INFRASTRUCTURE FOR WEB SERVICES THAT PERFORM AUTOMATED REASONING

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ABSTRACT

Despite much research into Artificial Intelligence (AI) and Intelligent Agents (IA) over the past few years little 'intelligent' behaviour is displayed by modern computer systems. AI planning and intelligent systems are failing to be generally used. The intellectual abilities such as learning, analysing, problem solving, planning and abstracting are features that we do not entirely associate with today's computer systems.

In AI we recognise that although machines are beginning to overtake the human brain in terms of sheer processing power and perhaps storage capacity, they still cannot approach the level of human intelligence in terms of general purpose cognitive capability. Part of the reason for this is that software technology that supports general intelligent processes is difficult to use, understand and maintain.

*With the advent of the Internet, the Web as we know it is an enormous collection of information stored in a variety of formats and held loosely together by hyperlinks. This is adequate for humans who are able to understand natural languages, but it is of no use if we want machines to be able to process as well as understand the information. To deal with this issue, the next Web generation promise to deliver Semantic Web Services; services that are self-described and amenable to automated discovery, composition and choreography. They can be utilised by application or other services without human assistant or protocols; where information is encoded according to well defined vocabularies, often known as Ontologies. In this research, we aim to create the infrastructure to enable intelligent software to be recast as semantic web services, and lead the way to "*Service Oriented Intelligence" – distributed software intelligence using the Internet.

Keywords Automated Planning, Semantic Web, Web Services

1 INTRODUCTION AND MOTIVATION

Service Oriented Intelligence – SOI is the term used to describe distributed software intelligence. Web Services, also, are the fundamental building blocks in the move to distributed computing on the Internet. The focus on communication among people and applications has created an environment where Web Services are becoming the platform for application integration. Future information systems will have to support smooth interaction with the large variety of independent multi-vendor data source, running on different platforms as well as distributed networks. Metadata and ontologies will play a very important role in describing the contents of such data sources and of course facilitating their integration.

On the other hand, Automated Planning has an important role to play in the *orchestration* of Web Services. It can be used to construct efficient execution plans of multiple Web Services for the achievement of a complex task, by viewing service composition as a planning problem [22]. By doing so, various already available planning techniques and systems can be used to tackle Web Service composition, probably with the addition of a few new techniques. The ability to perform automated service composition would radically change many application areas for Web Service technology including e-commerce and systems integration.

Within this scenario, planning systems could also be deployed themselves as Web Services, allowing their interoperation with other information integration Web Services and incorporation into larger Web Information Management Systems.

2 THE PLANNING PROBLEMS AND WEB SERVICES

AI Planning deals with finding a course of actions that can take an agent from the initial state to a goal state, given a set of actions (legal state transformation functions) in the domain. Formally, a planning problem [6] ***P*** is a 3-tuple < ***I, G, A*** > where ***I*** is the complete description of the initial state, ***G*** is the partial description of the goal state, and ***A*** is the set of executable (primitive) actions. An action sequence ***S*** (a plan) is a solution to ***P*** if ***S*** can be executed from ***I*** and the resulting state of the world contains ***G***. A planner finds plans by evaluating actions and searching in the space of possible world states or the space of partial plans. *Logical* composition of Web Services can be cast as a planning problem by using the description of Web Services as actions, and forming initial and goal states from the specification of the service to be built along with the domain model [9]. In general, a planning problem has the following components:

- a description of the possible actions which may be executed in some formal language. (*a domain theory*)
- a description of the 'initial state' of the world
- a description of the 'desired goal' or 'goal state'

3 CONCEPT OF SEMANTIC WEB SERVICES

The word *semantic* implies meaning or, as WordNet defines it, "of or relating to the study of meaning and changes of meaning." For the Semantic Web, *semantic* indicates that the meaning of data on the Web can be discovered not only by users, but also by machines. The semantic Web will bring structure and meaningful content to the Web, creating an environment where software agents can carry sophisticated tasks for users.

The essential property of the World Wide Web is its universality using the power of hypertext, and while today's Web is produced initially for human consumption, the next generation Web will to a great extent facilitate machine as well as human consumption. Ultimately, we will have programmes, and services that can automatically function with very little or perhaps no human intervention. The objective of Semantic Web, therefore, is to provide a framework that expresses both data and rules for reasoning from a Web based knowledge representation. Adding logic to the Web means using rules to make inferences, choose courses of action and answer questions. A combination of mathematical, automated planning and engineering issues complicates this task.

