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Calendar Agents on the Semantic Web

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The Web was designed to be a distributed information space that seamlessly supports human navigation across related, linked documents on the Internet. Its simplicity of use and the easy way users can create Web pages in HTML quickly captured public interest, and it evolved at a phenomenal rate into a vast knowledge base. During this growth, however, Web pages' information structure, which is crucial to making the information machine understandable, was sacrificed in favor of presentation and physical design. However, this lack of structure has not deterred agents from using information on the Web. Many agent systems track users' navigation habits as they click throughout the Web so they can suggest new, potentially interesting Web pages to them; others automate access to information sites, replicating human-oriented queries and parsing the resulting pages. Agents have also harvested taxonomies that guide human navigation toward clustered topics of interest. However, in each case, these agents have had to use bespoke parsers (code written specifically to parse a given Web page, such as Yahoo's restaurant information), and content scrapers (languages for defining rules used to extract information from and manipulate Web pages) to pull out the text before using keyword recognition or natural language recognition techniques to understand the content.[1]

Agent assistance on the Semantic Web

The emergence of the Semantic Web[2] has simplified and improved knowledge reuse on the Web. Agents can parse Semantic Web pages to elicit relevant information. They can now understand and reason about information and use it to meet users' needs and provide assistance through reference to ontologies, axioms, and languages such as DARPA Agent Markup Language.[3] The emerging symbiosis of knowledge about users' desires, preferences, and habits with information garnered from the Semantic Web results in superior agent-based assistance than that provided by existing agents.

In *Technology Review*'s "A Smarter Web,"[4] Tim Berners-Lee describes a travel scenario in which a user instructs an agent to organize a trip to a conference. To achieve this, the agent requires knowledge about the user's flight preferences, current schedule, and details such as credit card information. The agent obtains the conference's dates and locations from the semantic markup at the conference Web site. After booking a flight, the agent then stores the resulting itinerary in the user's calendar and cancels or reschedules pending meetings while the user is away. It highlights conference presentations and sessions that might interest the user and sets reminders to notify him or her (through PDA or phone, for example) of an impending talk.

RCAL

To address many of these tasks, we've developed the RETSINA (Reusable Environment for Task-Structured Intelligent Networked Agents) Calendar Agent,[5] which works symbiotically with Microsoft's Outlook 2000 and the Semantic Web. It can parse and reason about schedules, such as conference programs or recurring appointments that are marked up on the Semantic Web. Users can either type in the URI of the schedule markup or select and submit a schedule via a button on a Web page. Users can browse schedules using the agent's schedule browser (as Figure 1 shows) and compare the details of an appointment with existing appointments to identify conflicting events. RCAL can import and store schedules (or a subset of selected events) within Outlook 2000 and refer to these events to check if they have been updated, or to see if the user is free at a given time slot. It can also import contact details, such as people attending the meetings, into the user's contact list. Notifications of events can be sent via email or through another agent to a mobile device. Because the URI that refers to each event is stored with the event's information, RCAL can periodically check if the event has changed and then notify the user. Agents can explore other related information, such as visiting relevant Web pages, or they can invoke services that provide driving instructions or local restaurant recommendations.

Much of RCAL's functionality is possible because of the way the Semantic Web references and reuses concepts (that is, resources) across the Internet. Resources, such as a user's contact details, no longer must be presented inline within a document, but can be referred to remotely through a URI to a Semantic Web-annotated homepage that the user maintains. Thus, a schedule might simply consist of event resources defined elsewhere. Each event, in turn, might refer

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Useful URLs

DAML Meeting Agenda ontology:
www.daml.org/2001/10/agenda
Dublin Core ontology:
http://dublincore.org
Friend of a Friend:
http://xmlns.com/foaf/0.1
ICal:
http://ilrt.org/discovery/2001/06/schemas/ical-full/hybrid.rdf
RCAL (including download):
www.daml.ri.cmu.edu/Cal
RDF VCard ontology:
www.w3.org/TR/vcard-rdf

to existing resources corresponding to location or attendee information and the event's date, time, and duration. An agent then resolves this URI and replaces it with relevant information, such as the user's name or the venue's address. Agents can also extract and use additional information defined by the resource, such as the user's phone number or address, or the venue's fax number, which provides a richer environment for reasoning.

