Agent-Based Adaptive Learning Provisioning in a Virtual Organization*

Maria Ganzha[2], Marcin Paprzycki[2], Elvira Popescu[1], Costin Bădică[1], and Maciej Gawinecki[2]

[1] Software Engineering Department, University of Craiova, Craiova, Romania
{badica_costin, popescu_elvira}@software.ucv.ro
[2] Systems Research Institute, Polish Academy of Science, Warsaw, Poland
{maria.ganzha,paprzyck,gawinec}@ibspan.waw.pl

Summary. In this note we consider design of a learning provisioning subsystem for an agent-based virtual organization. Flexible delivery of learning content is based on matching of ontologically demarcated user profiles, domain specific knowledge and learning modules.

1 Introduction

Let us start from a sample scenario and consider an organization in which teams of researchers are engaged in R&D projects. Let us assume that teams and/or their members are geographically distributed (though this is not necessary as the proposed approach will work in either case). Team work requires collaboration between members and such collaboration should be supported by an appropriate technology.

It is obvious that support of collaborative research has to go beyond, even most sophisticated forms of, document versioning and flow of resources in the hierarchical structure of the organization. What needs to be taken into account is: (1) representation of domain specific knowledge – to provide context for management of resources pertinent to the project (e.g. establishing a specific "place" of a resource within the domain knowledge allows for resource indexing and clustering); (2) representation of structure and flow of interactions in the project – to route resources based on project needs and responsibilities of team members; (3) representation of user profiles (situated within the domain knowledge and the structure of the project) – specifies team member *interests*, *needs* and *skills* (e.g. specifies what to do with new/incoming resources); (4) adaptability of the system – as the time passes domain of interest to the project may expand, contract or shift; functional interrelationships between team members can change; their interests, needs and skills may evolve.

It is relatively easy to see that these four points can be generalized beyond the collaborative work scenario that we started with. Let us assume that we extend the

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second point by utilizing a notion of a virtual organization and within such an organization defining roles and interactions. Therefore, it is important to keep in mind, that the collaborative work scenario is used only as an example, while the overarching application is adaptive personalized information provisioning in a virtual organization. In this note we focus on the way in which in such an organization we can design an adaptive learning content delivery subsystem.

To this purpose, in the following section we overview our approach to modeling virtual organizations, with focus on need of worker education. The next three sections illustrate the use of ontologies, agent systems and resource matching respectively. Finally, we draw some conclusions, outlining future research directions.

2 Overview of the General Approach

Knowledge management is at the core of our approach and nowadays it is very often claimed that the best technique for knowledge representation is ontological demarcation. In this context, representation and management of knowledge flow can be achieved as a result of a two-step process. First, roles of participants are specified, and second, the real-world organization is represented as a virtual agent-based system. For human resources, agent roles are combined with domain ontologies, while for other resources only domain ontologies are used. In both cases an overlay model allows specification of profiles of individual resources (see [3], [12], [16], [13], [4]).

Let us add that ontological representation of resource profiles naturally supports various forms of automatic reasoning (e.g. resource matching, query rewriting etc.). Furthermore, ontologies, overlay-based profiles and agent systems are naturally adaptable. Ontologies can be easily modified, adaptation of overlay-based resource profiles involves changes in weight of individual features, while changes in virtual organization are easily transformed into changes in agent interactions ([5]).

We can now summarize the fundamental features of our approach to building an environment for supporting context aware personalized resource provisioning:

1. *Domain knowledge* will be represented in terms of ontologies.
2. *Organizational structure* will be decomposed into interacting agents.
3. *Overlay model* will be used to represent resource profiles.
4. *Resource matching* will utilize reasoning involving resource profiles.
5. *System adaptability* will be obtained through: a.adapting structure of the agent system; b. adapting resource profiles.
6. *Human resources adaptability* will also be achieved by learning.

