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An Open Agent Environment for Context-Aware mCommerce

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Abstract

In this paper, we introduce MyCampus, an agent-based environment for context-aware mobile services, which we are in the process of developing and validating on Carnegie Mellon University's campus. The environment revolves around a growing collection of customizable agents capable of (semi-) automatically discovering and accessing Intranet and Internet services as they assist their users in carrying out different tasks (e.g. planning an evening out, organizing a study group or filtering incoming messages).

The openness of the MyCampus architecture directly derives from a set of ontologies for describing contextual attributes, user preferences and web services. Preference and contextual ontologies make it possible to develop agents that can automatically understand user contexts and preferences, allowing users over time

to pull new agents into their personal environments. Similarly, service ontologies facilitate the introduction of new Web services by allowing agents to (semi-) automatically discover and access them. Such openness could one day play a key role in helping create a more open playing field for producers of Web services. It could also open the door to new markets for a wide variety of simple, task-specific agents capable of automatically adapting to their user's context and preferences.

Keywords: *Intelligent Agents, Semantic Web, Context Awareness, Mobile Internet Services, Mobile Commerce, Privacy.*

Introduction

With tens of millions of Internet-enabled mobile devices, the mobile Internet is opening the door to a slew of new mobile applications and services that will assist users as they engage in time-critical, goal-driven tasks. Yet today, the mobile commerce landscape is dominated by relatively simple infotainment services. Moving beyond these simple services requires overcoming the inherent input/output limitations of mobile devices through higher degrees of automation and the development of services that understand the *context* within which their users operate – e.g. their locations, the activities they are engaged in, who their friends and colleagues are as well as a number of other contextual attributes and preferences.

MyCampus is a semantic web environment for context-aware services, which we are in the process of developing and validating on Carnegie Mellon University's campus. The environment revolves around a growing collection of customizable agents capable of (semi-)automatically discovering and accessing Intranet and Internet services as they assist their users in carrying out different tasks (e.g. planning an evening, organizing a study group, looking for a place where to eat, filtering incoming messages). The power and scalability of the environment directly derives from a set of **ontologies for describing contextual attributes, user preferences and web services**, making it possible to easily accommodate new task-specific agents and new Web services.

MyCampus Architecture

Like many other campuses, CMU's can be viewed as an everyday life microcosm. Members of the community engage in a broad range of activities from working and studying to socializing, practicing sports, attending a variety of events, shopping,

eating, etc. MyCampus users access personalized, context-aware agents from their PDAs over the campus's wireless LAN.

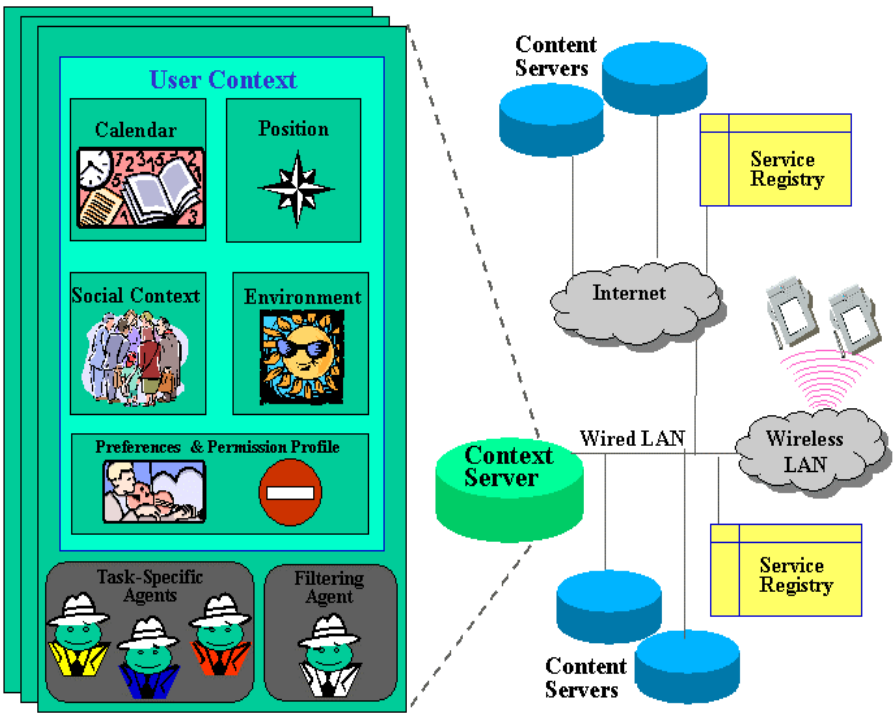

Figure 1: *Overview of MyCampus Architecture*

Specifically each user has a personal environment (aka an e-wallet) that controls access to his or her personal preferences and contextual attributes. Current contextual attributes include the user's location on campus, his calendar, friends and classmates, as well as information about the weather. Location information is obtained using location tracking functionality deployed by local startup Pango on top of CMU's WiFi (IEEE802.11) Wireless LAN. Weather information is currently obtained by connecting to an outside Website.

