Improving Personal Information Management by Integrating Activities in the Physical World with the Semantic Desktop

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ABSTRACT

Semantic desktops are a novel approach to improve user interfaces by recording, semantically annotating, and learning from the user's activities to create a personalized user experience and improve search. Such activities, however, are restricted to the information universe, i.e., they only cover events on the local desktop. A next step towards smart mobile devices is the integration of those desktop events with the user's activities in the physical world. Establishing such mappings enables the device to draw conclusions from the recorded desktop events to those that the user is likely performing in the physical world. A Personal Information Management (PIM) system can then better assist the user in task planning and routing. In this work, we propose activity ontologies as blueprints to model the user's activities in the physical world, and use these ontologies to link the Semantic Desktop and the information available on the Web of Linked Data. We discuss the principles of designing the activity ontologies and how to employ them to associate local files and applications with complementary information from the Web. We design a specific activity ontology for a conference use case and present a user interface that extends the *Zeitgeist* Semantic Desktop to evaluate our approach.

Categories and Subject Descriptors

I.2.13 [**Knowledge Management**]: [Knowledge personalization and customization]; I.7.1 [**Document and Text Editing**]: [Document management]; I.2.12 [**Intelligent Web Services and Semantic Web**]: [Ontology design]

General Terms

MANAGEMENT

Keywords

Personal Information Management, Semantic Desktop, Semantic Web, Events, Ontologies, Activities

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1. INTRODUCTION AND MOTIVATION

Each of us is creating and maintaining an increasing amount of personal information, such as emails, ToDo lists, pictures, bookmarks, or notes. The volume and variety of information created by consumer electronics, reveal the limitation of traditional information organization mechanisms such as those based on hierarchical directories. Users have to pre-define and constantly maintain a folder structure as well as decide on how to file a particular information object. A recent study analyzing email organization shows that even well structured folders do not provide better performance than using the search-file function[12]. One reason for this is that the same information item can be categorized according to different contexts, such as filenames, topics, timestamps, and content.

Semantic Desktop is a new technology which facilitates personal information management by establishing connections among the user's documents, emails, tasks, as well as software applications. Two typical examples of the Semantic Desktop are *Nepomuk* and *Zeitgeist*. Both have implemented ontologies to organize the user's data (which may be accessed by different applications and stored in different formats) and, thus, offer search abilities beyond simple keywords[9].

However, current semantic desktops have two major limitations. First, they rely on the availability of metadata to structure the information items. Consequently, a *semi-automatic annotator* is often provided to extract file descriptions as well as to allow the user to input metadata manually [6, 4]. Unfortunately, only a fraction of metadata can be automatically extracted from existing files, and most users do not annotate their data manually. Second, semantic desktops are restricted to those activities that are performed on the desktop – a mechanism to match them with the user's experiencing in the physical world is missing. As a result, while the semantic desktop can learn to open a bibliography tool whenever the user opens an Office document, understanding that this may be part of a larger activity, such as preparing a conference paper, is difficult. Therefore, existing semantic desktops cannot address queries such as *'which research papers did I read while preparing my ACMGIS 2012 paper'*.

In this work, we argue that a next generation of Personal Information Management (PIM) systems need more than just accessing to a rich set of contextual information and semantic annotations: an understanding of human activities is necessary for such systems to execute advanced informa-

tion queries. To do so, we propose to associate activities in the physical world with those on the Semantic Desktop. We model activities in the physical world via activity ontologies, and discuss how these activities are related to their digital footprints on the local Semantic Desktop as well as on the Web of Linked Data. By doing so, we construct a personal information space in which information items from both the Web and the Semantic Desktop are well organized and managed. An extension to the Zeitgeist semantic desktop has been implemented to illustrate our approach.

The remainder of this paper is structured as follows. Section 2 introduces related work on the Semantic Web, the Semantic Desktop, and personal information management. Next, section 3 discusses the need for activity ontologies and how they link the data from the Web and the Semantic Desktop. Section 4, presents an implementation showing first results from our work. Finally, section 5 concludes our work by pointing out limitations and directions of future research.

