Adaptive Information Provisioning in an Agent-Based Virtual Organization—Ontologies in the System *

Michal Szymczak[1], Grzegorz Frackowiak[1], Maciej Gawinecki[1], Maria Ganzha[1], Marcin Paprzycki[1], Myon-Woong Park[2], Yo-Sub Han[2], and Y.T. Sohn[2]

[1] Polish Academy of Sciences, Systems Research Institute, Warsaw, Poland
{Maciej.Gawinecki,Maria.Ganzha,Marcin.Paprzycki}@ibspan.waw.pl,
[2] Korea Institute of Science and Technology, Seoul, Korea
myon@kist.re.kr

Abstract. In this paper we consider utilization of ontologies in an agent-based virtual organization. Specifically, in the system flexible delivery of information is to be based on matching of ontologically demarcated resource profiles, work context(s), and domain specific knowledge. In this paper we introduce basic ontologies and their applications.

1 Introduction

Let us consider a *virtual organization* (*VO*) in which workers access resources to complete their tasks [1–3, 8]. Access to resources should be adaptive (change with tasks, and evolve as tasks/projects evolve) and personalized (workers require access to different resources depending on their roles in the project and the organization). In our earlier work [13] we have outlined processes involved when a project is introduced into an organization. Later, in [6], we have considered roles played by various entities (humans and agents) identified in [13]. Separately, in [7] we have proposed how e-learning can be introduced into the system in support of adaptability of human resources. In our work we have stated that ontologies will play a crucial role in the system. Thus, the aim of this paper is to present a top level overview of ontologies used in the system and their applications. Observe that in our work ontologies appear at least in the following contexts:

1. *domain specific knowledge*—framework for management of resources(e.g. to specify relations between projects and resources, or humans and resources),
2. *structure and interactions within and between projects*—to manage resources on the basis of needs of project and responsibilities of team members,
3. *resource profiles* (which utilize previous two ontologies)—that specify among others: (a) place of a resource within an organization, (b) employee' *interests*, *needs* and *skills*, and (c) what to do with new/incoming resources,

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4. *system data model and data model access infrastructure*—to manage demarcated data, provide rapid system extensibility and persistence.

We proceed as follows. We start with an overview of two existing approaches to ontological representation of virtual organizations. Next, we introduce the proposed system and its actual application—the Duty Trip Support. This allows us to describe the most important features of the proposed ontology of an organization as well as the way it will interact with a travel ontology.

2 Related work

2.1 Toronto Virtual Enterprise (TOVE)

TOVE project run at the University of Toronto. Its main goal was to establish generic, reusable enterprise data model with the following characteristics [5, 15]:

- to provide a shared terminology for the enterprise,
- to define the meaning of each term in a precise and unambiguous manner,
- to implement the semantics in a set of axioms, to enable *TOVE* to automatically deduce the answer to "common sense" questions about the enterprise,
- to define a set of symbols for depicting a term or concept constructed thereof in a graphical context.

According to documents found within the project WWW site, ontology developed by the project included terms such as: resource, requirement, time, state or activity, and was created in Prolog. We thought about relying on the *TOVE* project and utilizing data model constructed there. Especially, since *TOVE* was based on extensive research and considered work of an enterprise from the design and operations perspectives [9]. Unfortunately, inability to find actual ontologies (except of conference papers), a long list of important features to be added found at the project web site, and the last update of that site made on February 18, 2002, resulted in utilization of only the theoretical part of *TOVE*.

2.2 OntoWeb

OntoWeb Network is an initiative aiming at promoting the Semantic Web [10]. Within the project the *OntoWeb* ontology was developed and made available at [11]. Unfortunately the *OntoWeb* ontology has also important drawbacks:

- The *OntoWeb* ontology is created in RDF Schema, which does not have rich enough semantics [14]. Reusing the *OntoWeb* ontology as the system core ontology would lead us to restricting types of reasoning available in the system (e.g. due to the RDF Schema's inability to represent quantifiers).
- The *OntoWeb* ontology does not support resource profiles and information access restrictions, while they are necessary for the proposed system [6, 13].

Summarizing, we dropped the idea of reusing the *OntoWeb* ontology due to the limited expressivity of the RDF Schema and lack of necessary concepts. Instead, we followed guidelines and results obtained within both *TOVE* and *OntoWeb* projects and developed an ontology matching our project's needs. To introduce it, let us first describe main features of our system and present an application that is being developed using the proposed approach.

