An Urban Fault Reporting and Management Platform for Smart Cities

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ABSTRACT

A good interaction between public administrations and citizens is imperative in modern smart cities. Semantic web technologies can aid in achieving such a goal. We present a smart urban fault reporting web platform to help citizens in reporting common urban problems, such as street faults, potholes or broken street lights, and to support the local public administration in responding and fixing those problems quickly. The tool is based on a semantic data model designed for the city, which integrates several distinct data sources, opportunely re-engineered to meet the principles of the Semantic Web and linked open data. The platform supports the whole process of road maintenance, from the fault reporting to the management of maintenance activities. The integration of multiple data sources enables increasing interoperability and heterogeneous information retrieval, thus favoring the development of effective smart urban fault reporting services. Our platform was evaluated in a real case study: a complete urban reporting and road maintenance system has been developed for the municipality of Catania. Our approach is completely generalizable and can be adopted by and customized for other cities. The final goal is to stimulate smart maintenance services in the "cities of the future".

Categories and Subject Descriptors

J.1. [**Computer Applications**]: Administrative Data Processing – *Government*, H.3.5. [**Information Storage and Retrieval**]: Online Information Services – *Web-based services,* I.2.4. [**Artificial Intelligence**]: Knowledge Representation Formalisms and Methods – *Semantic networks*.

General Terms

Experimentation; Management; Standardization.

Keywords

Linked open data applications; smart cities; urban fault reporting and management; linked open data extraction and publication; e-government; semantic data modeling.

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1. INTRODUCTION

Urban population in cities has been foreseen to double by the middle of this century, according to the United Nations Global Health Observatory[1]. Cities are expected to deal with increasingly pressing issues such as environmental sustainability, economic growth and citizen mobility. Two trends are evident [18]. First, urban areas worldwide are rapidly increasing in scope and population. Second, with rapid advance and utilization of smart information and communication technologies (ICT), smart city services are becoming a norm rather than exception in developing and managing city services for citizens [17]. On top of a variety of city services developed throughout the industrialization in the last centuries, new services are being conceptualized, developed, and implemented over the last decades across the globe in cities [4][11]. Many cities are expanding their efforts to make their cities more competitive by becoming "more digitalized", "intelligent" and "smarter" [21].

In the last few years, the smart city paradigm [7] has begun to spread in academic and industry fields, with the development of various solutions to address issues brought by the fast growing urbanization [5]. Besides, several local governments have invested heavily to improve public service delivery. FixMyStreet.com [16] was one of the first citizen-driven systems for road maintenance and general public service improvement. Other similar services today available are: PDX Reporter[2], Citizen Connect[3], Click Fix (SCF)[4] and CITY FEED [19]. In general, state-of-the-art works usually focus on urban crowdsourcing for improving local public services [3][6][12][23]. Following the citizen-centric smart city services classification by [18], these services belong to the AUMP (Automate–Utilitarian–Mandatory–Passive) typology, which consists of cases of automation of services falling into utilitarian, mandatory and passive categories. In particular they can be associated to the main class "Facility Management", and the sub-class "Street Furniture Management", including "Traffic/Street Facilities Maintenance Service". For more details see also [4].