2. RELATED WORK

This section briefly introduces related work on personal information management, as well as background readings on the Semantic Web and Semantic Desktops to help understand the presented work.

2.1 Semantic Web and Semantic Desktops

The Semantic Web is an enhancements of the classical Web. It employs a stack of technologies and principles to give well-defined meaning to the information on the Web, and weaves the data into a structure that can be understood by both humans and machines. With a rapidly increasing number of *Linked Open Data* projects, a large amount of data have been published or converted into the standard Resource Description Framework (RDF) format and are linked to other external datasets. Open web knowledge bases, such as Freebase and DBPedia, enables everybody to contribute timely information about people, places, events, and other entities. As a result, the Web of Data provides us with *digital counterparts* of many aspects of the physical world.

The concept of the Semantic Desktop is derived from the Semantic Web. Its core idea is to bring Semantic Web technologies to desktop, and turn a personal device into a *'personal Semantic Web'*[9]. Similarly, related data items on the Semantic Desktop are interlinked. Researches show that people memorize things by topics and their interrelations[10]. Thus, the Semantic Desktop organizes personal files in a way that is close to how people naturally think.

2.2 Personal Information Management

Personal information management is defined by Jones Williamas et al. as '*both the practice and the study of the activities people perform in order to acquire, organize, maintain and retrieve information for everyday use*'. More than six decades ago, Vannevar Bush proposed his vision of a PIM system, called *Memex*, in which an individual can store all his or her documents, photos, records and other files, and semantically associate these items together [3]. To fulfill the vision of *Memex*, a number of PIM systems have been developed, such as *MyLifeBits*[6], *Haystack*[7], *Gnowsis Semantic Desktop*[8], *SEMEX*[5], and Cruz and Xiao's layered PIM framework[4].

However, existing PIM systems only focus on the local information universe. A closer integration with data and services on the Web is still under research. For example, while a traditional PIM system may group the conference-related information objects using a tag *ACM GIS 2012*, relating those information items to the data from previous ACM GIS conferences is difficult. However, the necessary information to do so already exists on Web knowledge base such as Freebase. A semantic desktop that understands the relation between a conference and its series therefore can interlink related tags and information items stored on the user's machine. Besides, current PIM systems do not have an understanding on the associations between the user's desktop activities and those carried out in the physical world. Connecting both can help people to quickly find the data they used when performing a particular activity in the real world. For instance, such a system could answer the questions such as *which papers I have read when preparing this ACM GIS 2012 manuscript, or which people I may have met during the conference.*

3. LINKING DATA VIA ONTOLOGIES

In this section, we discuss how activities in the physical world can be aligned with those recorded on the Semantic Desktop, and how to construct activity ontologies to link information items from both the Web of Data and the personal Semantic Desktop.

3.1 Activity Ontologies

We argue that a next generation of PIM systems should have an understanding of the user's activities in the physical world. Such activities can be related in several ways: they can follow each other, overlap in time, or compose a more complex activity. Consider the example of attending a conference in which a user will write a paper, arrange the trip, and participate in the conference. The travel arrangement activity will be followed by the conference participation activity, since attending the conference always succeeds planning the trip. However, the paper writing activity and the trip planning activity may overlap, as one can start to arrange the travel while still writing the paper. All of the three activities are associated to compose a more complex activity: attending the given conference. In addition, some activities have well defined start and end dates, while others do not. For instance, travel arrangement, such as booking a flight, can be made at any time but need to be finished before the conference. Similarly, while the starting point for paper writing is unknown, the activity has to end before the final submission deadline set by a conference.

Activities in the physical world can have their corresponding footprints on the Semantic Desktop. For instance, writing a paper may involve using TexMaker or other programs to edit TEX files as well as employing a PDF Reader to open other papers. Similarly, travel arrangements may have a digital counterpart of using a Web browser (e.g., Firefox) to visit a Webpage, and a presentation will, more likely, be given using a PDF reader or an office software suite.