3 Proposed system

In Figure 1 we represent high level view of the proposed system through its use case diagram (see also [6, 13]). Let us assume that a task is proposed to the sys-

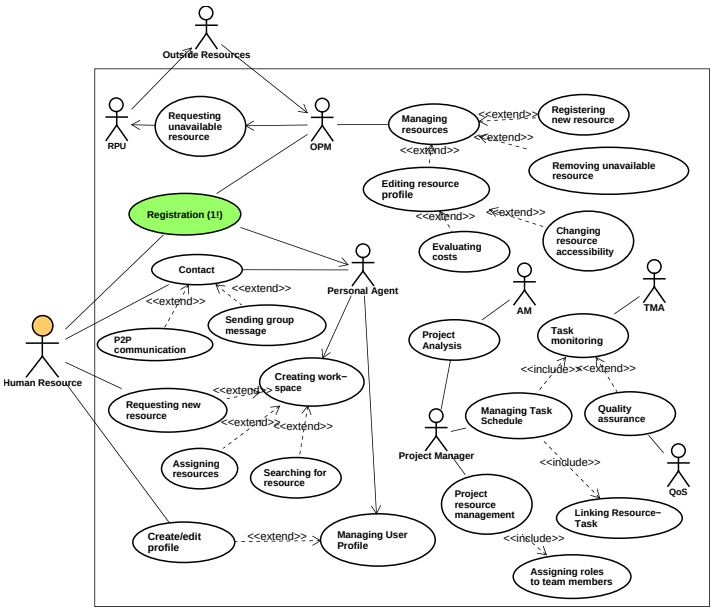

Fig. 1. Use case of the system

tem. To handle it, a *Personal Agent* undertakes a role of a *Project Manager*(PM) and orders the *Analysis Manager* (AM), to analyze the proposal and create document(s) required to decide whether to accept the job. If the job is accepted the PM creates a *Project Schedule* (based on analysis of available and needed resources). We assume that every PM has knowledge about some resources in the *VO*. As a result, available resources are reserved (a *Resource Reservation* is created). If the project requires additional resources the PM contacts the *Organization Provisioning Manager* (OPM) and requests them. The OPM has a knowledge about all resources in the *VO* and can either find them within the

organization or ask the *Resource Procurement Unit* (*RPU*) to provide them from the "outside." The *Project Schedule* is used to divide tasks among workers and assign *Task Monitoring Agent*s (*TMA*s) to control their progress. Tasks completion is evaluated by a task-specific *Quality of Service* (*QoS*) module.

4 Duty Trip Support application

Let us now discuss how the proposed system supports personalized information provisioning. The application is the *Duty Trip Support* at a Research Institute in East Asia. Here, workers use the intranet to apply for the *Duty Trip* and to submit trip report. Our aim is to provide them with additional functionalities. First, note that cost of air travel (to most destinations) is much higher—in a relative sense—than costs of a stay extended by a few days. Thus, employee traveling to a given city, may visit also near-by-located institutions (e.g. universities or companies), or persons that her institute has contacts with. Second, a recommender where to stay and eat could be of value (e.g. consider Thai researchers confronted with typical Finnish food). In addition to personalized information delivery, the system is expected to help researchers in all phases of duty trip participation; from the preparation of the initial application until filing the final report. Note that the *Trip Assistant* is actually a role played by the *OPM*, which provides the requested personalized input to the *PA* (see function *Searching for resource* in Figure 1). In Figure 2 we present the activity diagram of duty trip support (see also [6]). In this diagram we can see two moments when the *PA* communicates with the *Trip Assistant* (*OPM*), first when the application for the trip is prepared (and institutions/people to visit are sought), second, when actual details of the trip (e.g. hotels) are to be selected. Let us now utilize the general depiction of the organization (as presented in Figure 1) and the *Duty Trip Support* scenario to describe how we define (1) the *Generic Virtual Organization Ontology*—which delivers basic concepts for our system, and (2) the *Domain Ontology*—Institute of Science and Technology Ontology—which describes data model for the considered scenario and supports necessary scenario-specific reasoning operations.

5 Ontology of the Organization

Before we start let us note that delivering a comprehensive ontology for modeling an organization is beyond the *current* scope of our project. Our main aim is to deliver a framework for adaptive information provisioning. Hence, ontology requirements considered at this stage have been specified to support currently-necessary functions of the system. However, they are flexible enough to support its future extension to support comprehensive organization modeling.

