

An Integrated Ontology Set and Reasoning Mechanism for Multi-Modality Visualisation Destined to Collaborative Planning Environments

Natasha Queiroz Lino

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

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 way to address the problem of visualization in intelligent planning systems via a more general approach. It consists in an integrated ontology set and reasoning mechanism for multi-modality visualisation destined to collaborative planning environments. This framework will permit organizing and modeling the domain from the visualization perspective, and give a tailored support for presentation of information.

Introduction

Visualisation is an aspect that is still not much explored in intelligent planning systems. Although efforts have been made in improving and developing new techniques and approaches in the field of intelligent planning, such as, more efficient search algorithms, few works addresses the problem of visualisation.

Among the existing planning systems, some well know planners even doesn't have a solution for visualisation proposed, others only consider a unique approach when this solution sometimes is not appropriate for every situation. So, how will users make the most of planning systems if they don't have appropriate support for interaction with them? This problem is even more enhanced when considering mixed initiative planning systems, where agents that are collaborating in the process, have different backgrounds, are playing different roles in the process, and have different capabilities and responsibilities, etc.

Depending on how it is approached, visualisation can play two main crucial roles in planning: allow proper interfacing between the planner and its users, and permit collaboration in the case of mixed-initiative planning systems. However,

the existing lack of more elaborated approaches for the problem of visualisation in planning systems compromises a broaden application and use of such systems; and their application and use in real world problems and situations, where assisted planning services can be applied and supported by more sophisticated visualisation approaches.

The focus of this work is the problem of visualisation in intelligent planning systems. To address the problem we propose a general framework for visualisation in planning systems that will give support for a more appropriate visualization mechanism. The general approach that is being proposed for dealing and modeling this problem consists in an integrated ontology set and reasoning mechanism for multi modality visualisation destined to collaborative planning environments. This framework is divided in two main parts: a knowledge representation aspect and a reasoning mechanism. In the knowledge representation aspect of this work, the ontology set will permit organising and modeling the complex problem domain from the visualisation perspective. The reasoning mechanism will give support to reasoning about the visualisation problem based on the knowledge bases available for a realistic collaborative planning environment, including agents preferences, devices characteristics, planning information, and visualization modalities knowledge base, etc.

This PhD program also intends to produce a study about visualisation in intelligent planning systems, presenting the state-of-the of approaches most adopted in planners, and in additional, in schedulers systems, due to the similar nature of information that these systems present and manipulate. This study being carried out is permitting to identify existing gaps, such as the need of more elaborated and general approaches to deal with planning information and support user interaction. Furthermore, it is allowing the detection of many research opportunities in the area, for instance, the integration of mobile computing and mobile devices with artificial intelligence and visualization approaches. This integration can add value to real world applications and have been applied in other artificial intelligence areas. Details in (Lino et al., 2003).

Some of the requirements that the approach should have are: to be general, technologically independent, and extensible. General because it will consider several aspects of planning visualisation, and should be applied in general cases. Technologically independent due to the fact that part of the knowledge and expertise for building the framework will come from current available technology, although, the framework should be extensible enough to permit that future technologies would be applicable. Also, we intend to model the problem and investigate the use as knowledge representation real standards, such as XML (W3C, 2003) RDF (W3C, 2003) and related technologies. This aspect will permit extensions of the framework and its application in the Semantic Web.

To conclude, in brief, the objective of this PhD thesis will be de construction of a general framework for visualization in intelligent planning systems via an ontology set and reasoning mechanism for describing and reason about multi modality visualisation destined to collaborative planning environments. The main contributions of this approach will be: (1) it is a general framework for the problem of visualisation in planning systems, that will permit model the domain and allow a better and optimized approach for planning and visualisation of information; (2) based on real standards that will ease communication and interoperability with other systems and services; (3) with a broad potential for its application on the Semantic Web, and (4) the framework will serve as base for implementations.

