Knowledge Based Support for Project Planning

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Abstract

This paper describes a number of new ideas and technologies from the field of knowledge based planning systems which could be used to build the next generation project management system. The type of project management system described would allow different systems and users to cooperate in the project management task and communicate plans, tasks, alternatives and options between them. The paper surveys the current state of project management tools and highlights their problems in dealing with distributed, multi-project programmes and initiatives. A number of key knowledge based technologies have been identified which could be built of top of existing legacy systems. A number of demonstration systems and prototypes have been developed to show the benefits of these technologies and some of them are described in the paper.

1 Introduction

The aim of this paper is to outline some new ideas that could form the focus for the next generation of project management technology. A number of demonstration systems and prototypes have been developed to show the benefits of these technologies and some of them are described in the paper. This paper has four main sections. The first of these defines the problem to be addressed, the second outlines the strengths and weakness of existing project management software tools, the third describes what intelligent project planning could provide, and the fourth lists the particular technology items that need to be developed to provide an intelligent project planning environment.

2 Problem to be Solved

What is planning?

> Planning is thinking through the five *w* questions: *who*, *what*, *why*, *when* and *how*. *What* is the situation and *what* do we want to turn it into? *How* do we turn the undesirable situation into the one we want? *Who* should do it and with *what* equipment and resources? *Why* will our method and assignments work? *When* should each step occur? and *when* will each part of what we want to accomplish actually be completed?
>
> *Donald Mitchell, Proactive Solutions*

Put more simply project management is the coordination of a set of tasks in order to achieve some goal. In the modern business environment where organisations are separated across countries and continents and where programmes can be made up of a number of different initiatives, controlling the programmes and projects becomes very difficult. This type of problem has been referred to as wide area project management. The essence of the wide area project management problem was summarised by Robert Neches (of ARPA) in a talk he gave at a workshop on wide area collaboration and cooperative computing. In that talk, he discussed rapid response collaboration, a kind of project planning, and broke the overall problem into the following three phases:

- **locate**
  identify individuals, software and organisations for candidate components of a new enterprise;
- **integrate**
  negotiate and specify how those components will work together
- **operate**
  link the components' information systems into a network information system that allows components to exchange information while maintaining a global picture of the status of the enterprise.

Existing project management software does not come close to supporting this sort of wide area collaboration and project management. One potential way of implementing such a system would be to use intelligent planning techniques to allow existing tools to communicate better and to keep track of the knowledge used and the rationale behind the decisions taken.

The AI planning approach focuses on producing results rather than managing a time line. The user needs to know that the plan does the right things at the right time using the right resources to accomplish the task without wasted activity. The requirements of the project are the driving force in AI planning, not the schedule chart on the wall.

The key to this powerful capability is recording and using the plan rationale. An intelligent planning tool is told what the project is supposed to produce and either automatically or through user dialogue suggests and adapts tasks from other plans or personnel as appropriate. The planner chooses resources, objects, etc, for the task according to the qualifications stated. This way the system knows why each task and resource is in the plan and can communicate this knowledge to the user, project staff and other interested bodies.

Avoiding failure is the responsibility of all project members with many areas of expertise influencing the project plan. An intelligent planning tool stores everything it learns in an adaptable form so it can inform the user of which solutions from other areas can fit together to solve the current tasks and needs. This helps the user leverage success by preventing him from re-inventing the wheel. By embedding the rationale behind the decisions and options within the plan it provides the ability to change plans dynamically. Plans never execute according to plan, intelligent planning tools show the user how changes to the situation, resources and requirements impact the plan. Remove a requirement and the tool can remove all parts of the plan that contributed exclusively towards that requirement. Add a requirement and the tool will identify the existing parts of the plan that already help satisfy it and then guide the user to fill in the gaps. This type of interaction can easily support "what if" analysis during contingency planning as well as real time changes during actual plan execution.

3 Strengths and Weaknesses of Existing Project Management Tools

The aim of this section is to describe the strengths and weaknesses of existing project management tools. Software tools exist to address the problem of project management, but they fall far short of what is actually required and needed. Project management software is an existing and recognised category in the software industry and a number of products have been developed.

