

A CASE STUDY: USING WORKFLOW AND AI PLANNERS

MD R-Moreno¹, Paul Kearney² and Daniel Meziat¹

¹*Departamento de Automática. Universidad de Alcalá. (Madrid). Spain*
{mdolores,meziat}@aut.uah.es

²*BTexaCT Research, British Telecom. (Ipswich). UK.*
paul.3.kearney@bt.com

ABSTRACT

This paper argues that the use of AI planning techniques with existing Workflow Management Systems can improve overall system functionality and help to automate the definition of business processes. It is based on a short study carried out at BT Research Laboratories as part of a larger programme that aims to provide technologies for a new generation of business support systems. An initial overview of an operational system is introduced to discuss about some of the background to the problem and how these problems can be resolved using contingent planners.

We describe a simple construction problem to demonstrate the advantages of the approach advocated.

INTRODUCTION

The success of companies depends not only on matching their products and services to market requirements, but more and more on the processes and methods used to produce them. This is evident in the interest in recent years in techniques such as Business Process Re-engineering [7,19]. Challenges include achievement of: shorter times from order to delivery; the ability to launch a new product or service rapidly; efficient logistics; and the right balance of quality and price. Quality of customer service is also extremely important, and the needs of not only external but also internal customers has to be considered.

A core business process is the end-end chain of activities involved in delivering a product or service to a customer. 'End-end' signifies that a business process starts with initial contact with the customer and runs through to completion of the contract (including billing and payment). In addition to core business processes, there are management processes (including processes concerned with designing the core processes) and support processes that facilitate the other types of process. The set of business processes for an organisation comprises the organisation's working practices. Organisations differ in how explicitly the processes are defined, and in the form they are represented. In some cases the processes are implicit, in others they are recorded in textual codes of practice, in others they are documented in (semi-) formal representations and/or software modelling tools.

In recent years, a new class of software infrastructure product to support business processes has emerged: Workflow Management Systems (WfMS) [3,4,18,24]. A WfMS can provide active support to a business process by controlling the routing of work around the organisation automatically. This is done based on input describing the flow, the decisions, the exceptions, the resource to be used, etc. It co-ordinates user and system participants, together with the appropriate data resources, which may be accessible directly by the system or off-line to achieve defined goals by set deadlines. The co-ordination involves passing tasks to participants' agents in correct sequence, ensuring that all complete their tasks successfully. In

case of exceptions, actions to resolve the problem can be triggered, or human operators alerted.

Prior to WfMS, many enterprises created special-purpose bespoke applications to support their processes. The advantage of WfMS-based solutions is that the workflow representation is explicit, and separated from the application code. This means that a WfMS can be customised quickly to support a new business or process, and that workflows are relatively easy to modify should a process change. Current WfMS do not address all aspects of the problem, however. Specifically, they do not deal with scheduling or resource management/allocation. Similarly, while they provide means of generating exception events when things go wrong they do not have a built-in re-planning function. They do, however provide interfaces so that application-specific modules performing these functions can be integrated.

To date, there is no clear classification of workflows [12], but there is broad agreement in classifying them into three categories: *ad-hoc* (require extensive human co-ordination for their operations, the execution path may be different for different workflow instances and is defined as the same time as it is performed) *administrative* (in which the workflow execution is repetitive and predictable, and it follows a well defined execution path) and *production* (involve the co-ordination of organisational information processing systems that are usually based on database management systems). Current WfMS primarily address *administrative workflows*. The system on which we have based our research can be categorised as *administrative workflow*, but with a requirement for integrated scheduling, resource allocation and re-planning during execution.

Recently, there has been considerable interest in the application of Artificial Intelligence techniques to Workflow Management systems. The lack of maturity that the area of Workflow Management presents due to its short history can be addressed by introducing techniques from other fields. Some researchers have seen the advantages of the integration of this approach, as shown by the existence of a Technical Co-ordination Unit of the European research network on planning and scheduling, PLANET [27], on applications of planning and scheduling to workflow. This has led to some exploratory work reflected in a roadmap and some published papers [17,22,25]. Although the MILOS project [8] of the Artificial Intelligence Group at the University of Kaiserslautern and the Software Process Support Group at the University of Calgary or the AI group at Edinburgh University in the TBPM project [16,30] have addressed the problem, to date very few tools have been developed using these ideas [23].

In this paper we highlight the improvements that a legacy system can gain by incorporating contingent planners into its day-to-day operation.