Related Work

In mixed-initiative planning research, natural language and direct manipulation have been the most adopted approaches for permitting visulisation of information and interaction between planner and user agents.

Natural language processing research has been applied in the TRAINS (Ferguson and Allen, 1996) and TRIPS (Ferguson and Allen, 1998) systems, where interaction between the user and the system is viewed as a form of dialog. TRAINS and TRIPS approach for interaction consists in being conversational systems that provides problem-solving assistance.

Direct manipulation and GUI (Graphical User Interface) techniques dominate modern interactive software. However in planning systems there is a lack of mixed initiative interaction through visual medias. Nevertheless, some approaches has been explored this aspect, as is the case of (Amant et al., 2001) (Pegram et al., 1999). In these works is proposed communication between human planners and intelligent planning systems via shared control of a three-dimensional graphical user interface, using an ecological view of human-computer interaction. The planning environment is focused on strategic, physical planning problems in AFS (Abstract Force Simulator) simulator.

The O-Plan (Tate and Drabble, 1995) planning system user interface approach focuses on the differentiation of the various roles played by users. The system gives support for users agents to interact with the planning agent, and also with the other system agents of the architecture: task assign (strategic level), planner (tactical level), and execution system (operational level). The support is given by providing different views of plan structure that can be technical *plan views* (charts, structure diagrams, etc.), and domain-oriented views, called *world views* (simulations, animations, etc.). This reference has also an useful analysis of basic requirements for graphical interaction in planning systems.

To conclude we can say that although spoken dialog is a natural and powerful way of human-computer interfacing, it has also being argued that speech recognition has limitations (Shneiderman, 2000) in some aspects: viability to present information due to slow processing, difficult to review and edit information, etc. Nevertheless speech is suitable for interaction for blind and motor-impaired users, messages, and alerts in busy environments. However, what it is missing is a more general way to approach visualization in mixed initiative planning considering the related aspects including: collaboration, multi agents and their roles, capabilities and responsibilities, multi modalities of visualisation, devices diversity, type of planning information, etc. A general and related approach is under development by the W3C, the Multimodal Interaction Activity (). The objective is to adapt the Web to allow multiples forms of interaction, enhancing interaction between humans and computers considering the paradigms anywhere, any device and any time. The way intended to archive the objective is via the developing of standards for a new class of mobile devices that support multiples modes of interaction. Our approach however, despite be also based on W3C standards, is more specialised since is concerned with collaborative environments of intelligent planning and related aspects.

A General Framework for Multi-Modality Visualisation in Mixed-Initiative Planning

To propose a new solution for visualization in intelligent planning systems we intend to build a general framework that will permit describe and model the problem and provide adequate reasoning about visualization, planning components and the concepts involved.

The proposition of an ontology set and reasoning mechanism for describing and reasoning about multi-modalities visualization intends to be a general and extensible framework destined to collaborative planning environments. The framework is divided in two parts: knowledge representation and reasoning mechanism.

In the knowledge representation aspect of this work, the ontology set will permit describing planning data, in the context of a realistic collaborative planning environment. This means that the ontology set will include vocabulary for information about agents members of virtual organisations, virtual organisation characteristics and relationships, information about devices (mobile devices, desktops) for visualization display (capabilities, resources available, screen characteristics, etc.), and also visualization modalities ontology. The reasoning part of this work will be able to reason and map, based on the ontology set, from a global scenario description to specific and suitable visualisation categories or modalities.

In addition, correlations and applications of this work in the Semantic Web will be considered. Semantic Web is a research area that cannot be des-considered in ontology researches. In this way, our intention is to develop the ontology in consideration with semantic web concepts that will permit a natural extension and adaptation of the proposed ontology for application in the Semantic Web.

An Ontology Set

In this subsection it is being described in more details the ontology set. First it will be explained about which scope each ontology will be concerned. Second, the knowledge representation approach and languages being investigated for building the ontology set will be discussed. Third, as some of the ontologies that are being integrated in the ontology set are existing and/or extended ontologies, considerations will be made about integration. Finally, examples will be given of the ontology set being proposed.

