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Adaptive Knowledge Services Based on Grid Architecture

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Abstract. Grid Technology has proven to be a suitable means for the efficient sharing of various resources within a well–defined community. The EC–funded projects LeGE–WG and e–LeGI have set out to apply this technology for technology enhanced learning services. Previously, the applicability of distributed skill maps for adaptive e–Learning within a grid network has been discussed. In this paper, we propose a further extension of that idea to be applied for personalised knowledge and skill management and human resource selection and development. This extension combines the flexibility of GRID as a service oriented environment, capable of delivering both adaptive services, and a content distribution network, suitable for delivering learning content.

1 Introduction

Over the recent years, grid technology has evolved as a powerful infrastructure for application service provision. While the original aim was to share computing resources for high performance computing tasks, the focus has shifted towards more general application provision and data sharing in the meantime (see, e. g. [1]). This is also reflected in the development of respective specifications, e. g. the Open Grid Services Architecture (OGSA) specifications[4].

The e–LeGI and LeGE–WG R & D projects[5] aim at Progressing from the original applying grid technology for e–Learning in a human–centered manner. This includes especially an adaptation of the services to the individual learners and their needs.

One way to achieve adaptivity in e–Learning is the use of prerequisite structures in order to adapt navigation in respective hypertexts to the learner's current knowledge [2]. Distinguishing between concrete learning objects and the rather abstract concepts or competencies taught therein supports adaptivity in dynamic courses [3, 4]. Ideas for realising these concepts in a grid context have been discussed [5, 6].

[4] See `https://forge.gridforum.org/projects/arch`.
[5] See `http://www.lege-we.org`.

The distinction between concrete objects and latent competencies also opens a door to other applications, namely in the area of knowledge management and human resource (HR) management. In the sequel, we will focus on how these applications might be used in a grid environment.

2 The Grid as an Application Service Environment

Progressing from the provision of computing power to the provision of general application services, new and more open standards for the interoperability of Grids are currently developed. The basic idea is that of a *virtual organisation* (VO) consisting of several persons or institutions who share the access to services provided by some member of the VO, e.ġ. data, programs and services, or physical resources.

Increasingly there is a movement to adopt such a virtual organisation approach to the delivery of higher education. Within Europe the EU Bologna objectives [19] has spurred studies into virtual campuses, where European universities collaborate in developing content, delivering eLearning services and collaboratively offering courses. In such a virtual campus a student at one institute may take a course that consists of modules offered by different institutes reflecting their respective local expertise in the module content. Technology enhanced learning in a virtual campus required making eLearning service available over the web to suitably registered students at other institutes. These services will offer access to eLearning content, opportunities to interact with tutors in remote institutes who are experts in this content area and even interacting with students studying the same content in other institutes, e. g. for attempting group exercises. Such a virtual campus must support interaction between organisations at three levels:

1. Exchange of services, where lecturers or students form one institute have authorised and accounted access to web services at another
2. Exchange of content, where courses offered at one institute reuse conceptual learning concepts originating from another, but adapted to a different course structure and to pedagogical, cultural, institutional and linguistic norms.
3. Exchange of knowledge, where the human capital on one institute is made available in others, for instance tutors who are expert in particular conceptual content or researchers expert in a specific experimental technique needed in a dissertation project.

This paper outlines how GRID technology can form the backbone for such virtual campus interactions.

The basis of Grid services then consists of two essential elements, (i) the technological Grid infrastructure and (ii) mechanisms for offering, discovering, and using the services within this infrastructure. While there exist also other, more proprietary approaches, we will in the sequel restrict to the case of a web service based Grid.

2.1 The Technological Grid Infrastructure

By *technological Grid infrastructure* we denote the rather general Grid concept of providing access to other Grid members' resources:

- Users need a seamless access to Grid services, i. e. once they are authorised to use the Grid their user/institution information has to be passed on to any other host in the Grid where they want to use resources without any further re–authentication requests.
- The technological infrastructure also has to take care of the members' rights, i. e. based on the information specified by each provider for each of their resources, usage costs have to be billed automatically to the using member. This may, of course, include that a user is informed about and asked for confirmation for taking over such costs.

