Semantic Support for Visualisation in Collaborative AI Planning

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Abstract

In the last decades, many advances have been made in intelligent planning systems. Significant improvements related to core problems, providing faster search algorithms and shortest plans have been proposed. However, there is a lack in researches allowing a better support for a proper use and interaction with planners, where, for instance, visualization can play an important role.

This work proposes a general framework for visualisation of planning information using an approach based on semantic modelling. It intends to enhance the notion of knowledge-based planning applying it to other aspects of planning, such as visualisation. The approach consists in an integrated ontology set and reasoning mechanism for multi-modality visualisation destined to collaborative planning environments. This framework will permit organizing and modelling the domain from the visualisation perspective, and give a tailored support for presentation of information.

1 Introduction

The need for a broader use of knowledge-based planning has been discussed in recent years. In [Wilkins and desJardins, 2001] it is advocated that the use of knowledge-based planning will bring many advantages to the area, mainly when focusing in solving realistic planning problems. Complex domains can benefit from methods for using rich knowledge models. In this perspective, among the existing planning paradigms, hierarchical task network (HTN) [Erol et al., 1994] is the one more appropriate to this proposition, in contrast to methods that use a minimal knowledge approach, such as the ones using a simple knowledge representation such as these based on STRIPS [Fikes and Nilsson, 1971]. However, despite the HTN paradigm having many advantages, it also has limitations. So, there are many researches opportunities in order to improve and permit a broader use of knowledge models in real world planning problems.

According to [Wilkins and desJardins, 2001] and based on their experience in planning for military and oil spill domains, the following capabilities are needed to solve realistic planning problems: (1) numerical reasoning, (2) concurrent actions, (3) context –dependent effects, (4) interaction with users, (5) execution monitoring, (6) replanning, and (7) scalability. However, the main challenges in real-world domains are that they cannot be complete modelled, and consequently they raise issues about planner validation and correctness. So, in order to make AI planning technology useful for realistic and complex problems there is a need of improvement of the use of knowledge models in several aspects related to planning; and the development of methods and techniques able to process and understand these rich knowledge models.

Three types of planning knowledge are identified by [Kautz and Selman, 1998]: (1) knowledge about the domain; (2) knowledge about good plans; and (3) explicit search-control knowledge. [Wilkins and desJardins, 2001] extended this list about planning knowledge mentioning that knowledge-based planners also deal with: (4) knowledge about interacting with the user; (5) knowledge about user's preferences; and (6) knowledge about plan repair during execution.

Recent researches are following these principles to develop more expressive knowledge models and techniques for planning. For instance [McCluskey and Simpson, 2004] is proposes work in this perspective of knowledge formulation for AI planning, in a sense that it provides support to knowledge acquisition and domain modelling. GIPO (Graphical Interface for Planning with Objects) consists of a GUI and tools environment to support knowledge acquisition for planning. GIPO permits knowledge formulation of domains and description of planning problems within these domains. It can be used with a range of planning engines, since that the planners can input a domain model written in GIPO and translate into the planner's input language. GIPO uses an internal representation that is a structured formal language for the capture of classical and hierarchical HTN-like domains. Consequently it is aimed at the classical and hierarchical domain model type. The advantages of GIPO are that it permits opportunities to identify and remove inconsistencies and inaccuracies in the developing domain model, and guarantees that the domains are syntactically correct. It also uses predefined "design patterns", that are called Generic Types, that gives a higher level of abstraction for domain modelling. To permit a successful use of AI planning paradigms GIPO has an operator induction process, called opmaker aimed at the knowledge engineer that doesn't have a good background in AI planning technology. The GIPO plan visualiser tool allows engineers to graphically view the output of successful plans generated by integrated planners. However it assumes knowledge about the domain.

Based on these ideas of a knowledge enrichment need in AI planning, in this paper we argue that this vision should be even more augmented in other aspects of planning. Our claim is that knowledge enhancement can bring benefits to other areas, and we highlight the planning information visualisation area. Knowledge models developed from the information visualisation perspective will permit modelling and reasoning about the problem, and in this paper we contribute present our approach of semantic support for visualisation in planning systems

The remainder of this document is organised as follows. Section 2 presents the approach overview and architecture. Section 3 details the knowledge models in which our approach is based. Section 4 discusses an information visualisation reasoning motivation in the I-Rescue domain. Finally, we draw some conclusions on Section 5.

