Delivering Intelligent Planning Information to Mobile Devices Users in Collaborative Environments

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Abstract

The use of mobile devices is becoming increasingly more frequent. Although very limited, these devices now have capacities for running more advanced systems. Opportunities for developing applications using artificial intelligence have emerged with the release of APIs that are not aimed at proprietary platforms, such as J2ME. This paper discusses some approaches of artificial intelligence planning aimed at mobile computing and subsequently presents an approach to delivering intelligent planning information to users of mobile devices that are participating in collaborative planning environments. Access to planning information by human agents on the move can improve several aspects of planning processes, including collaboration.

Introduction

New prospects for mobile computing are emerging in the post-PC era development that we are witnessing. Mobile devices (such as pocket computers, wireless handheld devices, mobile phones, etc) are being used more often as personal and commercial tools, which means that new services aimed at such devices need to be developed and improved, running to the construction of a new mobile world.

Modalities of applications and services that have been developed aiming at desktop (fixed) platforms have now the challenge to be developed for mobile limited platforms. In addition to the usual difficulties of developing new systems with new technologies, in such cases there is also the aspect of dealing with a very limited platform. Limitations exist in all senses: processing power, memory, screen space, connection bandwidth, etc.

Recent and continuing advances in wireless networking and fast progress of general APIs, such as J2ME (Sun Microsystems 2003a), make feasible the development of such new applications, overcoming some obstacles.

J2ME, the Java Sun platform aimed at mobile limited platforms, brings new opportunities for applications requiring artificial intelligence techniques. J2ME is an open, portable (operating system and hardware platform independent) and an object-oriented API that helps the development of applications requiring agent reasoning, deduction, or other intelligent behavior. Although logic languages, such as Prolog and Lisp, match more artificial intelligence paradigms, these languages are not very flexible when developing systems that require graphical interface and connectivity, for instance. Developing in Java APIs eases the design and integration of all aspects of a system.

Data portability provided by XML and related technologies, and the extension of the current web through the semantic web, will permit programs to manipulate meaningfully and automatically data and the web content, also increasing opportunities for applications.

In this context, a few approaches have been proposed to integrate artificial intelligence in mobile services that require some level of reasoning or intelligent tasks to provide processed and/or elaborated information access. This paper firstly discusses some issues and requirements for developing advanced mobile services. Next we summarise proposed approaches for integrating artificial intelligence in mobile services providing mobile users with different mechanisms for information access. Subsequently we present our approach of integrating planning information aids to mobile services. Finally, conclusions and directions for future work are given.

Issues and Requirements for Advanced Mobile Services

The next sections discuss issues and requirements regarding the development of advanced mobile services and the need of artificial intelligence incorporation in these services.

Mobile Computing and Pervasive Computing

There has been a fast evolution in mobile computing. Devices of various types and advances in wireless technologies allow now their users to run more sophisticated services in their handheld devices. The new trend of pervasive computing (Huang et al. 1999), where the tendency is to embed computing in devices[1], has followed the paradigm "anywhere, anytime" for information accessing and services providing.

The Internet is no longer only an information repository, but also a service repository, and it is moving towards becoming a huge intelligent resource of information and services, capable of reasoning with autonomy. Mobile device's users will also require these powerful resources in their hands.

In this way, development and migration from services that run on desktops to handheld devices will be necessary, and the recent advances in mobile computing increase application opportunities for that platform.

Mobile Devices Limitations

Although the perspectives for mobile computing have broadened, there are some limitations due to the devices' downsizing so desired by users. Handheld devices have limited computational resources, such as memory, processing power, battery; and also limited network facilities, for instance, lower bandwidth and not reliable wireless connectivity.

Considering these aspects, web services and applications developed aimed at desktop platforms cannot be straightforwardly adapted and applied to mobile devices. There is a need of investigating new approaches to develop advanced mobile services that respect the existing limitations.

Desired Component Features and Requirements

Two main features are initially desired when developing mobile systems: portability and facility of service composition to use legacy systems. However these aspects are not always possible.

Early development for mobile computer platforms was only possible by proprietary solutions. Although aspects such as performance can be increased by proprietary solutions (since software and hardware are more closely related), portability is practically unfeasible. Enhanced by the fact that there is a significant diversity of device types available, and no standards have been defined for mobile computing yet, portability should be envisioned when developing mobile services.

