Plan Delivery and Visualisation in Collaborative Planning Environments

Natasha Correia Queiroz Lino

Ph.D. Proposal

University of Edinburgh

2002

Content

1 INTRODUCTION **3**

2 RELATED WORKS **5**

2.1 MULTI-AGENTS SYSTEMS FOR COLLABORATION 5

2.1.1 CoAX *5*

2.1.2 CoAKTinG *6*

2.2 VISUALISATION OF PLANNING INFORMATION 7

2.2.1 PRODIGY System *7*

2.2.2 TRAINS/TRIPS System *8*

2.2.3 Visual Interaction Dialog (VID) System *9*

2.3 VIRTUAL ORGANISATIONS 10

2.4 MOBILE COMPUTING 11

2.5 PROFILING 13

3 CENTRAL IDEAS **15**

3.1 I-X PROJECT 16

3.2 PLANNING INFORMATION VISUALISATION APPROACH 18

3.2.1 Visualisation of Plans, Objectives, Tasks and Activities *20*

3.2.2 Visualisation of Agents and their Relationships *21*

3.2.3 Visualisation of Performing Agents *22*

3.3 PROFILING 23

3.4 QUESTIONS AROUND TECHNOLOGIES 23

3.4.1 Java Programming Language *24*

3.4.2 XML and Related Technologies *24*

3.4.3 Mobile Computing *25*

4 WORK SO FAR **27**

4.1 EXPERIMENTS IN MOBILE COMPUTING 27

4.1.1 Emulation Experiments *27*

4.1.2 Real Device Experiment *29*

4.2 AN INSTANT MESSAGING TOOL FOR AGENT COMMUNICATION 29

4.3 JAVA APPLICATIONS PROGRAMMING INTERFACES EVALUATED 30

5 FUTURE TARGETS **31**

6 LIKELY OUTCOME **32**

7 BIBLIOGRAPHY **33**

1 Introduction

One important aspect of realistic intelligent planning systems is that they have to allow collaboration between users and computer systems, supporting a mixed-initiative style of planning. Recent studies has been applying the Virtual Organisation concept to join both human and computer strengths to solve problems. Examples of large-scales virtual organisations are Humanitarian Relief Operations and Military Coalitions, which in many critical and unpredictable situations have to be rapidly created and flexibly changed.

In order to accomplish better synergies between human and software agents in collaborative planning environments, virtual organisations need to improve the level of integration between participant agents and also provide better understanding of the whole process by individual and global perspectives. These issues can be addressed by planning visualisation and delivery approaches.

In this context, the main goal of this PhD thesis is the investigation and design of new advances in planning visualisation and delivery that fits the requirements of a collaborative planning environment. This new approach will provide support to presenting information involving the planning process itself (generation, execution, simulation, skeletal plans), organisational relationships (subordinates, superiors, peers, contacts) and links between participants and activities/objectives.

The ideas of this research project will be anchored in the I-X approach. The I-X project provides a set of technologies for intelligent systems that support the principles of collaborative planning environments. The I-X [19] is based on shared models for task-directed communication between human and computer agents who are jointly collaborating or the synthesis of an artefact such as a plan or a design.

Thus, the proposed advances will be focused upon the improvement of the communication interface between human and software agents. Human agents will be able to understand their personal perspective of the planning process (the roles that they are playing in the organisation, the agents that they can interact with, etc.), but also the global context where they are performing (the others agents capabilities and responsibilities, the whole plan status, etc.). In addition, the project will extend these ideas to mobile computing platforms, where a personal planning aid in portable devices with limited interfaces can be a solution for planning delivery and visualisation to mobile agents in critical situations.

In brief, the new facilities provided by this project will increase the cognitive power and efficiency of decision-makers, and of all the others members of a virtual organisation that are jointly participating in a mixed-initiative style of intelligent planning system.

The rest of this document is structured as follows:

- Section 2 presents related works, which are relevant to this project.
- Section 3 discusses the central ideas and goals of this project.
- Section 4 describes work already carried out.
- Section 5 lists the specific targets that will be pursued during this project.
- Section 6 discusses expected results of the project.

2 Related Works

This section summarises previous research works in correlated areas, which are relevant to this project. Section 2.1 introduces works in multi-agents systems for collaboration. Section 2.2 highlights visualisation approaches in intelligent planning systems. Section 2.3 discusses some key concepts of virtual organisations. Section 2.4 presents opportunities and problems in the area of mobile computing. Finally, Section 2.5 addresses previous work in profiling.

2.1 Multi-Agents Systems for Collaboration

2.1.1 CoAX

The Coalition Agents eXperiment (CoAX) [20][21] is an international initiative whose goals are to demonstrate that the agent-based computing paradigm offers a promising new approach to dealing with complex real world problems, such as military operations for Operations Other Than War (OOTW). CoAX is a Technology Integration Experiment (TIE) within the control of Agent-Based Systems (CoABS) program of DARPA, and its experiments are been carried out in a military domain.

To support the integration of a variety of agents and systems, CoAX is built on a grid computational framework (CoABS Grid), where agents can be added, removed, updated, discover other agents and exchange massages. The Knowledgeable Agent-oriented System (KAoS) provides domain management, with policies for secure, scalable and robust agents' execution. Also declarative constraint domain policies (for authorisation, encryption, access control, and resource control) govern the agents behaviour.

The main issues being investigated in this research program are: (i) using the agents metaphor for dealing with complex real-world systems; (ii) supporting efficient coalition operations by an agent based framework; (iii) enabling systems interoperability (legacy and incompatible systems) by software agents; (iv) permitting the creation of virtual organisations using the CoABS Grid; (v) structuring agent relationships and coalition policies by domain policies; and (vi) improving collaboration among agents using intelligent task and process management, using semantic web technology to improve agent interoperability.

These investigations have confirmed that the agent paradigm provides a good computational support for coalition operations, and it allows the creation of agent organisations to work together in realistic applications.

2.1.2 CoAKTinG

The main ideas of the CoAKTinG (Collaborative Advanced Knowledge Technologies in the Grid) project [22] are centred on advanced collaborative environments. The CoAKTinG aim is to develop advanced collaborative mediated spaces for distributed e-Science collaboration, using advanced knowledge technologies (ontologies, knowledge-based planning and task support, scholarly discourse and argumentation to enhance collaborative meeting structures, presence and visualisation to enhance group peripheral awareness at a distance).

CoAKTinG will provide tools to assist scientific collaboration, using several approaches. An approach proposed by CoAKTinG that is relevant to this research project is the “enhancement of presence management and visualisation”. The challenges of this work are [22]: (i) to investigate how best characterise presence, (ii) how to make it easy to manage and visualise, and also (iii) how to remain consistent with the user’s own expectations, work habits, and existing patterns of Instant Messaging (IM) and other communication tool usage.

Aspects of the dynamic management of context in multi-agent systems could draw on work on "presence". Presence is a concept originally used in Instant Message (IM) tools to indicate users’ status (online/offline/away/busy/do not disturb) for individual "buddies" or small groups on rosters or buddy lists. Such systems are designed on peer-to-peer principles, but the tools are intended for small-scale human mediated collaboration.