2 Framework Approach Overview and Architecture

This work proposes a way to address the problem of visualisation in intelligent planning systems via a more general approach. It consists in the development of several semantic models which when used together permit the construction of a reasoning mechanism for multi-modality visualisation destined for collaborative planning environments. This framework will permit organizing and modelling the domain from the visualization perspective, and give a tailored support of information presentation.

The framework is divided in two main parts: a knowledge representation aspect and a reasoning mechanism. In the knowledge representation aspect of this work, a set of ontologies permits organising and modelling the complex problem domain from the visualisation perspective. The reasoning mechanism will give support to reasoning about the visualisation problem based on the knowledge base available and designed for realistic collaborative planning environments.

The main aspects considered in the semantic modelling include: the nature of planning information and the appropriate tailored delivery and visualisation approaches for different situations; collaborative agents that are playing different roles when participating in the planning process; and the use of mobile computing and its devices diversity. This needs a powerful approach with great expressive power and flexibility. The semantic model is composed by the following (sub) models: Visualisation Modalities, Planning Information, Devices, Agents, and Environment.

Section 3 will be presenting these models in more details, but here we give an introductory explanation:

- **Visualisation Modalities**: Permits the expression of the different modalities of visualisation considered in the approach;
- **Planning Information**: Representation of planning information at a higher level of abstraction, and it is partially based on the I-X <I-N-C-A> (Issues-Nodes-Constraints-Annotations) ontology [Tate 2001];
- **Devices**: Permits description of features of the mobile devices types being targeted, such as, cell phones, PDAs, pocket computers, etc;
- **Agents**: Allows the representation of agents' organisations, including different aspects, such as agents' relationships (superiors, subordinates, peers, contacts, etc.), agents' capabilities and authorities for performing activities, and also, agents' mental states;
- **Environment**: This model allows the representation of information about the general scenario. For instance, position of agents in terms of global positioning (GPS), etc.

Figure 1 illustrates the framework architecture. Using semantic modelling techniques (ontologies), several knowledge models complement each other to structure a planning visualisation information knowledge model. This knowledge model permits modelling and organising collaborative environments of planning from an information visualisation

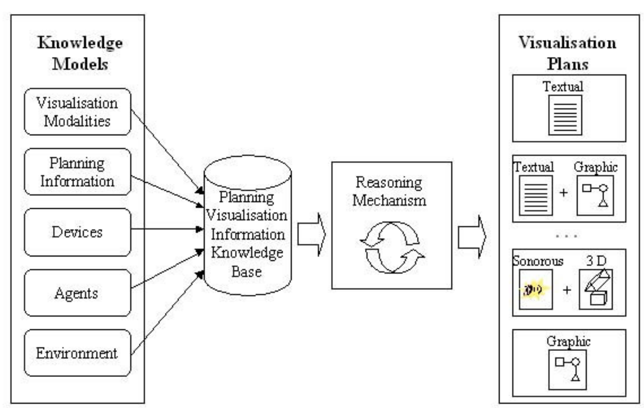

Figure 1- Framework Architecture

perspective. Then, a reasoning mechanism based on the knowledge available, outputs visualisation plans tailored for each situation.

The following sections explain the framework in more details; where Section 3 is concerned with the semantic modelling aspect, while Section 4 exemplify how the reasoning mechanism would work in a search and rescue scenario (I-Rescue domain).

3 Semantic Modelling

In the proposed approach, the definition of the *Planning Visualisation Framework* [Lino and Tate, 2004] is expressed through five different models that define the main aspects of the problem. The next subsections will explain each of them in detail.

3.1 Multi Modal Information Visualisation Ontology

Information Visualisation (IV) is defined by [Card et al., 1999] as the use of computer-supported interactive visual representation of abstract data to amplify cognition. Many classifications of visual representation exist on the literature. [Shneiderman 2004] classifies data types of information visualisation in: 1-Dimensional, 2-Dimensional, 3-Dimensional, Multi-Dimensional (more then 3 dimensions), Temporal, Tree, and Network data. [Lohse et al., 1994] propose a structural classification of visual representations. It makes classification of visual representations into hierarchically structured categories. This classification is divided in six groups: graphs, tables, maps, diagrams, networks and icons. Another classification of visualisation types is proposed in [Burkhard 2004] from a perspective of architects. The visualisation types described are: sketch, diagram, image, object, and interactive visualisation.

These classifications are relevant in many aspects, including help to construct the framework categorisation, to understand how different types of visualisation communicate knowledge, and help identifying research need. Furthermore, the existing development of prototypes for each category offers design guidance.