[1] http://www.who.int/gho/en/

[2] http://www.portlandoregon.gov/bts/article/419527

[3] http://www.cityofboston.gov/doit/apps/citizensconnect.asp

[4] http://it.seeclickfix.com/

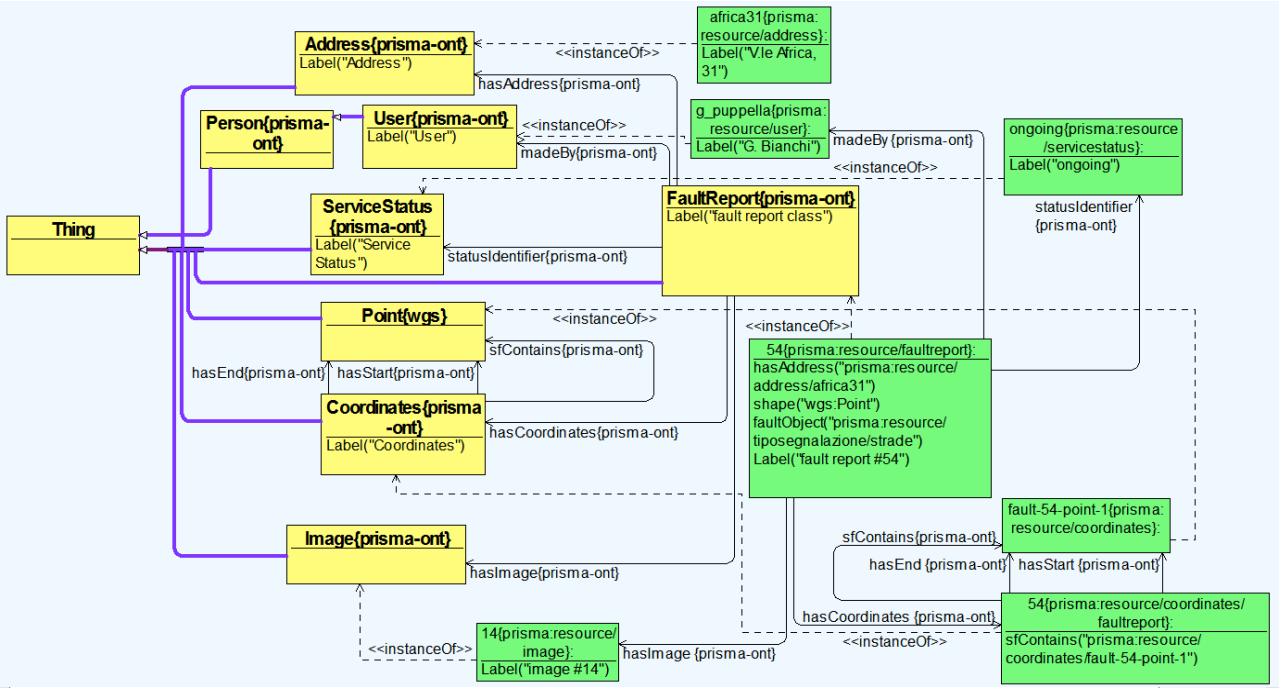

Figure 1: Example of the ontology that models the fault reporting and management service.

According to MIT[5], cities are systems of systems, and there are emerging opportunities to introduce digital nervous systems, intelligent responsiveness, and optimization at every level of system integration from that of individual devices and appliances to that of buildings, and ultimately to that of complete cities and urban regions. In this context, a good interaction at every level between citizens and public administrations is crucial. Road maintenance is a field where a good communication between citizens and the administration can greatly aid in improving the quality of urban life. Current systems do not have the appropriate level of integration between fault reporting services and road maintenance management. They only provide user-interfaces to citizens for reporting urban faults, but they do not really provide management environments for the fault life cycle to local officers. For example, the popular FixMyStreet[6] allow users to send fault reports to the local council in the form of private email messages, which are then arranged independently by the local public administration in order to fix the reported fault. That is, the full operational management of the fault is left to the internal operational maintenance systems of the local administration.

We aim at filling this gap by designing an urban fault reporting and management platform for smart cities. Our platform overcomes the limits of existing platforms by facilitating the integration between fault reporting and fault management. To this purpose, we make extensive use of semantic web technologies. We developed a prototype application by implementing a comprehensive system that integrates an urban fault reporting service available to the citizen and a road maintenance management system for the public administration.

We designed a semantic data model for urban fault reporting and management based on the principles of linked open data (LOD), and integrated it with a complete data model for the municipality of Catania [9][10]. We reconcile data sources of different nature into our integrated semantic data model, thus enabling interoperability at syntactic, semantic and conceptual level. We developed a platform for urban fault reporting and management that supports application developers in developing customized related services. We also provide a prototype web based application that is being evaluated by the municipality of Catania and will be released soon as a complete urban fault reporting and management service.

The paper is organized as follows: Section 2 describes the platform we propose in this paper and the ontology we adopted. Section 3 explains the application itself and how fault reports are handled. Finally, Section 4 ends the paper with future directions where we are heading.

