Providing Universal Accessibility Using Connecting Ontologies: A Holistic Approach

Shuaib Karim[1,2], Khalid Latif[1,3], and A. Min Tjoa[1]

[1] Institute of Software Technology & Interactive Systems, TU Wien - Austria
[2] Department of Computer Science, Quaid-i-Azam University, Islamabad – Pakistan
[3] Department of Computer Science & I.T., Islamia University, Bahawalpur – Pakistan
{skarim,klatif,amin}@ifs.tuwien.ac.at

Abstract. Accessibility implementation efforts are generally focused towards some typical user impairments and a few interaction devices for a particular user scenario. Whereas there are numerous factors in the prevalent context which can leverage the overall accessibility to its full potential, only if those are orchestrated together. In absence of a common and unifying approach the industry has little choice in abstaining from legacy and is therefore not very successful in producing universally accessible software. Exploiting enabling technology of Semantic Web, we present an approach by developing Connecting Ontologies for these different factors. Exemplars are developed to show its correctness and practicability.

Keywords: Universal Accessibility, Diversity, Connecting Ontologies, Mapping Ontologies, Ontology Design Patterns.

1 Introduction

In absence of a generic framework the provision of universally accessible software is a precarious task for the producers. Attempts for independent resolution of accessibility and diversity issues, which indeed complement each other, have further elongated the goals for both and the vague boundary between the two still prevails. According to descriptions by W3C[1], ANSI[2] and ISO[3] accessibility is not only related with user impairments but a wider range of contributing factors which are part of the overall context. Different types of interaction devices, varying user needs & impairments, and the specifications of the task at hand are some significant components of the context. User interfaces and visualizations are the means to carry out the tasks in a particular context. Also, visualizations are not *a priori* suitable for all types of information entities which are a combination of data and the related semantics for their description. Consequently, there are many contributing components interacting with each other. **In order to improve universal accessibility the components' semantics must be exploited to produce an accessible presentation for the end user. In this paper special attention is laid on accessibility for users with special needs or impairments.**

[1] http://www.w3.org/TR/WAIWEBCONTENT/ (January 15, 2007)
[2] http://acm.org/sigchi/bulletin/1997.2/standards.html#HDR3 (January 15, 2007)
[3] Available from http://www.stcsig.org/sn/internetISO.shtml (January 15, 2007)

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Automation of this process consists of two major steps; a) formal description of semantics for each component and b) formal description of semantics of consequences and effects of potentially interacting component on each other. Ontologies for the formal semantic description of user impairments, device profiles, tasks related to a particular domain, and their inter-connections are being developed using recently emerging semantic web technologies. Ontologies could be developed and arranged by following different approaches such as taxonomic and faceted. For this research we have restricted ourselves to a hierarchical approach which will lead to further approaches in future. Instead of developing the ontology from scratch we have adopted concepts mainly from existing specifications, domain thesauri and foundational ontologies. In this paper we propose a framework for providing accessibility at a generic level using the notion of the *Connecting Ontologies.*

This work is an extension of our previous paper [1] which describes the connection between user interface characteristics and the user's impairments data using OWL-DL. The paper is structured as follows:

Next section describes the related work. Section 3 describes the concept of *Connecting Ontology* and how it is different from other apparently similar concepts like ontology mapping and ontology integration. This is followed by our methodology of exploiting ontology design patterns in Section 4, leading to architecture of Accessibility Framework in Section 5. The description of the method adapted for connecting user's life time information items & events is presented in Section 6. Finally, conclusions and future directions are given.

2 Related Work

The usefulness of connected knowledge was highlighted in [2] by describing the initial results where medical domain ontology can be seamlessly scaled and integrated with ontology of another domain. Similar discussions lead to the foundation of *Semantic Web Health Care and Life Sciences Interest Group*[4]. However, to the best of our knowledge the concept of connecting ontologies is not yet fully exploited to connect heterogeneous domains, especially for improving accessibility.

