Who's Who – A Linked Data Visualisation Tool for Mobile Environments

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Abstract. Reduced size in hand-held devices imposes significant usability and visualisation challenges. Semantic adaptation to specific usage contexts is a key feature for overcoming usability and display limitations on mobile devices. We demonstrate a novel application which: (i) links the physical world with the semantic web, facilitating context-based information access, (ii) enhances the processing of semantically enriched, linked data on mobile devices, (iii) provides an intuitive interface for mobile devices, reducing information overload.

Keywords: linked data, semantic web, visualisation, mobile devices.

1 Introduction

Mobile devices are increasingly becoming an extension of the lives of humans in the physical world. The popularity of these devices simplifies *in-situ* management of the ordinary end user's information needs. Specifically, smart phones' embedded devices (e.g., built-in cameras) allow to build an abstraction of the user's environment. Such abstraction provides contextual information that designers can leverage in adapting a mobile interface to the user's information needs. Further, context can act as a set of parameters to query the Linked Data (LD) cloud. The cloud connects distributed data across the Semantic Web; it exposes a wide range of heterogeneous data, information and knowledge using URIs (Uniform Resource Identifiers) and RDF (Resource Description Framework) [2,6]. This large amount of structured data supports SPARQL querying and the *follow your nose* principle in order to obtain facts. We present *Who's Who*, a tool that leverages structured data extracted from the LD cloud to satisfy users' information needs ubiquitously. The application provides the following contributions:

1. **Exploiting contextual information:** *Who's Who* facilitates access to the LD cloud by exploiting contextual information, linking the physical world with the virtual.
2. **Enhanced processing of Linked Data on mobile devices:** *Who's Who* enables processing of semantic, linked data, tailoring its presentation to the limited resources of mobile devices, e.g., reducing latency when querying semantic data by processing triples within a mobile browser's light-weight triple store.
3. **Mobile access to Linked Data:** *Who's Who* uses novel visualisation strategies to access LD on mobile devices, in order to overcome the usability challenges arising from the huge amount of information in the LD cloud and limited mobile device display size. This visualisation also enables intuitive, non-expert access to LD.

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2 Application Scenario

To illustrate our work consider the following scenario:

Bob is a potential masters student invited to an open day at a university. He will tour different departments to get to know their facilities and research. To make the best of the open day, Bob will use his mobile phone as a location guide, allowing him to retrieve information (encoded as LD) about each department he visits, with the aid of visual markers distributed around the university. This will allow him to identify researchers he would like to meet and potential projects to work on.

We demonstrate the approach taken in *Who's Who* to realise this scenario, i.e., to support user- and context-sensitive information retrieval from the LD cloud using a mobile device. We exemplify this using the *Data.dcs* [6] linked dataset, which describes the research groups in the Department of Computer Science at the University of Sheffield.

3 The *Who's Who* Application

Who's Who facilitates entry into the LD cloud by exploiting context (section 3.1), reduces potential latency due to resource restrictions on even advanced mobile devices (section 3.2) and enables seamless management of information load (section 3.3).

3.1 Exploiting Context to Augment Physical Entities

The digital augmentation of physical entities has become a popular feature of many outdoor and indoor mobile applications [4]. For example, outdoors, a user's GPS (Global Positioning System) provides a contextual parameter for retrieving nearby points of interest. However, GPS is not suited for indoor use, due to among others, poor signal strength and range accuracy. Alternatives to location-based augmentation for indoor environments are visual detection and RFID (Radio Frequency IDentification) tags, which can be used to attach hyperlinks to real-world objects. In contrast to RFID readers, visual markers enable widespread use since they can be easily produced by regular printers, and read by standard cameras, which are now integrated into most mobile phones.

To bridge the gap between a physical entity's representation and existing information regarding it in the LD cloud, we follow the approach illustrated in Fig. 1, which consists of the following process: (1) a URI encoded in a visual marker represents a physical entity – in our scenario (section 2), a research group housed in the building at the location in question; (2) this URI translates to a server-side request which queries the LD cloud to enrich the information related to this entity – in our scenario, with research group members, their collaborations and publications; (3) this information is processed on the mobile device and presented to the end user.

3.2 Processing of Linked Data on Mobile Devices

Increments in memory capacity and processing power in mobile devices, particularly in smart phones, allow semantic processing of large numbers of triples (e.g., the Apple

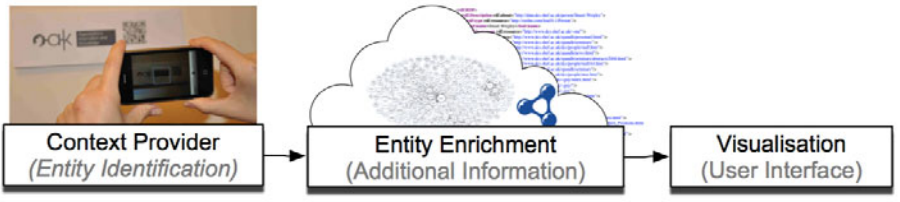

Fig. 1. The *Who's Who* application in a nutshell

iPhone 3GS has a 600Mhz CPU and 256MB RAM, and the HTC Hero has a 528MHz CPU and 288MB RAM; see also benchmarks for semantic data processing in small devices in [3]). Although it is possible to handle triples in local RDF stores in Android-based mobiles, this is not possible in other platforms such as the iPhone. An alternative is to use existing lightweight developments such as rdfQuery[1], which runs on web browsers, and HTML 5 features for persisting storage.

