“Search-the-City” – A versatile dashboard for searching and displaying Environment and User Generated Content in the context of the future Smart City

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ABSTRACT

The modern city incorporates a large amount of heterogeneous data, which are produced by diverse sources like sensors, cameras and social networks and present a new challenge: harnessing these data in a usable approach providing suitable views for the city’s numerous stakeholders. In this paper we shall present a Visualization Framework based on SMART FP7 project, that allows users and developers to build visual applications that empower these environmental- and user-generated data in a meaningful way, appropriate for the future Smart City.

Keywords

Future Internet, Sensors, GUI, Web 2.0, Social Networks, Smart City

1. INTRODUCTION

The Future Internet will include a large number of internet-connected sensors (including cameras and microphone arrays), which provide opportunities for searching and analyzing large amounts of multimedia data from the physical world, while also integrating them into added-value applications. Despite the emergence of techniques for searching physical world multimedia (including the proliferation of participatory sensing applications), existing multimedia search solutions do not provide effective search over arbitrary large and diverse sources of multimedia data derived from the physical world.

Future Internet in the context of a Smart City [1] defines an environment where a huge amount of data is produced from heterogeneous sources. These sources include real time environmental sensors (cameras and sensors), user generated content and content produced by the various city authorities. The volume of data and the diversity of sources render these data difficult to be consumed, by the end users, thus making them unusable for any practical application.

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The numerous stakeholders increase the complexity of the problem. These include the municipal administration that aims at increasing the quality of life within the city, the citizens that work and live, the private contractors that provide services to the city and the visitors. These groups have different interests in the information produced. **The goal of the current contribution is to describe a holistic approach followed in the framework of SMART FP7 [2] project with specific emphasis placed on the visualization of data to suit the specific needs of the stakeholders**. The visualization framework offers the required tools to the **Web 2.0 Smart City application developer** to easily create new applications to consume these open data, thus enabling the open services vision and the development of an ecosystem.

In the following sections we first present (Section 2) the related work, we then proceed with the presentation of the enabling architecture (Section 3). In section 4 we present the proposed Visualization Framework and finally in section 5 we present the future developments of the framework.

2. RELATED WORK

The ability to explore and discover the city through the data gathered is essential for the Smart Cities of tomorrow. This is a common problem and various efforts have been made up-to now to tackle it. IBM with Intelligent Operations Center [3] provides an executive dashboard to help city leaders gain insight into various aspects of city management. Other efforts include the CityDashboard [4], a project of the University College of London (UCL). It is designed to offer an at-a-glance view of eight cities around Great Britain. It combines official, observational and social media data into a single screen, the dashboard, which updates continuously high level data.. Suakanto in [5] presents a city dashboard for the city of Bandung in Indonesia that summarizes the condition of the city in terms of traffic congestion, water supply, energy supplies, air quality and public health quality. Michael Batty in [6] defines a smart city and how existing infrastructure is merged with ICT using new digital technologies.

A common place of the above related work is to present city’s heterogeneous data on a mashup, i.e. a web site that combine information from various sources presenting them visually by using different “web widgets”[1]. These widgets are not connected

[1] http://en.wikipedia.org/wiki/Web_widget

and do not allow designers to create new interactions with displayed data. The designer just "drops" these widgets on a page thus offering the city's dashboard. Based on the idea of the mashup and the flexibility that widgets offer to the designer, we propose a Visualization Framework that attempts to provide a similar visual solution, and at the same time add interactions between the different widgets, offering a more interactive environment that enables the city monitoring and allows the searching of specific information. The latter is enabled by the SMART FP7 infrastructure that gathers and annotates semantically the information generated from various data sources, by the use of the SMART Search Layer. The proposed Visualization Framework targets the developer of the city's dashboard by providing him a) with the means to build an interactive mashup and b) the best practices to extend it functionality. In the following section we present the architecture drives the Visualization Framework.

3. ENABLING ARCHITECTURE

As we mentioned above, the Visualization Framework is tightly coupled with the SMART Search Layer. Considering this fact, we give a brief presentation of the enabling architecture.