The Sun platform aimed at mobile devices, J2ME, opens up opportunities for the development of portable applications. J2ME is an open, platform-independent (of hardware and operating system) and general API that permits the development of new challenging services in the wireless world. Portability can be achieved not only between ranges of devices, but also allowing applications running in both desktops and handheld devices.

In addition, J2ME eases the composition of m-Services and e-Services[2], since it is part of the Java Sun platform. As many Java services (Sun Microsystems 2003b) (Sun Microsystems 2003c) are already available all over the Internet (e-Services), and new services have also been developed in Java (J2ME) for handheld devices (m-Services), it is possible to integrate these services. This integration will: (1) allow the combined use of several legacy systems, (2) permit a good synergy between m-Services and e-Services, and (3) decrease load on the client side (m-Service) or server side (e-Service) when needed.

Finally, J2ME also attends the requirement of being a lightweight platform, suitable for running in limited devices.

Advanced Mobile Services and Artificial Intelligence

Despite all the new opportunities allowed for the development of mobile services, some advanced applications need intelligent behavior, such as:

- Reasoning mechanisms such as deduction and intelligent planning;
- Intelligent agents capabilities, for instance, autonomy, communication, cooperation, coordination, goal-driven reasoning, reactivity and adaptation.

Agents can act as intelligent aids in advanced mobile services for users' benefit. Having the right agents at the right time running in devices can be very useful, and artificial intelligence techniques can be applied in many situations in order to turn Personal Digital Assistants (PDAs) into Intelligent Personal Digital Assistants (IPDAs).

In addition, resources such as GPS (Dana 2000) and Galileo (European Directorate-General Energy and Transport 2002) for global positioning permit the integrated development of advanced location-based services.

Approaches for Developing Services to Handheld Devices Using Artificial Intelligence

Following the trend of migrating e-Services to handheld devices, approaches are being proposed to develop m-Services using artificial intelligence. Artificial intelligence has being integrated to handheld devices in several modalities, such as deduction, or agent communication frameworks. Although these approaches have had motivating results, tools are still limited by the state of the art of the new technologies.

Deduction

The work of Albuquerque et al. (2002) proposes an embedded inference engine for handheld devices developed in J2ME. A deduction mechanism is developed

[1] Mobile handheld devices, AutoPC, Internet-connected ScreenFridge, Microwave Oven/Home Banking Terminal, etc.

[2] m-Services stands for mobile services and e-Services stands for electronic services or web services.

as a J2ME API for using in handheld devices. This object-oriented approach uses objects to represent facts, while rule conditions are implemented as a conjunction of object method calls. If the objects filtered by rule conditions allow the rule to be fired, the rule action represented as an object method is executed. Representations as complex hierarchical object structures of this approach give more expressive power than imperative languages structures. However, J2ME presented limitations that restricted the direct mapping from the original desktop deduction API to the mobile version.

Agents Technology

The proposal of the LEAP – Lightweight and Extensible Agent Platform (Bergenti and Poggi 2001) project is to provide a basic technology for running FIPA (FIPA 2001) agents in Java enabled devices, with sufficient resources and connected to a mobile or a fixed network. The LEAP objectives are: (1) develop a FIPA compliant platform for fixed and mobile devices; (2) allowing this platform capable to run in different operating systems; and (3) having this platform the ability of configuration with respect to the capabilities of a target device. LEAP permits the development of agents in a mobile network using an open infrastructure. The advantage of this approach is that FIPA is a standard for both mobile and fixed systems.

Agent Communication

KSACI (Albuquerque et al. 2001) is a tool that proposes a communication infrastructure among agents running in handheld devices. KSACI allows agents embedded in handheld devices to exchange information and knowledge with other embedded agents or with agents located in desktops. KSACI extends SACI (Hubner and Sichman 2000), an open-source Java API for agent communication, and its architecture design is based on a client server structure, where the main functions are concentrated in the server, and clients use the services provided. KQML (Labrou and Finin 1997) and XML (World Wide Web Consortium 2002a) are used in the project as outer and inner agent communication languages respectively.

