Web Service Based Knowledge Grid for Biomedicine

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The ability of Grids to share resources across organizational boundaries appeals to larger communities than the original computational grids. A specific resource which can be shared is knowledge.

Architecture is presented for sharing biomedical knowledge that can be captured in the form of algorithms, and exposed as semantically annotated grid web services.

Techniques of semantic grid can be used for discovery of such services and composition to larger workflows that provide quality of service well above the current level of biomedical knowledge sharing. In such knowledge grid, special requirements arise for management of credibility of services, in addition to standard security, authentication and authorization.

The user interface for composing workflows from knowledge services may have collaborative features, enabling experts to cooperate even when they are geographically dispersed to remote areas.

I. INTRODUCTION

The main feature of the Grid, which appeals to communities outside of the high performance computing community, is its ability to share resources across boundaries of institutions and organizations, or in other words, resources that are not subject to centralized control [1]. In computational grids, the shared resource is computing power of processors, thus a computational grid forms a large virtual supercomputer. In data grids the resources are large disk storages and fast networks needed for holding and moving large quantities of data. Collaborative grids create virtual environments for cooperation among geographically dispersed individuals, by using tools for videoconferencing and remote control of shared instruments like telescopes or microscopes. In knowledge grids, the resource shared across organization boundaries is knowledge, so a knowledge grid can constitute a virtual expert system.

In this paper, an architecture is presented, designed for sharing biomedical knowledge in the form of a grid consisting of semantically annotated web services, with collaborative user interface. The work presented is part of ongoing research in the project MediGrid, targeted to semantic grid applications in biomedicine.

The paper is further structured as follows. In chapter II we discuss how a biomedical knowledge may be encapsulated as a grid service and may be used to build a complex workflow. Chapter III describes how participants may collaborate over a workflow solving a particular task. In the last chapter we will propose a model of an adaptive workflow environment providing a way how to recover from errors occurring during a workflow instance run. The conclusions are then provided.

II. EXPERTISE PROVIDED AS GRID SERVICES

A. Encapsulating knowledge as services

Biomedical knowledge can have many forms, including skills. The type of knowledge we are concerned with here is the type of knowledge that can be captured as medical algorithms, as formulae for converting input data into output data, eventually using some databases. For example, one such formula may provide body skin area if values for body weight and height are known. Another formula can take body weight, height, gender and age as inputs, compute body mass index (BMI) and use a local database of distribution of BMI in population in relation to gender and age, finally producing the position of the given patient to the rest of the population (how many percent of population are more overweight or underweight).

Nowadays, such knowledge is developed or gathered by some biomedical experts, and then it is transferred to other experts by publishing it in printed media as text descriptions, or in more technologically advanced cases, as forms on dynamic web pages or as Excel spreadsheets downloadable over the Internet. Other experts, who can use such knowledge, must be aware that such formulae exist to be able to find and use them, and if they need to feed results of some formulae as inputs to other formulae, they must manually copy them from one place to another (from a spreadsheet to a web form etc.).

However, such algorithmic knowledge can be encapsulated as grid services based on web services and thus provided in machine accessible form, which can be discovered and invoked in a platform independent way. That removes interoperability barriers.

B. Semantically aided workflow building

If such grid services are semantically annotated, or more precisely, if the input and output data are assigned an explicitly declared meaning by referring to entities in some domain ontologies (e.g. this number is body height in centimeters), the semantic information can be used for composing the grid services into more complex workflows, which can be seen as composite services. For example, if one service takes as inputs the body weight and height, producing body skin area, and another service computes a drug dosage from body skin area and drug type, then the two services can create a workflow, which can be seen as a virtual service with inputs of body weight, height, and drug type, producing required drug dosage. That virtual service provides a new quality by combining knowledge gathered from different domains.

The matching of input and output data types can be done in the strictest case by comparing identifiers used for semantic annotations of data types on equality. However, as ontologies contain hierarchies of classes (taxonomies), in which classes are in subsumption relation (more general class – more specialized class, e.g. organisms - animals), semantic matching can be employed [4]. That semantic matching enhances searching for adept services as not only exactly the same type must be found, but types which are more specialized can be used, as they still fit the requirement. For example, if the meaning of an input is body height, strict matching allows only such values. But semantic matching also may allow values with more specialized meaning, like body height in the morning.

The semantically aided matching plays role in service discovery and selection. The user does not have to choose services using only their names (and potentially wrongly guessing their function) or text descriptions in natural language, but can use computer assistance in selecting services that match the intended purpose.

When a workflow is composed from the knowledge grid services, it is ready to process biomedical data, thus saving the user manual work with copying data from one place to another or manually computing formulas.

Communication inside an established workflow needs to be secured. As the grid services are web services, the communication consist of XML messages. One option is to use standardized XML encryption and cryptographic signatures; however that was reported as highly inefficient when compared to SSL [5]. On the other hand, SSL provides only two point security and does not provide digital signatures. That is why we are considering an approach where encryption is done by SSL, but signatures are done using S/MIME standard, which allows signatures of whole messages.