Let us now observe that in such a system we can immediately conceptualize *learning*. Imagine that a given worker has been assigned a task with a given profile. Additionally, the worker currently has a set of skills that are represented within her profile. If reasoning signals a mismatch of the human profile with the task profile then an e-learning task may be triggered. Based on the mismatch, an initial goal of the learning task is formulated and the worker (now learner) is enrolled to an e-learning process. At the end of the learning process, assuming that during learning the learner has also been appropriately evaluated, her profile is updated accordingly.

3 Ontologies

It is a well known fact that relations described in ontologies allow the discovery of knowledge which has not been captured explicitly. For instance, such reasoning could be used for: (1) inferring interest in concepts along relation of domain ontology, e.g. from interest in extreme programming and UML specification, it can be inferred that a given team member is interested in software engineering in general; (2) classification of keywords found in resources with respect to the definition of classes specified in the domain ontology.

To be able to properly support the learning process, we will have to extend the utilization of ontologies in the system.

For non-human resources we will use standard ontologies for educational material (LOM – IEEE Learning Object Metadata [6], IMS MD – IMS Learning Resource Meta-data [8]). This will allow us to introduce relations between concepts such as *prerequisites*; e.g. each non-human resource will be linked to a list of concepts that are intended to be mastered after studying that resource content. Second, the user profile will be extended to include such learning-related features as: performance level and learning preferences (this extension could be based on PAPI – IEEE Personal and Private Information [7], or IMS LIP – IMS Learner Information Profile [9]). Finally, relations describing interactions between the human and non-human resources (type of interaction, start and ending time, etc.) will be included.

Note that a lot of the information about learners can be inferred from their interactions with resources (consulting a certain educational material or asking a peer for help on a specific problem increases the likelihood that the learner acquired the corresponding knowledge; a somewhat more accurate indication of the learner knowledge level is the outcome of his interaction with an assessment type resource). All these interactions will lead to adjustments of weight in the overlay represented profile.

4 Agent System

Following [1], we have envisioned the following basic types of agents in the system: i) *Personal Agent* (known also as *Interface Agent*); ii) *Task Agent*; and iii) *Middle-Agent*. The latter two categories belong to *infrastructure agents*.

The most basic agent in the system will be a *Personal Agent* (*PA*) representing each worker in the organization (regardless of her/his position). *PA*'s responsibilities include human user assistance and management of user profile. On the other hand, *TA*s are specialized for dedicated tasks like connecting to a database or provision of resources. Finally, *MA*s are specialized in intermediating between requesters and providers (usually users and/or their *PA*s and appropriate *TA*s acting as resource managers) and their responsibilities include tasks like matchmaking and/or brokering.

A number of additional infrastructure agents will be created, e.g. meeting scheduling, resource management (searching, indexing and clustering), resource profile updating, etc. While the initial set of infrastructure agents will be identified during the requirement specification phase, we may decide later to incorporate additional agents. Here, note that one of important advantages of agent-based software engineering is that adding functions to the system is relatively easy as it involves adding agents and defining their interactions with agents already existing in the system.

Finally, in the context of this note, an important feature of the agent-based approach is that it can be easily integrated with any of existing Learning Management Systems (LMS). LMSs offer support for a wide area of activities specific to e-learning, such as: communication and collaboration tools, registration and authentication tools, security features, curriculum design support (authoring tools), assessment support (on-line testing, automated grading, online gradebook), student tracking and reporting tools, student portfolio, groupwork support, instructional standards compliance [15]. All that is needed is the creation of an agent intermediary that will become an interface between the LMS and the agent-based system ([14]).