2. DESCRIPTION OF THE PLATFORM

The designed application is aimed at supporting the local public administration and citizens on reporting and resolving urban faults, such as potholes, public lighting faults, etc. The proposed platform allows experiencing the e-government digital environment developed within the PRISMA project [9][10]. The application involves a user interface and a complex management system. They rely on a linked data model based on the principles of the Semantic Web, which allows interoperability at both syntactic and semantic levels.

2.1 Data model

To conceive, design and prototype the "smart" urban fault reporting application for the municipality of Catania, the provision of a "smart" semantic ICT model on data gathered from the city is central. In this scenario, we believe that producing LOD for the city, which are open, interoperable, authored and

[5] MIT City Science, Smart Cities Vision, http://smartcities.media.mit.edu/frameset.html

[6] http://fixmystreet.org/

annotated, obtained with principled inheritance and aggregation relation hierarchies, offers an ease understanding and reuse of core city data, useful to support the provision of new smart services to citizens. Therefore the proposed urban fault reporting and management application relies on a semantic data model designed for the municipality of Catania in the context of the PRISMA project [9][10]. The model tackles the issue of reconciling large city data sources of different nature into a uniformed and integrated semantic data model. The methods employed for extracting, modeling and publishing LOD for the municipality of Catania followed W3C standards[7], pattern-based ontology design techniques [14][22], and guidelines for LOD production and publication, issued by the Agency for Digital Italy [1][2].

Collected data sources related to the municipality of Catania were geo-referenced data taken from the Geographic Information System (GIS) [20] concerning the toponymy of the city; data on lines and stops of the public transport bus system; data on maintenance of the public lighting system, state of roads, sidewalks, signs and markings; historical data on municipal waste collection[8]. Those data have been re-engineered and converted into the LOD paradigm, following the directions given by information analysts and data experts of the municipality of Catania with respect to the considered reference domains.

Data on urban fault reporting and management contains information related to fault reports, actions required, status, workflows, localization addresses and geographic coordinates. We aligned the resulting RDF (Resource Description Framework) triples to existing vocabularies, in particular *NeoGeo*[9], an ontology for geo-data, and the *Collections Ontology*[10], an OWL 2 DL ontology for creating sets, bags and lists of resources, and for inferring collection properties, even in the presence of incomplete information. In addition we used the standard geodetic system *WGS84* [13][11] for representing shapes associated to geo-referenced objects. An example of the ontology is given in Figure 1. Classes are colored in yellow, instances in green and datatype properties in orange. The key class is **FaultReport**, which represents a report of a citizen about a fault in the road system. A fault is associated with an **Address** and with geographic **Coordinates**, i.e. a set of points (class **Point**). A fault report has also an associated **Image**, i.e. a picture that shows the fault, and a **User**, which is the person that reported the fault. We used the class **ServiceStatus** for representing the status of the maintenance service associated with the report. The figure also gives an example of a report instance. In the example, the report is about a fault occurred at the address "V.le Africa 31" and its status is "ongoing".

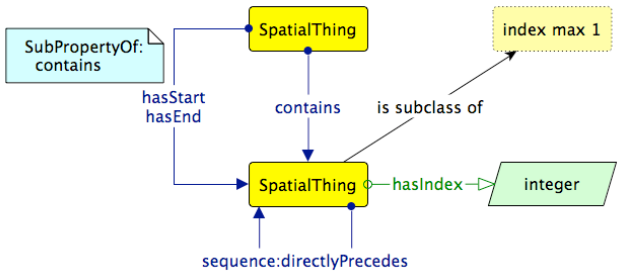

Figure 2: Modelling choice for "SpatialThing" objects.