BDI Agents Optimization Use

The work of Wai Loke (2002) discusses issues about storing and running Beliefs-Desires-Intentions (BDI) (Rao and Georgeff 1995) based agents on mobile devices, from a database perspective. Based on a simple BDI-model of agents, this work discusses requirements for caching, transactions, querying, and use of push technology with such agents. A BDI agent needs computational capacities (storage, connectivity) that are not abundant in limited devices. Storage is necessary for its beliefs (knowledge about the environment and itself), intentions (selected plans for execution), and code.

To surpass existing memory limitations in mobile devices, the execution of such agents is proposed by caching of agents and parts of agents, to enable queries to be answered locally (without connection), faster, and processed on the client side (minimizing processing on the server side). Nevertheless, updates need special attention involving conflicts and consistence.

A Planning Approach to Handheld Devices

The planning approach to handheld devices is based on I-X (Tate 2003) technology for intelligent systems. I-X has, among its several aspects, a lightweight planning concept that should allow the development of applications in handheld devices with limited computational resources. Additionally, the I-X Process Panels (I-P^2) (Tate, Dalton, and Stader 2002) supports collaborative construction and execution of plans.

The next subsections describe the I-X system and its components, followed by a description of our approach of integrating planning as a tool for developing m-Services in handheld devices. This approach will permit intelligent planning information to be delivered to mobile users participating in a planning process.

I-X System and <I-N-C-A> Ontology

I-X (Tate 2001) is a technology for building intelligent systems with different aspects that intends to permit cooperation between human and computer systems in the synthesis and modification of a product (such as a plan, design or physical entity).

The I-X approach uses shared models for task-directed cooperation between human and computer agents who are working together on the synthesis of a product. I-X agents or systems carry out their process in two cycles: (1) handle issues, and (2) respect domain constraints.

<I-N-C-A> (Issues – Nodes – Constraints – Annotations) (Tate 2001) is the I-X ontology used to represent a product as a set of constraints on the space of all possible products in the application domain. <I-N-C-A> ontology can be used to describe objectives, specifications, or mixed-initiative synthesis processes and products.

The following aspects of I-X are particularly relevant for this work: I-P^2 (Tate, Dalton, and Stader 2002) and I-Plan (Tate 2002). I-P^2 are the I-X Process Panels used to support user tasks and cooperation, and I-Plan is the I-X Planning System.

The aim of an I-X Process Panel (I-P^2) is to act as a workflow aid, providing users with reporting and messaging. I-X Process Panels support collaborative users in selecting and carrying out processes and creating or modifying process products.

I-Plan, the I-X Planning System is used within I-P^2, providing generic facilities for supporting planning. I-Plan is a planning system based on mixed initiative principles. I-Plan is modular, can be extended via plug-ins and is intended to be a lightweight planning system. These aspects should permit I-Plan to be used with other applications including the ones aimed at mobile devices.

The I-X system works based on shared models handles specified as plug-ins that can be extended via an open plug-in interface according to new requirements. Shared models and the ability of defining handles as plug-ins are concepts that support the extension of planning mechanisms to a mobile platform. An I-X Process Panel is a desktop-based I-X application that is using these concepts. Our intention is to integrate that application with the mobile platform, compounding a unique environment of planning and execution.

Mobile Planning

Considering the opportunities for artificial intelligence development in mobile devices, permitted by platform independent and general APIs such as J2ME; and also the need of personal intelligent agent services running in portable devices, this work proposes an approach for integrate intelligent planning support in such devices. This m-Planning (mobile-Planning) approach will permit the development of m-Services using intelligent planning technology, where information regarding intelligent planning processes can be delivered and accessed by mobile users.

There are four possible different models (Figure 1) to integrate planning technology into mobile devices: a) complete embedded model, b) client-server model, c) hybrid model and d) requirement-based model.

The complete embedded model provides the full and self-contained facilities of a planning system to mobile users. However it is not a practical approach due to limited resources of mobile devices. The client-server model also provides all the facilities of planning systems, however there are several kinds of dependences regarding connection, availability of server, transmission rate and so on. An initial experiment using that approach is shown in (Nixon, Levine and Tate 2000), where a mobile phone interface is linked to the O-Plan Planning System (Tate 1994) – the predecessor of I-X. The hybrid model is a blend of the two last approaches that tries to decrease the dependence regarding to server. However the programming logic turns more complex because it is necessary to consider synchronisation and co-ordination of issues between the planning processes running in the server and client sides. Finally the requirement-based model considers only the planning mechanisms/features that in fact are required by a user to be implemented into its device. Consequently it is the model that more suits our approach.