However, processing and rendering of semantic resources on mobile web browsers is still limited by low memory allocation (e.g., 10-64MB in Webkit and Firefox mobile on iPhone and Android phones). Leaving entirely the processing and rendering of semantic resources to the mobile client improves the user experience by reducing latency due to multiple requests. However, memory allocation restrictions make this a sub-optimal option. On the other hand, executing the semantic analysis and data processing entirely on the server-side results in the execution of continuous calls to the server, which translates to high data latency and a degradation of the responsiveness of the user interface and interactivity. There must be a compromise between the number of triples handled by a (mobile device) web browser and visualisation flow performance.

Who's Who follows the mobile and server-side based architecture in Fig. 2. Based on the parameters encoded in a visual marker, *Who's Who* queries *Data.dcs*. The *Data.dcs* triples are loaded in-memory via Jena on the server-side, following which SPARQL queries are executed. The triples retrieved are encoded with JSON – a lightweight data-interchange format – using JSONLib[2], and returned with a JavaScript callback to the mobile device. On the *Who's Who* mobile-side, the triples are loaded into an rdfQuery lightweight triple store. Interaction with the visualisation triggers local SPARQL queries that further filter the information.

The advantages of adopting this approach are that: 1) users need not download the application in advance (as is the case with applications relying on local RDF storage); 2) users need not know the URI corresponding to the physical entity they want to enrich, as contextual information is pre-encoded in the visual markers; 3) there is a balance between the triple load handled by the server- and mobile-sides, which translates to more responsive user interfaces; 4) the mobile-side triple store allows semantic filtering on the views exposed to the user, reducing latency and improving the interface's usability.

[1] rdfQuery: `http://code.google.com/p/rdfquery`
[2] JSONLib: `http://json-lib.sourceforge.net`

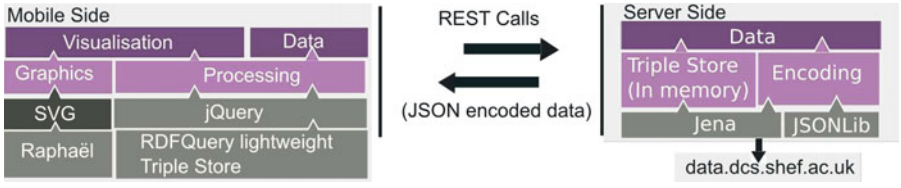

Fig. 2. Mobile- and server-side interaction in Who's Who architectural design

3.3 Visualisation

Who's Who supports the user in retrieving information stored in the LD cloud with visualisations tailored to the application domain. User requests are automatically translated to SPARQL queries executed on the lightweight triple store on the mobile device itself. If required, additional triples are retrieved from the *Who's Who* server. Fig. 3 describes the interaction flow for retrieving publications: 1) the user is presented a list of researchers corresponding to the physical entity encoded in the scanned visual marker; 2) when the user taps on a researcher – in this case *Fabio Ciravegna* – a SPARQL query is executed; 3) the publication view is presented, providing an additional filtering layer.

The publication view shows a graph containing the triples resulting from the SPARQL query – the number of publications per year and the number of collaborators involved in each publication. In Fig. 3 (3), the user has tapped on the graph bubble corresponding to the year *2009*, which links to two collaborators. The publications are arranged in a "card deck", where the first publication appears in the foreground. The user can traverse through the publications – where there are multiple – by selecting the next in the deck.

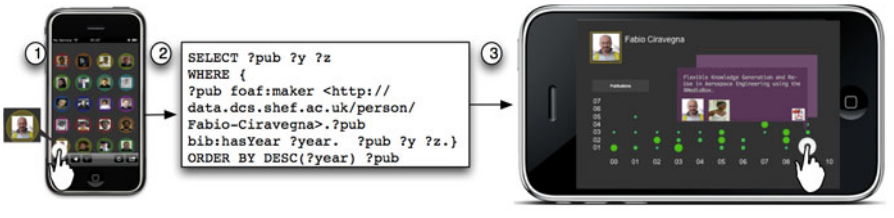

Fig. 3. (1) After selecting a researcher; (2) a SPARQL query is executed; (3) the resulting triples are presented in the graph in the publication view

4 Related Work

Searching for information about entities and events in a user's environment is an oft-performed activity. The state of the art focuses on text-based browsing and querying of LD on desktop browsers, e.g., *Sig.ma* [8] and *Marbles* [1], targeted predominantly at technical experts (see also [2]). This excludes a significant part of the user population – non-technical end users – who make use of advanced technology embedded in everyday

devices such as mobile phones. One of the best examples of a visual browser targeted at mainstream use is *DBPedia Mobile* [1]; which is a location-aware Semantic Web client that identifies and enriches information about nearby objects. However it relies on GPS sensors for retrieving context, which makes it unsuitable for our indoor scenario. Our approach improves on existing LD browsers for mobile devices in that *Who's Who*: 1) extracts contextual information encoded in visual markers; 2) hides explicit SPARQL filters from the user, increasing usability for especially non-technical users.

5 Summary

Who's Who was developed to support especially those end users who may have little to no knowledge about where to find information on nearby physical entities. It provides exploratory navigation through new environments, guided by the user's context. Studies (see, e.g., [5,7]) evaluating the utility and usability of tag-based interaction with mobile device applications illustrate the potential of lowering barriers to LD use.

We have demonstrated the use of a set of visual markers, corresponding to research groups in a university department, to explore the linked data exposed in *Data.dcs*, using a smart phone equipped with a camera and a QRcode scanner. We have also illustrated how the approach taken in *Who's Who* simplifies such tasks, by using visualisation of structured data to extract relevant context and manage information load, to reveal interesting facts (otherwise difficult to identify), and to facilitate knowledge extraction.

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