Currently the “presence” concept has been improved to contemplate the presence not only of people, but also of system agents and collaboration products (e.g. documents and plans). An example is the Jabber framework [23][24], which supports flexible inter-agent presence subscriptions and notifications of change of status using XML.

Advances based upon these ideas will be addressed by CoAKTinG that is seeking to link ideas on teleconferencing, presence/context management, collaborative planning and workflow aids, real-time multi-media markup tools, and issue-based argumentation.

2.2 Visualisation of Planning Information

Realistic and complex planning domains require a mixed initiative planning framework in which human and computers interact to build better plans. Several researches has been carried out in the subfield of mixed-initiative planning, aiming to reach better levels of interaction, and consequently, the effectiveness of the planning process. Visualisation of planning information is one important aspect that needs great advances.

At the beginning, the early planning systems had poor interfaces, for example, command line interfaces, making very hard the user effort when using planning systems, mainly for user with no background in the planning area. With the growing of the subfield of mixed-initiative planning, advances in visualisation of planning information have been explored in planning systems for better levels of interaction between human and systems. In this section will be discussed some works done in projects related to planning visualisation.

2.2.1 PRODIGY System

The Prodigy Project [14] addresses the complex task of improving visualisation of planning information in mixed-initiative systems. The approach of the PRODIGY planning system contributes for research in planning in three ways facilitating the process of planning [15][16]. First allows the user to control the planning process, switching between a generative, hierarchical and cased-based approach to planning. Second the graphical user interface (GUI) supports graphical and mouse-sensitive visualisation and inspection of the plan, the planing goals and plan rationale. Finally the GUI also allows the user to control the presentation of information in accordance with the user expertise in planning domain and planning technology.

Human and systems have different strengths, play different roles in planning processes, and also have different cognitive metaphors. While case-base metaphor is more accessible to the human user comprehension, planning systems assume a model of actions in the world and generate new plans by searching the space of possible actions [15]. Consequently, problems about the integration of human and systems come from these differences. The Prodigy approach to solve several of these problems is to use both generative and case-based algorithms within the same planning system.

The Prodigy interface provides mechanisms to save planning cases created generatively or analogically, to retrieve old cases that match current demands (automatically or manually), and to choose various cases interleaving strategies for adaptation and reply. Plans are graphically presented as goal-tree structures, and justifications for automated choices are displayed upon demand.

The aims of the Prodigy interface is to facilitate the interaction between human and computers in mixed initiative planning processes, providing plan visualisation and plan rationale information, supported by a more flexible architecture.

2.2.2 TRAINS/TRIPS System

The approach of the TRAINS [27][28] project and its successor TRIPS [29][30] is to apply natural spoken dialogue to interactive planning. The domains of these projects involved initially routing and schedule of trains, but posterior works are also supporting other domain situations of more complex logistic, such as the Pacifica domain. In the Pacifica domain (that is also supported by O-Plan [25][26]), the objective is to co-ordinate the actions of multiple agents to rescue people's life in an island, which is subjected to natural disasters. TRAINS investigates a dialog-based approach to a mixed-initiative planning assistant.

In the TRAINS project, mixed-initiative planning is studied in the context of command and control or logistic situations, to help a manager to solve routing problems in environments where human and systems work together. Interactions in the TRAIN system can be done by both spoken and typed English and also by graphical displays and control.

TRAINS is implemented as a set of independent modules. In the speech and display modules the speech input is made using the Sphinx-II recogniser [18]. The output is a sequence of words (and control messages for when a hypothesis needs to be revised) that is post-processed by another module, which uses techniques from machine translation to adjust the output of the recogniser. The speech generation component uses a program with speech generation and a range of intonational and inflectional controls. An object-oriented display module permits different types of inputs, other than speech, such as typed input, menu selection, and direct mousing on display elements. Output to the display is provided also by graphical elements. Different types of dialog-box can be popped up in another input modality [28].

The modules of language and dialog processing are the core of the system. Language processing is performed by a parsing system, and this approach to natural language processing is crucial to a robust system. Domain reasoning in the TRAINS project maintains a knowledge base describing the state of the world and provides planning and plan recognition services to the languages modules.

The TRIPS project, the successor of TRAINS, is another research prototype of end-to-end conversation with a human to accomplish a planning-like task. The differences between TRIPS and its predecessor TRAINS are [29][30]: (i) TRIPS operates in more complex logistic and transportation world, for instance, co-ordinate a variety of vehicles; (ii) TRIPS performs more complex planning, for example, co-ordinating actions of multiple agents, reasoning about temporally extended actions, and handling resource constraints; (iii) TRIPS has a more sophisticated graphical view of the plans, such as, task palettes, charts; (iv) TRIPS supports options comparison among plans; and (v) TRIPS includes a simulator module.

In brief, TRIPS is a collaborative planning assistant, which goal is to allow interaction between human and system using natural language and graphical displays (maps, charts, windows, etc.).

2.2.3 Visual Interaction Dialog (VID) System

The approach of the Visual Interaction Dialog (VID) [31][32] system aims to improve interaction between users and system in mixed initiative planning systems by exploring visual perception and the benefits of direct manipulation. The question in this approach is whether the interaction is best viewed as a dialog or an action in an environment.

This work uses some concepts of ecological view of human computer interaction, where interface designers are encouraged to provide cues (*affordances* [31][32]) in the environment. These graphical cues indicate how object can be used, in order to improve ease of use, reduce the need for instructions, and enhance the familiarity with the interface.

In the VID system, agents manipulate the location and direction of cameras used for evaluating and editing in a three-dimensional (3-D) planning environment. The agents may add, remove and edit hierarchical plan components overlaid onto domain specific representations.

The effectiveness of the interaction between users and systems in the VID system is based in three aspects: (i) the ability of the system to provide flexible visualisations, (ii) context registration that involves agents information in the process of plan construction, and (iii) dialog-based task management support.

2.3 Virtual Organisations

The purpose of virtual organisations [37] is to provide support for agents of several real organisations that are physically distributed or/and unable to get together. We can imagine different kinds of virtual organisations:

- Military: several countries sharing strategic and tactical information to improve the effectiveness of their operations;
- Medical: distributed medical teams acting together during urgent surgical procedures in sites where specialised professionals do not exist;
- Industrial: mechanical engineers, designers, specialists in security and others professionals involved in developing advances to a new project of solar-powered cars;
- Corporate: executives and directors in different cities merging financial information, statistics and trends during a decision-making meeting.

These examples differ in many aspects: the number and type of participants, the types of activities, the duration and scale of the interaction, and the resources being shared. On the other hand, we can also underline common features.

In each kind of organisation a number of members with changing levels of prior relationship want to share resources to perform specific tasks. Sharing can involve complex forms of information (e.g. medical images) and/or remote access to both computational software (e.g. intelligent planners) and devices (e.g. telepresence robots). Each participant normally provides policies to constrain when, where, and what can be done with its resources.

As an organisation is dynamic, its relationships can change over time, in terms of the resources involved, the nature of the access permitted, and the participants to whom access is permitted. Thus, organisations need to provide mechanisms for discovering and characterising the nature of the relationships that exist at a particular point in time so that agents are able to determine which resources they can access and which are the constraints on each of them.