5.1 Generic Top Level Ontology

We have decided to use OWL-DL as the ontology demarcation language, as it guarantees computational completeness and rich semantics[16]. The main idea

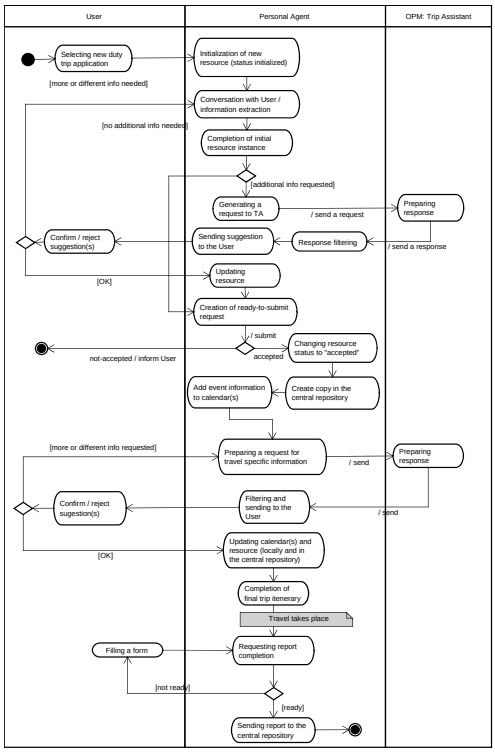

Fig. 2. Activity Diagram of the system

of our approach is to model *every* entity and person within the organization as a *resource*. Furthermore, each resource will have a *profile*. In Figure 3 we depict the generic resource and the generic profile concepts.

A *resource profile* provides detailed information about any resource (human or non-human). It is composed of a resource specific data and "opinions" about other ontology concepts or ontologically demarcated objects [17]. Classes *VOResource* and *VOProfile* are designed to be extended by any organization specific resources and their profiles (assuring that the concept is robust and flexible). For instance, this allows us to specify skills of a worker 1, as well as well as place a *Duty Trip Report* as a specific document within an organization 4 "subsystem."

Note that resource profiles may consist of private or classified information (e.g. personal data) therefore it is necessary to build an infrastructure which can restrict access to the information. This is also important since accessibility to a number of documents depends on the position within an organization (e.g. annual evaluation of a worker should be visible only to that worker and her supervisors). Note also, that each resource may be associated with multiple profiles (see the next section). A *VO Resource Profile Privilege* is a class which describes restrictions "on top" of a profile. It binds a profile with a restriction type which

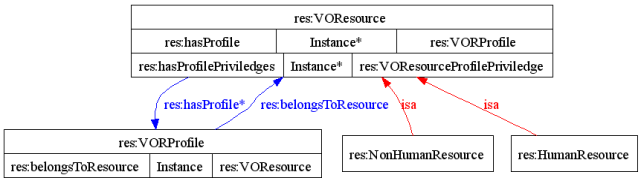

Fig. 3. Generic resource and generic profile concepts

is applied to all resources from a particular *Organization Unit (OU)*—whenever information is requested by, or matched with, resources. The binding of the *OU* and a particular *Profile Privilege Type* is realized by the *Profile Privilege* class. The *Profile Privilege Type* is an enumerable type specifying supported access privileges: *Read*, *Write*, *Read And Write* and *Admin*. Names of the first three are self-explanatory, the fourth type represents an administrative privilege which allows to modify access restrictions of the profile. Here, for instance, the *HR Department* is expected to have *Read and Write* privileges for worker profiles, while the *PA* is going to have *Read* privileges for information provided by the *DTS* (*OPM*) (see Figure 1). The design of the Profile Privilege is depicted in Figure 4.

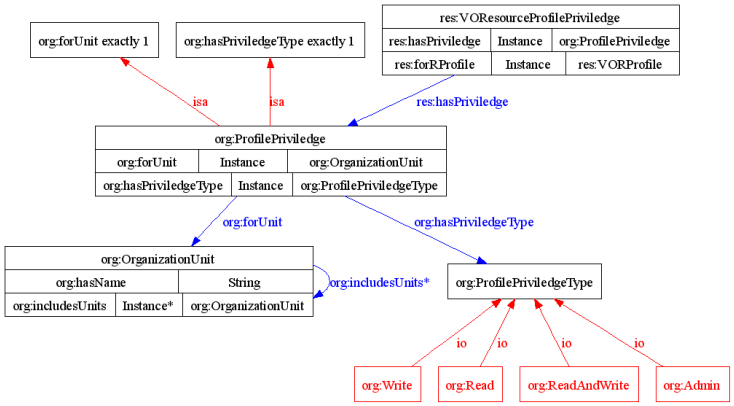

Fig. 4. Profile Privilege design

5.2 *Institute of Science and Technology IST* Ontology

To illustrate how the proposed ontology can be applied, let us discuss briefly its application to selected features of an ontological model of an Institute of Science and Technology. In the architecture of our system, the *Domain Ontology* is an extension of the *Generic Ontology* outlined in Figure 3. Here, human resources

are modeled in a way that is specific to the *Institute of Science and Technology*, though similarities with common human resource descriptions can be seen. The *ISTPerson* is a class of all employees of the Institute. While human resources have (multiple) general profiles, the following restrictions on profiles have been assumed:

- at least one profile should represent experience (*IST Experience Profile*).
- at least one should represent personal information (*IST Person Profile*).
- at least one should represent "position" in the organization (*Organization Profile*).

The *IST Experience Profile* allows to describe both educational and professional experience. Additionally, multiple research field can be listed in order to describe employees competences (research fields used here are based on the South Asian RFCD [12]). It is possible to assign level of competence for each research field [18]. *Personal Profile* is a set of data typically stored by the *HR Department*. *Organization Profile* specifies, for instance, a division in which the employee works; it can be also used to establish who is the supervisor of an employee. Additionally, for each human resource, her location and dining opinions (as well as other characteristics) can be assigned [18].

5.3 Duty Trip Ontology

In addition to being able to model human resources, the same general model can be applied to non-human ones. For instance, the *Duty Trip Report* is such a resource; an abstract of a report created by an employee during her duty trip. Its attributes are grouped in the *Duty Trip Report Profile*. These attributes specify trip's period, destination, objectives, expenses, a person who substitutes the departing employee at work, attachments and contacts which were made during the trip. Additionally, user opinions concerning accommodation and dining may be associated with the report. However these opinions cannot be considered as an opinion profile of a duty trip. Instead, this association is a link between a person's opinion and a context which was set by the duty trip. This information will be used in the future for reasoning within advisory functions of the system. The general structure of the *Duty Trip Report Profile* is depicted in Figure 5 and should be viewed together with the example presented in the next section. Note that for "travel objects" we utilize ontologies introduced in [19].

5.4 Example

Let us now present an extended example of utilization of the proposed ontology to model both an organization as well as the specific *Duty Trip*. Due to the limited space we can only point to a few aspects and we hope that the reader will be able to follow the example and find more features. Here, we depict a *Duty Trip* to a conference in Annaville, Canada, where Axel Foley will stay in a Four Seasons Hotel (and visit also Stephanie Brown). We can see also, (1)