MyCampus users can over time pull new task-specific agents into their personal environment – in a way reminiscent of today's mobile phone users who download new ringtones and caller group icons on their handsets - except that MyCampus agents may very well reside on servers rather than on the mobile device itself. As users pull individual copies of task-specific agents into their personal environments, these copies are instantiated, taking into account relevant user preferences and contextual attributes. Permission profiles are used to control access to resources in a

user's personal environment. This includes access by the user's own agents as well as those of other users (e.g. allowing your classmates and their agents to see where you are between noon and 4pm or allowing your girlfriend and her agents to schedule activities in your calendar on Friday night). In general, access to a user's personal resource may involve:

- Requesting the value of a contextual attribute at a particular time (e.g. where is the user right now, or does the user already have a meeting between noon and 1pm today?)
- Requesting regular updates about the value of one such attribute (e.g. send me updates on the user's location every 5 minutes)
- Requesting updates as the value of a particular attribute changes (e.g. let me know each time the user enters or exits a building)
- Modifying the value of an attribute (e.g. scheduling a meeting in the user's calendar)

MyCampus Agents

An example of a simple agent implemented at the time of writing is a "restaurant concierge" that gives users suggestions on where to have lunch, depending on their food preferences, the time they have available before their next meeting or class, their location on campus and the weather. For instance, when it rains, the concierge will look for places that do not require walking outside and, if the student only has say 20 minutes before her next class, it will limit its recommendations to nearby fast food places. The recommendations listed in Figure 2 include restaurant ratings that are both context and preference specific.

Other agents our group is currently experimenting with include context-sensitive message filtering and message routing agents, context-sensitive reminder agents, as well as more sophisticated agents endowed with planning and automated Web service access functionality. Context-sensitive message filtering agents are used to filter push messages such as announcements about events on campus (or promotional messages companies could be sending you). Our system relies on a taxonomy of messages (e.g. promotional messages versus seminar announcements) and on context-sensitive preferences (e.g. "when in class, I don't want to be disrupted by promotional messages) to decide which messages to show to the user.

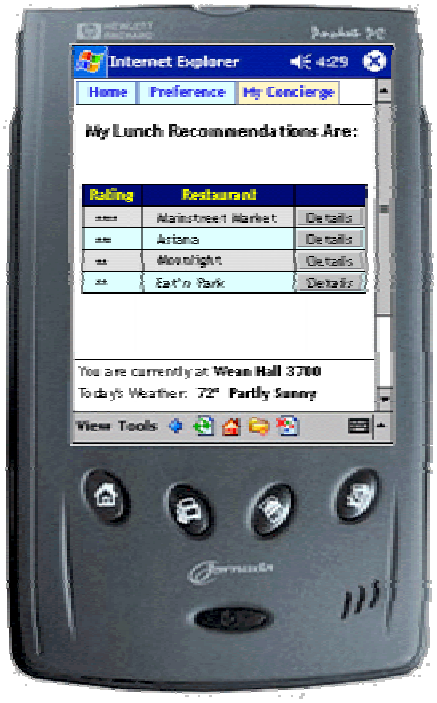

Figure 2: *This Restaurant Concierge is an example of a MyCampus Agent. It returns recommendations on where to have lunch, based on the user's current context and preferences (i.e. restaurant ratings are context and preference specific).*

Our group is also experimenting with other message filtering agents and message routing agents in the context of projects with Alcoa and with the Department of Defense (e.g. to decide how to reroute important messages if their intended recipient is not available). Context-sensitive reminder agents remind students of tasks they have in their to do list such as buying milk as they get close to the local grocery store or picking up a homework assignment when they approach the right building on campus.