Relationships are often peer-to-peer. In this way, agents can play different roles. For example, the same agent is both a surgeon doctor to an organisation X, and a director of a research institute in an organisation Y. Delegation authority is another important aspect that has to be done in controlled ways, as well as mechanisms for coordinating operations across multiple resources. The same resource may be used in different manners, depending on the restrictions placed on the sharing and the goal of the sharing.

These characteristics and requirements define the concept of virtual organisation. In brief, virtual organisations enable disparate groups of organisations and/or individual agents to share resources in a controlled manner, so that participants may collaborate to achieve a shared goal.

2.4 Mobile Computing

Mobile computing can offer interesting support to mixed-initiative planning systems, because agents can join an organisation anywhere and at any time, independently of their current locations. As being one of the fastest growth areas of computing, technologic advances in mobile computing are still evolving and changing rapidly the current scenario.

In recent years, computer scientists have become increasingly interested in mobile computing, and researches have been carried out on the improvement of wireless networking and mobile devices' usability. In this way, this PhD project aims to integrate mobile computing in its platform, considering both present and future generations of mobile devices.

Nevertheless, some difficulties have been experienced with the current mobile devices. The urgent need of improvements in mobile computer interfaces has been highlighted in several recent researches [3][4][5][6][7]. The major problems that can be pointed out are:

- Mobile computers have a limited amount of screen space, and the screen cannot be enlarged as the device must be able to fit into the hand or pocket to be easily carried;

- The screen can become cluttered with information as designers try to cram on as much as possible;

- In many cases standard graphical interfaces styles (defined where space is not a problem) have been simply applied to mobile computers, and consequently the devices are hard to use due to small text which is difficult to read, has cramped graphics and provides little contextual information;

- The output of dynamic information is a problem since the screens are small, and mobile computing devices present mainly static information and do not make use of the fact that they can present dynamic data;
- The wide variability in mobile computing based equipment, since there is no standard yet;
- Navigation and interaction problems caused by the physical structure of the interfaces, that reduce the usability these devices, and;
- The increase of functions available contributes towards making them difficult to use.

Nowadays, with the wireless network advances, these problems discussed above are even more stressed. Wireless networks allow the delivery of the Internet content to these mobile computers, and the number of possible applications increases exponentially.

There has been little previous research in the area of interfaces for mobile computing devices. Some research has been done in the specific area of sound use to enhance mobile interfaces capabilities.

As a solution for information cluttering problems in mobile devices screens, the works [3] [4] proposed to substitute visual cues by non-speech sounds. According to the proposal, sounds could be used to present information about widgets (buttons, menus, windows, etc.) so that their size could be reduced. This would permit more information to be presented. For instance, the data input by buttons could be assisted by non-speech sounds that signal if the data is being entered correctly or not. The results of this research are that: (i) sound can have important effects on usability in mobile computing devices (usability was improved as participants of the experiment were able to enter significantly more data, and sound helped users target the buttons better); (ii) sound had a big effect on workload as workload was reduced when sound was present; (iii) sounds improve the qualitative experience users have with mobile devices, and didn't annoyed them; (iv) sounds improve usability; (v) most sophisticated sounds were the most effective; and (vi) give designers a simple way to increase the usability of buttons in mobile devices.

In [5] is investigated the problem regarding output of dynamic information on mobile computers screens. Wireless networks are becoming more popular, so it is possible to deliver real-time data to mobile devices, but it is extremely difficult to display efficiently information given the small screens of typical devices. In this study is investigated the use of non-speech sounds to present dynamic information without using visual display space. The use of sound is proposed to present data rather than graphics, supported by the fact that ears have a higher temporal sensitivity than the eyes. Thus, audio can be a good way to present time-varying data. The results presented in this work are: (i) non-speech SoundGraphs [5] have been shown as an effective way of presenting dynamic, time-varying data on mobile computers; and (ii) they have the advantage that they can be monitored whilst the user is performing another visual task and do not take up screen space.

One of the major problems in usability of mobile interfaces centres in navigation. A framework proposed in [6] addresses the problem of navigation, particularly in mobile phone menus, by integrating non-speech audio to hierarchical menu structures considering that visual feedback is limited. The case study is the sonification [6] of a complex mobile phone menu to improve navigation in menus. The evaluation made indicates that: (i) non-speech sound improves the performance of navigation tasks, and; (ii) the study provides insights about the design of audio cues intended to support navigation in complex menu structures.

2.5 Profiling

One objective of using profiles in mobile applications is to support the trend of managing and manipulating the Web content to mobile users based on their preferences and locations. For this reason, several purposes and applications, such as mobile electronic commerce, and delivering of information in general, are using this concept.

In [1] is proposed a multilevel profiling framework to support mobile business operations based on different levels of profiles. Profiles are defined as XML documents and designed to permit the reaching of consensus between buyers and sellers in a mobile business environment. The high level profiles specify general features of their relationships and low level profiles specify particular features. There are different types of profiles related to preferences, security, privacy, transaction management, etc.

An approach of the use of profiling in XML documents is showed in [2]. Profiles are assigned to customers that describe their needs, requirements and interests based on personal information provided by the customer (musical preferences for example) and operations made (for instance purchases and clicks). Further, these profiles are used to personalise information delivery, for instance, particular products' offers. To assign profile to data the following types of profiling are defined: profiling for groups, individuals, characteristics, output type and products. The profile classes have relationships (inherit and exclude) and dependencies that impact the assignment of profile to the data.

This metaphor of use of profiling to deliver information in electronic commerce can be generalised for delivery of information in general. In particular, we intend to define a set of profile classes to users (human agents participating in a collaborative process) and devices (pocket PCs, such as PDAs or mobile phones) to personalise the plan information delivery in accordance with these profiles. The advantage of use of profiling will be an optimised delivery of information, strongly based in the user's necessities and devices potentialities.

3 Central Ideas

The main goal of this PhD project is to investigate and develop a new set of approaches and tools for visualisation and delivery of planning information, following the I-X [19] project metaphors and concepts for building intelligent systems. In order, we will investigate multi-perspective ways of presenting planning information, such as plan descriptions, the process of planning and execution, plan execution tracking, plan repair, use of pre-compiled procedures, etc.

I-X[1] is a technology for intelligent systems developed by the Artificial Intelligence Applications Institute at the University of Edinburgh. This new technology will allow the design of new re-usable components and systems, that can be referred to as I-Technology and I-Tools. Java is being used to develop these components for portability reasons and to maximise reusability.

I-X allows the construction of intelligent systems using a new approach of intelligent planning technology, supported by I-Plan. I-Plan [33] is designed as the basis for realistic planning system, where is important users and computers systems co-operate and work together, in a mixed initiative style. Many situations need more than fully automated solutions, and human expertise and capabilities can be crucial in critical situations.

I-Plan is intended to be a lightweight planning system which can be embedded in other applications, and that can be easily extended via plug-ins. The aspect of being a lightweight planning system gives opportunities for the development of visualisation applications for mobile computers. The access of planning information in mobile devices will assist mobile agents in collaborative planning environments, adding planning facilities into them. These mobile applications will be able to identify and understand the roles of the human agents and other systems involved in the planning and execution processes, and provide a way of communication between users and systems, supporting visualisation for the performing agents.