In [3] the concept is used to connect external business processes and internal work flow processes using *LAV (Local-As-View)* data integration approach [4] to map the two models. *LAV* approach provides a uniform query interface using a global mediated schema to be defined independent of the data sources. Its relationship with the data sources is then made possible by connecting global schema with specialized views for each data source. Looking at the *Accessibility Framework* (see Fig. 4) there is a conceptual similarity with our approach where *Query Interface* is realized using a global schema and the *Connecting Ontologies* are acting as mediation interface between global schema and the data sources (ontologies and instances for context components). However their concern is to connect process work flow models pertaining to "similar domain", which is not the case in our work.

The recent work described in [5] is an example of how OWL [6] in combination with RDQL rules [7] is employed for connecting heterogeneous ontologies in an

[4] http://www.w3.org/2001/sw/hcls/ (January 15, 2007)

electronic medical record application. More specifically, the concepts in SNOMED[5] are linked with an ontology containing drug / medicine related concepts such as drug classes, their interactions, allergies and formularies. The purpose is to limit the generation of disputed medical insurance bills which are created due to inconsistencies in coding schemes used during diagnosis (such as ICD9CM[6]) and the corresponding list of approved medical procedures as permitted by insurance companies. The semantic annotations are applied in XML files which allow using Web technologies such as XSL and XPATH, and rules interpretation by RDQL. However, the domain is not modeled in OWL which confines the benefits because of inability to use convenient querying by SPARQL and sophisticated inference capabilities offered by ontology reasoners.

The work about Contextualizing Ontologies [8] shows the mappings of GALEN medical ontology with Tambis genetic ontology by aligning both with another medical ontology called UMLS. Bridging rules using C-OWL (Context-OWL), are defined for mapping the individual concepts or concept expressions belonging to ontologies in similar domain of discourse. In contrast, our approach provides interconnection between concepts in varying domains of discourse.

3 Connecting Ontology

An ontology formally describes the concepts in the domain of discourse [9] or more realistically speaking, helps to formally specify the concepts. A System, by definition an integrated whole, is essentially composed of heterogeneous components or domains which have to interact with each other to achieve a certain goal. Each of these has its domain ontology which is composed of concepts description about that domain. By *Connecting Ontology* we mean an ontology which links two heterogeneous ontologies or in other words, which describes the linking of heterogeneous entities (concepts, relations and properties) across two ontologies. This is analogous to the famous wine and food ontology described in [10].

To illustrate it further, let us assume that ontology O_1 has a concept c_1, and ontology O_2 has another concept c_2. The *Connecting Ontology Oc* will contain either the concept c_3 to link c_1 with c_2 or extend c_1 with new features which in turn links it with c_2. Once the ontologies O_1 and O_2 are populated with instances, their connections are dynamically generated by the reasoner based on their connections present in *Oc*. It is often the case that the two ontologies were developed based upon different formalisms ensuring decidability of axioms. Although components of both the ontologies may be decidable, but when combined together the decidability may not be guaranteed. As described in [11], E-Connection is such a method to link two ontologies in terms of Abstract Description Systems (ADS) [12].

The concept of *Connecting Ontology* is different from other apparently similar notions like ontology mapping, alignment, articulation, merging or integration. The term *ontology mapping* is described as “the task of relating the vocabularies of two ontologies that share the same domain of discourse in such a way that the mathematical structure of ontological signatures and their intended interpretations, as

[5] http://www.snomed.org/snomedct/index.html (January 15, 2007)
[6] http://icd9cm.chrisendres.com/ (January 15, 2007)

specified by the ontological axioms, are respected" [13]. *Ontology alignment* is concerned with the process where binary relations (also called atomic roles such as properties) between vocabularies (more specifically concepts or unary predicates within these vocabularies) of two ontologies belonging to the same domain of discourse are established. This leads to *articulation of two ontologies* when these binary relations are specified in terms of ontology in itself. Properly specified articulation ontology helps in *merging or fusion* of the concerned ontologies. *Ontology merging or fusion* is closer to our notion of *connecting ontologies.* However, contrary to fusion the two ontologies are not merged but connected using additional features and relations. The aspects of composition of ontologies to build a new unified ontology, extending the existing ontologies to build new ones, and incorporating ontologies into the applications are described under *ontology integration.* We envision the distinctive features of *Connecting Ontology* as follows:

- The ontologies to be connected are not related with the same domain of discourse. Though they may be part of the overall application.
- Their vocabularies are independent of each other. Even if there are apparent similarities, they are still assumed to be independent.
- Each of the ontologies to be connected is supposedly developed using its own design pattern(s) - explained later in Section 4.
- There might be similarity between the design patterns of two ontologies which may prove helpful for connecting them together.
- Connecting ontologies from heterogeneous domains are in fact creating new knowledge in the light of user's experience, whereas other notions of ontology mapping help to reorganize the existing knowledge.