RCAL can understand calendar schedules that are marked up using several different ontologies. Web site authors or annotators mark up (or describe) the schedules and events using the Hybrid ICal ontology. The Friend-of-a-Friend ontology currently describes user resources, and the Dublin Core ontology provides metadata about schedules.

RCAL's ability to refer to resources defined in different ontologies facilitates the navigation of information that is not directly related to a schedule. For example, RCAL extracts the name of an individual attending an event, referred to by the resource (<foaf:Person>, as Figure 2 shows), when listing the events in the Semantic Web schedule browser. It can also use other information, such as email or Web page properties, to facilitate additional browsing or offer more services. For example, a Web browser could be invoked to display the Web page if a user or an agent provides a relevant URL. RCAL offers additional services to the user when he or she selects a *concept*. A concept is a resource that might have an associated string. If this string is displayed, the user can select it, and when the user right-clicks with the mouse, a menu will appear containing other things they can do with that resource (such as sending the user an email; Figure 3 shows the user right clicking on the concept Katia Sycara). It can locate these services by sending service requests to a discovery service, an automated lookup mechanism for locating agents and services that perform a desired task (such as a DAML-S Matchmaker[6]) and listing the resulting services. By using discovery services, RCAL agents can locate and invoke other services that let them understand new markup as ontologies evolve, or they can serendipitously discover new services that the user might like.