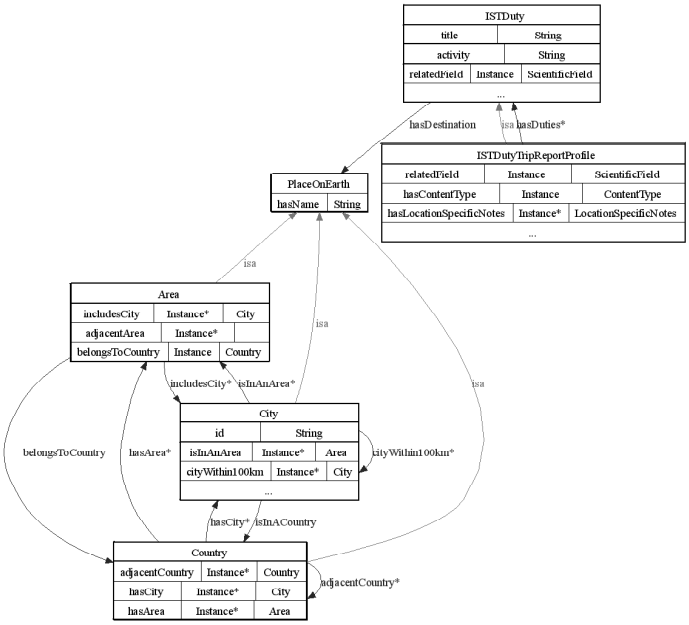

Fig. 5. Duty Trip Report Profile

how the geo-location will be demarcated (following the travel ontology proposed in [19]), and (2) the direct connection between the travel ontology ([19]) and the organization ontology as the city *geo:AnnavilleCity* is an instance of travel ontology element: *SpatialThing* and organization ontology class *City*.

```
geo:CanadaCountry a onto:Country;
        onto:name ''Canada''^^xsd:string.
geo:QuebecArea a onto:Area;
        onto:name ''Quebec''^^xsd:string;
        onto:isInCountry :CanadaCountry.
geo:AnnavilleCity a onto:City;
        onto:name ''Annaville''^^xsd:string;
        onto:long ''-72.433''^^xsd:float;
        onto:lat ''46.217''^^xsd:float;
        onto:isInCountry :CanadaCountry;
        onto:isInArea :QuebecArea.
geo:AnjouCity a onto:City;
        onto:name ''Anjou''^^xsd:string;
        onto:long ''-73.533''^^xsd:float;
        onto:lat ''45.6''^^xsd:float;
        onto:isInCountry :CanadaCountry;
        onto:isInArea :QuebecArea.
hot:AnnavilleFourSeasons a tss:Hotel;
        onto:locatedAt geo:AnnavilleCity.


:ContactPerson#1 a onto:ContactPerson;
                onto:fullname ''Stephanie Brown''^^xsd:string;
                onto:doesResearch science:Aerodynamics-30501;
                onto:worksIn geo:AnjouCity.


:HROU a onto:OrganizationUnit;
```

```
  onto:name ''HR Organization Unit''^^xsd:string.
:GOU a onto:OrganizationUnit;
  onto:name ''Default Organization Unit-for all employees''^^xsd:string.
:Employee#1 a onto:ISTPerson;
            person:fullname ''Axel Foley''^^xsd:string;
            person:gender person:Male;
            onto:hasProfile (<:PersonalProfile#1>);
            onto:hasProfilePriviledges :ResProfPriv#2.
            onto:belongsToOUs (<:GOU>).
:Employee#2 a onto:ISTPerson;
            person:fullname''John Doe''^^xsd:string;
            person:gender person:Male;
            onto:belongsToOUs (<:GOU> <:HROU>).
:DTR#1 a onto:KISTDutyTripReport;
       onto:hasProfile (<:DTRProfile#1>);
       onto:hasProfilePriviledges :ResProfPriv#1.

:DTRProfile#1 a onto:KISTDutyTripReportProfile;
   onto:destination geo:AnnavilleCity;
   onto:traveler :Employee#1;
   [a onto:Period;
   onto:from ''2008-06-07T00:00:00''^^xsd:dateTime;
   onto:to ''2008-06-19T00:00:00''^^xsd:dateTime.].
   onto:stayedAt hot:AnnavilleFourSeasons
   onto:expense ''4000''^^xsd:integer;
   onto:expenseCurrency ''USD''^^xsd:string;
   onto:visited :StephanieBrown;
   onto:purpose ''Conference''^^xsd:string.
:PersonalProfile#1 a onto:ISTPersonalProfile;
   person:birtdate ''1968-03-07''^^xsd:date;
   onto:currentSalary ''6000''^^xsd:integer;
   onto:currentSalaryCurrency ''USD''^^xsd:string;
   onto:privateAddress ''Alma Drive 0007 Nothingam''^^xsd:string.

:ProfPriv#1 a onto:ProfilePriviledge;
            onto:forUnit :HROU;
            onto:hasPriviledgeType priv:Admin.
:ProfPriv#2 a onto:ProfilePriviledge;
            onto:forUnit :GOU;
            onto:hasPriviledgeType priv:Read.
:ResProfPriv#1 a onto:VOResourceProfilePriviledge;
            onto:forRProfile :DTRProfile#1;
            onto:hasPriviledge (<:ProfPriv#2>).
:ResProfPriv#2 a onto:VOResourceProfilePriviledge;
            onto:forRProfile :DTRProfile#2;
            onto:hasPriviledge (<:ProfPriv#1> <:ProfPriv#2>).
```

Observe that defined privileges allow members of the *HR* unit (e.g. John Doe) to administer selected profiles (e.g. *:PersonalProfile#1*), while members of the *General Organization Unit* are not allowed to access it (by default all access is forbidden). On the other hand the *:DTRProfile#1* can be read by all employees of the *GOU*. In this way we assure control of access rights within the organization.

6 Concluding remarks

Concluding, we would like to stress the need for ontology verification and testing, especially of the *VO Generic Ontology*. The first step will be creation of the *Duty Trip Support* application and a somewhat related *Grant Announcement Support*. During their implementation and testing completeness of our ontologies will be verified. Furthermore, we will devote our attention to resource matching

methodologies, as one crucial functions of the proposed system. Specifically, it is necessary not only to model profiles of resources, but also to establish their "distances." This would allow, for instance, to specify who should receive a grant announcement, or which restaurant should be suggested to a given employee.

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