We first introduce the terminology of Workflow Management Systems. COSMOSS, a purpose-built legacy workflow application in use at BT is then described. Then we review contingent planners, an AI technology that addresses issues found in the COSMOSS application. After this, the similarities between both workflow management and planning are presented. We conclude with an example, based on a COSMOSS scenario, that illustrates how ideas from the two fields may be merged.

WORKFLOW TERMINOLOGY

This section introduces some workflow terminology used in the paper. For a deep description see [6,33]:

- *Activity*: is a description of a piece of work that has to be done.
- *Agent*: an entity (software or human being) that can perform an activity. Each agent has a role in the process.
- *Organisational Unit*: an entity responsible for managing the resources (agents) able to perform the activities. An organisational unit can be a department, a working group, etc.
- *Pre-condition*: a logical expression which may be evaluated by a workflow engine to decide whether an activity within a process instance may be started.
- *Process*: one or more linked activities to achieve a specific goal or goals within the context of an organisational structure, defining roles and relationships.
- *Post-condition*: a logical expression which may be evaluated by a workflow engine to decide whether an activity within a process instance is completed.
- *Roles*: a positions in a hierarchy of responsibilities that the agents can occupy.
- *Transition condition*: a logical expression which may be evaluated by a workflow engine to decide the sequence of activity execution within a process.

To provide a frame of reference, we identify four stages in Workflow Systems as in [25], although some authors only identify three [15,29]:

- *Process Modelling*: is the stage where the user designs, models, optimises, simulates the organisation's processes. We include in this stage design of the process templates that can be instantiated and enacted by a workflow system.
- *Process Planning*: is the stage where the activities required to achieve a user goals are instantiated in a determined order, resources assigned, and preliminary scheduling performed.
- *Enactment/Execution*: in this stage the agents (software and humans) carry out the activities, with the workflow system coordinating execution .
- *Monitoring*: this is conducted concurrently with Enactment/Execution. The system enacting the workflow is monitored, with status information being made available to human operators. Exceptions, such as deviation from the plan, and subsidiary processes initiated to rectify problems.

The use of AI planning techniques has been applied to the *Process Planning* stage.

A LEGACY WORKFLOW SYSTEM

COSMOSS (Customer Orientated System for the Management Of Special Services) [5] provides support for progressing orders concerning provision of private lines. It was built at the beginning of 90's and it handles about a dozen main product families divided into digital and analogue categories.

The business processes start with a customer contacting a call centre to place an order. The representative in the call centre gathers information from the caller about the customer and the service required in the form of a Service Order. This is passed automatically to COSMOSS for completion where it becomes a job. The job is decomposed into activities by matching against a set of job templates. Target times are then derived for these activities based on information stored in the job and activity templates and the customer requirements. These activities, with target start and completion dates, are passed to other OSSs¹ where they are allocated and enacted. Progress is reported back to COSMOSS.

The main COSMOSS modules are:

- Order taking module.

¹ Operational Support Systems

- Product Register. This interfaces to the portfolio database - PDB – which holds information on 90% of BT's product range. This is also used by other systems.
- Customer and site database. This holds information on customers and their premises, and is basically specific to the COSMOSS system.
- An engineering database.
- Job Management module.

A service order (with its parameters) is used to create a job, which is decomposed into activities linked by dependencies. When a job template is created, activity templates are copied into it as job template activities, which can then be modified. There is no link between job template activities and activity templates but there are properties of activity templates that can be overridden by a job template. One can define up to 10 attributes of an order which are used to drive template selection. There are selection criteria associated with a template. The selection is performed using template selection rules. The rules are defined by human experts, and validating rules and data is a significant problem.

Activity templates may have conditions to be met for them to complete. Activities also have 'input criteria': these are similar to pre-conditions. They can be used to prune branches of the process tree that are no longer potentially relevant. When a process is initially instantiated, it generally is under-specified, including alternative branches, only some of which will be used. Activities early in the process tend to gather information, which will contradict the input criteria of some later activities, ruling out the associated branches.

This adds complexity to the date rescheduling process and to job progression generally as activities will only be copied from the template data into the job when they are actually needed.

This corresponds to *Process Planning*; the appropriate template is identified, instantiated, and the instance is elaborated in sufficient detail to be executed. In COSMOSS, the *Process Modelling* stage corresponds to design and creation of the Job and Activity Templates.

Conditional processing controls which activities actually become part of the job by prompting the users with questions that they must answer. Different answers will cause different activities to be created in the job.