5 Resource Matching and System Adaptability

As indicated above, we plan to use an overlay model for defining resource profiles. In the case of non-human resources we will overlay the profile over the domain ontology. In the case of human resources, we will utilize not only the domain ontology, but also the organizational ontology (e.g. the fact that a given personal agent represents a human manager at a given level of system hierarchy and thus has to communicate with specified other agents). Resource profiles will provide context for directing flow of resources in the system. This will be achieved in two ways: (a) on the basis of information directly stored in the ontology of the organization, and (b) through context matchmaking, which should be broadly understood as comparing profile of a given resource to that of another resource and deciding if there is close enough match for these resources to be of interest to each other (e.g. establishing on the basis of their profiles – by comparing them and reasoning over the results – if a given learning module is appropriate to a given member of the organization).

Finally, resource profiles will be used for collaborative information processing, e.g. an agent searching for information on a topic will query other agents, profiles of which indicate that they may be interested in a given subject (and thus store pertinent resources), for useful information.

The implicit feedback method is the most desirable to adapt resource profiles, since (1) it can be applied both to human and non-human resources, and (2) it is more comfortable to the user (who doesn't need to fill questionnaires or mark resources by hand). Typically, the notion of implicit feedback is considered to be highly dependable on the environment in which it is collected. However, our innovative approach can be made environment independent, since we utilize ontology-based resource profiles. As mentioned above, in our approach any interaction between two resources constitutes an implicit feedback and a potential reason for profile adaptation. Therefore, implicit feedback resource profile conceptualization proposed here can be used in a variety of context aware information provisioning environments.

In the context of e-learning (as learning is also an important component of the system), adaptation refers to the creation of an educational experience that is dynamically changing in order to suit each learner's needs, with the purpose of maximizing the subjective learner satisfaction, the learning speed (efficiency) and the assessment results (effectiveness) [2].

There are three factors that must be taken into account when talking about adaptation in e-learning ([15]): (1) the *learner* (which is characterized by his knowledge level, technical background, learning goals, interests, motivation, cultural background, learning styles, personality traits etc.); (2) the *hardware and software platform* (PC/laptop/PDA/mobile phone etc, screen size, available input devices, connection bandwidth, processor performance, memory size, operating system, Web browser etc.); (3) the *environment* (the physical environment where interaction takes place - surrounding light, noise, geographical location and other external elements that may have a influence).

Thus matching between resources can also be based on the above criteria. For example, a non-human resource (e.g. an educational material) will be considered appropriate to a learner if there is a correspondence between the following characteristics of the non-human and human resource profiles, as described in their respective ontologies: i) the prerequisites level and the knowledge level; ii) the intended purpose and the actual learning goal; iii) the most appropriate learning style and the recorded cognitive characteristics; iv) the desirable hardware and software features of the used device and the actual platform available.

The resource matching will be managed by a dedicated infrastructure agent. The matching logic will be flexible, unlike traditional fixed-pedagogy approaches, being able to incorporate various instruction strategies (e.g. matched learning style in case of high activity level learners and mismatched learning style in case of low activity level learners [11]).

Rules for matching human resources are different and depend on the objective. In case of collaborative problem solving (group forming), a "heterogeneity rule" may be applied, since studies have shown that learners work best in mixed-ability groups [10, 17]. Slavin [17] for example recommends a group size of four: one high achiever, two average achievers, and one low achiever. Other learner characteristics can be taken into account, like personality traits (introvert or extrovert), attitude toward team work, motivation, goals, interest for the subject.

In case of offering support as peer help, a "near-peer-matching" rule could be applied [18]: when a learner needs help, she/he will be directed to a peer with a slightly higher knowledge level. This will insure a fair distribution of help demands (avoiding the situation that the highest proficiency learners will be overcome) and also provide learners with the opportunity of explaining to others what they have just understood ("learning by teaching"). The matching will be done by means of negotiations between the personal agents of learners, and will be based on their profiles.

6 Concluding Remarks

In this note we have outlined how a conceptualization of a virtual organization utilizing ontologies and software agents can be used for personalized adaptive delivery of educational content. We have discussed how the overlay model on profile instantiation allows for resource matching and thus helps establishing when a human resource is in need of training and which training module should be utilized. As future work we intend to implement the suggested approach and provide real-world validation.

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