Following are some of the benefits of *Connecting Ontologies*:

- Users think in an application or need oriented way, find available artifacts & then try connecting them together to fulfill their needs. *Connecting Ontologies* would facilitate this top-down approach.
- The incompatibilities between two ontologies are solved at the ontological level without delving into the application code.
- By elevating one ontology with rich design patterns based upon new user needs, it is possible to trace the corresponding effects on the other ontology due to already established *cause-effect* relationship between them.
- In other words, connecting ontologies are helping to automate the coding process.
- The approach will be beneficial for many domains including future interfaces for e-Learning. Travel on the interface and way finding consisting of tasks such as exploration, search and maneuvering can be greatly improved by interconnecting ontologies of user's tasks, impairments, interaction devices & visualizations in use.

4 Exploiting Ontology Design Patterns

Recent research in *Ontology Design Patterns* [14] is the stimulating factor for improvising some useful patterns for our system. *ODPs* help to identify the objectives and conceptualize scope and components of the application and the related ontologies.

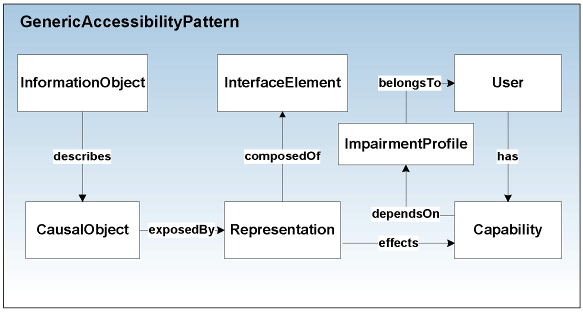

Fig. 1. A Generic Accessibility Pattern

4.1 Generic Accessibility Pattern

A generic accessibility pattern for connecting user profile and visualization ontologies is shown in Fig. 1. This pattern is further extended to implement various scenarios in *SemanticLIFE* system [15]. Its different components are described below. A few specializations are also shown which are explained later in this section.

- *InformationObject*: Information items in our system with associated semantics.
- *CausalObject*: Derived from information objects. For example, life events may be derived from the information items.
- *Representation*: The interface or visualization which is used for the visualization of the causal objects. There can be different visualizations for diverse users (specifically user's impairments profile contain impairments related data for people with special needs) in different contexts. The representation semantics are described in terms of their composition, intended users, data to be shown, & tasks for which it is designed. For example, tabular view is better for numerical data, whereas geographical map is more suitable for spatially significant information.
- *InterfaceElements*: Appropriate interface elements are selected for composing a representation based upon information objects and user characteristics. The semantics of interface elements are related with their usability measures and composition with other interface elements to form composite interface elements.
- *Capability*: It is the ability of the user to carry out a certain task. It depends upon the user's impairments data and the domain oriented task ontology. Based upon the user's task completion statistics the system can be fine-tuned by configuring the different components in the specified pattern.
- *ImpairmentsProfile*: This is the ontology about user's impairments (disability) related data, discussed in detail in [1]. The user's capability to carry out certain tasks is dependent upon the related impairment value in the impairments profile.

4.2 Memory Recall Pattern

A specialization of our proposed Generic Accessibility Pattern for helping the people with memory deficit is shown in Fig. 2. It shows the relationship between the user's ability to recall things, the lifetime information items which are associated with life events, and the representations to present or expose those events to the user.

