M-PLANNING: A MOBILE TOOL TO SUPPORT COLLABORATIVE PLANNING

Natasha Queiroz Lino, Austin Tate
Centre for Intelligent Systems and their Applications
School of Informatics, The University of Edinburgh
Appleton Tower, Crichton Street, EH9 9LE, Edinburgh, UK
{Natasha.Queiroz, a.tate}@ed.ac.uk

Abstract

This paper presents M-Planning, a mobile tool to support collaborative planning, and its conjunction use with the I-X Process Panels. M-Planning works like an intelligent mobile panel for agents on the move. The tool permits agents' interaction, visualisation and manipulation of information related to collaborative processes of planning. The architecture of the M-Planning tool is integrated with the I-X System, and based on some of its concepts. The relevant I-X concepts for this work are discussed in the paper. M-Planning is intended to be used in real world domains and applications. To motivate and illustrate M-Planning use, a mixed initiative planning application is described in a fictitious scenario of disaster relief operations.

Key Words

Visualisation, Mobile Computing, Intelligent Planning, Collaboration.

1. Introduction

Realistic planning systems should allow collaboration between software and human agents. In a mixed initiative style of planning, systems and users can put together their strengths to achieve mutual goals. Many efforts have been made in the development and improvement of intelligent planning systems, for instance, in respect of search algorithms, and in many other aspects. However, there is a lack in supporting tools for planning and execution processes. Opportunities exist for the development of tools that will provide better interaction and synergy between collaborative agents, having a more flexible use.

In this scenario, a promising solution is to integrate mobile computing and artificial intelligence. Mobile devices (such as cell phones and PDAs) can be transformed into intelligent personal digital assistants via tools, developed to support users working in collaborative planning environments.

Some approaches proposing integration between artificial intelligence and mobile computing are discussed in a brief survey in [1]. Deduction [2], agents technology [3], and agents communication [4], are examples of artificial intelligence technologies that have been applied in mobile computing. Also in [1] an initial version of the M-Planning tool is presented.

In this paper we intend to present the M-Planning tool in more details, its concepts, architecture, and application, focusing on the collaborative aspect and integrated use with I-X Process Panels (I-P^2) [5]. The approach of the M-Planning tool is integrated with the I-X System [6], and is inspired in some of its concepts. M-Planning intends to be a tool to support mixed initiative planning, that permits human agents to access and exchange planning information via mobile panels. Due to limited resources of mobile devices (processing power, memory, bandwidth, etc.), M-Planning provides a light approach as a way to avoid the overload of applications, which would compromise execution.

The reminder of this document is organized as follow. Section 2 describes a domain (the Nagoya Domain) that will be used to demonstrate how the M-Planning mobile agents can be used together with I-X agents via its Process Panels (I-P^2). Section 3 discusses aspects of the I-X Project that are relevant for this work. The M-Planning tool is presented in Section 4, where its concepts, approach, and architecture are discussed. Furthermore in this section an application in the Nagoya domain is described illustrating a collaborative planning and execution process where M-Planning and I-X agents are joined together working in the process. Finally, Section 5 discusses conclusions and future works.

2. A Disaster Relief Operation Domain: A Collaborative Planning Environment

This section describes a collaborative scenario for using and testing the M-Planning tool. The Nagoya [7] domain has been specified to test new artificial intelligence technologies and methods, and will also be used to

demonstrate approaches of the I-Rescue [8] project, that is being developed at the Artificial Intelligence Applications Institute at the University of Edinburgh. The Nagoya domain consists in a disaster relief scenario.

This domain is based on the Japanese city of Nagoya and describes its urban area: streets, buildings, agents, resources, a fictitious natural disaster (earthquake) and its consequences. A natural disaster like an earthquake can have numerous tragic effects: buildings collapse, fire spreading through the city, civilians injuries, blockage of roads that make difficult transit and evacuation, etc. This scenario will require different types of abilities to control the situation, such as, medical team to take care of injured people, fire brigades to extinguish fires, search teams, police to control evacuation of risky areas, etc. These activities need intelligent and automatic support of tools, to improve collaboration, communication, information and efficiency.

All the agents involved in disaster relief operations have a general mutual goal that is: saving people lives, and control the situation. However it's necessary coordination and collaboration between agents to achieve the mutual goals. This scenario can motivate many research opportunities in artificial intelligence, and in particular, intelligent planning based technologies and tools.