To represent the geometric object associated to a fault report, i.e. points, lines or polygons, we used the *ordered spatial composition pattern*, shown as Graffoo diagram[12] in Figure 2. The pattern has been developed by taking inspiration from the *Collections Ontology* [8] and from the *sequence pattern*[13] for arranging the various spatial elements as a (possibly ordered) sequence of other spatial objects. A geo-referenced object in our ontology contains a **prisma:Coordinates** entity, which has a relation **geo:sfContains** of a sequence of points (defined according to the *NeoGeo* and *GeoSparql*[14] ontologies). Points are linked to the next point in the sequence through the **sequence:directlyPrecedes** relation. In addition, each point has associated an index (**xsd:int**) by means of the *BBC Programmes Ontology* **po:position**[15] relation, identifying its position in the sequence. Start and end points within the sequence are also indicated by, respectively, the **ont:hasStart** and **ont:hasEnd** relations. Coordinates of a single point are then expressed as according to the standard geodetic system *WGS84* [13]. The following code shows an example of coordinates for a single point.

```
prisma:resource/coordinates/fault-101
        a prisma-ont:Coordinates ;
        geo[13]:sfContains
        prisma:resource/coordinates/fault-101-point-1 ,
        prisma:resource/coordinates/fault-101-point-2 ,
        prisma:resource/coordinates/fault-101-point-3 ;
        prisma-ont:hasStart
        prisma:resource/coordinates/fault-101-point-1 ;
        prisma-ont:hasEnd
        prisma:resource/coordinates/fault-101-point-3 ;

prisma:resource/coordinates/fault-101-point-1
        a wgs:Point ;
        po:position "1"^^xsd:int ;
        sequence[12]:directlyPrecedes
```

[7] http://www.w3.org/standards/semanticweb/

[8] Raw data, in Italian, are available upon request.

[9] http://geovocab.org/doc/neogeo.html

[10] Collections Ontology (CO), version 2.0: http://purl.org/co

[11] WGS84 Geo Positioning RDF vocabulary: http://www.w3.org/2003/01/geo/wgs84_pos

[12] Graphical Framework for OWL Ontologies, Graffoo V 1.0, http://www.essepuntato.it/graffoo/specification/current.html

[13] http://www.ontologydesignpatterns.org/cp/owl/sequence.owl

[14] http://www.opengis.net/ont/geosparql

[15] po: http://purl.org/ontology/po/

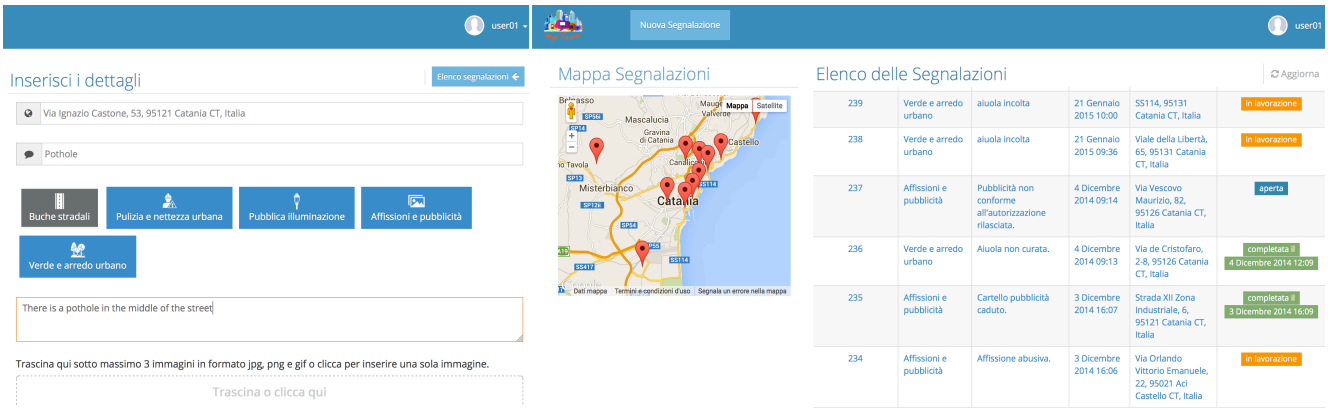

Figure 3: Some views on the front office web application. On the left, the form for the insertion of a new fault report is shown. On the right, the interface with the list of fault reports is shown.

prisma:resource/coordinates/fault-101-point-2 ;
wgs18:lat "37.3462" ;
wgs:long "15.6474" .

prisma:resource/coordinates/fault-101-point-2
a wgs:Point ;
...

Once the data were represented in RDF and the triples for each data object were produced, we performed a knowledge discovery step in order to enrich the resulting knowledge base by linking to knowledge from DBpedia. In particular, all addresses and names of extracted data objects were sent to TAGME[16], a popular entity-linking tool freely available. We introduced new DBpedia RDF relations **owl:sameAs** and **dul:associatedWith** based on string similarity.

