Putting Knowledge Rich Process Representations to Use

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1 Introduction

Research into the generation of plans using knowledge based techniques is now maturing and finding practical application in the commercial, industrial and defence sectors. This has led to a rapid expansion in the last couple of years of investment in this area. Ways to represent plans which have emerged from the research have been found to be of benefit in a number of areas – even when the *generation* of a plan is not the primary concern. One way in which the research is being exploited is via the use of knowledge rich plan *representations* to allow systems to improve their monitoring, analysis and advisory capabilities.

These knowledge rich plan representations are now finding use is in the area of Process Modelling – in particular for business process modelling. Enriched process models can lead to enhancements of the analysis and critiquing of business processes and can open up a variety of ways to support the synthesis and re-engineering of processes, the creation of plans and intelligent workflow management systems.

Knowledge based approaches are acknowledged as a key component in facilitating the integration of "islands of automation" in today's enterprises. Means to connect executive strategic decision making, analysis and direction with tactical planning and scheduling capabilities and on to effective operations management within an organisation may be facilitated by using AI based plan representation approaches.

The First Conference on Enterprise Integration Modelling [6] identified support for the management of change as an important area for the success of enterprise integration efforts. The working groups of the conference also believed that a combination of Artificial Intelligence (AI) and Operations Research (OR) methods as explored by the knowledge based planning community could be a good basis for this work.

2 Knowledge Rich Plan Representations

Plan representations have been developed over several decades of AI planning research [2]. They can support a rich model of processes, tasks, plans, resources and agents. These representations can be used for purposes other than plan generation. Some key concepts include hierarchical plan representations, rich activity and resource models, the capturing of the intentions behind plan steps, and languages or ontologies in which to express the activity and process models.

Knowledge rich plan representations such as those in the Edinburgh O-Plan [4] and O-Plan2 [8] planners have been used successfully in a number of projects.

The PLANIT work [5] is a prototype system produced during the UK Alvey Programme in which rich plan representations were *used* without plans being actually generated. In PLANIT, flexible plan representations provided integration across an enterprise involving project management (interfaced to the ARTEMIS system), process planning (interfaced to a Jaguar Cars' process planner) and job shop scheduling (interfaced to the UK Atomic Energy Authority's WASP scheduler). PLANIT could help the user to browse on a plan, monitor its execution and make single step modifications to it as necessary, taking into account knowledge of resources, agent capabilities, how the original plan was constructed and what the aims of the plan were.

OPTIMUM-AIV [1] is a more recent example of the use of flexible plan representations in a project management domain alongside ARTEMIS project support tools. OPTIMUM-AIV is a flexible planning and re-planning system for spacecraft assembly, integration and verification at the European Space Agency.

These two systems explicitly represent the causal structure of a plan, to hold the dependencies between the preconditions and effects of activities involved in the plan – therefore showing the rationale or intentions behind the plan. Dependencies of the same kind are useful in all aspects of plan generation, execution monitoring and plan repair.

3 The O-Plan Triangle Model of Activity

The O-Plan2 team at Edinburgh are working to simplify some of these notions from AI planning and to relate them better to existing systems engineering requirements capture and modelling languages and methods (like IDEF, CORE, HOOD, etc).