The SMART Search Layer is a core component responsible of providing effective and efficient real-time indexing and retrieval of social and sensor data streams. It is built with Terrier and a MapReduce (termed as "SmartReduce") architecture using open source Storm stream processing framework to scale to a large volume of social and sensor streams produced by multiple edge nodes. The architecture has been designed as layered system consisting of three main layers, namely:

- **A layer of sensor edge servers**, which ensures the interfacing of the SMART with data stemming from the real world. The sensor edge server undertakes the tasks of acquiring physical world data via sensors (notably cameras and microphone) and accordingly structuring data based on standard formats (such as XML, RDF/Linked Data) to allow the upper layers to consume these data.

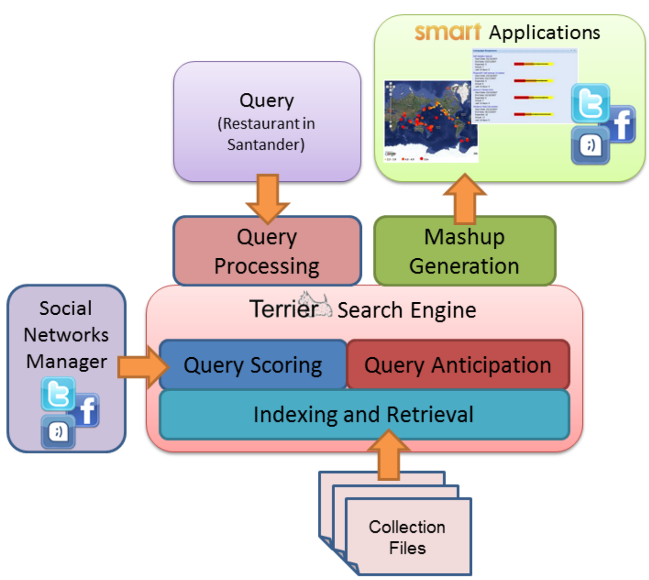

Figure 1. High-Level Overview of the SMART Architecture

- **A search layer** comprising a customized version of the Terrier search engine, adapted to the SMART project's needs. This layer indexes and retrieves data from the layer of edge servers. At the same time it retrieves, parses, analyzes queries and uses them for the selection (or prioritization) of appropriate edge servers where data of interest can be found. It can also support event-driven queries («pull» mode), in which case the search engine subscribes to events and updates the upper layer upon the occurrence of these events (i.e. recurring queries).
- **A layer of end-user applications** (including text-based interactive queries), which submit queries to the search engine and visualize the results. In addition to interactive-text based queries, this layer supports the Web2.0 compliant visualization of information stemming from the physical world (according to a mash-up concept).

A high level overview that describes the general architecture is depicted in Figure 1. SMART promises also to augment query results on the basis of information stemming from the social networks, while also using social networks information (such as information stemming from facebook, twitter and foursquare) in order to personalize the query results. To this end, a Social Media Manager has been developed that removes the heterogenity of the various social networks and inserts their data as sensor data (feeds) to the edge sensor server layer ensuring that the SMART system can additinally process and consume data stemming for social networks, thereby allowing sensor networks and sensor networks processing algorithms (e.g., sentiment analysis [7], event detection [8], gender analysis) to be included in the SMART system. At the same time, passing personalized information to the search layer allows the acquisition of personalized information for the specific user on the basis of their personal social networks' accounts and associated social graphs.

4. VISUALIZATION FRAMEWORK

The goal of the Visualization Framework is to offer components and describe the best practice for building applications based on intuitive interfaces, tailored to the needs of the city stakeholders by combining these components. Hence it is crucial to provide the whole functionality in visual components (widgets) that can communicate with each other and combine them on a dashboard that adheres user management and access control management capabilities, based on a Role Based Access Control (RBAC) approach. The RBAC enables the definition of roles that map on the different city's stakeholders, permitting specific fine-grained view based on user's role. Thus the same dashboard can have a public view that reveals the data that the citizen or the visitor expects to see and private views for authorized users such as the municipal administration or the private contractors that reveal a special view to satisfy the stakeholder's requirements.

On the functionality aspect, an application composed by these visual components must provide the capability of adding new components to the dashboard (via a drag-and-drop functionality) and configuring their behavior, like the sources that provide their data. To this end we have identified (based on our experience on the SMART FP7 project), some standard functionality and developed a number of Web2.0 reusable widgets. These widgets (visual components) consume services and semantics that originate from the underlying A/V processing algorithms, sensors and social networks. The availability of such widgets, aims at facilitating embedding queries made and search results returned from the Search Engine into applications. These widgets are indicative of the functionality that the framework offers. Following their design principles and methodology, a developer can create new ones to meet specific use case requirements.