Requirement-Based Model for M-Planning

This work, based on the I-X concepts, supports the implementation of the requirement-based model of planning agents into mobile devices so that they can assist users during their activities. The basic idea is to adapt processes that will be running inside the mobile assistant in accordance with the activities carried out by the user. Thus, each mobile device will use only a subset of planning processes and information.

The I-X system supports a mixed-initiative style of planning; consequently a possible scenario application can have several agents (human and computer agents), working together in a collaborative planning process. Human agents may use different mobile devices to access information and participate in the process while on the move. Therefore, the delivery mechanism for planning information should take into account several aspects such as agents' characteristics and roles, devices' capabilities, information type, and progress of situation.

Making use of <I-N-C-A> ontology, mixed initiative planning information can be accessed and delivered among agents. This information delivery process should be

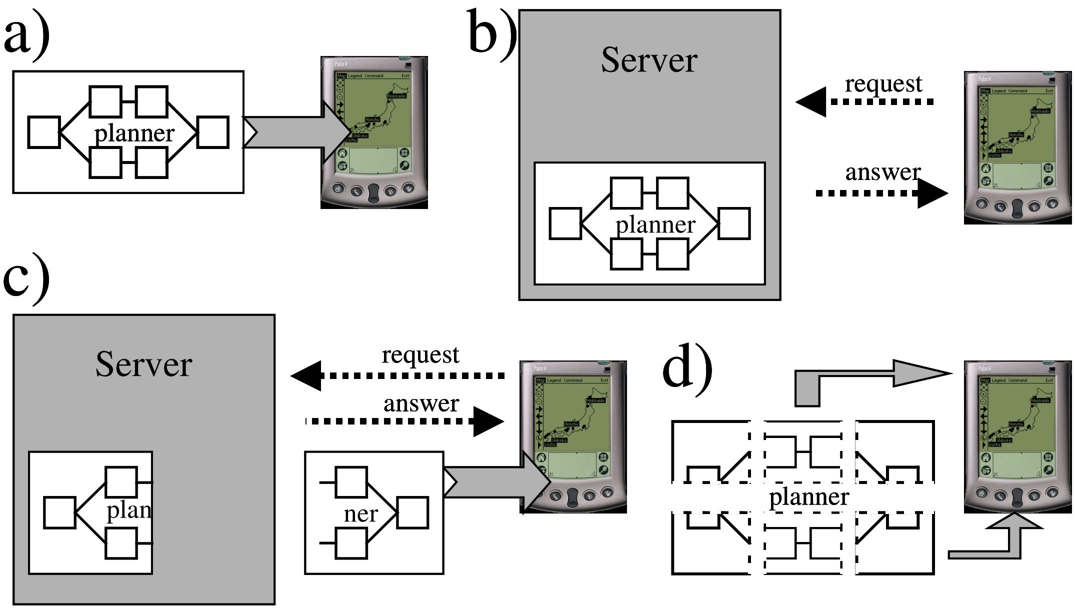

Figure 1 – Four different models to integrate planning into mobile devices: (a) complete embedded model, (b) client-server model, (c) hybrid model and (d) requirement based-model.

controlled by an intelligent visualisation and delivery framework, which uses XML and related technologies (World Wide Web Consortium 2002b) (DARPA 2002) as knowledge representation or inference/deduction tools.

The information visualisation delivery framework is based on scenario characteristics, such as the agent that is requesting planning information and its preferences, the planning information being requested, the mobile device where the planning information will be delivered and its capabilities, and the available resources (map or sketch tools, GPS, etc.). Based on a scenario characterisation, planning information is delivered in a suitable way to mobile devices' users.

Furthermore, considering the way that the information is structured and its underlying ontology, a general use of planning services is permitted in mobile devices' applications.

In our application, in particular, we are interested in collaborative environments where users perform complementary tasks, playing different roles during a joint operation. In this way the first step to design planning assistants is to consider the users' activities. Then, based on their requirements we can implement both plug-ins to support the planning processes and policies to control the information that each agent can access. Generally plug-ins do not change during joint operations because users carry out the same set of activities. On the other hand the information access policies could be variable, depending on interests, location and particular issues of users.