As a result, we obtain an architecture as sketched in Fig. 1. This architecture reflects an interpretation of all resources available in the Grid as services [7]. On the network side, the architecture is based on the TCP/IP protocol family

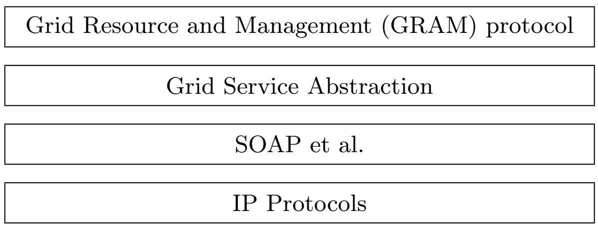

Fig. 1. Simplified architecture for the technological Grid infrastructure

including the HTTP protocol. Based on this fundamental network infrastructure, all Grid related communication is done through the SOAP protocol (in case of a non–proprietary solution). The Grid service abstraction then provides the interpretation of all different types of resources as a service. Finally, the GRAM protocol (Grid resource and management) provides the request of and access to the services.

2.2 Mechanisms for Offering and Discovering Grid Services

Besides the technical infrastructure, there is another fundamental issue in Grid service provision, i.- e. offering, discovering, and using the services. While originally Grid specific functionalities had been planned (OGSI: Open Grid Services Infrastructure), more recent developments go towards applying open standards for web services. We will refer to three central standards which are all XML based:

1. The SOAP protocol provides mechanisms for the communication between machines, e. g. for sending data to be processed to the requested service and for sending back the results [8].
2. The web service description language (WSDL) allows for the description of web services, i. e. while SOAP defines how to exchange the data, WSDL describes what type of data are requested and/or delivered by a certain web service [9].
3. The web services inspection language (WSIL) supports the discovery and the construction of new services from existing services. WSIL records contain basically references to one or more WSIL and/or WSDL records [10]. Although this language is not part of the W3C web services protocol suite it may be very helpful in deploying web services.

3 Knowledge Management Based on Grid Technology and Knowledge Prerequisite Structures

Some current EC–funded R&D projects[6] investigate the application of Grid technology to technology enhanced learning (TeLearning). Our own work in this area focuses on integrating adaptive TeLearning based on knowledge prerequisite structure with the Grid approach [5].

On the other side, these knowledge prerequisite structures can well be used beyond TeLearning, e. g. in knowledge and skill management [11]. After a brief introduction into knowledge prerequisite structures and their use in TeLearning, we will discuss the broader application in knowledge management.

3.1 Knowledge Prerequisite Structures

Doignon and Falmagne have developed the theory of *knowledge spaces* originally aiming at the adaptive assessment of people's knowledge [12, 13]. They structure a set Q of test items by a *surmise relation* in the sense that, from a person being able to solve an item a correctly, it can be surmised that this person will also be able to solve another item b correctly. If we define the *knowledge state* of a person as the subset of items this person can solve, the set of possible knowledge states (called *knowledge space*) is restricted by the surmise relation. In fact, in most domains of knowledge, the knowledge space will be much smaller than the power set of Q, i. e. the set of all subsets of items. Such a structure allows for an adaptive assessment of knowledge by inferring, after a correct solution, that all prerequisites are also mastered or, after a wrong solution, that all those items are not mastered which have the current item as a prerequisite.

More recently, this model has been applied for adaptive TeLearning. Albert and Hockemeyer [2] have built the adaptive tutoring hypertext system RATH that limits the learners' navigation within a TeLearning hypertext by offering links only to those documents for which all necessary prerequisites are fulfilled by the individual learner.

[6] See, e. g., http://www.legewg.org/.

Albert et al. [14] have extended this theory by regarding not only the concrete test items but also the latent, underlying skills (or competencies) needed for finding the correct solution. This resembles the fact that we are normally less interested in the items a person can solve than in the competencies and skills this person has.

This extension has been applied by Conlan [3, 4] in the APeLS system. On the practical side, this separation of concrete learning objects and abstract competencies facilitates the system's adaption to changes in the course: While in the RATH system, changing or adding one document might well result in the necessity to change prerequisite links in many other documents, the APeLS system links the documents to the abstract competencies and, therefore, changes in one document do not require such changes in other places.

In addition to that, the APeLS system also marks the step forward from an adaptive server to an adaptive service. The user's learning environment can pass the user data directly to the APeLS service without any visible login request and, vice versa, results are passed back automatically to the learning environment. All communication with and about the APeLS service [15, 16] are done through standardised means like IEEE LOM [17] and ADL SCORM [18].