3. APPLICATION PROCESS

The platform allows experiencing the e-government digital environment developed within the PRISMA project, and is currently under active development. Users of the application are citizens and public administration officers, which are the main actors behind its business process involving the following key elements:

• A "back office" module, developed following the principles of *business process management* (BPM), which aims at controlling and monitoring the complex process of urban fault reporting and management, and that coordinates the different management systems within the local administration offices;

• A "front office" module, implemented as a web application[17] with advanced usability and communication features allowing citizens interaction on faults reporting and management, and the control of their resolutions.

The back office module is a management system that allows municipal officers to validate user reports concerning faults and situations that need to be addressed (e.g. unauthorized advertising) and forward them to the responsible management departments. The list of target departments were identified as a result of a careful analysis conducted with the local public administration, and consists of the following five municipal offices: 1) maintenance of potholes on roads and sidewalks; 2) cleaning, sanitation, and disposal of municipal waste and large-size garbage; 3) protection and management of public parks and street furniture; 4) removal of unauthorized advertising; 5) maintenance of the public lighting system of the city. These municipal offices schedule maintenance activities to respond to reports received.

A citizen can also post an alert on a detected fault by means of the front office module. On the left of Figure 3 it is depicted the form of insertion of a new alert. Citizens may provide the address of the fault, geo-localize the position within a map, and provide some notes along with a maximum of three images. In addition, they can also specify the fault type (e.g. pothole, broken streetlamp, etc.), in order to speed up the assignation process to the responsible department. Citizens can also monitor the status ("opened", "ongoing", "completed") of other faults already reported (right side of Figure 3).

Once a new fault has been signaled, the back office module allows municipal officers to accept or refuse it; if accepted, it is also validated and registered with a unique identifier. The validation step consists of verifying the completeness and validity of inserted information to avoid abuse, spam or law violations. Next, the report is forwarded to the competent maintenance department responsible to handle it, if indicated by the user. Otherwise, the report is forwarded to the municipal public relations office, which identifies the office responsible to manage and resolve the problem. If several alerts concerning the same fault are received at different times, they will be all connected to each other and registered as a unique fault item. The fault is then processed and then closed either successfully (maintenance performed) or as a failure (maintenance not performed for some issues). Each status change in the process is updated in the corresponding fault item and presented to users through the front office.

The management systems in use within the different local administration offices in charge of the management and maintenance of city services are connected to the back office system by means of the *task oriented user interface* of the *business process management* suite, related to the PRISMA project, providing updates on the status of the different activities.

[16] http://tagme.di.unipi.it/

[17] https://ehtcloud02.servizi-etnahitech.com/mytown/, username: user01, password: etnahitech

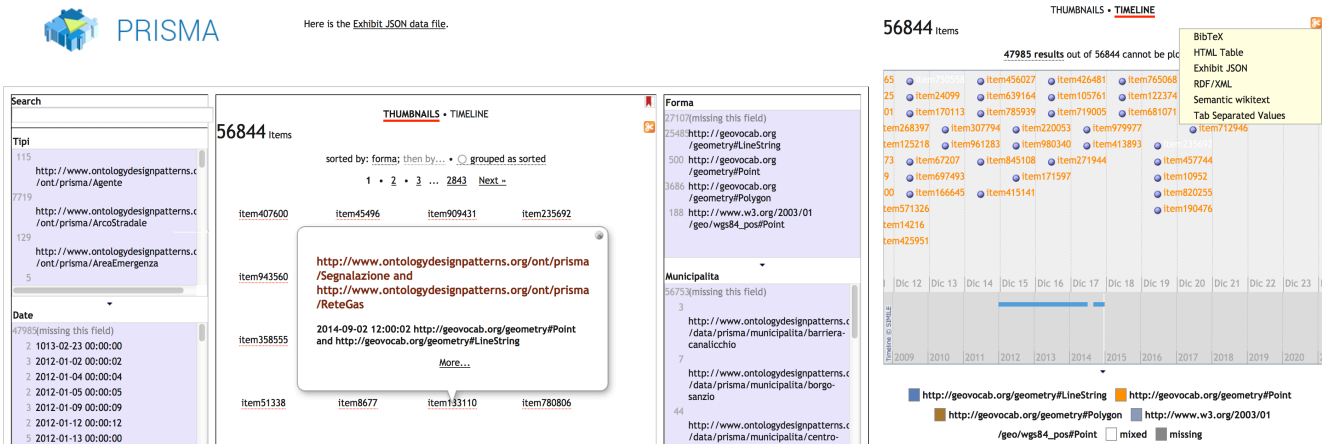

Figure 4: A view on the Exhibit installation for the urban fault reporting and management data. On the left it is shown the thumbnail faceted browsing, while on the right it is shown the timeline view for the fault items.