The planning-based agents are able to assist users because they operate in a mixed initiative style. In other words, agents are autonomous to take decisions, however under supervision of their users. This approach results in several advantages: it intensifies the user control and involvement, permits user interaction during the whole decision process so that they are able to understand why ways were chosen or avoided, and removes the premise of complete and bug-free knowledge.

The integration between the mobile and fixed platform in that approach is carried out in a natural way since all agents of both platforms make commitments on the same ontology. That is an essential feature to collaborative environments because they will certain operate with agents of both platforms and, in addition, the organisation can be easily extended.

Referring to implementation aspects, the mobile agents are been developed via J2ME Sun Microsystems API, which enable an easy integration with the current I-X system developed to desktop-based platform (also developed in Java) and the use of several others Java API's and tools.

This approach will permit the development of services that need intelligent planning tasks support. Planning technology being available in portable devices can improve planning process in many ways (Gray 2000). For example, during planning execution it will help human agents on the move participating in collaborative processes to access and exchange information necessary to execution of tasks.

System Description – Architecture and Technical Aspects

The approach of the limited media interface (Nixon, Levine and Tate 2000) of the O-Plan Planning System, the I-X predecessor, was developed aimed at mobile telephones as a Java Servlet application communicating with the O-Plan System and WML (Wireless Mark-up Language) server pages.

The Java Platform for mobile computing (J2ME) has brought significant flexibility when developing for mobile devices. The complicating factors derived from the diversity of mobile devices available are diminished by J2ME, since its defined profiles and configuration try to group devices with similar characteristics. Profiles are sets of APIs defined on top of configurations that offers the program access to device-specific capabilities in a transparent way, and configurations define grouping of devices based on available memory and processing power. J2ME eases systems integration that are compounded by different devices, and also allow the development of more advanced services. These aspects are explored and explained on the mobile planning approach being presented.

The mobile planning approach (m-Planning) is aimed at

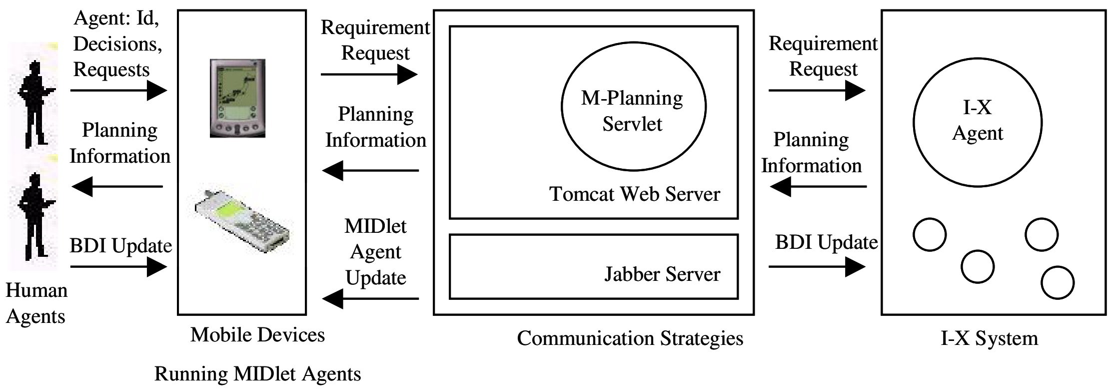

Figure 2 - Mobile Planning System Architecture

mobile telephones and PDA's (Personal Digital Assistants) and has been developed using the following platforms and applications:

- The I-X system;
- Java 2 Micro Edition API and Wireless Toolkit (Profile/MIDP-2.0 and PDA Profiles);
- Java Servlet (Sun Microsystems 2003d);
- Jakarta Tomcat (Apache 2003) servlet engine; and
- Jabber Technology (Saint-Andre, P. 2001).

The architecture of the m-Planning is illustrated in Figure 2 and it is divided in the following components: human agents participating in the planning process; mobile agents (MIDlets) running in mobile devices; communication strategies that can be implemented in different ways; and I-X agents that are based on <I-N-C-A> ontology.

Human agents on the move participating in the planning process need to interact with the system to access information that could help executing their tasks. Equipped with handheld devices, they will be able to access planning information in accordance with their needs and role in the process. Human agents are identified by an agent id, and when interacting they can ask specific planning information and make decisions based on these. The importance of roles and authorities to control the execution of actions or delegations will be addressed in future works, and not commented in details here.