The tools suffer from a number of major drawbacks which include the fact they are often platform, operating system, and windowing system specific, ensuring the systems do not interoperate, making it hard or impossible to share data between them. Current project management systems only work over a local area network e.g. an office or a building and not over wide area networks, such as the Internet. This makes them completely unsuitable for managing many of todays project which are split over a wide area. With all current project planning tools the user has to remember a wealth of information and it can be difficult for them to communicate the plan to other project members or to those who must further develop the plan. Responding to a changing environment is a extremely difficult with such tools. The products can be divided into four main groups:

- **Project Planners**
  The current range of project planning software is excellent for drawing PERT and Gantt charts, for representing basic task dependencies, for generating reports and overhead slides, for calculating the critical path in a project network, for calculating and displaying resource histograms, and for carrying out very simple resource leveling (typically implemented via first-fit dispatching).

  Current project planning software does not provide any sophisticated planning or scheduling reasoning. These tools can not handle constraints that state a fact should hold between two points in the plan and thus provide no account of a plan's rationale (the plan's causal structure). Also, current systems do not provide mechanisms for calculating a plan's robustness and how one plan relates in domain terms to other plans generated to solve the same task. These two aspects are of major importance for real-world plans. In addition current project planning systems do not provide an ability to consider "what-if" scenarios and the provision of contingent alternatives. This leaves the project manager with no ability to develop a true contingent project plan. Such a plan allows for advance consideration of multiple alternatives, with one particular path through the plan chosen during execution.

- **Simulators**
  These tools provide a way of defining the situation and provide some help to the user to model the effects of some activities. However, they do not model many critical aspects e.g. moving equipment, setting up work areas, etc. Additionally they do not record the plan in a form which can be easily communicated. They do not provide help in identifying the right steps in the right combinations with the right resources. There is no way to query the tool to verify all the planned activities actually accomplish their desired results, leaving the user to do the *real* planning.

- **Scheduling Tools**
  These tools provide a way to record the project activities in a time line but not the variables of the situation or the effects of the user's responses. The user must remember what the current context is and what the desired aims of the project are. The user must also determine how the problem will be solved before the plotting of the time line can begin. Each step is specified with a tag, an exact resource and ordered with respect to all other steps. The tool does not provide a means to record the effects of the step or the user criteria for assigning resources.

  The user must decide the who and which resources each activity will use. The user must also decide why each activity is included and what it should accomplish together with when the activity should occur. This leaves most of the real planning to the user.

- **Personal Information Systems**
  These tools allow project managers to construct a "to-do" list of tasks with the ability to manually check off tasks as they are completed and to automatically forward tasks to the next day if they are not completed.

  However, these tools are working in isolation and very often make simple assumptions, e.g. forwarding an uncompleted "to-do" task to the following day which can often be the wrong thing to do. The tool should examine the context and state of the plan in order to decide what to do with the task because usually it is part of some larger project in which the individual is engaged. However, being isolated the tool has no notion of this, so it can not appropriately handle the pending task. In addition the "to-do" tasks must be manually entered by the user creating the possibility of errors and keying mistakes.

4 What Project Planning Could Be

The aim of this section is to present a view of what project management could be using an intelligent tools approach. There is a need to breakaway from the view that one tool can do everything a project manager needs to one in which planning tools are viewed as situated agents. While a planning agent deals with plan generation aspects, other agents are concerned with aspects such as task elicitation, plan analysis, reactive execution, plan repair, etc. Each of these systems has its own perspective on the planning problem and each of the systems must be capable of communicating in a way which allows other systems to assimilate new information into their perspective of the problem. Within such a collection of agents a situated planner takes task assignments from a superior agent and creates a plan or further elaborates it before passing it to the execution support agents for further processing or enactment. The reason for taking this view is that planners cannot be considered as functioning in isolation. In addition to being able to communicate about the overall task being performed, the planner must be able to interact closely with the environment in which it is placed.