An alternative for multi-modality user interfaces is proposed in (Moran et al., 1997). In this approach, a multi agent architecture, called Open Agent Architecture (OAA), is used to support multimodal user interfaces. The Open Agent Architecture is a multi agent system that supports the creation of applications from agents, where part of the focus is on the user interface of the applications. The supported modalities are: spoken language, handwriting, pen-based gestures, and Graphical User Interface (GUI). The user can interact using a mix of modalities. When certain modality is detected by the system, the respective agent receives a message and processes the task. In this way, the Facilitator Agent is the key for cooperation and communication between agents, since it's his job register capabilities of agents, receive requests, delegates the agents to answer requests. However the Facilitator Agent can be a potential bottleneck.

In the past 2003, 2002, and 2001 International Conferences on Information Visualisation, a session has been dedicated to visualisation and ontologies. Several works are proposing the use of ontologies in visualisation problems, and their application in the Semantic Web. In (Telea et al., 2003) is proposed a graph visualisation tool that allows construction and tuning of visual exploratory scenarios for

RDF (Resource Description Framework) data. Other approach (Fluit et al., 2002) shows how visualisation of information can be based on ontological classification of that information, by a cluster map visualisation.

The approach proposed in this PhD program has similarities and is inspired in a mix of concepts of these mentioned works. It intends to be a multi-modality visualisation framework for intelligent planning systems based on ontological representation.

Ontology Set Description. The ontology set will be composed by the following sub-ontologies:

- **Multi-Modality Visualisation Ontology.** This ontology will be able to express the different modalities of visualization. Each visualization category will be described following its characteristics.
- **Plan Ontology: <I-N-C-A> Ontology.** The ontology used to represent plans will be based on the <I-N-C-A> ontology (Tate, 2001). <I-N-C-A> (Issues-Nodes-Constraints-Annotations) is the I-X Project (Tate, 2000) ontology that permit represent a product, such as a plan, as a set of constraints on the space of all possible products in the application domain.
- **Devices Ontology.** The devices ontology will permit describe the types of devices being targeted, for example, mobile devices, such as, cell phones, PDAs, pocket computers, etc. The representation will be made in terms of their characteristics: screen sizes, features, capabilities, etc. However, the representation is intended to be generic enough to permit easy extensions to future technologies. This is a positive aspect, mainly because the mobile computing area is presenting a very fast development.
- **Agents Organisation Ontology.** This ontology will permit represent the agents organization, including agents' relationships (superiors, subordinates, peers, contacts, etc.), agents' capabilities and authorities for performing activities, etc. This ontology will also be inspired in some of the I-Space concepts. I-Space is a I-X project concept for managing agents structures and relationships in a virtual organization.
- **Agents Mental States Ontology.** BDI (Beliefs-Desires-Intentions) (Rao et al., 1995) will be used as a start point to compose the ontology for representing agents' mental states.
- **Environment Ontology.** This ontology will allow represent information about the general scenario. For example, agents' localization in terms of global positioning, etc.

Knowledge Representation Approach. The knowledge representation approach that we are investigating for using is based on XML - Extensible Markup Language (W3C, 2003) and related technologies, following W3C standards. In a first phase, these technologies will be used as knowledge representation tools, however a Semantic Web

(W3C, 2003) application will not be aimed at first. These technologies filled a gap, providing first a syntax for structured documents (XML, XML Schema), and second a simple semantic for data models (RDF – Resource Description Framework), that evolved for more elaborated schemas (RDF Schema, OWL). RDF Schema permits semantics for generalization-hierarchies of properties and classes. OWL – Web Ontology Language, adds more vocabulary with a formal semantics, allowing more expressive power, permitting, for example, express relations between classes, cardinality, equality, and characteristics of properties, among others.