Mobile agents, J2ME MIDlets[1] that run in mobile devices, are human agent's representation in the mobile world and mirror of an I-X agent. Their objective is to provide requested planning information, for example, some course of action, or state of the process, in accordance with their current state and needs. MIDlet Agents are able to manipulate Issues, Activities, and States from <I-N-C-A> ontology like any I-X Agent. When a mobile agent first needs an information, it is requested from the I-X system. Subsequent requests are first tested if they can be solved locally (in the mobile agent itself) or need a new request from I-X System. These requests are implemented by a communication strategy.

Communication strategies permit the communication between the mobile agent, and its I-X Agent mirror in the I-X System. Communication strategies can be implemented in many ways, for instance, using Java servlets, or Jabber technology. The application being presented in the next section uses Java servlets to implement communication between the two agents (mobile and I-X agent). A servlet called m-Planning is available to attend requests from agents.

I-X agents are mirrors of mobile agents, what means that they should share the same beliefs, desires and intentions (BDI). They have two main objectives: minimize load in mobile agents, and permit interaction among other agents (mobile or I-X agents). A generic I-X agent is able to handle issues, perform activities, add constraints about the domain and support annotation (Tate 2001).

[1] MIDlets are Java applications that run in mobile devices.

This approach has the advantage of having agents running in handheld devices providing planning information, without overloading it. The I-X agent has the whole information about the planning process (from the agent point of view), permitting that the mobile agent mirror shares the knowledge with it and manipulates only partial planning information at a time. In this way, processing power and memory use is optimized in mobile devices.

Another advantage is that the communication strategy used is transparent, functioning as a mediator between each two agents (mobile and I-X agent), where both understand the I-X <I-N-C-A> ontology for describing a product, such as a plan, as a set of constraints on the space application domain.

Application Demonstration

An application has been developed in the Binni Scenario (Rathmell 1999) to demonstrate the proposed mobile planning approach to information access in mobile devices.

Binni is a coalition command and control fictitious scenario developed to evaluate technical solutions that can improve coalition campaigns. The Binni specification is intended to be diverse and representative, and contains the requirements necessaries for building a collaborative planning scenario that we need. Figure 3 illustrates the fictitious countries and their borders in the Binni Scenario. An envisaged case is where a human agent equipped with a mobile device (for example, a PDA or cell phone) is on the move, collaborating in a planning process in Operations Other Than War (OOTW) in the Binni domain.

Figure 3 - Binni Scenario

In this scenario, the human agent will need to exchange information about the planning process in general, the mutual objectives, his personal tasks and, the planning process execution status, and also information about the domain, involving for example, localisation of resources.

Typical communications mechanisms used by participants in real world campaigns can sometimes be not sufficient. For instance, when an agent asks an urgent information to a peer or superior about the localisation of a plan resource, such as a hospital. The requested agent may not be available to answer promptly, because he/she can be either off-line or busy. Having this kind of information available and accessible in a mobile device can be of great help, and it is what the mobile planning approach proposes.

When a human agent start the Mobile Planning application it is firstly requested his identification, which, if validated as a subscribed agent, will allow the access of information pertinent to this user, for example, domains in which the user is collaborating, his preferences, authorities, capabilities, etc. The identification will be used to create a mobile agent with this identification, and also an IX agent.

For a validated user a list of applications (domains) will be presented, that describes the environment the user collaborates. Choosing the Binni option will permit the human agent to sending and receiving information pertinent to the collaborative planning process.

The Figure 4 shows a menu of services available in the Mobile Planning Application. The 'Planning Info' service provides information services about the planning process. This is the main service, where information about Issues, Activities, States can be accessed, manipulated and updated. The description of plans is made following the I-X <I-N-C-A> Ontology for describing products. The others services available will be explored in future works. Comments about them are made in the Future Works section.

Figure 4 - Services Available in the Mobile Planning Application Displayed in a Palm OS III Emulator

Human agents can access information about Issues, Activities and States by demand. The mobile agent will not be overloaded, since the use of its limited resources of memory and processing power are minimised due to the mirror approach of the Mobile Planning System. The mobile agent has only the knowledge of the problem in which the human agent is working in the moment. The partial knowledge is requested from the IX agent mirror of the mobile agent, which has the whole knowledge of the domain (from a specific user perspective).