3.2 Adaptive TeLearning in the Grid

Proceeding from adaptive TeLearning to Grid–based knowledge services basically involves two steps, (i) going from adaptive services to Grid–based services. and (ii) going from TeLearning to knowledge management.

First ideas of using the Grid approach for adaptive TeLearning based on prerequisite structures have been given by Hockemeyer, Albert, and Stefanutti [5, 6]. If contents and their competence assignments are distributed over several servers, the system providing the adaptive service to the user and his environment cannot use a rather static map of these assignments any more but it has to work with and merge *distributed skill structures*. This means that the Grid has to provide the infrastructure to pull together quickly the distributed structure information which are then merged "on the fly" by the adaptive server. Please note, that such a distributed context makes the separation between concrete objects and abstract competencies or skill absolutely inevitable looking at the strongly increasing probability that some documents may be changed or added at some of the co–operating servers in the Grid.

3.3 Adaptive Knowledge Management in the Grid

There exist some close relationships between TeLearning and knowledge management within an organisation [7]. Talking about knowledge management, this contains, e. g.

[7] An adaptive TeLearning system may well be integrated with knowledge management by passing information about a learner's current knowledge at the beginning of a further education measure and, vice versa, by updating the database of the knowledge management system after an employee has finished an education activity.

– Intellectual capital reports of the organisation or sections thereof
– Composition of project groups based on the participants' knowledge and the project's needs
– Selection of new employees based on their knowledge and possible gaps in the organisation
– Selecting needs and appropriate measures for further education including the selection of suitable employees for such measures.
– Evaluation of employees

Applying the Grid technology for knowledge management would then be useful especially in the case of distributed organisations (the virtual organisations in Grid terminology may well coincide with real organisations distributed over many places). A Grid–based knowledge management system might then, e. g., support finding specialists from remote subsidiaries who can fill a gap in a local team with their competencies. Thus, it may become unnecessary to have local employees acquire that knowledge themselves if it is needed only rarely. Or, if an employee moves from one subsidiary to another, the information about their knowledge would immediately and seamlessly be available at the new place.

Applications of Grid–based knowledge management, however, are not limited within organisations. Job agencies (or companies offering casual employees) could share their data about specialists between each other and also with seeking companies.

4 Scenario

Section 2, The Grid as an Application Service Environment, indroduced the *virtual campus* scenario. Elaborating this scenario it is possible to envisage the formation of a new Masters Programme that is being developed jointly by a number of institutions that are geographically remote. The goal of this distributed development is to produce a highly focused, and possibly niche, Masters Programme that will leverage both the facilities and expertise of each of the institutions involved. In this scenario, or any that entails the formation of a *virtual organisation*, the principles of utilising GRID technologies described in this paper may be used. For example, an adaptive information service, accessed through GRID infrastructure, may provide a personalised course outline for an aspect of the Masters Programme. As described in Section 3.1, Knowledge Prerequisite Structures, this personlaised course may only be described conceptually, i. e. the actual learning content to teach the course has not been selected. Here, again, GRID can for the basis for delivering appropriate content. In this example GRID has been used as both a service delivery environment and a content distribution network.

With respect to Knowledge Management in GRID it is feasible to envisage a specialised Masters Programme involving tutor-tutee relationships, where the capacity to match tutors and tutees based on KM techniques provides a distinctive added value. This is especially true in the case where the tutor and tutee reside in geographically different areas. GRID could also be leveraged to provide appropriate collaboration services to support the relationship.

5 Conclusion

In this paper, we have discussed the applicability of Grid technology for adaptive services in general and especially for knowledge management and TeLearning. Through the scenario presented in Section 4 we presented a possible use case to illustrate how these adaptive services could utilise GRID as both a service oriented environment and a content distribution framework, thus facilitating the dissemination distributed knowledge. Through employing adaptive hypermedia mechanisms such as conceptual abstraction, as in APeLS, and prerequisite knowledge structures, as in RATH, as services available in a GRID environment rich adaptive experiences may be delivered to end users. The scenario also presents a model of learning that empowers the learner towards an *anytime–anywhere* learning paradigm.

Currently, however, many basic issues are still under discussion. For example, the open grid service architecture is still under development. Experiences from the e–LeGI project will be a useful source to evaluate the appropriateness of the Grid approach for adaptive hypermedia services in general.

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