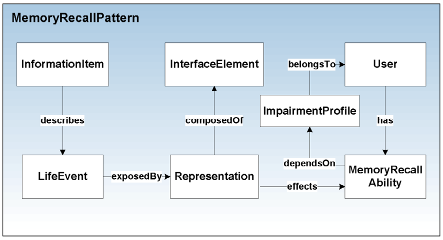

Fig. 2. Ontology Pattern for Inferring Effect on User's Memory Recall

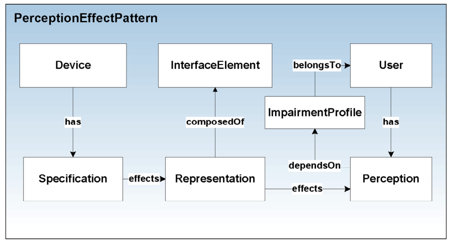

Fig. 3. Ontology Pattern for Inferring Effect on User's Perception

Following is the pattern's explanation in context of our *SemanticLIFE* system:

– *InformationItem*: Feed items such as emails, files of multiple types, web browsing history, chat sessions, processes running on user's PC, contacts, calendar.
– *LifeEvent*: Important events in user's lifetime which are helpful in recalling other entities and events such as birthdays, anniversaries, and other important occurrences. The events are identified and explicitly specified by semi-automatic analysis and annotation of the information items. It is important to keep in mind that there exists an *m:n* relationship between lifetime information items and events.
– *Representation*: The interface or visualization which is used to show these life events to the user. There can be different visualizations for different users because, for example, the preferred events sequence and events identification may vary according to user's impairments profile.
– *MemoryRecallAbility*: The ability of the user to recall the events or entities such as person and location with the help of representation. It can be measured against some specific tasks performed by the user designed heuristically.

4.3 Perception Effect Pattern

The *Memory Recall Pattern* is a specialization of the generic accessibility pattern where as the *Perception Effect Pattern* (Fig. 3) is its variation. It depicts *cause-effect* relationship between the user impairments, device profile and interface capabilities. The components modified or added for this purpose are described below:

– *Device*: Interaction device or parts thereof; like keyboard, display and cell phone.
– *Specification*: Semantic description of the device, known as the device profile [16].
– *Perception*: User takes time for making sense of the presented information, and then understanding how it is fulfilling his / her intended task. It can effectively be measured quantitatively and qualitatively when connected with task ontology.

4.4 Outcome of Ontology Design Patterns

These patterns are to be implemented in OWL-DL to enrich the connecting ontologies for the following domain models:

– User information space covering information items and life events
– Representation or Visualization

- User impairments
- Domain related tasks
- Device profile

The above analysis and outcomes helped us to define the accessibility framework.

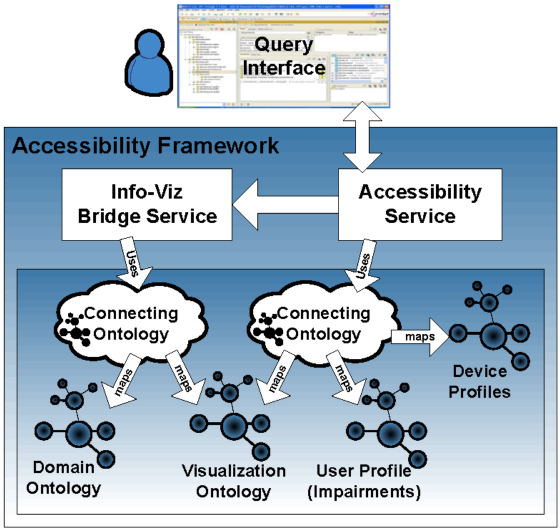

Fig. 4. Overview of Accessibility Framework

5 Accessibility Framework

The proposed framework (see Fig. 4) exploits *Connecting Ontologies* for its work. User's request is forwarded to the accessibility service that asks Info-Viz Bridge service to suggest, for example, appropriate interface elements or visualizations.

The recommendations of Info-Viz Bridge service are based on the rules and patterns established between visualization / representation and tasks ontologies. It is important to note that *we envision tasks as related to domain. Therefore those are modeled within the domain ontology.* The recommendations are sent back to the accessibility service. The interface is later adapted and made accessible using another connecting ontology which connects user impairments with device profiles and visualization recommendations through ontology design patterns and rules.

Our accessibility service may also be useful for providing accessibility extensions to existing ontology based UI frameworks such as Haystack [17]. Successive dry run of the inference system based on ontology design patterns and rules in connecting ontology were made to ensure its validity in real world scenarios.