[1] A complete listing of I-X references can be found at: http://www.aiai.ed.ac.uk/project/ix/documents/

Sub-sections below discuss more clearly these ideas regarding planning information visualisation/delivery, also contemplating its opportunities and difficulties when applied to mobile computing platforms.

3.1 I-X Project

Significant work in Intelligent Planning and Activity Management has been carried out at the University of Edinburgh in the last decades. Currently, these previous works have been generalised and extend in a new program called I-X.

I-X is a technology for intelligent agents and tools that will permit the development of new components and systems that will be referred to as I-Technology and I-Tools. Its open style of architecture, based on the O-Plan[2] project, allows several services which can be provided as plug-ins, contrasting with the old fashioned architecture of monolithic systems. Plug-ins can be developed to provide management of the internal model representations, reasoning and functional capabilities

In its approach, I-X involves the use of shared models for task-directed communication between human and computer agents who are jointly exploring a range of alternative options for the synthesis of a product. The I-X shared model representation, called <I-N-C-A> (**I**ssues - **N**odes – (Critical/Auxiliary) **C**onstraints - **A**nnotations) [34], provides ways for representing and manipulating plans and other synthesised artifacts as a set of constraints, which can be set by users (via a mixed-initiative approach) or by the system itself.

Example of I-X applications and tools are: I-D, a domain editor initially for support process and activity modelling; I-P2, a process panel to support user issue and "to do" lists; I-Config, a tool for intelligent configuration; I-Plan, an application for planning tasks; I-Rescue, an application for humanitarian relief operations, etc.

Another important I-X concept, that is relevant for this work, is I-Space. I-Space is the concept for managing I-X Process Panel and agent structures and relationships in a virtual organisation. I-Space is a way to specify the organisational relationships between agents or I-X Process Panels acting on behalf of their users. An I-Space tool might show the

[2] A complete listing of O-Plan references can be found at: http://www.aiai.ed.ac.uk/project/oplan/documents/

relationships between agents graphically, where the relationships can be of four types: superiors, subordinates, peers and contacts. But, ideally, an I-Space tool might also support information about capabilities and authorities in an alternative presentation that might shows all known panels and agents in a suitable visualisation. In addition, other information might be provided, such as: panel or agent name; relationships (superior, subordinate, peer, contact or none) among agents; links for a capability description provided by other agent/system, and; a way of checking and authorising whether the other system will authorise the use of a capability by the sending agent.

Figure 3.1 shows the I-Space relationships (superiors, subordinates, peers and contacts) from the perspective of the "Me" agent. There are two aspects to be considered when presenting planning information to performing agent member of a virtual organisation: (i) an agent can be a member of many virtual organisation, playing different roles in different contexts, (ii) both the role that an agent plays and its context influence the information visualisation required.

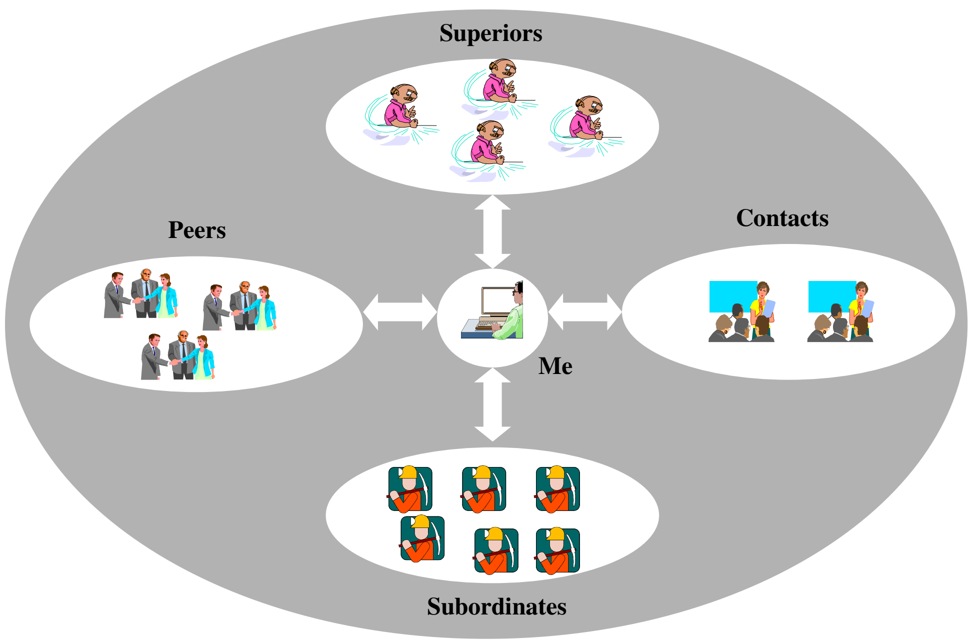


Figure 3.1 – I-Space Relationships from the View Point of the "Me" Agent

In this scenario, the aims of this research project is to investigate an approach to planning information visualisation that fits the requirements of a realistic mixed-initiative planning system, where users and computer systems co-operate and work together, composing virtual organisations, and using that to perform tasks in a flexible way.

3.2 Planning Information Visualisation Approach

The central question in research in mixed-initiative AI-based planning is to explore the strengths of both people and systems to produce effective plans. The current generation of planning systems does not support an adequate integration between human and software agents for collaborative planning environments. Therefore there is a need of investigation on how these agents can be better integrated to work as collaborators in planning environments.

In [8] is discussed some issues in the development of mixed-initiative planning systems, where is emphasised the needs of supporting positive synergy in interactions between human and software agents in a new generation of planning systems. In this new mixed-initiative style of interaction, each agent works in the area where its performs best. Questions about network technological advances and also of electronic conferencing and workflow tools should also be considered when developing such new systems.

We believe that, to achieve a good level of interaction between human and software agents, research in planning visualisation information is necessary, since that, more and effective ways of presenting planning information will increase the level of integration and synergy between the collaborators engaged. In this research project we will investigate effective ways of presenting planning information of different kinds of plan activities, for example, in formulation, development, management, refinement, analysis and repair of the plans, to support a realistic collaborative planning environment.

To investigate effective ways of presenting planning information in mixed-initiative planning systems we should categorise the areas of visualisation in the research as:

1) Visualisation of plans, objectives, tasks and activities: in this category will be explored the presentation of the planning information in the whole process context, for example, plan descriptions, plan status, etc;

2) Visualisation of agents and their relationships: in this category will be investigated ways of presenting planning information in the perspective of the agent who is visualising the information, for instance, showing the relationships to other agents holding objectives or performing activities, giving also information of the capabilities and responsibilities of each agent, etc., and;

3) Visualisation of Performing Agents: in this category the visualisation will give emphasis to the performing tasks of agents.

Another differentiation exists between planning visualisation using limited mobile devices and standard large screen desktop visualisation. The first category (of limited media interface) will assist human agents on the move, and nowadays, the most popular mobile devices are PDAs (Personal Digital Assistants) and cell phones. However, the focus of our study will not be limited by the current devices available, since mobile computing is one of the fastest growth areas of computing, and in few years, the technology will reach great advances and innovations.

