitable ambient ontology, it is easy to understand that defining a well structured ontology is a complex task, but once the ontology is defined, it is simple to insert novel instances, such as further monitoring devices, as soon as they are installed in the system. For example, a novel ECG, i.e., the one named ECG02 worn by John whose current heartbeats are 75 bpm, may be represented by inserting into the OWL file of the outlined ontology the following few statements:

```
<ClassAssertion>
  <Class IRI="ECG_-_Electrocardiogram_Sensor"/>
  <NamedIndividual IRI="ECG02"/>
</ClassAssertion>
<ObjectPropertyAssertion>
  <ObjectProperty IRI="IsWornBy"/>
  <NamedIndividual IRI="ECG02"/>
  <NamedIndividual IRI="#John.200100"/>
</ObjectPropertyAssertion>
<DataPropertyAssertion>
  <DataProperty IRI="heartbeats"/>
  <NamedIndividual IRI="ECG02"/>
  <Literal datatypeIRI="http://www.w3.org/2001/
   XMLSchema#float">75.0</Literal>
 </DataPropertyAssertion>
```

Let us note that the last assertion deals with the ECG measurement at a certain moment in time, and therefore it should be stored into a data base with date and day time information. In fact, at the reception of an update ECG measurement the older values are substituted by the new ones and are no longer available on line.

The management of the data collected by the environment sensors may be carried out analogously as shown by the interface implemented at the Wi-City server (fig.9): the current data coming from the weather stations are on line, the older ones are archived and may be analyzed by choosing the option "archived data".

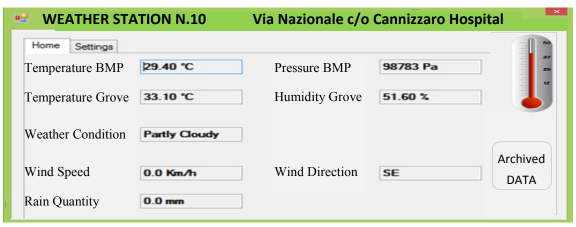

Figure 9: Wi-City Monitoring system to check the wheater conditions and to analyze the archived data.

Since both the current and the older data are stored in OWL format, any mobile may visualize the current and previous ambient data on its display as shown in fig.10 independently on how the data were collected by the proprietary monitoring systems.

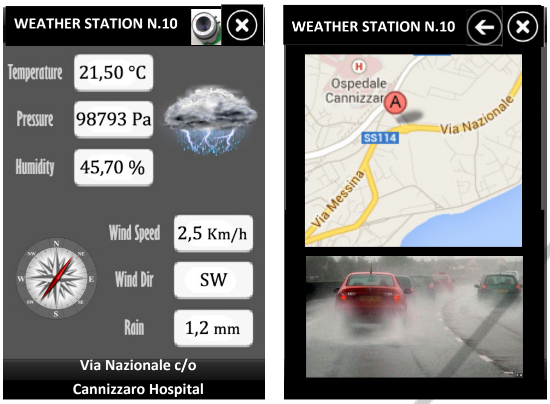

Figure 10: User interface to display on the mobile the road weather conditions, map and photo in real time.

4 CONCLUSIONS

In the paper we have illustrated how the implementation of a pervasive ambient intelligence platform in the IOT era should be based on a ubiquitous user's model ontology. Indeed, the availability of cheap and small monitoring devices addressable through internet is only one side of the coin, since it is also important that the monitored data should be open and interoperable.

This clarifies why the dedicated navigators installed on the cars that don't take into account the real time car traffic flows neither the personal and weather conditions are more and more substituted by modern applications implemented on the user mobiles that not only facilitate e-commerce and e-government operations but also help the people mobility using timely information coming from field sensors, as foreseen in (TRG, 2008). In fact, such data are able to characterize the user status in a deepened way and the traffic and weather conditions in real time, thus allowing the DSS to satisfy effectively the ubiquitous request of user assistance.

However, the available Location Based Services (LBSs) of this second generation are mainly proprietary systems, thus they don't meet the basic requirements of the LBSs inspired by the IOT paradigm, i.e., the requirement that the data of user interest should be open and interoperable, as claimed in (Teller, 2010).