C. Credibility management

The fact that services encapsulating knowledge in a grid can come from different organizations which are not under centralized control brings new challenges in security. In addition to usual grid authentication and authorization we need also management of credibility of services. The reason is that with authentication, we know the name of the person who provides the service, but that does not directly provide us the information how credible the person is. Also the same person can provide several services encapsulating different pieces of knowledge with different level of credibility. For example, one service may encapsulate evidence based knowledge which was gathered during experiments on large groups of subjects, while other service may provide a formula which is not as well founded.

Credibility of services can be asserted by third parties of various types. They can be authorities with large sphere of competence, like government agencies; they can be local authorities like a committee established by a local hospital; they can be persons a user trusts, like user's boss or co-workers; or they can be all the other users of the grid. In the case of all other users, the credibility can be estimated from the fact whether the service is used often or rarely, or users can assign their evaluation on some scale to any service, like the stars assigned by users to books on Amazon. Or, a user can keep a list of services which he or she already used and found them credible.

In every case, the final decision whether a service is credible enough to be used must be made by the user.

III. Collaborative Environment

Possibility to work together with other colleagues helps the medical specialists to resolve given tasks more efficiently. In our model we would like to support several different manners of collaboration. Generally we can distinguish between implicit and explicit collaboration over a workflow for solving biomedical tasks. Both manners of collaboration bring different requirements on the support from the collaborative environment.

A. Implicit Collaboration

The implicit collaboration means that the participants will provide new services, which can be built into a workflow for solving some special subtask, to other users or will even provide instruments or human resources acting as services within the workflow (e.g. computer tomograph or a specialist acquiring and providing input data for the workflow instance run). New services may be created from the scratch to incorporate some entirely new functionality or may be composed using existing services to simplify solution of the most common tasks.

B. Explicit collaboration

Since we work with extended understanding of grid environment which is not understood only as manner how to share computational resources or data storage facilities but may serve as well as collaborative environment allowing general resource sharing, we will also provide videoconferencing facilities allowing participants to consult during building the workflow while solving the biomedical task underneath.

Last but not least we would like to provide the participants with the possibility to build the workflow collaboratively. Our model reckons on a shared workplace for workflow building as well as with other usual tools supporting the collaborative work (e.g. text chat, shared whiteboard and shared editor).

The collaborative manner of work also means that the participants will be able to work with all input data provided by the others to the workflow instance run and will be able to share together the results of the respective workflow instance. Since we suppose deployment of the environment in medical or biomedical area, there is a strong focus on input data, services communication and workflow results security, which also means that the collaboration may be limited. Participants may be restricted from accessing some delicate input data or part of the results of the workflow instance run. The restrictions may be even related to the whole workflow so that a participant would be able to see, access or modify just a part of the whole workflow.

IV. Adaptive Workflow

Adaptive workflows provide a way how to solve two different situations. First of all we need to automatically modify a currently running instance of a workflow to recover the instance run from a previous failure. Second, it may be also necessary to modify some part of the workflow during a run of the workflow instance (e.g. it may be necessary to add some additional input data and process them in a new workflow branch to refine the result of the whole workflow run).

Concerning the failure of a workflow instance run we work on an algorithm providing us a way how to solve a situation when one or even several services within the workflow become inaccessible or are failing for some reason. The algorithm should find a feasible and correct way to finish the run of a workflow instance building a path using all possible and available services that would replace those services or some larger part of the workflow which failed to run. It is obvious that the functionality of the modified workflow must remain exactly the same as the functionality of the original workflow. This is achievable by replacing just the smallest possible part in the workflow that has failed [3]. The newly created path must preserve the semantics of the replaced part of the workflow as well.

We can simplify the workflow adaptation process by not taking into account the unreachable branches of the original workflow. Those branches of the workflow are evidently incorrectly designed, incorporated grid services will be never triggered and that's why it is nonsense to correct those workflow branches algorithmically during the run of the workflow instance. Such branches should be obviously removed from the workflow before the launch of its instance. We can furthermore simplify the task omitting those parts of the workflow instance that already finished correctly [3] and then launch the algorithm on the rest of the workflow instance.

It is necessary to prove that the algorithm is correct, what means that the function of the modified workflow remained unchanged and the results given by the modified workflow are the same as if the original workflow instance run would finish correctly. This is particularly important considering that the workflows would be used for solving biomedical tasks where the results may be vitally important. However, from the nature of the area of deployment is clear that the final decision whether the result of the whole workflow is correct must be again done by the user.

VI. Conclusions

We provided overview of a model of knowledge sharing with collaborative user interface, suitable for solving tasks in biomedical domain. The knowledge is exposed to the grid as grid services implementing biomedical algorithms.

Semantic annotation then helps computer aided selection of services and composition of complex workflows providing new services not available before.

This model brings new challenges, as it is different from the traditional model of computational grids, which are concerned with management of computationally intensive jobs. One of the challenges is management of credibility of the exposed services, which can be solved by evaluating credibility assertions made by third parties about a service.

The described model of biomedical knowledge sharing is by far more technologically advanced that the ways of knowledge sharing currently employed in biomedicine, as it helps in discovery of knowledge and evaluation of its credibility, and automates data processing.

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