The Visual Framework offers the required functionality by utilizing the SMART Search Layer to query the results and get the required data in the form of events. An event is an aggregation of data. E.g. a demonstration that takes place in a city is an event that is linked with a place, date of event, data from sensors near the event (video feeds, audio feeds), and user-generated data (tweets, posts) from social networks.

The Visual Framework consists of two main components:

- The Dashboard
- Standard Visual Components (mash-ups)

The Visual Components (VCs) retrieve their data using the underlying Search Layer. They have the ability to provide data representation following their design and communicate with each other, sharing information via “software application events”. For example, a VC, acting as a master, can upon users input, retrieve some results from the undelaying search layer and fire an software event that other VCs catch and process showing some details, thus, implementing a master-detail GUI functionality.

The stakeholders that have logged-in the system, may create their preferred view of the application by adding (as simple as drag-and-drop) the visual components that meet their own requirements on condition that they have the required privileges.

Besides, application developers can extend the visual framework by designing and developing their own VCs that exploit the services provided by the SMART Search Layer, following the frameworks guidelines.

4.1 The “Demonstration” Application

A demonstration of such Web Environment built on the Visual Framework and the standard Visual Components is presented in

Figure 2. The application is the “Developer scenario” for the SMART FP7 project that demonstrates the functionality of an event search application. The numbers on the figure show the different VCs that compose the application as well as their position in a sequence of actions the user performs.

In the example a “Search” visual component (1) is used to fetch results according to the user’s input. It makes a request to the SMART Search Layer and receives a list of results relative to events of interest for the specific search performed, ranked according to the score awarded by the search layer.

The results are displayed on an “Event Billboard” visual component (2). When a user selects a result, an event in our case, this event is shown on the “Event Map” visual component (3). The event as explained in section 4, may be accompanied with other data. These data are displayed according to their type to the suitable visual component. Images and videos from nearby cameras relevant to an event matching the search made are displayed in the “Media Player” (4). Crowd analysis of the event and the indicative measurements from non-Audiovisual sensors critical for the understanding of the event (e.g. heavy rainfall) are presented in a “Measurements Display” visual component (5). Finally, mentions in social media related to the event are shown on a “Social Data Display” visual component (6).

4.2 The dashboard

The dashboard of our visual framework is the foundation, as it provides user identification and access control. Moreover it allows the deployment of visual components by the users. It is based on the Liferay portal. Liferay is a free and open source enterprise portal project providing a web platform with features commonly required for the development of websites and portals. It differs from the mainstream Web Content Management System (CMS), as it employs Java-based technologies. It offers a user and role management system with single-sign-on support as well as a built-in Web CMS which offers the users with the familiar features required to build websites and portals, i.e. an assembly of themes, pages and portlets. The portlets supported adhere to the Java JSR-286 portlet specification.