Planning information delivered to human agents assisted by intelligent personal assistants running in mobile devices (such as, PDAs, cell phones) can be of great help. It can, for instance, assist users, improve collaboration among (software and human) agents and support execution of activities, which are goals of the M-Planning tool. In Section 4 the M-Planning tool will be described in details and the scenario described here used to illustrate examples. However, first will be necessary for a better understanding of the M-Planning approach, a brief discussion of relevant aspects and concepts of the I-X Project in Section 3.

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

I-X [6] is a technology for building intelligent systems. Among its different aspects I-X 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) [6] 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 [5] and I-Plan [9]. I-P^2 are the I-X Process Panels used to support user tasks and cooperation, and I-Plan is the I-X intelligent planning concept.

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 concept is intended to be 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. I-X Process Panel is a desktop-based I-X application that is using these concepts discussed. Our intention with M-Planning is to integrate that application with a mobile platform, compounding a unique environment of collaborative planning and execution.

4. The M-Planning Tool

M-Planning is a tool to support human agents on the move that are working in collaborative environments of planning. M-Planning works as a mobile panel that provides human agents on the move with intelligent planning processes related information. Via M-Planning, human collaborators can receive updated information about the process that they are carrying on, for instance, they can visualize what activities has been assigned to them, or also, information about the domain, as the localization of resources (such as a hospital).

Next subsections explain in more details the M-Planning approach. Subsection 4.1 describes the M-Planning architecture and technical details. Subsection 4.2 explains how the M-Planning tool works, using an application developed in the Nagoya domain. A conjunction use of a M-Planning mobile agent and an I-P^2 agent is exemplified, showing how agents can interact and collaborate in a planning and execution process.

4.1 Architecture: An Approach for Limited Resources

Mobile computing platforms are very restricted in resources if compared to desktops. There are limitations related to processing power, memory capacity, network bandwidth, screen space, etc. Mobile computing applications have to consider all these limitations in order to not compromise execution.

In order to surpass some of these restrictions M-Planning architecture was designed with the objective of saving computational resources where possible. The form of integration between M-Planning and the I-X system is the principal factor responsible for the 'resource saving' architecture approach.

M-Planning is inspired in some of the I-X concepts (such as I-P^2, I-Plan, I-Space), in this way, many I-X software components are adapted, integrated and used by M-Planning. Taking advantage of that, the integration architecture tries to minimise computation in the mobile computing platform side (M-Planning), using software components and plug inns of the I-X System. In this way, the integration allows a light computation on the M-Planning side, leaving the heaviest computation to the I-X System components and the desktop platform.

More details about the architecture that will be given will permit a better understanding of this approach. The M-Planning architecture is represented in Figure 1, and is integrated by the following components:
- Human Agents participating in the planning process;
- Mobile Agents running in mobile devices;
- Communication strategies that can be implement in different ways;
- I-X Agents that are based on <I-N-C-A> ontology and run in desktops.

Before the discussion of each component is necessary an outline about technical aspects. M-Planning is aimed at mobile telephones and PDA's (Personal Digital Assistants) profiles, and has been developed using the following technologies:
- The I-X system [6];
- Java 2 Micro Edition API and Wireless Toolkit (Profile/MIDP-2.0 and PDA Profiles) [10];
- Java Servlet [11];
- Jakarta Tomcat [12] servlet engine; and
- Jabber Technology [13].

The architecture components were developed using these technologies listed above. The components functions, meanings, and roles in the architecture are described as follow.

Human agents on the move need to interact with the system to access information that could support their task execution. 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 (Java applications 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 information, this information 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 are implemented in different ways. Currently, for instance, they have been implemented using Java Servlets and Jabber technology.