Figure 5 - Binni Map Displayed in an Emulator

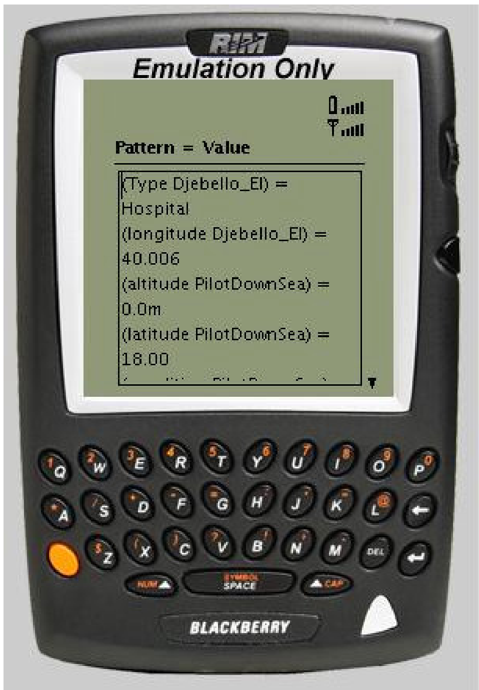

Figure 6 – Plan States Loaded in an Emulator by the Mobile Agent

The Figure 5 displays Binni map in a cell phone emulator and the Figure 6 shows an example of tates being loaded in a mobile device, where information of resources localisation (latitudes, longitudes and altitudes) is presented among others.

Human agents while performing their tasks can update the mobile agent knowledge base and consequently the IX agent mirror knowledge base. For example, when an agent asks the mobile agent to load activities, the activities assigned to him are displayed in the mobile device. If an activity is completely performed by the human agent, it should be marked as done. The mobile planning agent and its IX agent mirror is then notified. These aspects will have an impact in the collaborative planning process in general, not only locally, as it will affect the participant agents BDI (Beliefs-Desires-Intentions).

Future Works

This approach of mobile planning is leading to several aspects that need to be investigated in future works.

One aspect is related to the other services (as shown in Figure 4) that will be made available for the human agents.

For instance, the 'Organisation' service will be based on the I-X I-Space concept, which is a concept for managing I-X Process Panels and agent structures and relationships in a virtual organisation. A mobile I-Space service might show relationships (peers, subordinates, superiors and contacts) between agents, and also support information about capabilities and authorities of agents' panels. This kind of information provided by a mobile service will help to improve the collaborative process. For example, agents will be able to request advice or help from other agents in a virtual organisation, in a specific area of expertise, based on information about their capabilities and authorities.

Another future work is investigate how integrate location services, such as GPS (Global Positioning System) and map tools to integrate intelligent localisation based services.

As a future application we intend to apply the approach in an emergency rescue scenario (Siebra and Tate 2003), where different agents will be able to integrate capabilities and share knowledge to solve mutual goals. In this scenario, several agents that can be software agents (intelligent planner), or human agents playing different roles (fire brigade, police force, ambulance team and their coordinators) will work in a mixed initiative style to plan and execute emergency and relief operations. Mobile planning aids in portable devices will permit access of planning information by agents while on the move improving synergy and collaboration.

Conclusion

The fast development of the mobile computing area, together with the huge amount of information and services available in the Internet are promoting research regarding development and adaptation of desktop based systems to the new mobile scenario.

Opportunities for Artificial Intelligence in mobile computing have increased with the release of general solutions, such as J2ME. J2ME permits the development of platform independent (hardware and operating system) applications. It is a good advantage since there are no standards well defined yet in the mobile computing area, and there is a great variety of devices available.

In this scenario, this paper proposes an approach of intelligent planning information delivery for human agents participating in collaborative planning environments via their mobile devices. The approach is based on the I-X system that permits a mixed-initiative style of planning, and its <I-N-C-A> ontology for describing the planning products and specifications.

This approach contributes in many ways for the integration of mobile computing and artificial intelligence. First, it allows that human agents on the move access intelligent planning information while performing their activities or collaborating in a planning process in any way. This aspect helps to improve the collaborative planning process, permitting a better understanding of the planning process by individual and global perspectives. Second, access to planning information in mobile devices is being provided in a generic way, using standard patterns as XML and related technologies for knowledge representation. This characteristic permits an easy extension and development of mobile services supported by intelligent planning technology.

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