We will keep the focus on effective ways of presenting planning information considering the requirements and needs of the users participating in planning processes. For example: “Which required features will be needed for presenting each type of information?”, “Which features each registered device has?”, “Which role(s) each device user (human agent) is playing?”, and “How effective is delivery and presentation of information among the agents considering all the previous questions?”.

However, some difficulties come from the dealing with mobile computing and wireless technology. First, because there is currently no well defined standards in mobile computing. Second, due to difficulties in presenting information on the limited screen sizes of mobile devices, mainly when we are manipulating dynamic information. Finally, because there is a large variety of mobile devices, each with different features, consequently mobile applications should be developed with a minimum of system dependability.

This scenario becomes more problematic because we are dealing with complex domains as collaborative planning environments, where there is much data (for instance a lengthy plan description), which consequently leads to longer download times and hard data navigation in mobile devices. In addition, as mobile computing is an emerging area, it is also a very undefined area even thinking in the short term. How will mobile devices look in future? Which features will they have? Which advances in wireless network technology will reach in the medium term?

In the next subsections we shall briefly discuss some aspects of the three categories of planning visualisations cited above being proposed in this research project.

3.2.1 Visualisation of Plans, Objectives, Tasks and Activities

The aim in this category is to investigate answers for the question: “What kind of information are more crucial to help performing agents in mixed-initiative planning?”. The answers of this question will help to find appropriate ways to present information about plans, objectives and activities.

In an informal study of collaborative planning [9], the frequency of interaction between user and system was observed, where pairs of people were working together to solve a planning problem in an artificial environment. In the environment consisting of trains that could travel between cities, one person played the role of the “system” and the other the role of the “manager”. They could neither see nor know each other, and they only had as information the map of the TRAINS [27] domain. Categorisations were made of each interaction between players according to its general propose, as showed in the Table 3.1.

Evaluating and comparing options	25%
Suggesting courses of actions	23%
Clarifying and establishing state	13.5%
Discussing problem solving strategy	10%
Summarising courses of action	8%
Identifying problems and anternatives	7%

Table 3.1 – Frequency of Interactions by Type

Although these data come from an informal study and are just suggestive, it indicates that there is a strong need of interaction improvements in collaborative plan development. Effective ways of visualisation of plans, objectives, tasks and activities will permit better management and support the variety of interactions for collaborative problem solving.

In [28] a similar investigation was carried out in the same TRAINS domain, however the interaction analysed was between the user and the system itself by dialogues. The user and the system were constructing, evaluating, and correcting simple plans, in a dynamic environment. The results founded were extremely similar to the previous study (Table 3.1), and, in the same way, they are good indicators of which types of information are more necessary to improve interaction between performing agents (users and systems) in mixed-initiative planning.

3.2.2 Visualisation of Agents and their Relationships

In mixed initiative planning systems human and software agents work together in complex virtual organisations. Examples of large-scales virtual organisations are Military Coalitions and Humanitarian Relief Operations. Some important aspects of such virtual organisations in collaborative planning should be considered, for example:

- While agents (software or human) are contributing with management matters, others could be executing their duties on the move;
- There are relations between agents;
- Each agent has responsibilities and capabilities for each aspect that they are performing, and;
- In such domains, circumstances can alter in an unforeseeable way.

As mentioned previously, I-Space is the I-X concept for managing organisational structures and relationships in virtual organisations. The relationships that an agent can establish to another in the initial I-Space mechanism are: superiors, subordinates, peers and contacts. Following organisational rules the agents can interact among themselves. For example, one superior agent can delegate one task/objective to one subordinate agent. But, this can only happen where the subordinate agent has the capability for taking on the delegated task. The organisational structures are also dynamic, so that agents can integrate and leave the I-Space structures. For instance, if in some situation a required capability is identified, an agent with this capability can be asked to join the I-Space and then can be integrated in a collaborative plan.

RETSINA [35] is a multi-agent system that supports communities of heterogeneous agents and provides agent relationship visualisation. The RETSINA project has the premise that agents in a system form a community of peers engaged in peer-to-peer interaction. In this way, RETSINA does not use a centralised control, but applies distributed services to facilitate the interactions between agents, instead to manage them [35]. The proposal of Agent Visualisations in the RETSINA project (RETSINA CoAX Visualiser) is being used in the CoAX [21] project. It permits the visualisation of: (i) coalition domains; (ii) agents; and (iii) non-agents entities. For the CoAX demonstration, RETSINA is providing visualisation of the following aspects: (i) relationships among different coalition domains; (ii) membership of agents and non-agents entities within the domains; (iii) dynamic reconfiguration of coalition domain, agent and non-agent entity membership; and (iv) communications among agents and non-agents entities.

Thus, in this research project, some questions about planning information visualisation for an effective collaboration among agents of a virtual organisation should be investigated. How to integrate, in a flexible and effective way, the members of a virtual organisation? How to present objectives, tasks, plan and activity information to these agents? And for the agents on the move? How to receive feedback or information of changes of circumstances from them?

In this category of visualisation we shall investigate how to make possible the development of a new set of applications and visualisation tools that will give support to these requirements of realistic collaborative planning systems. Advances in mobile computing and wireless networks will permit reaching a great level of integration between the agents on the move and the "fixed location" agents.

To investigate, test and validate our planning visualisation approach we are likely to use a domain/application called I-Rescue. I-Rescue[3] is an I-X intelligent planning application of virtual organisations working together in a collaborative planning environment for Humanitarian Relief Operations. I-Rescue is being developed as another PhD research of the CISA/University of Edinburgh.

3.2.3 Visualisation of Performing Agents

In this category will be contemplated visualisation of links for "performing" relationships of agents to activities and to "holds purpose" relationship of agents to objectives. While an agent is performing activities, it is also necessary to allow for informing the other agents (at least the agents' superiors) on progress, and to receive information about what to do next. In this category of visualisation will be investigated ways of doing it. For example, delivering of information to the agents on the move and checking off work already done in "to do" lists during planning execution, via a mobile device, could be initial possible approaches.

[3] The I-Rescue evaluation site is: i-rescue.org

WOPlan [36] is a limited media interface for intelligent planning systems, which was developed for the O-Plan [25][26] project, to present plan information in mobile telephone. In the mobile planning interface of WOPlan a client can connect to the O-Plan system, select a domain from a list of available problem domains, and choose a task within that domain. Then, the user can view, execute or evaluating the resulting plan, or to get a different plan. A great contribution of the WOPlan project was the development of a plan execution facility, where the user is presented with an ordered list of executable actions dependent on what actions have been executed so far. This plan execution facility indicates also an interesting area to be explored in this research project, that is the area of delivering courses-of-actions to mobile human agents.

3.3 Profiling

As explained earlier, users can operate under different roles in each domain, and consequently could have different responsibilities, capabilities, authorities and needs. Profiling will be the proposed solution to manage, personalise and also solve several problems about mobile devices' diversity, when delivering planning information among members of virtual organisations.

Two categories of profiles will be defined:

1) Personal Profile: each agent will have a personal profile with its properties defined. Information such as rules, responsibilities, capabilities, etc., will be specified for customisation of planning information delivery.