I-X agents are mirrors of mobile agents, what means

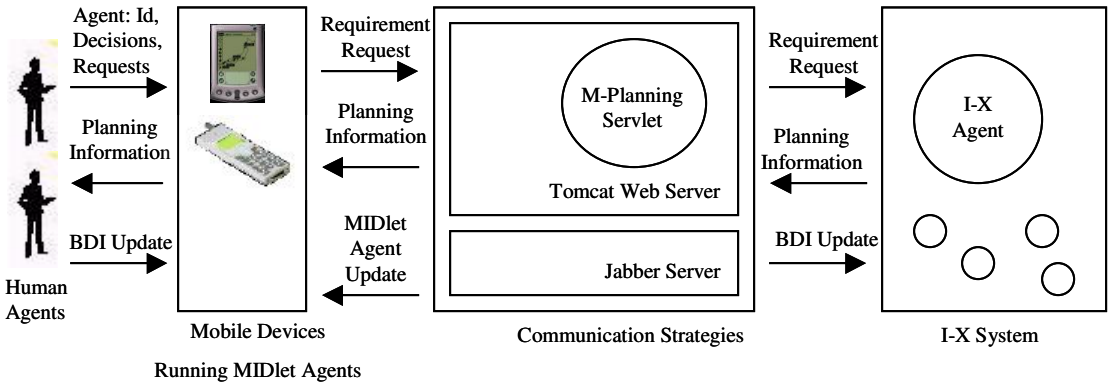

Figure 1 - M-Planning architecture

that they should share the same beliefs, desires and intentions (BDI) of their respective mobile agents. They have two main objectives: minimize load in mobile agents, and permit interaction among other agents (mobile or I-X agents) running in different platforms. A generic I-X agent is able to handle issues, perform activities, add constraints about the domain, and support annotation [6].

This architecture approach has several advantages. First it permits planning based agents to run in mobile devices without overloading them due to the mirror mechanism: the I-X agent mirror has the whole information about the planning process (from the agent point of view), and the mobile agent mirror shares the knowledge with it, but manipulates only partial planning information at a time. I-X agents provide information to their respective mobile agents mirrors by request. In this way, processing power and memory use is optimized in mobile devices. Another advantage is that the communication strategy is transparent, functioning as a mediator between each agents pair (mobile and I-X agent mirrors), 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 application domain.

In this way, using this architecture approach it is possible to provide advanced mobile services using intelligent planning based technologies, since it is a lightweight propose that considers the limited resources aspect of the mobile computing platform.

4.2 Collaboration Support to Agents on the Move

Our intention is to support realistic scenarios of planning and execution processes. So, an envisaged (fictitious) possible real world case in the Nagoya domain is where human agents equipped with mobile devices (PDA or cell phone) are on the move collaborating in a planning and execution process. The general mutual goal is to re-establish order and save human lives after a natural disaster as an earthquake.

Human and software agents need to exchange information about the planning and execution process: mutual goals, personal tasks, status of the planning execution process, and also information about the domain (for example, localisation of resources, such as a hospital).

The main M-Planning tool objectives are: (1) be a tool to support mixed initiative planning; (2) permit human agents access and exchange information via mobile versions of I-X Process Panels (I-P^2); and surpass some of the existing limitations of typical communication mechanisms (such as radio) used by participants of search and rescue operations.

Like I-P^2 (the I-X Process Panels), which support collaborative users in carrying out processes and modifying products or plans, M-Planning has a similar, but lighter proposition, destined to the mobile computing platform. Collaborative users can access, exchange, and update information about plans that are specified following the <I-N-C-A> (Issues, Nodes, Constraints and Annotations) ontology. In this way, M-Planning tool permits users manipulate the following planning related information according to <I-N-C-A> ontology: Issues (represent potential requirements that can be transformed in activities or nodes); Activities (the ontology's Nodes are activities in a planning process); and States (that are modelled in <I-N-C-A> as a type of constraint).

Next subsections illustrate how collaborative users on the move can use the M-Planning mobile panels to participate in a mixed-initiative planning and execution process together with an I-P^2 collaborator in a desktop. The objective is to show a conjunction used of M-Planning and I-P^2 in a collaborative planning process, in an application supported by intelligent planning technology.

4.2.1 Visualising and Manipulating Issues and Activities – A Collaborative Use of M-Planning and I-P^2

An integrated use of an I-X Process Panel and a M-Planning mobile panel will be described in this section. Human agents playing different roles (firemen, police, doctors), having different responsibilities and authorities, are collaborating in a planning and execution process in the Nagoya domain (described in Section 2).

To illustrate, we will analyse two users: one user working as a task assigner (superior), and another user working as a performing agent (subordinate). Agents' relationships are organised following I-X I-Space concepts. Planning based computer agents will assist the users: an I-P^2 agent will assist the task assigner user, while a mobile agent of the M-Planning tool will support the performing user, permitting collaboration between these two agents.

An I-P^2 agent is able to handle issues, perform activities and add constraints (state). Via I-P^2 the task assigner user can reroute or delegate issues and activities to other panels or agents. An I-P^2 agent can also receive reports and messages and sometimes interprets them to understand current status of issues, activities and constraints or current world state.

