

# A Visualisation Approach for Collaborative Planning Systems Based on Ontologies

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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 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.*

**Keywords---** Visualisation, Intelligent Planning, Ontologies.

## 1. 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 address the problem of visualisation.

Among the existing planning systems, some well know planners don't have a solution for visualisation proposed yet, others only consider a unique approach when this solution sometimes is not appropriate for every situation. In this way, 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 human agents, that are collaborating in the process, have different backgrounds, are playing different roles in the process, are using different devices to interact with the planner, and have different capabilities and responsibilities, etc.

Visualisation can play two main crucial roles in planning systems: allow proper interaction between the planner and its users, and permit collaboration in the case of mixed-initiative planning. However, the existing lack of more elaborated approaches for the problem of visualisation in planning systems compromises a broader 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.

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 organise and model 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. Among the knowledge bases available, are included: agents preferences, devices characteristics, planning information, visualization modalities knowledge base, etc.

Furthermore, for the solution proposed, it has been detected opportunities in the problem area for the integration of planning applications with mobile computing and visualization approaches. This integration can add value to real world applications and have been applied in other artificial intelligence areas. More details of artificial intelligence and mobile computing integration can be found in (Lino et al., 2003).

The requirements considered in the approach proposed 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 investigating the use, as knowledge representation tools, real standards, such as XML (W3C, 2003) RDF (W3C, 2003) and related technologies. The use of markup languages will permit extensibility of the framework and its application on the Semantic Web.

## 2. Related Work

In mixed-initiative planning research, natural language and direct manipulation have been the most adopted approaches for permitting visualisation of information and interaction between the planner and the 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 approaches for interaction consist 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 communication between human planners and intelligent planning systems is proposed 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 and 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 user agents to interact with the planning agent, and also with the others system agents that compose the O-Plan architecture, such as: task assign (in the strategic level), planner (in the tactical level), and execution system (in the 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.). In (Tate and Drabble, 1995) an useful analysis of basic requirements for graphical interaction in planning systems is also provided.

In brief, 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

in specific situation, for instance, 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 that will consider several aspects and different forms of visualisation. It is necessary consider 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 related approach (but not for planning domains) is under development by the W3C (W3C, 2003), 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 and markup languages, is more specialised since is concerned with collaborative environments of intelligent planning and related aspects.

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

To propose a new solution for visualization in intelligent planning systems we are building a general framework that will permit describe and model the problem and provide adequate reasoning about visualization, intelligent planning components and 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 information, in the context of a realistic collaborative planning environment. 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 a vocabulary of visualisation modalities.

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, tailored and suitable visualisation categories and modalities.

This work has a potential to be extended to the Semantic Web. So, in addition, correlations and applications of this work on the Semantic Web are being considered and investigated. With this propose, the development of the ontologies is considering Semantic Web concepts that will permit a natural extension and

adaptation of the proposed ontology for applications in the Semantic Web.

### 3. An Ontology Set

In this section 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 investigated for building the ontology set will be discussed. Later, considerations will be made about the ontology set integration. Finally, examples will be demonstrated.

An alternative for multi-modality visualisation 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, and delegate the agents to answer requests. However, the Facilitator Agent can be a potential bottleneck in this approach.

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 here has similarities and is inspired in a mix of concepts of these last mentioned works. It intends to be a multi-modality visualisation framework for intelligent planning systems based on ontological representation.

#### 3.1 Ontology Set Description

The ontology set will be composed by the following sub-ontologies:

**3.1.1. Multi-Modality Visualisation Ontology.** This ontology is able to express the different modalities of visualization considered in the approach, but the ontology vocabulary is extensible to express new modalities that eventually will be necessary in the problem domain or due to new technologies. Each

visualization category is described following its characteristics.

**3.1.2 Plan Ontology: <I-N-C-A> Ontology.** The ontology used to represent plans is 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. In order to be integrated, extensions concerning the visualisation perspective are considered in the definition of this ontology.

**3.1.3 Devices Ontology.** The devices ontology permits 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.

**3.1.4 Agents Organisation Ontology.** This ontology permits represent agents organizations, including agents' relationships (superiors, subordinates, peers, contacts, etc.) aspects, agents' capabilities and authorities for performing activities, etc. This ontology is inspired in some of the I-Space concepts. I-Space is the I-X project concept for managing agents structures and relationships in a virtual organization.

**3.1.5 Agents Mental States Ontology.** Based on BDI (Beliefs-Desires-Intentions) (Rao et al., 1995) approach, this ontology permits represent agents' mental states.

**3.1.6 Environment Ontology.** This ontology allows the representation of information about the general scenario. For instance, localisation of agents in terms of global positioning (GPS), etc.

### 3.2 Knowledge Representation Approach

The knowledge representation approach is based on XML - Extensible Markup Language (W3C, 2003) and related technologies, following W3C standards. In a first phase, markup languages are used as knowledge representation tools, but a Semantic Web (W3C, 2003) application will not be aimed.

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 syntactic freedom of RFD, but without computational guarantees.

The OWL ability of processing the semantic of information fits our needs to be used in the general framework, to build the integrated ontology set, and reasoning mechanism in the problem domain. Hence, the resulting framework is considering the semantic of 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, further investigation will be carried on, in order to consider the framework extension for application on the Semantic Web. One potential application is to provide mechanisms for a semantic and automatic knowledge bases update. For example, directions can be formalised to build agents for mobile devices profile update.

#### 4 A Reasoning Mechanism

The set of ontologies allows the development of reasoning mechanisms related to visualization in collaborative planning environments. In this section we will be given an example of reasoning considering devices profiling.

Current device's profiles approaches available permit express information about device's features, for example, via a device profile it is possible to obtain the information that a specific device is Java enabled. It means that it is 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 mobile devices. What is that really means a device be Java enable, apart from being able to run J2ME? Is J2ME supporting Java 3D for instance?

To answer questions like that is that the 'Devices Ontology' will be used, permitting a proper reasoning for tailored information visualization and delivery.

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 of the previous paragraph 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 that 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="#CLDCConfigDevices"/>
</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=
        &xsld: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="&xsld:boolean"/>
</owl:DatatypeProperty>

<!-- Datatype Properties -->
<owl:DatatypeProperty rdf:ID="3DSupport">
  <rdfs:domain rdf:resource=#J2ME" />
  <rdfs:range rdf:resource="&xsld: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 environments of planning. Hence, the reasoning mechanism uses the knowledge base and reasons upon for a tailored deliver and visualization of information.

#### Conclusions

In this work 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 in a visualisation perspective. 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 facilitate communication and interoperability with other services and systems and also permit extensions for its use on Semantic Web applications .

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