Original Web characteristics	Current Web characteristics	Projected Web characteristics
Information display for humans only.	Information display for human, but business logic/Web server moved to specialised framework servers (.Net and J2EE).	Semantic Web servers compete with proprietary server pages for business logic.
Simple Markup Language	eXtensible Markup Language (XML)	Machine-readable/understandable information and semantics.
No metadata	Little metadata	Significant metadata
Limited search	Keyword search	Inference/Semantic search

Table 1: Web Evolution Comparison [23]

The establishment of the Semantic Web will not be possible until software agents have the means to "understand" tasks and services by themselves. Artificial Intelligence gives two tools to help make this possible. First, knowledge representation is a field that defines how we might represent knowledge in computers. Second, inference - or derivation - is a way of using formal logic to approach further knowledge from what is already known. All of this forms a system of representing and synchronising knowledge that is often referred to as an Ontology. The leading ontology system is OWL [2]. OWL allows to formally express ontologies.

With the new generation of Web markup languages including OWL, there has also developed an ontology of services, called OWL-S, which could facilitate automated functions. Following are the fundamental automatic OWL-S tasks:

1) **Automated Web Service discovery** – involves the automatic location of Web Services. For example, the user may want to find a service that sells theatre tickets.
2) **Automated Web Service invocation** – involves the automatic execution of an identified Web Service by a computer programme or an agent. For example, the user could request the purchase of a theatre ticket. Currently, with today's Web, a user must find and then go to the Web site offering that service, fill out form, and click on a button to execute the service.
3) **Automated Web Service composition** – involves the automatic selection, composition, and interoperation of Web Services. For example, for event arrangement.
4) **Automated Web Service execution monitoring** – individual services and compositions of services of ten require some time to execute. A user may want to know during this period what the status is. For example, a user may want to make sure that a taxi reservation to theatre venue has already been made.

4 AI PLANNING AND WEB SERVICE COMPOSITION

There has been a great deal of activity in the last few years in the application of AI Planning to Semantic Web Service Composition. The idea is to utilise planners to synthesise composite services by reasoning with the declarative semantics of individual component services. Various types of Planner have been used for this, and a range of Web Service applications have been abstracted to demonstrate the feasibility of this approach (Carman et al. 2003, Parsia et al. 2004, Peer 2005, Martinez et al. 2005). These experiments show the potential of Web Services composition as an application area for planning, but also highlight many problems. For example, translating knowledge representations from Web to planner input is problematic. Web languages such as OWL utilises the 'Open World Assumption' rather than the 'Closer World Assumption' as is common in planning technology. In a closed world, like Databases, the information we have is everything, however, in an open world, we assume there is always more information than is stated. Where a database, for example, returns a negative if it cannot find some specific data, the reasoner in an open world, makes no assumption about the completeness of the information it is given.

5 SCOPE OF STUDY

In this doctorate research we are exploring the internet infrastructure that enables the functioning of intelligent semantic Web Services. The idea consists of encapsulating planners as Web Services. This will involve internet programming, and ontology engineering. In contrast to the main thrust of research into Planning and the Semantic Web – that is of utilising planners to reason with semantic Web Services – we aim to use the semantic Web to deploy planners and other related tools as Web Services themselves, forming an intelligent utility. We intend to research into ways of 'wrapping' up planning tools by specifying their functions in semantic Web languages. The planning tools will then be developed into a set of intelligent services that provide planning services over the intranet or the Internet to globally-distributed clients. This will provide a significant contribution to the field of distributed intelligence, and we anticipate that it will lead to globally accessible, interoperable, intelligent reasoning services.

To encapsulate an AI planner or planners in Web Services by specifying their functions in Semantic Web languages, we draw a 'goals and roles structure' which is shown in figure 1.

To evaluate the research, we will test the services in terms of the ability of users to describe their needs or goals in a convenient fashion, and the ability of the intelligent services to perform the tasks of identifying and correctly combining Web Services to achieve the goals specified by users. The idea is that the user sends its problem description in a format suitable for the called planner, and gets back a plan latter. A planner wrapped as a Web Service will run its original environment and language, so no porting effort is required. The Web Service will get the request over a normal Web protocol, deliver it to the planner and return the result (a plan) to the client (requester), which is a user in our case, but could be any artificial agent in general. Thus, the client can be anywhere in the Internet, which is connected to the server, or any operating system.