OWL (W3C, 2003) is an evolution of DAML+OIL (McGuinness, et al., 2002) and is aimed for use when is necessary to process information, and not only present it, because facilitates machine interpretability via its additional vocabulary and formal semantics. OWL is divided in three sub-languages, with increasing expressiveness: OWL Lite, that provides classification hierarchy and simple constraints; OWL DL that has maximum expressiveness with computational completeness and decidability, founded by description logics; and OWL Full that allows maximum expressiveness and systatic freedom of RFD, but without computational guarantees.

The OWL ability of processing the semantic of information seems to be appropriate technology to be used in the general framework being developed, to build the integrated ontology set, and reasoning mechanism in the problem domain. The resulting framework will considers the semantic of the information available, and it will be capable of reasoning based on real standards.

An important aspect to consider, however, is that the use of W3C standards doesn't mean necessarily a Semantic Web application. Nevertheless, it is intended a further investigation of the framework extension to apply in the Semantic Web. One way is to provide mechanisms for a semantic automatic knowledge bases update. For example, directions can be formulated to build agents for mobile devices profile update.

A Reasoning Mechanism

The set of ontologies will allow the development of reasoning mechanisms related to visualization in collaborative environments of planning.

Current device's profiles available permit express information about device's features, for example, via a device profile it's possible to get the information that a specific device is Java enabled. It means that it's possible to run Java 2 Micro Edition (J2ME) in this device. However this type of information can have a more broaden meaning when considering visualization of information in devices. What really means a device be Java enable, apart from being able to run J2ME? Is J2ME supporting Java 3D

for instance? It's to answer questions like that that the 'Devices Ontology' will be used, and will permit a proper reasoning for tailored information visualization.

Figure 1 has extracts of the 'Devices Ontology', using OWL as knowledge representation language. It shows the definition of classes and properties that permit the Java question example be represented, and used to reason upon. The class *PDADevice* allows the instantiation of individuals that represent a particular device. Through the *JavaEnable* property defined for this class, it's possible to express if a specific PDA is Java enable. The unique instance of the *J2ME* class specifies the features of the J2ME platform. For instance, this class has the property *3DSupport* expresses the semantic of supporting features of 3D visualization models or not.

```

...
<!-- Information about the Ontology -->
<owl:Ontology rdf:about="">
  <rdfs:comment>Devices Ontology</rdfs:comment>
</owl:Ontology>
...
<!-- Classes Definition -->
<owl:Class rdf:ID="PDADevice">
  <rdfs:comment>An instance of the class
    PDADevice represents the details of a
    particular device.</rdfs:comment>
  <rdfs:subClassOf
    rdf:resource="#CLDCCconfigDevices"/>
</owl:Class>

<owl:Class rdf:ID="J2ME">
  <rdfs:comment>The instance of the class J2ME
    express the features of this
    platform.</rdfs:comment>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:cardinality rdf:datatype=
        &#x2D;nonNegativeInteger">1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
...
<!-- Datatype Properties -->
<owl:DatatypeProperty rdf:ID="JavaEnable">
  <rdfs:domain rdf:resource="#PDADevice" />
  <rdfs:range rdf:resource="&#x2D;boolean"/>
</owl:DatatypeProperty>

<!-- Datatype Properties -->
<owl:DatatypeProperty rdf:ID="3DSupport">
  <rdfs:domain rdf:resource="#J2ME" />
  <rdfs:range rdf:resource="&#x2D;boolean"/>

```

Figure 1 – *Devices Ontology* example

Using the classes and properties defined in the 'Devices Ontology' it's possible to express instances of real world

devices used by human agents in collaborative environment. Hence, the reasoning mechanism uses the knowledge base and reason upon for a tailored deliver and visualization of information.

Conclusions

In this PhD program 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 this framework are: (1) it consists in a general framework; (2) the ontology set will permit organising and modeling the domain from the visualization perspective; (3) the reasoning mechanism will permit proper presentation of information 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 services and systems.