2) Device Profile: each device will have a profile with its features defined. Information such as screen size, number of colours, multimedia support, etc., will permit mobile applications portability and also increase the exploitation of available features in each device.

3.4 Questions Around Technologies

In the next subsections, the technologies that will be used for the development of our approach will be briefly discussed.

3.4.1 Java Programming Language

The first reason for using Java [10] is to follow the I-X project software platform. As said, I-X is a generalised and extended version of previous work in Intelligent Planning and Activity Management, that has been developed in Java.

The second reason is due to the fact that Java has an API (Application Program Interface) designed for mobile applications called Java 2 Micro Edition (J2ME) [11]. J2ME is a Java version of Sun Microsystems Java that is aimed at the mobile devices market. Through J2ME networked applications can be created to run in mobile devices, which includes cellular telephones, pagers, Personal Digital Assistants, and other small devices. Having Java provide this solution for small mobile applications, it fits properly with the requirements of a realistic planning system of mixed initiative.

Finally, we can enumerate some positive and well-know aspects of using Java:

- Java has a large variety of services and packages that can be easily integrated via APIs, for example, for security and graphical interface;

- Java is platform independent, which helps guarantee an application's portability;

- Java has built-in facilities for dealing with exceptions, which permits the development of more robust, clear and fault-tolerant applications;

- Java is an object-oriented programming language, consequently aspects such as inheritance and reusability help the codification process, and;

- Java is a real industry standard for Internet applications.

3.4.2 XML and Related Technologies

Exchange of information should be done using XML (eXtensible Markup Language) [12] and related technologies. XML is an industry-standard, system-independent way of representing data that makes data portable. Data, such as user's profiles, device's profile, relationships among agents, agents presence notification, etc., will be specified using XML in this research project.

XML makes data portable. Like HTML (HyperText Markup Language), XML encloses data in tags, but there are significant differences between the two markup languages. First, XML tags may relate to the meaning of the enclosed text, whereas HTML tags specify how to display the enclosed text in a web browser. The second major difference is that XML tags are extensible, allowing creation of new XML tags to describe particular entities.

Another important advantage is that Java has APIs for XML [13]. The Java APIs for XML let development of applications entirely in the Java programming language, and support XML industry standards, ensuring interoperability. The combination of Java and XML guarantees both portability of data (provided by XML), and portability of code (provided by Java).

3.4.3 Mobile Computing

Several difficulties were discussed in this proposal which refers to mobile computing. For instance, lack of standards in wireless networking and mobile computing, a large variety of devices with different features, limited screen space to present (dynamic) information, etc.

Nevertheless, mobile computing is an area that is making rapid advances. Advances in hardware (mobile devices), networking (wireless) and software (operating system) are being made. Table 3.2 illustrates some features of current top-line mobile devices. Every new generation that is released provides new features for them. Even thought this rapidly growth brings potential promises for the development of mobile applications, it causes certain problems of working with emerging and new technologies.

To enhance the expressive power and usability when presenting planning information in mobile devices, resources such as sound, images, graphs, virtual reality, GPS (Global Position System) can be used. Alternatives for the U.S global position system (GPS) are emerging such as the future European version of global position system called Galileo [17]. Galileo intends to give Europeans more autonomy, both industrially and military, since that the United States can selectively block access to GPS. Also, Galileo will not incorporate the deliberated error in tracking geographical position within 36 meters of error for civil use. (for U.S military use only, GPS has just 1 meter of error). Despite the fact that Galileo will give more independence for use in I-X applications, such as Military Coalitions or Humanitarian Relief Operations, it will be released only in 2008.

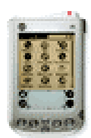
Memory	Display	Dimension/Weight	Other features
 **COMPAQ iPAQ Pocket PC H3870** 206 MHz Intel® Strong ARM 32-bitRISC Processor OS: Microsoft Pocket PC 2002			
64 MB RAM 32 MB ROM	2.26 x 3.02 inches 240 x 320 pixels 64K colours	5.30" x 3.30" x .62" 6.7 oz.	(1) Integrated Bluetooth for wireless link to Bluetooth devices.
 **SONY CLIE handheld - PEG-NR70V** Motorola Dragonball 66 MHz Processor OS: Palm OS® software v. 4.1			
16 MB RAM + Memory Stick expansion slot 8 MB ROM	2.26 x 3.02 inches 320 x 480 pixels 65K colours	5.50" x 2.88" x .69" 7.0 oz	(1) Built-in digital camera; (2) Built-in MP3 audio player; (3) Built-in keyboard.
 **PALM i705 Handheld** Motorola Dragonball VZ 33 MHz Processor OS: Palm OS® software v. 4.1			
8 MB RAM + Expansion Card slot 4 MB ROM	- 160 x 160 pixels Monochrome	3.1" x 4.7" x .6" 5.9 oz	(1) Built-in antenna for wireless operation support.
 **PALM Kyocera 7135 Smart Phone** OS: Palm OS® software v. 4.1			
16 MB RAM + Expansion Card slot -	- - 65K colours	3.97" x 2.43" x 1.17" 6.6 oz	(1) Built-in global positioning system; (2) Phone and PDA; (3) Built-in MP3 audio player; (4) Wireless fax and modem

Table 3.2 – Comparison of Mobile Devices Features

4 Work so Far

In this section is described a summary of the work so far. Aiming to reach the objectives of this research project, possible resources and approaches were evaluated and investigated while others researches related to this project were analysed. As possible resources, Java Application Program Interfaces (APIs) and mobile computing platforms (software and hardware) were tested. An initial communication approach to integrate agents of virtual organisations will be also discussed.

4.1 Experiments in Mobile Computing

Experiments were developed in mobile computing platform, testing both software (Operating System, Java APIs, emulators) and hardware (PDA device). In the next subsections we shall describe these tests.

The experiments were divided in two categories: emulation and real device experiments.

4.1.1 Emulation Experiments

First we developed some simple programs using the Java 2 Wireless Toolkit, the Java Sun Microsystems SDK (Software Development Kit) for wireless applications, and tested using several emulators of different devices (PDAs and mobile phones).

The objective of these tests was to familiarise with the Java 2 Wireless Toolkit, analyse possible available resources to help present planning information, and evaluate different devices by emulation.

The emulators used were:

- Default Gray and Colour Phones Emulators of the Java 2 Wireless Toolkit (basic phones);
- Minimum Phone Emulator (small size phone with extremely limited media interfaces);
- Motorola i85s Emulator (medium size phone with medium media interface);
- RIM Java Handheld Emulator (handheld with large media interface); and
- Palm OS Device Emulator (Palm Top with large media interface).

The following figure shows program executions and how some of these devices' interfaces look like.

Figure 4.1 – Multiple choice option interface in the default colour phone emulator (left); Launching application in the minimum phone emulator (centre); Accessing system properties in the Motorola i85s Emulator (right).

Comparing the emulators tested we can notice the problem of huge difference between screen space among the devices. Evident differences exist among mobile phone devices and, comparing this category (mobile phones) with PDAs, the differences are bigger. These differences make difficult the development of mobile applications, since that applications that run in a kind of device, possibly will not fit in another type of device. As an example of this problem, an application that executes normally in the Motorola i85s could not be launched in the Minimum Phone Emulator (the limited screen space cannot be sufficient). As said previously, an approach to be used to try to solve this problem is to present and delivery information in accordance with the device profile specified for each device connected. Device's profiles will be defined based on system properties of the device and their features.