6 Example Use Case

The connection between user interface characteristics and the user's visual impairments was explained in [1]. Here, the possibility to incorporate user's memory recall pattern (see Fig. 2) in the *SemanticLIFE* system is shown. This is a relatively simple case of memory dysfunction problems caused due to old age or otherwise. The ontology patterns exercise resulted in following *Connecting Ontologies*:

- User information Items ↔ Life Events
- Life Events ↔ Representation
- User Impairments ↔ Representation
- Tasks ↔ Representation
- User Impairments ↔ Tasks

The main classes in ontology for user's lifetime information items which are being stored in our system are shown in Fig. 5.

Information Item Information item on user's PC
Attributes {Description, Date, URI, Size}
- **Email** Emails sent or received by the user
  Attributes {Subject, Sender, Receiver, Attachments,…}
- **Chat** User's chat sessions
  Attributes {Participants, Start/End DateTimes, …}
- **File** Any kind of file on user's computer
  Attributes {Name, Path, URL, …}
- **Web Page** Pages browsed by the user
  Attributes {Title, URL, ..}
- **Contact** Items in user's address book
  Attributes {Name, Address, Tel, email, Contact Type (family, business, friends,..)…}
- **Calendar** Items from user's calendar
  Attributes {Title, Date, Location, Audience,…}
- **Process Monitor** Processes running on user's PC
  Attributes {process id, user id, command, argument(s), Date Time, …}

Fig. 5. Lifetime Information Items in Repository

Life Event User's lifetime events such as birth days of family members & friends, anniversaries, and other occurrences of user's interest
Attributes {Description}
- **Spatial Location** Geographical location of the place where event took place
  Attributes {Name, Coordinates}
- **Temporal Location** Event's starting and ending Date / Time
  Attributes {Start/End Times}
- **Disposition** Indicates the nature or mood of the event for the user
  Attributes {Description}

Fig. 6. Lifetime Events

The features of Life Events are described in Fig. 6. Life Events ontology is part of our comprehensive user model. The *Disposition* of an event can be categorized such as family, business, happy, sad, and important. *It is to be noted that our Life Events ontology will complement the events recorded in user's Calendar.* Some examples of the concepts which are part of the *Connecting Ontology* between lifetime events and lifetime information items are given below:

- ⟨InformationItem, *belongsTo*, LifeEvent⟩
- ⟨Contact, *participatesIn*, LifeEvent⟩
- Concept to specify role(s) of participants in the event
- Concept to identify the event of interest based upon user's preferences

In *Connecting Ontology* these concepts are formally specified using OWL-DL and the available rule languages are to be used for making sophisticated reasoning using Jess[7], and other reasoners such as Jena[8].

The state of knowledge about the domain of the *Connecting Ontology* being developed is very important. There are situations when the domain knowledge for the

7 http://herzberg.ca.sandia.gov/jess/ (January 15, 2007)
8 http://jena.sourceforge.net/inference/ (January 15, 2007)

CO exists either as (i) unstructured documents or as (ii) tacit knowledge with domain experts, or is (iii) still imaginative. In the use case under consideration, the domain knowledge about lifetime events exists as unstructured documents like emails, photo collections, file contents & chat session log. For generating *CO* the approaches under experimentation are based upon (a) text processing of *CO* domain knowledge and the two participating ontologies, or its refinement by (b) aligning participating ontologies with global standard ontologies, or (c) an approach exploiting all possible queries on the participating ontologies. However, the details are outside the scope of this paper.

7 Conclusions and Future Work

Bottom up approach of incorporating accessibility is a complex and unmanageable task which consumes a lot of resources. Consequently, it has proved to be a repulsive factor in itself for the software producers in providing universally accessible tools in general [18]. The presented approach tackles the problem space components' interactions from a holistic point of view using *Connecting Ontologies* while preserving the freedom of components' reuse by having individual ontologies of their own. Ontology design patterns are successfully being employed in our system which makes the approach more convincing for the practitioners.

This is a work in-progress for the *SemanticLIFE* project. Legal and ethical implications associated with a person's life time information, especially in case of memory and cognitive dysfunctions because of person's inability to make the right decision needs careful consideration and further research.

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