The software will construct a schedule for a job by trying to meet either the Customer Requirement by Date (CRD) or the Target Completion Date (TCD), whichever is the later. COSMOSS uses a common algorithm – critical path analysis to apply date rules to a template to adjust the overall dates of the order and the window lengths of the activities within the template, to ensure the Job is completed by the CRD. It is worth noting that when the job is created it will be scheduled according to the content of the whole template. Once the job and the corresponding activities have been selected, they are assigned to 'owners' (or rather queues) for its completion. Usually an owner is an organisational unit, but it could be a queue for another system.

At the moment the activities are assigned to agents (bearing in mind the computer programs and the human and material resources available in the system as well as the roles they can hold), the *Execution phase* begins. During execution information of the activities completion, delays and other problems must be detected and reported; this is the *Monitoring phase*. In COSMOSS this information is sent to a human manager in the customer service centre. This manager can take the appropriate measures to rectify the situation, or at least to try to ensure that the situation does not recur: in some cases, the problem can be resolved adding some templates. In other more drastic cases, a new job template must be required (that is, a new plan).

Figure 1 shows a real template used in COSMOSS. The alphanumeric codes designate specific activity templates. We will not attempt to explain their meaning as most of the

terminology is highly specific to the domain. We present the figure only to show the basic of a template as a network of activities linked by dependencies.

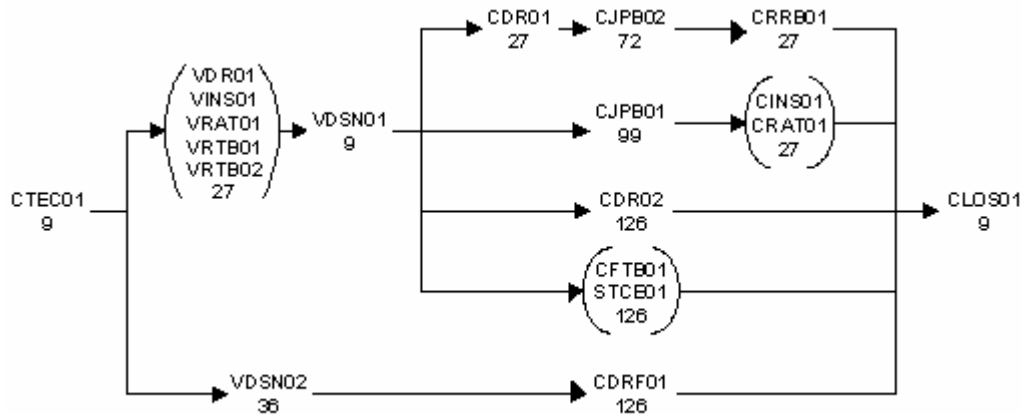


Figure 1. Job Template

This template is used for Generic International Cease (handling a customer request to cease an international line). The job starts with the execution of CTEC01. The owner of the CTEC01 activity will be asked the following questions on completion of the activity:

1. Is this a GENETIC² Cease? Y/N
 Y Include VDR01 Goto 2
 N Goto 3
2. Is any Copper plant to be ceased? Y/N
 Y Include VRTB01 exit
 N Exit
3. C=Copper or L=LLFN to be ceased C/L
 C Include VINS01 and VRAT01 exit
 L Include VRTB02 exit

The first question will produce two decisions: if the answer is “No” the activity VDSN02 will be executed, if the answer is “Yes”, it is also has to be considered if the *p*lant to be ceased is *Copper*, execute VRTB01, VINS01 & VRAT01, other ways (*LLFN*) VRTB01&VRTB02.

In the VDSN01 activity the following questions will be asked:

1. Is this a GENETIC Cease Y/N
 Y Goto 2
 N Include CJPB01 and CINS01/ CRAT01 exit
2. Cease S= STREAM A=AGGREGATE M= MULTISTREAM S/A/M
 S Include CDR01, CJPB02 and CRRB01 exit.
 A Include CDR02 exit
 M Include CFTB01 exit

The first question in the VDSN01 activity is the same one as the CTEC01, the reason to repeat the question is to avoid redoing all the design if the user answers the question incorrectly by an oversight. In that case, the user will have to choose between CINS01 or CRAT01 to repair the mistake. Sometimes this could be quite tedious, so the system allows an *Automatic conditional response*, that is, the system will consider that the answer of question 1 in VDSN01 is Yes (assuming that the answer to the first question in CTEC01 is Yes) and jump that question so the user will only answer the second question (S/A/M). The STCE01 activity is included only when special features of the line are required.