Exploring the Java API for wireless applications, possible resources that can be used to help present planning information were identified. Some of these resources are: sound, images, films, graphics (for example, bar and pizza charts), maps, system properties, etc.

4.1.2 Real Device Experiment

Tests were also made in a real device. The device used was the PALM IIIx PDA. In order to run Java applications in this device, the original Operating System of this device had to be upgraded to support the Java virtual Machine of Java 2 Micro Edition. The Operating System version upgraded was the Palm OS v4.1.

After the upgrading, the applications tested in the emulators also executed properly in this real device. The Figure 4.2 shows an application that is using bar and pizza charts graphics in the Palm IIIx device.

Figure 4.2 – Bar and Pizza Charts Graphs Application in the Palm IIIx

4.2 An Instant Messaging Tool for Agent Communication

To provide communication among agents (members of virtual organisations), that work together to solve problems, we have to develop a framework of communication. The Jabber IRC [23][24] can be a possible approach to communication by XML messages exchanging.

A simple Java 2 Micro Edition application was developed as a Jabber Client to integrate the use of Jabber IRC in mobile applications. Through this client application an user is able to connect at any Jabber Server where he is registered, using a mobile device. We tested this application using the CoAKTing server (for tests and evaluations) at 'jabber.open.ac.uk', and also a server that was configured to run in a CISA domain at 'snake.dai.ed.ac.uk'.

The Figure 4.3 shows this client application running in a mobile device, where two users are connected and exchanging messages.

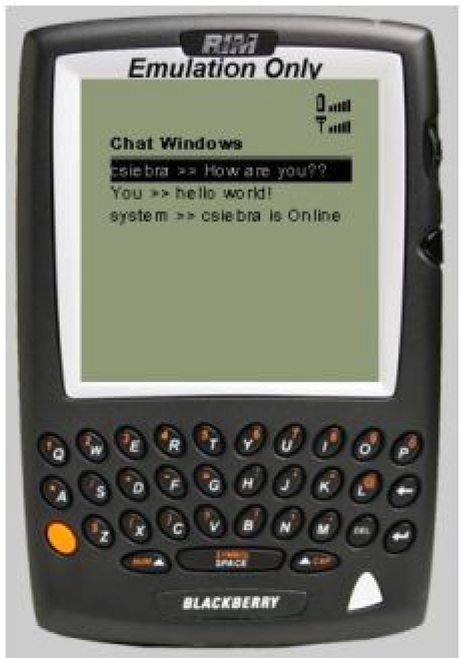


Figure 4.3 – User Using a Jabber Client to Exchanging Messages in a Mobile Device

4.3 Java Applications Programming Interfaces Evaluated

Some Java graphs drawers APIs were also evaluated, including GEF [38], JGraph [39], and Monarch Graph [40]. Analysing and comparing these APIs, the Monarch Graph API seemed to be more appropriated for using in the project because: (i) it is a well-documented Java API, in JavaDoc, that makes easier the programming task; (ii) it has great GUI components for representing nodes, arches and connectors in graphics; and (iii) the GUI components can be easily extended to fit new requirements.

5 Future Targets

The following list, itemises the main tasks that will be undertaken in this project:

- Task 1 (Literature Review): The literature review will be carried out during the research project to survey correlated researches and their approaches.
- Task 2 (Visualisation of Plans, Objectives, Tasks and Activities Module): Specification, formalisation and development of the module evolving the category of visualisation discussed in Section 3.2.1 (Visualisation of Plans, Objectives, Tasks and Activities).
- Task 3 (Visualisation of Agents and their Relationships Module): Specification, formalisation and development of the module evolving the category of visualisation discussed in Section 3.2.2 (Visualisation of Agents and their Relationships).
- Task 4 (Visualisation of Performing Agents Module): Specification, formalisation and development of the module evolving the category of visualisation discussed in Section 3.2.3 (Visualisation of Performing Agents).
- Task 5 (Integration of the Modules): The integration will couple the three modules of visualisation categories, so that they work properly together.
- Task 6 (Thesis Writing): Initial writing activities will start in parallel with development activities, to allow research work documentation (theoretic and practical) since in the early stages.

The Table 5.1 represents a schedule of the research tasks.

	Jul/02-Sep/02	**Oct/02-Dec/02**	**Jan/03-Mar/03**	**Apr/03-Jun/03**	**Jul/03-Sep/03**	**Oct/03-Dec/03**	**Jan/04-Mar/04**	**Apr/04-Jun/04**	**Jul/04-Sep/04**	**Oct/04-Dec/04**
Task 1	X	X	X	X	X	X	X	X		
Task 2	X	X	X							
Task 3			X	X	X					
Task 4					X	X	X			
Task 5							X	X		
Task 6			X			X		X	X	X

Table 5.1 – Research Schedule

6 Likely Outcome

Expected contributions of this research project that will advance research in mixed-initiative planning are:

- Improvement of visualisation and delivery of plan/planning process information in mixed-initiative planning environments, to effectively delivery and present information to agents engaged to solve problems;
- Better support to agents (software and human) team synergy, co-ordination and integration, in collaborative environments, providing visualisation of information related to capabilities and authorities of each agent member of virtual organisations.
- Provision of delivering information to the agents on the move while they are performing activities, and receiving information of their partial execution, that will help to keep a global planning execution status updated. This kind of information can be shared among other agents participating in the process, helping planning execution co-ordination.

In brief, the development of this approach to planning information visualisation and delivery in collaborative environments will permits better integration among agents in mixed-initiative planning systems.

7 Bibliography

[1] V. Terziyan. Architecture for Mobile P-Commerce: Multilevel Profiling Framework. Proc. *Workshop on E-Business & the Intelligent Web*, August 2001, Seattle, USA.

[2] T. Brown. The Use of Profiling in XML Documents: Using Profiling for Personalised Information Delivery. *Document Management Solution*, White paper, 1 January 2000, available in: http://www.arbotext.com/Think_Tank/XML_Resources/profiling_wp/index.html.

[3] Brewster, S.A. Sound in the interface to a mobile computer. In Proceedings of *HCI International'99*, 1999, Munich, Germany, Lawrence Erlbaum Associates, NJ, pp 43-47.

[4] S. A. Brewster, P. G. Cryer. Maximising Screen-Space on Mobile Computing Devices. In proceedings of *ACM CHI'99*, 1999, Pittsburgh, PA, ACM Press, Addison-Wesley, pp 224-225.

[5] S. Brewster, R. Murray. Presenting Dynamic Information on Mobile Computers. *Personal Technologies*, 2000, 4(2), pp 209-212.

[6] G. Laplâtre and S. A. Brewster. Designing Non-Speech Sounds to Support Navigation in Mobile Phone Menus. Proceedings of the *International Conference on Auditory Display*, April, 2000, Atlanta, Georgia, USA.

[7] A. Walker, S. Brewster. Spatial audio in small screen device displays. *Personal Technologies,* 2000, 4(2), pp 144-154.