However, despite the power of information visualisation, in certain circumstances it is not sufficient to transmit knowledge to users. People assimilate information in different manners, and have distinct limitations and requirements. For instance, deaf or hearing impaired people have different needs related to information acquisition. Therefore, different modalities of visualisation and interaction are needed for different users. For this reason, to permit broad possibilities of planning information delivery, it has been included in the framework not only visual representations but also others forms of user interaction, such as natural language interfacing, sonification and use of sounds, etc., as other forms for communicating knowledge. These concepts are modelled in the 'Multi Modal Information Visualisation and Communication Ontology'.

Therefore, this model and ontology definition is derived from previous work as classifications of information visualisation, and furthermore, in requirements for planning information visualisation to real problems [Wilkins and desJardins, 2001], which is representative of the type of scenarios that is being targeted. Then, the core of the semantic definition of this model is based on multi modal visualisation and interaction definitions and also on user tasks that can be performed upon the visualisation modalities.

The ontology includes the following main categories and concepts:

- **1-D Textual:** This category is based on textual representation of information. This modality is appropriated for simple devices that doesn't have many computational resources to present elaborated visual representations;
- **2-D Tabular/GUI/Map:** In this category, it is considered abstractions of information that are represented in two dimensions. For instance, tabular, GUI and map representation. Tabular defines a more structural way to present text (but not only) information, and together with GUI and map based, these representations requires devices with more computational capabilities to present information then text based ones;
- **3-D World:** This modality considers three-dimensional representations of the world for information presentation. Due to the more sophisticated nature of information structure, this category is suitable for more powerful devices;
- **Complex Structures:** In this category it is included complex abstractions of data representation for information visualisation, such as: Multi Dimensional, Tree and Network representations. Multi-Dimensional concerns about representations considering more then 3 dimensions. One example of abstractions of this type is the use of parallel coordinates [Macrofocus, 2004] that represent several dimensions, via a vertical bar for each dimension. Tree and Network visualisation are also included in this category of complex structures. In the literature there are many approaches to address these structures, and the nature of some data types can benefit from these forms of representation;
- **Temporal:** Many solutions for temporal data visualisation is proposed on the literature. Temporal data needs a special treatment. For instance, works such as LifeLines [Alonso at al., 1998] addresses the problem. In the ontology, this modality abstracts the concepts involved in the presentation of temporal data.
- **Sonore (Audio/voice):** In this category audio and voice solutions are incorporated in the ontology. Audio and voice aid can be very useful in certain situations, where the user agent is incapacitated of making use of visual information;

- **Natural Language:** Finally, natural language concepts are also considered in the semantic modelling. Although it is claimed that natural language cannot completely substitute graphical interfaces [Shneiderman, 2000], it is suitable for many situations as it is going to be discussed on Section 4 of this paper.

Other aspects also included the conceptual modelling of this ontology, for instance the user tasks that can be performed. The user tasks are classified as follows:

- **Obtain Details;**
- **Extract;**
- **Filter;**
- **Obtain History;**
- **Overview;**
- **Relate; and**
- **Zoom.**

Depending on the information visualisation and communication modality, the same user task can involve different mechanisms and components to be accomplished.

3.2 Planning Information Ontology

The 'Planning Information Ontology' categorises, at a high level, planning information of the following nature:

- **Domain Modelling:** In this category it is included concepts of planning information related to domain modelling;
- **Plan Generation:** Here, the semantic modelling is concerned with plan generation information concepts and abstractions;
- **Plan Execution:** In this category the ontology includes vocabulary regarding plan execution;
- **Plan Simulation:** Finally, this category models abstractions regarding plan simulation information.

Initially, the main focus of this ontology is the conceptualisation of plan generation information, however the conceptualisation is generic.

Apart from the core planning information definition of this ontology, another important aspect modelled is the aspect of planning for which the information is going to be manipulated. These concepts permit the understanding of planning information from a visualisation perspective. It helps, for instance, in defining strategies for information delivery, based on the aim.

In this way, for the modelling of this idea, the following concepts are considered in the ontology:

- **Planning Information Aim:** Here it is considered that planning information can be used for different aims, which can be domain modelling, plan generation, plan execution and plan simulation. According to the literature and existing planning systems, depending on the aim, planning information is approached in different ways. So, delivering information for domain modelling is not the same to delivering for plan generation.
- **Planning Information:** The conceptual definition of planning information for the purpose of the visualisation framework is based on the I-X <I-N-C-A> [Tate, 2001] model for collaborative planning processes.
- **Planning Information Delivery Strategies:** Based on the literature and existing planning systems it is possible identify that each one of the planning information aim categories (domain modelling, plan generation, plan execution and plan simulation), in general, they deal with different types of information. So for each one can be identified different delivery strategies, because there are different requirements of data presentation, summarisation, etc.