This is a simple and intuitive interface to support the execution of the maintenance service by reporting the status of the ongoing maintenance activity to the back office, and consequently to the front office and to citizens.

Datasets are also exposed to citizens by means of a CKAN (Comprehensive Knowledge Archive Network)[18] installation publicly available[19]. CKAN is a powerful web-based open source data management system for the storage and distribution of data maintained by the Open Knowledge Foundation. It is addressed to data publishers like national and regional governments, companies and organizations, which want to make their data open and available. CKAN makes data accessible by providing tools to streamline publishing, sharing, finding and using data, such as spreadsheets, databases contents, and linked data, as in our case. An additional website focusing on the mentioned data and designed ontologies has been further released[20]. This is an easy to understand demonstrator addressed to the general public. These installations enable the publication of our linked open data, which include statistics and location of city faults and census and localization of city assets. They enable the application of open government's principles of transparency and increase participation and collaboration [15], which are central keys for the integration of citizens within the smart city paradigm. In addition the portals are aimed at further promoting the proposed urban fault reporting and management system to the local community and to companies that want to exploit the service and its datasets to develop other services.

Last but not least, urban fault reporting and management data have been fed to an Exhibit[21] installation. Exhibit is an open source-publishing framework for data-rich interactive web pages. Exhibit enables the creation of dynamic exhibits of data collections without resorting to complex databases and server-side technologies. The data collections can be searched and browsed (through advanced text search and filtering functionalities) using faceted browsing. To properly use Exhibit and its widgets we prepared a JSON format of our data, according to Exhibit requirements. The resulting application is publicly accessible[22]. It allows users to see the data and filter them using the views that Exhibit offers.

Figure 4 illustrates a view of our Exhibit installation for the urban fault reporting and management data. On the left, the figure shows the thumbnail faceted browsing, which allows filtering alerts by fault types, alert date, geometric shapes, or municipality where faults are located. By clicking on a selected item it is possible to receive further details and to link to the selected item URI, so as to retrieve properties and data values associated to the fault alert. On the right of Figure 4, we show a timeline view for the fault items, where items are positioned on a timeline ordered by alerting date.

4. CONCLUSIONS

We proposed a smart urban fault reporting and management system that we designed and developed for the municipality of Catania. The system is based on a data mode that describes user fault alerts and is linked with a complete e-government data model developed within the PRISMA project. We showed the ontology we used to model the fault reporting service and the Semantic Web best practices we followed for its definition.

A first application prototype is available online. It is currently under development for further extensions. User-centric tests and an experimental evaluation are scheduled and will be object of investigation to assess the quality of reports, to measure the reliability of users, and to measure the performances of the involved public departments. User feedback will be crucial to evaluate the whole process.

The goal is to improve urban life through a sustainable and efficient solution, to promote transparency, to make citizens and businesses more involved in local politics, as well as to inspect the external evaluation of the public administration by measuring the community trust. Besides, future development will consider performance-based compensation models giving awards to users with the highest number of correct reports for example. This is a strong motivation and incentive for other citizens whose common goal is to provide services useful for the city itself.

[18] http://ckan.org/

[19] http://ehtcloud06.servizi-etnahitech.com/

[20] http://wit.istc.cnr.it/prisma/webcontent/home.html

[21] http://www.simile-widgets.org/exhibit/

[22] http://wit.istc.cnr.it/prisma/webcontent/exhibit/guasti.html

The proposed system can be generalized to other municipality and integrated to other fault reporting systems. Several other local organizations and municipalities already expressed their interest in our tool as they are willing to offer similar services to citizens.

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