Activities can also have their digital counterparts on the Web. Consider the conference that the user is going to attend. Its start date, end date, location, proceeding, keynote speaker, and other information may already be available on the Linked Data cloud. Besides, for each of these entities (e.g. the conference location), its detailed descriptions may

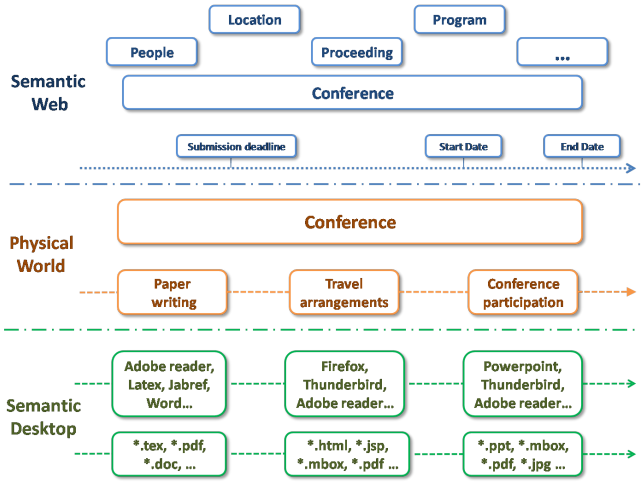

Figure 1: Some conference related activities in the physical world and their digital footprints on the Semantic Web and the Semantic Desktop

also be available on the Web of Data. Based on the conference example above, Figure 1 shows some conference-related activities in the physical world, and their digital footprints on the Web and the personal desktop.

Understanding physical-world activities and their digital footprints in the two information universes, we can design ontologies as blueprints to model them. Two principles are proposed to guide the ontology designing process. First, the ontology should be able to describe the relations between activities, such as temporally overlapped or thematically associated. To a certain degree, those relations can be mined and learned bottom-up from the data and the user's behaviors. However, a top-down approach can speed up this process, make it more robust, and also capture the cases that are difficult to learn. For instance, the relation between preparing a paper and traveling months later to a conference cannot be learned just by observing data and activities on the desktop– it requires an understanding of the activities in the physical world, and how both of them are related to attending a conference. When the PIM system sees the connection between booking a flight online and connecting to a free airport WiFi network, it will be able to pre-cache information that may be useful but not available on the flight.

The second principle for designing activity ontologies is that those ontologies should provide *hooks* which allow real-world activities to connect to their digital footprints. These hooks can associate the related information items from the two information universes with their corresponding activities in the physical world, thereby enriching the descriptions of these activities. Even more, such hooks effectively link the Web and the personal desktop and, thus, provide the user with a unified personal information space. In this space, users can efficiently retrieve the information items they need without having to think whether this information is actually from the Web or the desktop.

3.2 Conference Activity Ontology

To give a concrete example, we discuss how to construct a specific activity ontology as a blueprint for the task of *attending a conference* by combining three ontologies that have been adopted in existing applications. We also demonstrate how this ontology interlinks conference-related data from the Web of Linked Data and the personal Semantic Desktop using the example of attending ACM GIS 2012.

The three ontologies employed in this work are the Freebase conference ontology, the suite of Nepomuk ontologies, and the Simple Event Model. The Freebase conference ontology is a domain ontology used by Freebase [2] to associate the concepts related to conferences. The Nepomuk ontologies were first designed in the Nepomuk project (Networked Environment for Personalized, Ontology-based Management of Unified Knowledge), and provide a means to build semantic associations among applications, data resources, and the user's desktop activities. The Simple Event Model (SEM), proposed by van Hage et al.[11], provides comprehensive vocabularies to describe events. It can model *who did what, when*, and *where*, the roles played by the activity participants, and even conflicting views towards the same event.

By combining the three ontologies, we constructed a conference activity ontology for the ACM GIS 2012 instantiation[1]. In the Web information universe, there are groups of semantically associated information items from different Web sources (such as Freebase and DBpedia) which describe the conference and related entities in different perspectives. SEM is employed to represent the conference and related activities in the physical world, such as paper writing and travel arrangement. In the desktop information universe, the Nepomuk ontologies associate the local files and applications with the user's desktop activities (e.g. opening a document). The property of *isRelatedTo*, and the properties in the OWL Time Ontology (e.g. owl:before) models the relations between activities. The property of *hasDigitalFootprint* links the user's activities in the physical world to their digital footprints on both the Web of Linked Data and the local Semantic Desktop.