For this reason, the ontology approach until now used in K-Metropolis for integrating disparate urban data bases to support user mobility and to provide e-commerce and e-government services to desktop PCs and mobiles, was extended, as illustrated in this paper, to make available to all the DSSs implemented on the user mobiles the data needed to provide the users with recommendations that take into account personal and ambient information that influence greatly the user activities.

However, due to the lack of an agreed ontology at urban level, our future work will be mainly the one to study carefully the available urban ontology, e.g., (Heckmann et al., 2005) and (Heckmann, 2006), (Teller, 2007), (Berdier, 2007), (Zhai, 2008), (Faro, 2011b) and (Costanzo, 2013b), to choose the terminology and related properties that may favour the implementation of a standard smart city ontology.

REFERENCES

Acampora G., et al., *A Survey on Ambient Intelligence in Health Care*, IEEE Proceedings, Issue 99, 2013.

Aoun C., The Smart City Cornerstone: Urban Efficiency. Schneider Electric White Paper, 2013.

Banzi, M., *Getting Started with Arduino*. Make Books, 2009.

Berdier C., Roussey C., Urban Ontologies: *the Towntology Prototype towards Case Studies*. Springer, 2007.

Berthon B., et al., *Building and Managing an Intelligent* City, online, 2011.

Corlan, M., Flash Platform Tooling: Flash Builder, Adobe, 2009.

Costanzo A., Faro A., Giordano D., Wi-City: Living, deciding and planning using mobiles in intelligent cities, *3rd Int. Conf. on Pervasive Embedded Computing and Communication Systems*, PECCS, Barcelona, 2013.

Costanzo A., Faro A., Towards Open and Interoperable Information Platforms for Mobile Users: RDF Methodology and Case Study, IEEE *Proc. 7th International Conf. on Application of Information and Communication Technologies* (AICT), Baku, 2013.

Costanzo A., Pino C., An Arduino based Health Monitoring System for Elderly People Living at Home: Functions and Ontology, Int. *Conf. on Physiological Computing Systems,* PhyCS, INSTICC, Lisbon, 2014.

Faro, A., Giordano, D. and Spampinato, C., Evaluation of the Traffic Parameters in a Metropolitan Area by Fusing Visual Perceptions and CNN Processing of Webcam Images, IEEE *Transactions on Neural Networks, Vol.19* (6), 1108-1129, IEEE, 2008.

Faro, A., Giordano, D. and Spampinato, C., Adaptive background modeling integrated with luminosity sensors and occlusion processing for reliable vehicle detection. IEEE *Transactions on Intelligent Transportation Systems. Vol.12*(4), 1398-1412, IEEE, 2011.

Faro A., Giordano D., Spampinato C., *Integrating Location Tracking, Traffic Monitoring and Semantics in a Layered ITS Architecture. Intelligent Transport Systems, vol.5*(3),IET, 2011.

Heckmann D., et al., GUMO*, the General User Model Ontology*, LNCS, N.3538, Springer, 2005.

Heckmann D., Ubiquitous User Modeling, IOS Press, 2006.

Leduc, G., Road Traffic Data: *Collection Methods and Applications, Working Papers on Energy, Transport and Climate Change*, N.1, JRC European Commission, 47967, 2008.

Telematics Reserach Group (TRG), Preview portable navigation: the future is bright for connectivity. http://www. telematicsresearch.com/PDFs/ TRG_Press_ Jan_0.pdf.2008.

Teller J., John R. Lee J.R., Catherine Roussey C., (Eds.), *Ontologies for Urban Development*, Springer, 2007.

Teller J., Billen R., Cutting-Decelle A.F., Ontology based approaches for improving the interoperability between 3D urban models. *Journal of Inf. Technology in Construction*, 2010.

Zhai, J., Jiang, J., Yu, Y., Li J., Ontology-based Integrated Information Platform for Digital City. IEEE *Proc. of Wireless Communications, Networking and Mobile Comp.*, WiCOM ’08, 2008.