Combining Planning with Automated Web Service Discovery and Access

Beyond the relatively simple agents we just reviewed, our project is also experimenting with agents capable of developing and executing plans that involve

the (semi-) automatic discovery and access of Web Services. Suppose that you are visiting a new town and would like to eat pizza. You could try to have pizza delivered to your current location; you could go to a pizza restaurant; you could even send a colleague or friend to go and get you a pizza. Ultimately, the option you will choose will depend on your personal context (e.g. where you are, how much time you have, etc.) as well as the availability of restaurants that deliver to your location at this particular time or the availability of different modes of transportation. Accordingly, we are experimenting with task-specific agents (e.g. an agent to help you purchase items such as a pizza) that are capable of dynamically developing plans based on your current context and information obtained through automated Web service discovery and access. Specifically, our current agents rely on a simple STRIPS-like formalism where tasks are represented as goals (e.g. having a pizza and being at the same location as the pizza) and where primitive operators such as ordering a pizza for delivery are instantiated based on the discovery of relevant Web services. If the agent fails to discover a pizza restaurant that delivers to the user's current location, it moves on and tries to instantiate a primitive operator that will get the user to the location of a pizza restaurant – again through service discovery, looking for nearby pizza restaurants and available modes of transportation (e.g. walking if it is not too far or taking a bus). Fig. 3 depicts an example of one such scenario.

GOAL STATE: At(Peter LOC), At(Cheese_Pizza, LOC), Owns (Peter Cheese_Pizza)
INITIAL STATE: At(Peter, CMU), HAS_CASH(Peter), ~ HAS_VISA(Peter)

KNOWN OPERATORS
- **WALK(USER, LOC1,LOC2)**
  - **Preconditions: At(USER, LOC1), Walking_Distance(USER, LOC1,LOC2)**
  - **Postconditions: ~At(USER, LOC1), At(USER,LOC2)**

RELEVANT OPERATORS IDENTIFIED VIA SERVICE DISCOVERY
- **DOMINO'S_PIZZA_DELIVERY(USER,PIZZA)**
  - **Preconditions: At(USER,LOC1), Within_Domino_Delivery_Area(LOC1) On_the_Domino_Menu(PIZZA), HAS_VISA(USER)**
  - **Postconditions: At(PIZZA,LOC1), Owns(USER,PIZZA)**
- **DOMINO'S_PIZZA_LOCAL_ORDER(USER,PIZZA)**
  - **Preconditions: At(USER, Domino's_Location), On_the_Domino_Menu(PIZZA), HAS_CASH(USER) or HAS_VISA(USER)**
  - **Postconditions: At(PIZZA, Domino's_Location), Owns(USER, PIZZA)**
- **NAPOLI_PIZZA_LOCAL_ORDER(USER,PIZZA)**
  - **Preconditions: At(USER, Napoli_Location), On_the_Napoli_Menu(PIZZA) HAS_CASH(USER)**
- **TAKE_PITTSBURGH_BUS_LINE1(USER,LOC1,LOC2)**
  - **Preconditions: At(USER, LOC1), BUS_LINE1_STOP(LOC1), BUS_LINE1_STOP(LOC2), HAS_CASH(USER)**
  - **Postconditions: ~At(USER, LOC1), At(USER,LOC2)**

Figure 3: *A simple pizza example illustrating the use of declarative Web service descriptions, automated Web service discovery and AI planning.*

This research builds on work carried out by members of the DAML-S coalition.

Concluding Remarks

MyCampus is an ambitious project that aims at leveraging the power of recent Semantic Web concepts in support of mobile, context-aware services. Our work revolves around the development of a growing collection task-specific agents that users can pull into their personal environments. Thanks to the use of ontologies for representing user preferences and contextual attributes, agents can automatically access and exploit relevant user preferences and contextual attributes. Declarative Web service descriptions also make it possible for agents to automatically discover and access Web services as they assist their users. The openness of the MyCampus architecture could one day play a key role in helping create a more open playing field for producers of Web services. It could also open the door to new markets for a wide variety of simple, task-specific agents capable of automatically adapting to their user's context and preferences (e.g. services to help you filter messages, plan an evening out, etc.).

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References

Berners-Lee, T., J. Hendler, and O. Lassila, "The Semantic Web," Scientific American, May 2001.

The DAML Services Coalition (alphabetically Anupriya Ankolenkar, Mark Burstein, Jerry R. Hobbs, Ora Lassila, David L. Martin, Drew McDermott, Sheila A. McIlraith, Srini Narayanan, Massimo Paolucci, Terry R. Payne and Katia Sycara), "DAML-S: Web Service Description for the Semantic Web", to appear in *The First International Semantic Web Conference (ISWC)*, June, 2002.

J. Hendler, "Agents on the Web", *IEEE Intelligent Systems, Special Issue on the Semantic Web*, Volume 16, No. 2, pp. 30-37, March/April, 2001.

McIlraith, S. A., T. C. Son, and Honglei Zeng, "Semantic Web Services," IEEE Intelligent Systems, March/April 2001.

Sadeh, N., "Mobile Commerce: New Technologies, Services and Business Models", Wiley, April 2002.

Sadeh, Norman, "A Semantic Web Environment for Context-Aware Mobile Services," Wireless World Research Forum Conference, Stockholm, September 2001.