Smart Applications for Smart City: a Contribution to Innovation

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ABSTRACT
Main research activities and results of the project "TETRis – TETRA Innovative Open Source Services" are described that are aimed at enabling innovative services for Smart City/Smart Territory by means of technological tools and intelligent platforms for collecting, representing, managing and exploiting data and information gathered from sensors and devices deployed in the territory. Technological tools and intelligent platforms are integrated into two smart environments for monitoring of respectively mobility and environmental resources and for providing advanced services to citizens as well as to urban operators. The general architecture and goals of the two smart environments are illustrated and some insights on the prototype for the mobility monitoring environment are reported.

Categories and Subject Descriptors
K.6.1 [**Management of Computing and Information Systems**]: Software and People Management – *strategic information systems planning, systems analysis and design, systems development*.

General Terms
Management, Design, Experimentation, Human Factors, Measurement.

Keywords
Urban Monitoring, Urban Mobility, Intelligent Platforms

1. INTRODUCTION
The activities described in this paper are related to the design and prototypal implementation of innovative services aimed at an intelligent management of an urban territory for novel smart city application scenarios. Within these activities, a number of solutions and advanced technology platforms have been identified that enable the various entities operating in the area of interest (municipalities, provinces, regions, universities, etc.), as well as citizens and urban operators, to effectively cooperate for an efficient usage of urban resources.

The innovation scenarios and solutions described in this paper have been realized within the project PON 2007 2013 - Research and Competitiveness "TETRis - TETRA Innovative Open Source Services" according to reference general frame of "Internet of Things" for supporting Smart City/Smart Territory [1], in which the acquisition of data by objects is applied to large territorial areas by exploiting the widespread availability of communication networks [2]. The collected data, properly enhanced and enriched, foster innovative services oriented to the production and exchange of knowledge among the different actors interconnected in urban and regional networks. The development of these services has been realized through a smart environment enabling the cooperation of smart devices and objects as well as of operators and users of the services themselves.

Two smart environments have been designed to handle two relevant smart city application scenarios: (*i*) *Urban Mobility Monitoring* and (*ii*) *Territory Monitoring, Control and Maintenance*. The general architecture and the goals of the two environments are described in Section 2. In addition some insights on the design and prototype implementation of the smart environments on Urban Mobility Monitoring are reported in Section 3. Conclusions are withdrawn in Section 4.

2. TWO SMART ENVIRONMENTS FOR SMART CITY
Each of the two smart environments has been designed as a knowledge-based digital/physical system that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in stationary and mobile smart objects with embedded intelligence and in smart-phones, and connected through a continuous network. The specific goals of the two smart environments are described next:

Smart Environment for Urban Mobility Monitoring: it concerns the implementation of a model for the detection of mobility problems in urban areas through the use of stationary smart objects deployed in the territory and mobile ones installed in public transportation buses. Data from smart objects are collected and aggregated into a data warehouse feeding a Mobility Intelligence platform defined through the design of innovative techniques of space-temporal data analysis and mining of complex data, including trajectories [3]. The model also includes amenities to deliver services to operators and citizens through the use of mobile devices. The environment has been experimented in the town of Cosenza in Southern Italy.

Smart Environment for Territory Monitoring, Control and Maintenance: it is based on networks of physical sensors connected to smart objects as well as of "social" sensors (smartphones driven by citizens and urban operators) to detect the status of the territory in real time. These so-collected data are stored and aggregated into a data warehouse feeding a Territory Intelligence platform, which enables the extraction and processing of knowledge for monitoring the territory. Other important components of the environment are contextual applications and web portals for citizens and operators. The environment has been experimented in the town of Rende in Southern Italy.

3. A PROTOTYPE FOR URBAN MOBILITY MINING

The smart environment for Urban Mobility Monitoring includes a prototype for urban mobility mining based on advanced data mining techniques that are used into two tasks: (1) a *pre-processing task* (i.e., extracting data from spatio-temporal databases and converting them into a process log) and (2) a *mining task* (i.e., building a process model for a given input log).

During the pre-processing task, a number of possible anomalies are detected for which it is necessary to perform an in-depth analysis to discover causal dependencies that hold over them. To this end, starting from an input log, the mining task builds a dependency graph (e.g., a Petri Net) that represents the background knowledge in terms of *precedence constraints* over the causal dependencies that, in many cases, are available to the analyst. This is particularly useful in order to circumvent the problems emerging when frequent incompleteness of logs. Note that "traditional" process discovery methods do not provide any support to deal with prior knowledge.

A relational database is used to initially store data on bus mobility in the urban area of Cosenza. Then these data are filtered and reorganized in the form of specific sequences of events so that they can be seen as traces of a process. In more detail, each tuple of the database is a triple of the form <x, s, t> where x is an object identifier, s is spatial position and t is a timestamp (i.e., the time at which the event has been recorded). Then this set of spatio-temporal tuples are converted into a set of transition instances consisting of three properties: a route identifier, a starting instant of the instance of transition and a measure associated with the instance of transition (e.g., travel time).

Two consecutive tuples (w.r.t. the temporal order) $R_i = (x,s_i,t_i)$ and $R_j = (x,s_{i+1},t_{i+1})$ of the same object x are seen as an instance of transition for the route $\mathbf{s_i\_s_j}$ if the difference $t_{i+1} - t_i$ is below a certain threshold (e.g. events that have occurred in the same day). For example, in the specific case of a tuple for urban transport system mobility, the transition $s_i\_s_j$ corresponds to the pair of stops s_i and s_j for which there exists a line that connects s_i and s_j.

Next step is to generate a set of classes/intervals, according to which anomalies can be classified and events can be thereafter clustered according to their class ids. Basically, each class specifies how the measure associated with the event/activity, exceeded the average value associated with the aggregate view of the same event.

Finally, a cluster and a time interval duration attribute are chosen that will help to generate a *trace id* to label a set of unexpected related events forming a trace. In particular, two events E_i and E_j belong to the same trace if:

- both events occurred in a "fixed" time interval;
- there exists another event E_z which connects E_i and E_j.

Given the input log generated as described above, classical mining techniques have been applied. It is to be noticed that some of the process models presented two types of conceptual problems:

- congestion models (see Figure 1) on which causality between two routes, one after another, follow driving direction (traffic propagates causally in the opposite driving direction w.r.t. the origin of the obstruction).
- congestion models (see Figure 2) with causality between routes that are geographically distant.

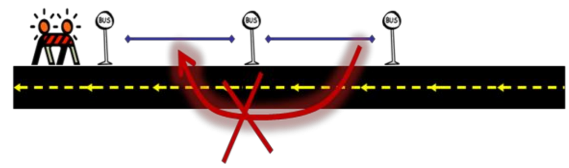

Figure 1. Inverted causal dependency example

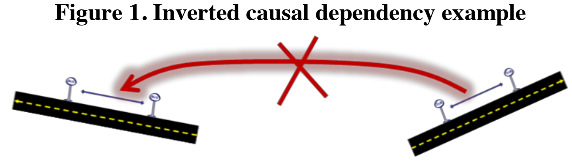

Figure 2. Causal dependency between distant routes

Finally using ad-hoc mining techniques developed in the research activities of the TETRis project, it was possible to encode the domain knowledge, thus restricting flow models to those that do not present the above-mentioned problems.

4. CONCLUSION

Some of the activities and results of the TETRis project have been illustrated that concern the definition and experimentation of innovative solutions for monitoring urban contexts according to the emerging integrated strategic vision of the Smart City and for providing ubiquitous services to both citizens and urban operators.

5. REFERENCES

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