[8] M. H. Burstein. Issues in the Development of Human-Computer Mixed-Initiative Planning Systems. *Chapter 17 of Cognitive Technology: In Search of a Human Interface*, Edited by B. Gorayska and J.L. Mey (Editors). Elsever Science B. V. 1996. (It is an edited version of a report that first appeared in the Proceedings of the *ARPA/RL* Planning Iniciative, February 1994, Edited by M. Burstein)

[9] J. Allen, G. Ferguson. Arguing About Plans: Plan Representation and Reasoning for Mixed-Initiative Planning. In *Proceedings of the 1994 ARPA Rome Laboratory Planning Initiative Workshop*, M. Burstein (Ed.), Morgan Kaufman, San Mateo, CA, pp. 123-132.

[10] Sun Microsystems. The Source for Java (TM) Technology Web Page, 2002. Available in: java.sun.com

[11] Sun Microsystems. Java 2 Micro Edition Web Page, 2002. Available in: java.sun.com/j2me

[12] W3C. Extensible Markup Language (XML) Web Page, 2002. Available in: www.w3.org/XML

[13] Sun Microsystems. Java (TM) Technology & XML Web Page. Available in: java.sun.com/xml

[14] The PRODIGY Project Home Page. Available in: http://www.cs.cmu.edu/afs/csproject/prodigy/Web.

[15] M. Cox, M.M. Veloso. Supporting combined human and machine planning: An interface for planning by analogical reasoning. In *D. B. Leake & E. Plaza (Eds.), Case-Based Reasoning Research and Development: Second International Conference on Case-Based Reasoning*, Berlin: Springer-Verlag, 1997, pp. 531-540.

[16] M. Cox, M.M. Veloso. Supporting combined human and machine planning: The Prodigy 4.0 User Interface Version 2.0 (Tech, Rep. No. CMU-CS-97-174). Pittsburgh: Carnegie Mellon University, Computer Science Department, 1997.

[17] European Communities. Official Galileo Information Web Page, 2002. Available in: www.galileo-pgm.org

[18] X. Huang, F. Alleva, H.-W. Hon, M.-Y. Hwang, and R. Rosenfeld. The SPHINX-II speech recognition system: An overview. *Technical Report CS-92-112*, Carnegie Mellon University, School of Computer Science, Pittsburgh, PA, 1992.

[19] A. Tate. I-X Project Page. Artificial Intelligence Applications Institute, University of Edinburgh, 2002. Available at: http://www.aiai.ed.ac.uk/project/ix

[20] D. Allsopp, P. Beautement, J. Bradshaw, E. Durfee, M. Kirton, C. Knoblock, N. Suri, A. Tate, and C. Thompson. Coalition Agents Experiment: Multiagent Cooperation in International Coalitions. *IEEE Intelligent Systems*, 2002, 17 (3): 26-35.

[21] A. Tate. CoAX - Coalition Agents eXperiment Page. AIAI, University of Edinbrugh. Available at: http://www.aiai.ed.ac.uk/project/coax

[22] S. Shum, D. De Roure, M. Eisenstadt, N. Shadbolt, and A. Tate. CoAKTinG: Collaborative Advanced Knowledge Technologies in the Grid. *Proceedings of the Second Workshop on Advanced Collaborative Environments, Eleventh IEEE Int. Symposium on High Performance Distributed Computing (HPDC-11)*, July 24-26, 2002, Edinburgh, Scotland.

[23] P. Saint-Andre. Jabber Technology Overview. *Jabber Software Foundation*, Inc. Boston, MA, 2001. Available at: www.jabber.org

[24] T. Muldowney and E. Landrum. The Jabber Programmers Guide: A Comprehensive Snapshot of Jabber. *Jabber Software Foundation*, Inc. Boston, MA, 2000. Available in: www.jabber.org

[25] A.Tate. Mixed Initiative Interaction in O-Plan. *Proceedings of the AAAI Spring Symposium on Computational Models for Mixed Initiative Interaction*, Stanford, California, USA, 1997.

[26] A.Tate. *O-Plan Intelligent Systems Demonstration Support Page*. AIAI, University of Edinburgh, 2000. Available in: http://www.aiai.ed.ac.uk/~oplan/isd/index.html

[27] G. Ferguson. The TRAINS Project: Natural Spoken Dialogue and Interactive Planning Web Page. Conversational Interaction and Spoken Dialogue Research Group, Department

of Computer Science, University of Rochester, 2000. Available in: http://www.cs.rochester.edu/research/trains/

[28] G. Ferguson, J. Allen, and B. Miller. TRAINS-95: Towards a Mixed-Initiative Planning Assistant. In Proceedings of the Third Conference on Artificial Intelligence Planning Systems (AIPS-96), Edinburgh, Scotland, 1996, pp. 70-77.

[29] A. Stent. TRIPS: The Rochester Interactive Planning System Web Page. Conversational Interaction and Spoken Dialogue Research Group, Department of Computer Science, University of Rochester, 2000. Available in: http://www.cs.rochester.edu/research/cisd/projects/trips/

[30] G. Ferguson and J. Allen. TRIPS: An Intelligent Integrated Problem-Solving Assistant. In Proceedings of the Fifteenth National Conference on Artificial Intelligence (AAAI-98), Madison, WI, 1998, pp. 567-573.

[31] D. Pegram, R. St. Amant and M. Riedl. An approach to visual interaction in mixed-initiative planning. In AAAI-99 Workshop on Mixed-Initiative Intelligence, 1999, pp.15--23.

[32] R. St. Amant, C. G. Healey, M. Riedl, S. Kocherlakota, D. A. Pegram, and M. Torhola. Intelligent Visualization in a Planning Simulation. Proceedings of Intelligent User Interfaces - IUI, 2001, Pp. 153-160.

[33] A.Tate. Intelligible AI Planning. *In Proceedings of the Twentieth British Computer Society Special Group on Expert Systems International Conference on Knowledge Based Systems and Applied Artificial Intelligence*, Cambridge, UK, December 2000.

[34] A.Tate. <I-N-OVA> and <I-N-CA> - Representing Plans and other Synthesized Artifacts as a Set of Constraints. *AAAI-2000 Workshop on Representational Issues for Real-World Planning Systems, at the National Conference of the American Association of Artificial Intelligence* (AAAI-2000), Austin, Texas, USA, August 2000.

[35] K. Sycara. RETSINA Project Web Page. The Intelligent Software Agents Lab, The Robotics Institute, Carnegie Mellon University - CMU 2002. Available in: http://www-2.cs.cmu.edu/~softagents/retsina.html

[36] A. Nixon, J. Levine and A. Tate. Limited Media Interface for AI Planning System. Proceedings of the 19th Workshop of the UK Planning and Scheduling Special Interest Group (PLANSIG 2000), Open University, Milton Keynes, UK, December 2000.

[37] I. Foster, C. Kesselman and S. Tuecke. The Anatomy of the Grid: Enabling Scalable Virtual Organizations. In International Journal of Supercomputer Applications, 2001.

[38] GEF Web Page. Available in: http://gef.tigris.org/

[39] JGraph Web Page. Available in: www.jgraph.org

[40] Monarch Graph Web Page. Available in: http://singleton-labs.com/mgraph.html