Acknowledgements

Natasha Lino's scholarship is sponsored by CAPES Foundation under Process No.: BEX1944/00-2. The University of Edinburgh and research sponsors are authorised to reproduce and distribute reprints and on-line copies for their purposes not withstanding any copyright annotation here on. The views and conclusions contained here in are those of the author and should not be interpreted as necessarily representing the official policies or endorsements, either express or implied, of other parties.

References

Amant, R. S., Healey, C. G., Riedl, M., Kocherlakota, S., Pegram, D. A., and Torhola, M. 2001. Intelligent visualization in a planning simulation. In *Proceedings of IUI. 2001*, pp. 153-160.

Ferguson, G., and Allen, J. 1996. Trains-95: Towards a mixed-initiative planning assistant. In *Proceedings Artificial Intelligence Planning Systems*, pp. 70-77.

Ferguson, G., and Allen, J. 1998. Trips: An intelligent integrated problem-solving assistant. In *Proceedings AAAI-98*.

Fluit, C., Sabou, M., Harmelen, F. 2002. Ontology-based Information Visualisation. In *Proceedings of Visualising the Semantic Web - VSW 2002*. Springer Verlag, Vladimir Geroimenko Editor.

Lino, N., Tate, A., Siebra, C. and Chen-Burger, Y. 2003. Delivering Intelligent Planning Information to Mobile Devices Users in Collaborative Environments, Workshop on Artificial Intelligence, Information Access and Mobile Computing (AI-IA-MC) at the International Joint Conference on Artificial Intelligence (IJCAI-03), Acapulco, Mexico, August 2003.

McGuinness, D. L., Fikes, R., Hendler, J. and Stein, L. A. 2002. DAML+OIL: An Ontology Language for the Semantic Web. In *IEEE Intelligent Systems*, Vol. 17, No. 5, pages 72-80, September/October 2002.

Moran, D. B., Cheyer, A. J., Julia, L. E., Martin, D. L., and Park, S. 1997. Multimodal user interfaces in the Open Agent Architecture. In *Proceedings of the 1997 International Conference on Intelligent User Interfaces (IUI97)*, Orlando, Florida, pp. 61-68, 6-9.

Pegram, D. A., Amant, R. St., and Riedl, M. 1999. An approach to visual interaction in mixed-initiative planning. *Mixed-Initiative Intelligence workshop, AAAI-99*.

Rao, A. S., Georgeff, M. P. 1995. BDI Agents: From Theory to Practice. In *Proceedings of the First Intl. Conference on Multiagent Systems*.

Shneiderman, B. 2000. The Limits of Speech Recognition. In *Communications of the ACM*, Vol. 43, No. 9, September, 2000.

Tate, A. 2000. Intelligible AI Planning. In *Research and Development in Intelligent Systems XVII, Proceedings of ES2000, The Twentieth British Computer Society Special Group on Expert Systems International Conference on Knowledge Based Systems and Applied Artificial Intelligence*, pp. 3-16, Cambridge, UK, December 2000, Springer.

Tate, A. 2001. I-X and <I-N-C-A>: an Architecture and Related Ontology for Mixed-Initiative Synthesis Tasks, In *Proceedings of the Workshop on Planning/ Scheduling and Configuration/Design*, Vienna, Austria.

Tate, A. and Drabble, B. 1995. O-Plan's PlanWorld Viewers. In *Proceedings of the Fourteenth UK Special Interest Group on Planning and Scheduling*, Wivenhoe House Conference Centre, Essex University.

Telea, A., Frasinca, F., Houben, G. 2003. Visualisation of RDF(S)-based Information. In *Proceedings of the Seventh International Conference on Information Visualization - IV 2003*, 294-299, London, England.

W3C. 2003. World Wide Web Consortium (W3C). <<http://www.w3.org>>