The project planning environment would be based on a network of project management tools and a plan feature server, all linked by a common project management communication language. The project management tools would be those that are currently available as commercial products, extended to be able to use the project management communication language. Existing personal information managers could also be extended to use the project management communication language.

The project management communication language would allow existing software to benefit from advanced capabilities of the plan feature server. The server would offer advanced multi-perspective planning and scheduling with multi-objective optimisation, robustness and contingency management, and would act as the central repository of progress and current world information. A project manager would be able to automatically delegate a task, via the server, and the person to whom the task is assigned would see this in his or her project management client. The project manager would be able to track progress on such delegated tasks and sub-projects, since all updates made to the central project database will be available through the project manager's client. It is essential that the client is capable of offering different perspectives on the plan e.g. activities, user roles, etc, each tailored to the need of the project manager.

The environment outlined in this vision directly addresses the problem of today's project management needs, i.e. collaboration between widely distributed organisations and it does it in a way that is consistent with government and industry investment in current project management software. Rather than ask users to throw away their existing legacy systems it aims to build on top of these existing tools. Existing software tools would require some extensions to operate using the new project management protocol and work flow management system, but the companies that provide this software will see the advantage of doing so. As with other open computing standards and environments, all participants benefit when the software communicates efficiently and effectively.

5 Applications of Knowledge Based Planners

The aim of this section is to describe a number of prototype systems which have been developed using a knowledge based approach to the generation, enactment and repair of plans. These systems are moving towards the vision described in the previous section but as yet do not fulfill the complete vision.

In each case the system is using knowledge provided by a domain expert together with a library of capabilities to guide it in the search for a solution or repair strategy. In each case the plan contains the rationale being the decisions taken in the construction of the plan. The systems described are prototypes and concept demonstrators which show how the technologies could be applied to a particular problem.

5.1 Assembly, Intergration and Validation

The OPTIMUM-AIV system developed for the European Space Agency (and now routinely used on Arianne 4 payload checkout) generates assembly, integration and validation (AIV) test plans for space vehicles and platforms. The system allows the user to monitor the progress of an AIV plan as it executes and warns the user of impending problems and plan failures. The user is presented with a series of "patch plans" (which have been defined to deal with particular plan failures) from which they can choose. The chosen patch plan is then integrated automatically into the AIV plan (using the plan's decision rationale as a guide) with any new problems e.g. resource balancing, new plan requirements, etc, dealt with automatically. The aim is to integrate the patch plan into the AIV plan with the minimum of disturbance to the other activities.

5.2 Oil Spill Recovery

The SIPE system developed at SRI in California was applied to the problem of oil spill recovery in the San Francisco bay area and was a demonstration system for the US Coast Guard. The objective of the planning task was to deploy a number of booms and skimmers to protect identified nature reserves. Using a library of different oil spill recovery methods, SIPE was able to construct a number of alternative plans which satisfied the planning task. The plans could be constructed automatically or under the guidance of a user acting in the role of a planning expert. The system used knowledge about sea conditions, tides, wind direction, etc, to decide on the position and length of booms to be deployed. The alternative plans generated by SIPE could be rated against domain dependent evaluation criteria such as cost, time, amount of oil recovered, etc. The user could then retask SIPE to develop "better" plans against these criteria.

5.3 Logistics Planning

The O-Plan system developed at the AIAI, University of Edinburgh was applied to a number of military logistics planning problems of the US military. The specific problem which was addressed was the development and enactment of plans for Non-Combatant Evacuations Operations (NEOs)[1]. The objective of the planning tasks was to fly a number of transport assets e.g. helicopter, buses, trucks, support personnel to the area, pick up the nationals from various outlying points and to fly them out of the country. Using a library of evacuations methods, and transport assets, O-Plan was able to construct, enact and repair a number of suitable plans for this task.

5.4 Search and Rescue

The search and rescue demonstrator was developed by AIAI, University of Edinburgh, for the Rescue Co-ordination centre at Petreavie near Edinburgh. The objective was to provide intelligent support to a planner who was responsible for the allocation, application and coordination of search and rescue assets e.g. helicopters, nimrods, search teams, etc. The system acted as a work flow manager showing the status of various rescues, allocated assets and those issues concerning the rescue which had yet to be addressed. The planner could then request advice as to how the issues could be resolved (and their order of solution) and be integrated into the ongoing mission.