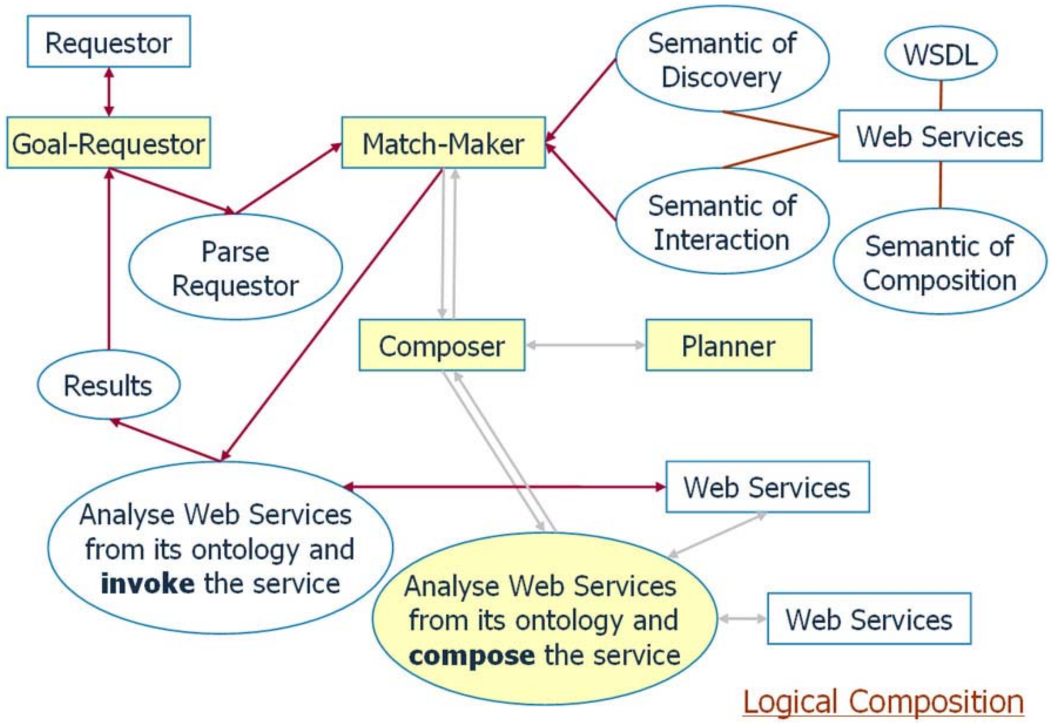

Figure 1: Goals and Roles structure in logical composition
(The coloured parts represent our research domain)

Requestor – an agent that allows user enters goal definition.

Goal-requestor – is responsible to analyse client's initial goal and to request parameters. Eventually, goal-requestor will send the information to the Match-maker.

Match-maker – is a searching engine that receives the goal request and tries to find appropriate Web service to achieve the requester's goal. It is also a bridge between services and clients. Semantic Web Service should register their profile information on Match-maker. There are two scenarios. One is that Match-maker gets a proper Service to achieve client's goal and sent the result to the Goal-requestor. Otherwise, it will de-compose the goal and sent searching space information to the Composer.

Composer – is responsible for composition. In the first place, composer will try to find final goal state, and then will attempt backward searching in order to find an appropriate plan. In the second place - after finding the plan - it will compose selected services and eventually will record the derived composition plan into the Match-maker.

6 RELATED WORK

The literature on Web Service composition and AI planning is extensive, consisting of promising results and many challenges [7] [8]. Part of our study aim to extend our research by preparing a survey of the most important planning techniques and by discussing their suitability for dynamic Web

Service composition as AI planning. Recently, several papers, e.g. (Srivastava and Koehler, 2003; Carman et al., 2003; Sirin and Parsia, 2004), have investigated the potentials and boundaries of applying AI planning techniques to extract Web Service processes that achieve the desired goals. Also much work has been performed on designing semantic Web standards for adding semantic mark-up to Web Service descriptions. In terms of planning based on these descriptions there has been some work on the instantiation (based on user preferences and service availability) of precompiled plans in (McIlraith and Son 2002) as well as on extending the planning domain description language PDDL to handle information producing actions (McDermott 2002).

In another work which assumes full knowledge of the semantics of operations (Aiello et al. 2002), the authors use a nondeterministic planning language with extended-goals and constraint satisfaction to model the Web Services planning problem. A different approach was taken by the authors of (Thakkar et al. 2002) in which automated service composition is achieved by modelling services as Web information sources (exposed by automated Web-site wrapping software) for which a common data model was already known. A common data model means that database query planning and transformation techniques can be used for plan synthesis and optimisation.

In all of these works the authors assume to be interacting with services that are described in a standard and possibly formal manner, i.e. all services which provide the same functionality are called in the same way, require the same inputs and produce the same outputs. By doing so the authors avoid some of the difficulties associated with the heterogeneity (not comparable in kind) of the Web Services planning domain, and are able to apply techniques from "simpler" (at least more similar or so-called homogeneous) domains such as database query processing.

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