Therefore the main aim of this ontology is to abstract and model these concepts regarding planning information regarding the framework objective of information visualisation.

3.3 Devices Ontology

In the 'Devices Ontology' [Lino at al., 2004] we investigated an approach of knowledge representation of devices capabilities and preferences concepts that will integrate the framework proposed.

CC/PP [W3 Consortium, 2004a] is an existing W3C standard for devices profiling. The approach of CC/PP has many positive aspects. First, it can serve as a basis to guide adaptation and content presentation. Second, from the knowledge representation point of view, since it is based on RDF, it is a real standard and permits to be integrated with the concepts of the Semantic Web construction. For our work, the Semantic Web concepts will also be considered. We envisage a Semantic Web extension and application of the framework that will be addressed in future publications. Third, another advantage of CC/PP is the resources for vocabulary extension, although extensibility is restricted.

On the other hand, CC/PP has some limitations when considering aplying it to the realistic collabortative planning environment we are envisaging. It has a limited expressive power, that doesn't permit a more broaden semantic expressiveness. Consequently it restricts reasoning possibilities. For example, using CC/PP it is possible to express that a particular device is Java enabled. However this knowledge only means that it is possible to run Java 2 Micro Edition (J2ME) on that device. But, it can have a more broaden meaning, for example, when considering '*what really means be Java enabled*?' or '*what is J2ME supporting?*'. Having the answers for questions like these will permit a more powerful reasoning mechanism based on the knowledge available for the domain. For instance, if a device is Java enable, and if J2ME is supporting an API (Application Program

Interface) for Java 3D, it is possible consider delivering information in a 3D model.

For that there is a need to develop a more complex model for devices profiling that will be semantically more powerful. It is necessary to incorporate in the model other elements that will permit enhance knowledge representation and semantic.

The 'Devices Ontology' proposes a new model approach that intends to enhance semantics and expressiveness of existing profiling methods for mobile and ubiquitous computing. Consequently, reasoning capabilities will also be enhanced. But, how will semantics be improved? In many ways, as we will categorise and discuss below.

Semantic improvement can be categorised as follow in the new model being proposed:

- **Java Technology Semantic Enhancement:** In this category is intended to enhance semantic related to the Java world. It is not sufficient to know that a mobile device is Java (J2ME) enabled. On the other hand, providing more and detailed information about it can improve device's usability when reasoning about information presentation and visualisation on devices. For that, in this new model proposed is included semantic of information about features supported by J2ME, such as support to 3D graphics; J2ME APIs (Application Program Interface), for instance, the Location API, that intends to enable the development of location-based applications; and also J2ME plug-inns, such as any available Jabber [5] plug in that will add functionalities of instant messaging, exchange of presence or any other structured information based on XML.
- **Display x Sound x Navigation Semantic Enhancement:** One of the most crucial things in development of mobile devices interfaces is the limited screen space to present information that makes it a difficult task. Two resources most used to by pass this problem are sound and navigation approaches. Sound has been used instead of text or graphic to present information; for example, give sound alerts that indicate a specific message to the user. Indeed, it can be very useful in situation where the user is on the move and not able to use hands and/or eyes depending on the task he is executing. In relation to navigation, this resource can be used sometimes to improve user interface usability, if well designed. However, good navigation design has some complexity due to: devices diversity and because in some devices navigation is closely attached to the devices characteristics (special buttons, for example). So, this category intends to enhance semantic related to these aspects, that will permit a good coordination and reasoning through these resources when presenting planning information to mobile device's users participating in collaborative processes.
- **Open Future New Technologies Semantic Enhancement:** This category of semantic enhancement is the more challenging one in this new model proposition. Mobile computing is an area that is developing very intensely. New devices and technologies are been created every day. In this way it's easy to create technologies that will be obsolete in few years time. Trying to overpass this problem, we envisage that will be possible to provide semantic to future new technologies in mobile computing via a general classes and vocabulary in the model and framework proposed.

3.4 Agents Ontology

This ontology is used to model and organise agents (software and human) regarding their mental states, capabilities, authorities, and preferences when participating in a collaborative process of planning.