4. IMPLEMENTATION & APPLICATION

As a proof-of-concept, we have implemented a prototype that utilizes the conference activity ontology to associate conference-related activities with the information items from both the Web and the personal desktop. This prototype has been designed as a plug-in for the *Gnome Activity Journal* on the Semantic Desktop *Zeitgeist*. The *Zeitgeist* framework is a Semantic Desktop based on the Nepomuk ontologies. It records the user's desktop activities (e.g., editing a document) using a logging service, and associates such activities with the files and applications used in these activities. The *Gnome Activity Journal* provides a graphic user interface (GUI) which displays the files used by the user according to their timestamps, e.g., Sunday afternoon or Monday evening.

Since *Zeitgeist* and *Gnome Activity Journal* have already provided a good framework for personal information management, we develop the prototype as a plug-in instead of a stand alone application. Our implementation uses the Python APIs for the *Zeitgeist* engine and the GUI interface. To efficiently manipulate the classes, properties, and individuals in the conference activity ontology, we employed InfixOWL in the FuXi framework [2]. We dynamically create a knowledge graph, and populate it with the conference-

[1]http://www.geog.ucsb.edu/~hu/ActivityOntology.png
[2]http://code.google.com/p/fuxi/

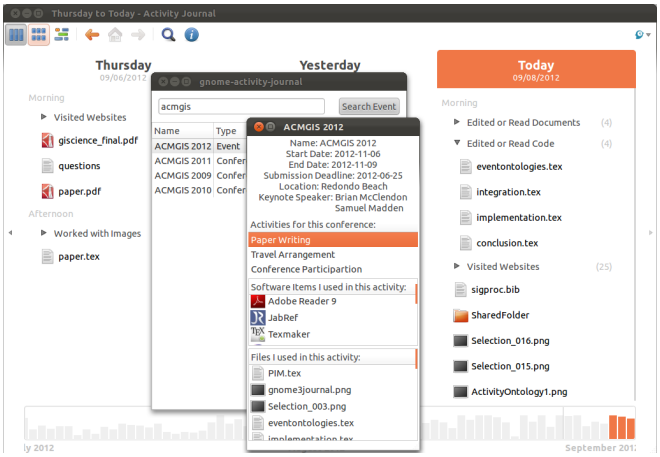

Figure 2: Graphical user interface of our plug-in to the Gnome Activity Journal.

related data from both the Web and the personal desktop[3]. Our plugin can then reason and answer more complex questions such as *what are the files and applications I opened when preparing my ACM GIS paper*, see Figure 2.

5. CONCLUSIONS AND FUTURE WORK

In this paper, we argued that a next generation of PIM systems requires an understanding of human activities in the physical world. Semantic annotation of desktop data, contextual information provided by sensors or Web services, and even data mining and classification alone are not sufficient. They only work on the level of the information universe. We proposed to develop ontology blueprints for common human activities, and align those activities to the files and applications monitored by Semantic Desktops as well as the information items on the Web of Data. We discussed conference related activities as an example and showed how three existing ontologies can be used to annotate data from the Linked Data Web as well as the user's desktop to answer complex queries such as *'which papers from the ACM GIS proceedings have I opened during the conference'*.

While we have implemented the required ontologies and query filters in a plug-in to the Gnome Activity Journal, other query capabilities are still in development. As proposed by Abdalla and Frank[1], the temporal and spatial characteristics of the activity ontologies can also be employed to pre-fetch important information, improve routing, and ensure the PIM system displays only the information that is relevant to the current and potentially following activities. In addition, Semantic Desktops for mobile devices are currently under development, and will also help to develop smarter PIM systems in the future.

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[3]For page limits, we omit technical details. You can contact the authors for more information.

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