A mobile agent in the M-Planning tool allows the user on the move to manipulate issues, activities and states in terms of loading and adding new ones. The Figure 2 shows a situation where an I-P^2 agent delegates an activity (keep Fire Brigades full tank) to a mobile agent to be

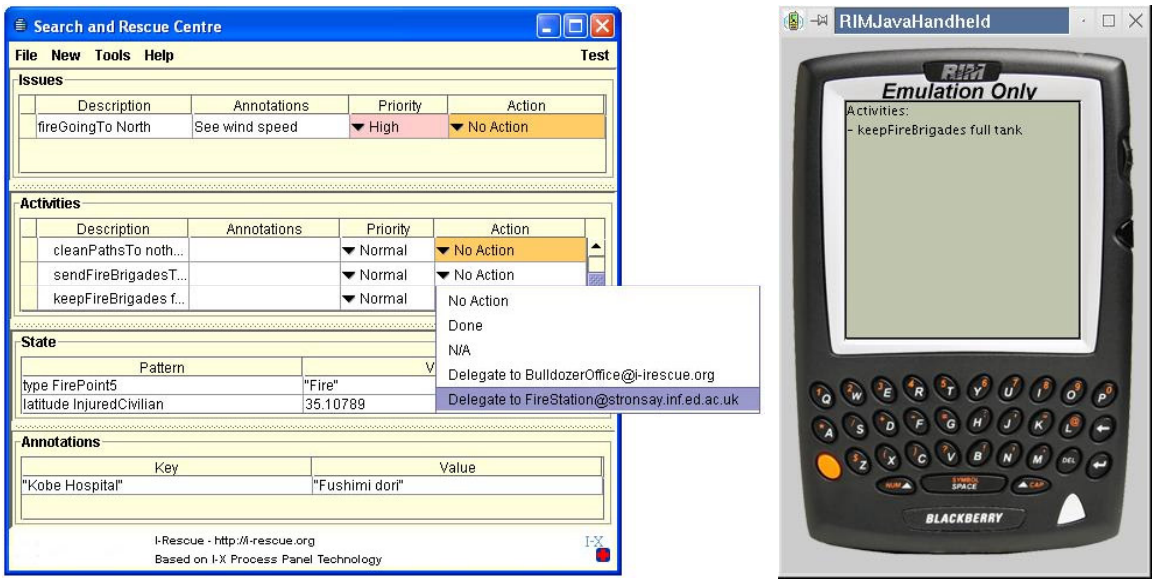

Figure 2 - Collaborative use of an I-X Process Panel agent (left) and a M-Planning mobile agent assistant (right)

performed. This new activity is added to the mobile agent knowledge base and then can be loaded and visualised by the mobile user when requested. In the same way, for example, the performing user can, via the mobile agent, create an activity and send it for another agent if it has capability for delegating activities. In the current version of the M-Planning tool, I-Space based rules to coordinate agents' relationships, authorities and capabilities, are under implementation.

4.2.2 Visualising and Manipulating States

In the I-X system approach, states are domain information specified as pairs of the type 'pattern = value'. It's the agents' beliefs about the world. A mobile agent can load and add new states constraints via the M-Planning tool.

The Figure 3 (right hand side) shows a list of states being loaded in a mobile device. States can include, for example, information about localisation of resources, such as a hospital in the Nagoya domain, in terms of its geographic position (latitude and longitude). In particular, in the States menu of M-Planning there is also the feature that permits to visualise the domain's maps. Figure 3 (left hand side) shows Nagoya street map being displayed in a mobile device. In future works we intend to extend States visualisation capabilities integrating location services, such as GPS (Global Positioning System) and map tools to provide intelligent localisation based services.

5. Conclusion and Future Works

M-Planning is a tool to support collaborative planning contributing in many ways. First, it allows planning based mobile agents' panels available in handheld device without overloading it, due to its light architecture approach. Second, it supports collaborative planning and execution processes, assisting human agents with intelligent planning services. The tool also has the advantage of providing advanced mobile services with an optimized use of mobile device resources.

M-Planning tool has been designed to use in real world domains and application. It counts with the flexibility of the I-X <I-N-C-A> ontology for modeling planning and execution processes, which is being demonstrated in a series of experiments.

To conclude we can say that M-Planning is an application that integrates artificial intelligence and mobile computing technologies that supports collaborative planning processes activities.

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Figure 3 - States loaded in a mobile panel (right), and Nagoya street map (left)

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