Of course, all this functionality assumes that the content provider or Web page

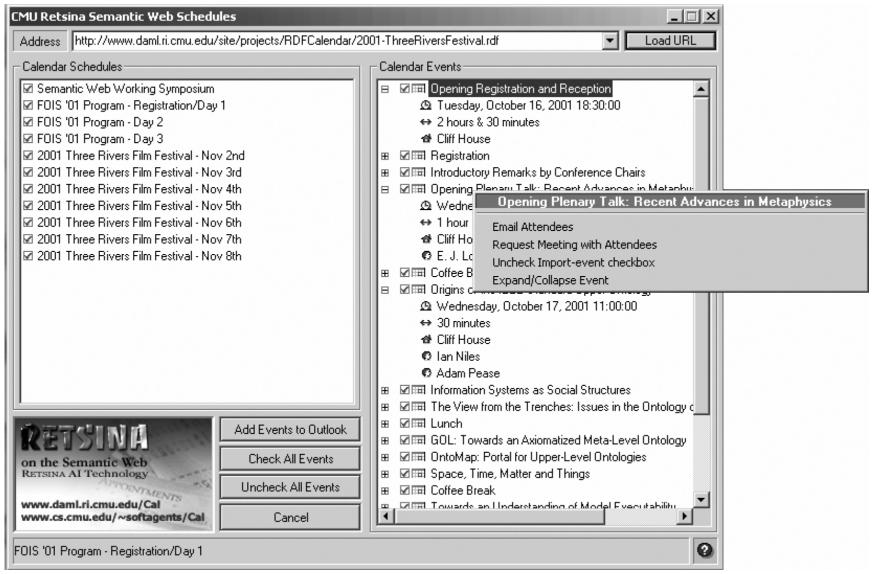

Figure 1. The RETSINA Calendar Agent Language Semantic Web schedule browser.

```
<foaf:Person rdf:ID="terrypayne">
  <foaf:name>Terry Payne</foaf:name>
  <foaf:mbox rdf:resource="mailto:terryp@cs.cmu.edu"/>
  <foaf:workplaceHomepage rdf:resource="http://www.cs.cmu.edu/~terryp"/>
  <foaa:RCalendarAgentName>terry_acm.org-CalAgent</foaa:RCalendarAgentName>
</foaf:Person>
<ical:VCALENDAR rdf:id="TAC01">
  <dc:title>Trading Agent Competition 2001 Workshop</dc:title>
  <dc:contributor rdf:resource="#terrypayne"/>
  <dc:date>2001-10-03</dc:date>
  <ical:VEVENT-PROP rdf:resource="http://www.tac.org/2001event.rdf#PainInNEC"/>
  <ical:VEVENT-PROP>
    <ical:VEVENT rdf:id="RetsinaTrading">
      <ical:DTSTART>
        <ical:DATE-TIME><rdf:value>20011014T134500</rdf:value></ical:DATE-TIME>
      </ical:DTSTART>
      <ical:DTEND>
        <ical:DATE-TIME><rdf:value>20011014T140000</rdf:value></ical:DATE-TIME>
      </ical:DTEND>
      <ical:LOCATION rdf:resource="#HRTampa" />
      <ical:ATTENDEE rdf:resource="http://www.daml.ri.cmu.edu/people.rdf#ks" />
      <ical:ATTENDEE rdf:resource="http://www.daml.ri.cmu.edu/people.rdf#yn" />
      <ical:DESCRIPTION>Presentation: Retsina</ical:DESCRIPTION>
    </ical:VEVENT>
  </ical:VEVENT-PROP>
</ical:VCALENDAR>
```

Figure 2. A schedule on the Semantic Web containing two calendar events.

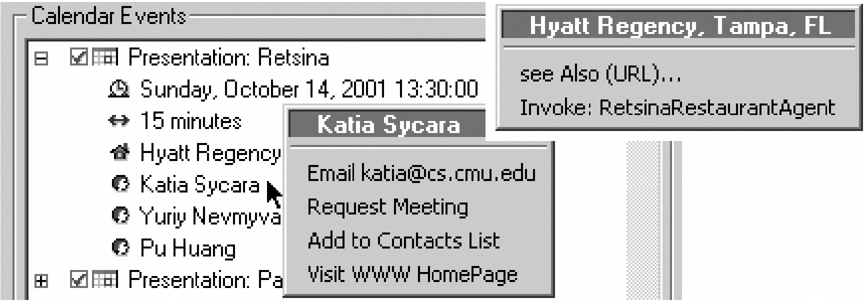

Figure 3. Browsing schedules and invoking context-based services and agents with RCAL.

creator has annotated the information using ontologies that the agent already knows. As the Semantic Web evolves and grows, this is unlikely. Several ontologies that describe contact details currently exist, such as the DAML Meeting Agenda ontology or the RDF VCard ontology. We cannot realistically assume that an agent will comprehend all these ontologies without additional rules (for example, articulation rules—rules that describe how similar concepts are related between two ontologies[7]) or using translation services. RCAL overcomes this by locating and soliciting the help of translation services that convert markup from one ontology to another. These services are located using discovery services based on the emerging DAML-S ontology,[8] which describes services in terms of their capabilities (through an advertised Service-Profile—a description of a service which an agent uses to advertise, compare, or look up that service), how the service works (through a Service-Model, which describes the workflow of how an agent would interact with a service), and how to invoke it (through a Service-Grounding, which defines the format of the messages that an agent and the service exchange and includes practical information, such as the address and port of the machine where the service is hosted).[9] The Service-Grounding builds on Web Service Description Language and SOAP standards to describe the service interface and a communication framework. A DAML-based Discovery Service[6] stores the advertised service descriptions (that is, Service-Profiles) and uses a semantic matching engine, (similar to a search engine) such as the DAML-S Matchmaker,[6] to compare these with service requests. After receiving the results of a request for service, RCAL can then contact the translation service by following the description in the Service-Model and generate SOAP messages via the Service-Grounding.

Although the Semantic Web heralds a change in the way people can access knowledge, agents will be some of the initial consumers of this knowledge. By combining knowledge about their user and the user's desires with information garnered from the Semantic Web, agents can automatically perform tasks via Web services,[10] and thus assist the user. ■

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