6 Technologies which need to be Developed

Current research into intelligent planning and the systems described in the previous section have identified a number of key technologies which would be needed to develop a

[1] A NEO operation consists of evacuating nationals from a foreign country whose government has asked for assistance.

fully integrated intelligent project management system. Existing systems provide some parts of the vision but other technologies to support the vision remain to be developed. Research has already begun in a number of these areas with some technologies already reaching the prototype stage. The main technologies identified are as follows:

1. **A Plan Features Server**
   The server would use commercially-available database technology to store and retrieve project-wide plans, resources, and the like. It would use Object Data Base Connectivity to ensure that a wide range of commercial databases could be easily employed. It would provide sub-project checkout and locking facilities, and implement advanced planning and scheduling algorithms, interfaces to tools which could analyse plan robustness, contingent plans and the quality of plans being generated.

2. **A Work flow Planning System**
   The work flow planning system would allow the system capability's e.g. editors, viewers, schedulers, resource allocators, activity planners, etc, to be selected automatically (or under user guidance) to deal with specific issues in the project planning process. A series of verb/noun/modifier action descriptions would be used to define system capabilities and would be used by the work flow planning systems to provide a mapping between the tasks the user requires e.g. analyse, refine, modify, etc and the capabilities of the system. Central to this approach would be an agenda or "do list" which describes those issues the user needs to address and the tools selected to deal with them. As stated earlier this could be achieved by the user or by the work flow planning system. The agenda would form the focus of the planning process with system capabilities raising new events as needed. Ultimately this could provide a Mixed Initiative Planning (MIP) framework in which parts of the planning process could be dealt with automatically by system capabilities and others through interaction with the user.

3. **A Project Management Protocol**
   This protocol would support client/server communication, as well as server/server and client/client communication. The purpose of the protocol is to allow existing project management software to inter-operate, and to allow this software to request advanced project management inferences from the server.

4. **Project Planning Ontology**
   The ontology would define the vocabulary (the set of terms used for modelling), the structure of the statements in the world and the semantic interpretation of these terms. The purpose of the ontology is more than just the vocabulary used as its role is to constrain the interpretation of what can be expressed in the Plan Feature Server.

5. **Plan Analysis and Support Tools**
   The plan analysis tool would allow the user to compare a number of plans through a series of domain dependent evaluation criteria. The purpose of the analysis would be to create a matrix with each cell showing how the plan rates e.g. high, low,

neutral, not-applicable against the evaluation criteria. This could then be used to re-task the planner to improve the plan against one or more of these criteria. Other support tools would be needed to support plan execution and repair, plan robustness as well as task assignment and user dialogue.

7 Summary

The aim of this paper was to show how intelligent planning techniques could be used to create an environment in which existing project planning and scheduling tools could be used to handle projects dispersed across a wide area. This needs arises from the nature of projects being developed today which involve organisations working together which are located throughout countries and continents. The strengths and weaknesses of current project planning software is described showing their limitations in addressing current project planning needs.

The paper motivates the need to breakaway from the view that one tool can do everything a project manager needs to one in which planning tools are viewed as situated agents. While a planning agent deals with plan generation aspects, other agents are concerned with aspects such as task elicitation, plan analysis, reactive execution, plan repair, etc. Each of these systems has its own perspective on the planning problem and each of the systems must be capable of communicating in a way which allows other systems to assimilate new information into their perspective of the problem. An intelligent approach to project management which allows existing tools and databases to communicate more efficiently and effectively is described.

The paper describes a number of systems which have been developed using a knowledge based approach to the planning problem and the areas in which they have been applied. These system have used aspects of the vision described here and have verified parts of the vision in real world applications.

The paper concludes with a description of five different types of technology which are being developed to address the needs of project planning. These will allow current tools and technologies to communicate and to share information and knowledge about the process of project planning and the data about a specific project.