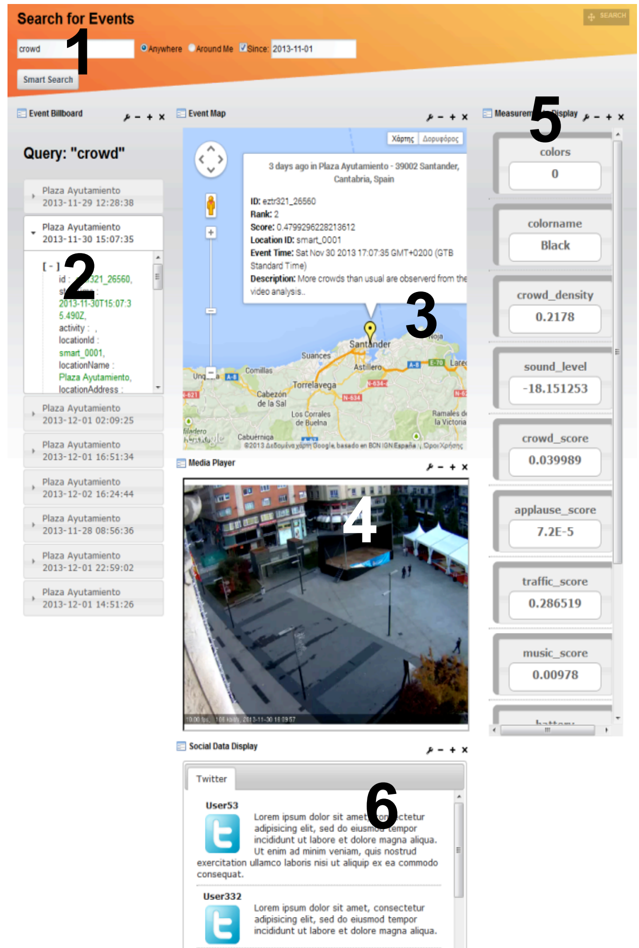

Figure 2. An example of Rich Application

The portal thus has been customized to be utilized as an Urban sensing / Urban monitoring platform, which may be customized to the user’s needs through the use of reusable portlets developed specifically for the project’s needs. The portlets are available for deployment in any way the user sees fit, thus personalizing the resulting dashboard to meet the needs of any scenario.

4.3 Standard Visual Components

The Visual Components described in this section are developed using Web 2.0 technologies, like the jChartFX and JQueryUI, which are open source Javascript libraries. The map-based Visual Component uses the Google Maps Javascript API V3. These VCs are developed as Java Portlets (JSR-286 Java API). Consequently, the VC-to-VC communication is implemented as inter-portlet communication using the event mechanism described in JSR-286, described as “software application events” in the previous sections so as to distinguish them from the real events that the search layer returns. A portlet (VC in our case) issues an event that encapsulates the data that need to be sent to other VCs. The VCs that are configured for listening for that specific event retrieve the data from the event, process and illustrate them according to the VC's designed functionality. In this section we shall present the visual components we have implemented.

4.3.1 Search Visual Component

The user is able to query the Search Engine VC about specific words or phrases of interest and define some search options such as the maximum radius of the event's location around the user's current location or events within specific dates. The Search VC retrieves the search results in a JSON format and fires an event with these results. Other VCs listening for this type of event receive the search results and process them according to their functionality.

4.3.2 Event Billboard Visual Component

The Event Billboard VC displays the top ten events provided by the search engines using accordion widget. The sorting of the results is based on the score awarded by the search engine. Upon clicking an event, the accordion expands providing the full event's details while it triggers the map VC to show the specific event on the map.

4.3.3 Event Map Visual Component

The Event Map VC features a map showing the selected event from the Event Billboard VC. The map moves to center around the event. Upon selecting an event, it provides the rank, score, location and date-time information of the event according to the classification returned from the Search Layer. Additionally the score of the event is visually indicated by its' map marker color. The red marker indicates a low score, the yellow color a medium score, whereas the green color indicates a high score. The score is computed by the Search Layer dynamically and it relates to the search terms given of the user.

4.3.4 Measurements Display Visual Component

This VC displays the various measurements recorded in proximity of the event selected on the Event Billboard VC at the date-time of the event. The measurements come from all sources from thermometer sensors in the area to the crowd density virtual sensors derived from a camera feed (if a camera is available at the event's location and a crowd density sensor has been defined for the location of the event taking place).

4.3.5 Media Player Visual Component

The Media Player VC provides audio and/or video playback for the clips recorded in the area of the selected event at the event's date-time.

4.3.6 Social Data Display Visual Component

Finally, the Social Data Display VC provides the social posts/tweets, which are geo-located around the area of the event and are relevant to the search term/phrase used in the search VC.

5. FUTURE WORK

In this paper we have presented a Visual Framework for building dashboards for Smart Cities using Future Internet technologies and demonstrated it's functionality by developing a number of Visual Components. Based on the experience gained, we will focus on the optimal combination of environment generated content originated from sensors and social networks, in order to provide new Visual Components that add value to a city's dashboard. Regarding the technical capabilities of the framework, we shall investigate the possibility to generalize the Visualization Framework by providing an abstract layer and an implementation that utilizes the search layer. The abstract layer will consist of an abstract data model that the VCs process and abstract services that acquire the data. This will allow the loosely coupling between the VCs and the underneath search layer, allowing the easy integration of new data sources.

6. ACKNOWLEDGMENTS

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