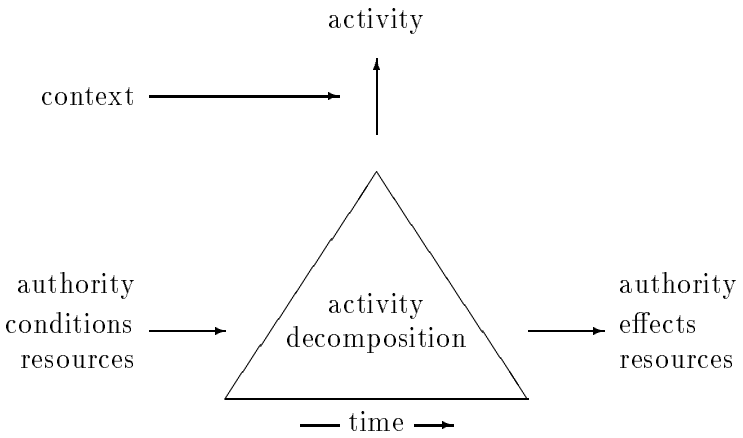

Figure 1: O-Plan2 Triangle model of Activity

This work is reflected in our "triangle" model of an activity (see figure 1). The vertical dimension reflects action decomposition, the horizontal dimension reflects time. Inputs and outputs are split into three principal categories (authority, teleology and resources). Arbitrarily complex modelling is possible in all dimensions. "Types" are used to further differentiate the inputs and outputs, and their semantics.

"Entry" to the model can be from any of the three points in the triangle model: from the top vertex to ask for activity expansions or decompositions, from the right to ask for activities satisfying or providing the output requirement (authority, goal or resource). These two sides are used mostly by AI planners to date. The third side from the left can reflect non-intended triggering conditions for an action and will be needed when improved independent processes are modelled.

The "intentions" or "rationale" behind the use of a particular activity can be related to the features of this triangle model. Normally causality or teleology via the pre-conditions/post-conditions has been used in AI planners for many years to record the plan rationale. In the richer model now in use in O-Plan2, rationale in terms of resource usage and supply or authority provision may also be stated. This makes it possible to use a uniform approach to the modelling of authority, product flow and resource requirements.

Note that there is a deliberate and direct mapping between the O-Plan2 triangle model of activity and the existing IDEF methodology (see figure 2). IDEF-0 is compared here since it has been used for modelling processes[1].

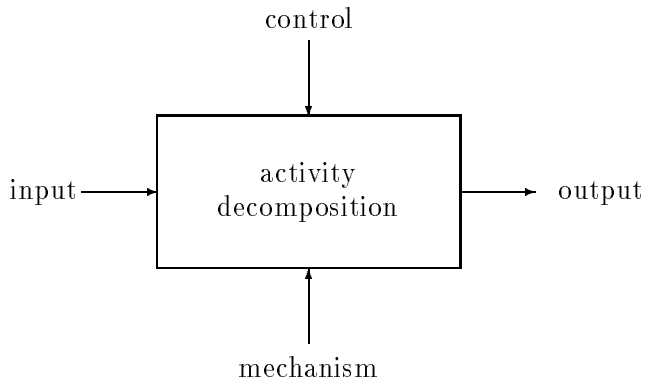

Figure 2: IDEF-0 model

IDEF modellers usually use "control" for authority related triggers and "mechanism" to reflect resource availability. A criticism of IDEF is the lack of direct support for modelling the different types of output and their intended destination. Experienced IDEF modellers use the arc labels, naming conventions and the "notes" system in an IDEF support "kit" to encode this information.

[1] IDEF-3 is a later more comprehensive IDEF method specifically targeted at the modelling of processes.

The O-Plan2 triangle model more directly supports this and will allow for improved support tools.

4 Using Knowledge Rich Plan Representations for Process Management

O-Plan2 has a three level modelling approach[2] that relates a high level of executive strategic decision making, analysis and direction with middle level tactical planning and scheduling capabilities and on to effective lower level operations management within an organisation.

Our approach is to offer an overall vision of an *Executive Communication and Control* environment in which an enriched corporate model (knowledge and data bases) is utilised to offer an "add-on" to existing tools used in companies such as those for option analysis, risk analysis, business case analysis, project management, workflow management, etc. In this framework, we are seeking to improve the types of process models that can be captured and to enrich these models in ways that may be done informally in today's requirements capture and modelling tools. The enriched representations allow for improved analyses and open the way to a new generation of tools for business process management that will provide enhanced aids to:

- reliably capture and maintain process knowledge and models
- make decisions using knowledge based simulation and analysis
- synthesise processes
- re-engineer parts of a process
- reliably execute processes
- simulate, animate, explain and justify processes