The development of this ontology is based on BDI [Rao and Georgeff, 1995] concepts, and also on the I-X ideas. I-Space [Tate et al., 2004] is the I-X concepts for modelling collaborative agents' organisations. Techniques such as agent profiling are being developed to permit adaptation of planning information presentation, since it permits to adapt the type of information delivery to the agent requirements.

3.5 Environment Ontology

The environment ontology is responsible for permitting expression of environment awareness. In particular, location based awareness is being considered, where this type of information is based on GPS (Global Positioning System). Dealing with location-based information will allow the guidance of presentation of information.

4 Motivating Scenario: Reasoning on the I-Rescue Domain

In this section an application of the framework will be motivated. The domain used for that is the I-Rescue [Siebra and Tate, 2003] domain.

The reasoning component of the framework will permit do adjustment of the visualisation and interfacing modalities to agents, devices, environment conditions and type of planning information requirements. In this way, planning information will be delivered in a tailored way.

The kind of reasoning that is performed is based on some principles designed from a study about information visualisation in existing AI planning systems. These principles are based on:

(1) The identification of the type of plan representation that differs depending on the planning approach adopted by the planners;
(2) Understanding of which kind of information is need to be presented and interacted with users;
(3) Classification of the different types of users involved in the planning process;

(4) Identification of most common visual structures (graphical and non-graphical) used in AI planning systems to present information, and;
(5) To which nature of planning information these structures are used to in the planners approaches of information visualisation; and
(6) Finally, in the attempts reported in the literature of adding new forms of interaction with the user, for instance, via natural language processing techniques.

Based on these principles described above and in addition in new requirements desired in collaborative planning information visualisation, rules are being created, in which the reasoning will be based on. For instance, an example of such new requirements is the need of a feedback of human agents that are collaborating on the move in the planning process. Regarding planning information visualisation, this feedback concerns the human agent setting his/hers preferences about change of current conditions while on the move (making use of mobile devices) that will affect the desired planning information visualisation modality for him/her. For example, if the human agent is engaged in an activity that requires extreme visual attention, a visualisation modality based only on graphical representation will not be useful for him/her, because can cause distraction from the main activity being performed. On the contrary, modalities that don't need only visual interaction can suit the situation requirements; such as the ones based on natural language processing and that are sound supported.

The framework is aimed at realist domains of collaborative planning, and the I-Rescue domain fits the requirements of such domains. On I-Rescue scenarios, human and software agents work together and share knowledge and capabilities to solve mutual goals in a coalition support systems fashion. An important feature in systems like that is their ability to support collaborative activities of planning and execution. During planning processes, joint agents share knowledge so that a plan can be built in accordance with the perspectives of each agent. Then the activities in the execution are assigned to specific agents, which will use their individual capabilities to perform the allocated tasks. I-Rescue scenarios consist of relief situations in natural disasters or adversities caused by humans. Situations like that need an immediate response of joint forces with the main objective of saving people lives and minimising suffering. The Kobe Earthquake of January 1995 is an example of how disasters have a tragic effect in urban areas. Most recently the tragedy of The Indian Ocean Tsunami in December 2004 shows the unseen proportions of effects. Situations like that need an immediate response to relief human loss and suffering, and the use of AI techniques and applications can help provide assistance.

5 Conclusions

In this paper it is proposed an integration of ontologies and reasoning mechanism for multi-modality visualisation in collaborative planning environments. The set of ontologies and its integration will permit the expressiveness of several aspects related to real world applications in environments of mixed initiative planning. The reasoning mechanism will allow a tailored delivery and visualisation of planning information. The main contributions of the framework are: (1) it consists in a general framework; (2) the ontology set will permit organising and modelling the domain from the visualization perspective; (3) the reasoning mechanism will give support to presentation of information tailored for each situation; (4) the framework will serve as base for implementations, and (5) the framework is based on real standards (W3C) that will ease communication and interoperability with other systems and services, such as web services.

In addition, we would like to highlight the originality aspect of this work. A semantic modelling approach has not yet been applied to planning visualisation as far as we are aware. The use of ontologies is becoming a trend in the information visualisation field, where an increasing number of works related to this subject have appeared in recent international conferences on the topic. However its use in an intelligent planning context has not been explored yet. This work is an attempt to apply semantic modelling techniques, more specifically via ontologies to a complex collaborative environment of planning.

Furthermore the framework discussed in this paper consists in a high level abstract model that is based, on an implementation level, on W3C standards, which permits the possibility of easy extension and application on the Semantic Web [W3 Consortium, 2004b].

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