Our approach uses *open* and *inspectable* knowledge based representations of processes, tasks, plans and schedules in which dependencies, constraints and preferences are maintained. Our work in process management draws on experience with Nonlin [7], O-Plan, O-Plan2, PLANIT and OPTIMUM-AIV as follows:

- the use of a 3-level view (at strategic, tactical and operational levels) with task assignment, planning and control roles (O-Plan2).
- knowledge rich plan representations summarised in the triangle model of activity (Nonlin, O-Plan and O-Plan2).
- process and plan impact assessment/critiquing (Nonlin, PLANIT).

[2] What is being done is to *augment* earlier methods and approaches, rather than starting afresh and replacing or reinventing what has already been achieved.

- constrained plan editing and single step plan modification option review (O-Plan and PLANIT).
- plan generation technology (O-Plan).
- plan question answering, state generation, simulation and animation (Nonlin and O-Plan2).

With enriched process representations and using knowledge based approaches, it is possible to go beyond *what if?* option analysis and to generate *how to?* option proposals. Higher level component processes can be selected, combined and tailored to specific requirements. Intentions and dependencies captured in process models allow for the enhancement of the capabilities which can be provided to the executive and operational staff.

5 AIAI's Vision for Process Management

Our visualisation of knowledge base supported process management in an organisation is:

Strategic Level Consider that there is support to establish the following:

- organisational processes and constraints reliably captured along with their underlying intentions and dependencies
- lead applications identified, cost benefit analysed, risk analysed and rated using business case support tools
- key objectives and tasks stated, constraints identified
- top level options generated and evaluated
- programme road map created

Tactical Level On the basis of the information generated above, we use constrained plan editing, partially or fully automatic plan elaboration, scheduling, etc. We fit this level to project management tools in the market today and show how these can inter-work. We add plan creation, querying, simulation and animation capabilities to significantly enhance the capabilities available to planners and schedulers today.

Operational Level Then we use the information and its embedded rationale, enriched resource and authority model to fit to (intelligent) work flow managers or process support environments (e.g. such as ProcessWise [3]) and use these as the point of delivery and control of reliable enactment of the plans and schedules in an enriched environment where plan tracking, question answering, explanation, options reworking, reaction and recovery are all possibilities future.

Acknowledgements

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References

[1] Aarup, M., Arentoft, M.M., Parrod, Y., Stader, J., Stokes, I. & Vadon, H., *OPTIMUM-AIV: A Knowledge Based Planning and Scheduling System for Spacecraft AIV*, in Knowledge Based Scheduling, (eds. Fox, M. & Zweben, M.), Morgan Kaufmann, 1994.

[2] Allen, J., Hendler, J. & Tate, A., *Readings in Planning*, Morgan-Kaufmann, 1990.

[3] Bruynooghe, R.F., Parker, J.M. & Rowles, J.S., *PSS: A System for Process Enactment*, published paper from ICL, Kidsgrove, Staffs ST7 1TL, UK, 1992.

[4] Currie, K.W. & Tate, A., *O-Plan: the Open Planning Architecture*, Artificial Intelligence, Vol. 51, No. 1, North-Holland, Autumn 1991.

[5] Drummond, M.E., & Tate, A., *PLANIT Interactive Planners' Assistant - Rationale and Future Directions*, AIAI-TR-108, AIAI, University of Edinburgh, 1992.

[6] Petrie, C.J. (ed.), *Enterprise Integration Modelling*, Proceedings of the First International Conference, MIT Press, 1992.

[7] Tate, A., *Generating Project Networks*, Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI-77), Cambridge, Mass. USA, 1977.

[8] Tate, A., Drabble, B. & Kirby, R., *O-Plan2: an Open Architecture for Command, Planning and Control*, in Knowledge Based Scheduling, (eds. Fox, M. and Zweben, M.), Morgan Kaufmann, 1994.