² Generic Network Integration and Configuration

Readers knowledgeable about AI planning will recognise many of the issues addressed here, though the terminology may be unfamiliar. The designers of COSMOSS developed an *ad hoc* and domain specific solution without knowledge of the great body of planning research that might have enabled a more elegant and manageable solution. As an example of the improvements that could have been achieved, we consider how AI planners can help to avoid the 'oversight' problems in the template answers and speed up all the design templates..

CONTINGENT PLANNERS

Most the classical planners [1] use the assumption that there is no uncertainty in the world: every action has a predictable output. To automate COSMOSS job template design we need a planner that could have different outputs depending on the action that is required to complete the service. That means that the majority of the classical planners cannot be used for this purpose.

Why contingent planners? A contingent plan is a plan that contains actions that may or may not actually be executed, depending on the circumstances that hold at the time. A contingent planner must be able to produce plans even if the initial conditions and the outcomes of some of the actions are not known . Several contingent planners can be used to automate the Activity Template selection in a Job Template: Cassandra [28] is a partial-order, contingency, domain-independent problem solver architecture based on UCPOP [14,31]. SGP[32] is an extension of the Planning Graph Analysis algorithm Graphplan [2] to support uncertainty in initials conditions and actions. CNLP [26] uses the basic SNLP algorithm to construct contingents plans, PLINTH [13] is a total order plan very similar to CNLP in its treatment of contingency plans. SENS_p [10] likes Cassandra is based on UCPOP but differs the way it represents uncertainty. All have in common the use of extended STRIPS-based action representation [11] Another type of planner that we considered was the probabilistic contingency planner exemplified by C-BURIDAN [9]. However, the fact that those planners are based on a probabilistic model make them unsuitable for use with COSMOSS.

For the purpose of this study we have used the planner Cassandra, but any of them could be used. To construct plans in Cassandra, all the possible uncertainty outcomes of actions must be known a priori., that is, the planner must be able to enumerate these contingencies. Each single operator may introduce any number of sources of uncertainty with mutually exclusive outcomes. Every source of uncertainty is a decision to make.

As explained in the last section, each Activity in COSMOSS may have conditions that define possible user answers. All the possible answers are known at design time. These answers will cause different Activity templates to become part of a job at execution time. This is also how Cassandra works: if a decision cannot be made in advance due to lack of information, the agent will choose which branch to follow when the information becomes available during execution of the plan.

POINTS OF CORRESPONDENCE

To can understand how a contingent planner could be integrated with COSMOSS, let us introduce the following relationships: (for a high level description of merging AI planning techniques and Workflow, go to [23])

Inputs of a planner:

- **Domain theory:** Actions are represented by so-called operators. Each operator will be used to represent each Activity in COSMOSS. The pre-conditions of the operator are the pre-conditions of the Activity, and the post-conditions or effects are the expected results after completion of the Activity. If the Activity has conditions (that will be used to prompt to the user at execution time), each of the possible answers will be used to represent each source of uncertainty in the operator.
- **Problem:** in COSMOSS the problem is to determine a process that will result in a service that will satisfy the customer's requirements. These requirements will be used to specify the initial state and goals. Actually in COSMOSS, the design of the process is done manually by a user who chooses which Activity template must be part of the Job in order to complete the service.
- **Initial state:** is determined by the information in the customer order, that is, the user location, the existence of a line that can be reused, the urgency of the work, etc.
- **Goals:** The service the user requires and that is offered by COSMOSS, e.g. the on-time installation of the telephone line.

Outputs of a planner:

The planner generates a sequence of instantiated Activity Templates that will be part of the Job. As Cassandra is derived from UCPOP, it also allows actions that can be executed in parallel.

In the next section, we present a simple example that illustrates all the concepts introduced in the last two sections.

A SIMPLE EXAMPLE

A customer contacts BT customer service (over the phone, in a BT shop or via the Internet) to ask for a new telephone line. At this point the business process starts (if the user agrees to the terms and conditions). The customer details are needed to see if he is an existing customer and already has a line with BT (in that case, a discount will be applied to the second line). If the customer is asking a line for the first time, a spare pair of wires must be available from the house to make a connection from the Distribution Point (DP, e.g.: telegraph pole). If no pair available then a new cable must be built (and feed back to customer that the delivery date will be delayed, as putting in a new cable from DP to exchange)

Afterwards, it is necessary to check that there is a spare line card available in the exchange (in that case it is reserved/allocated). If none is available installation must be arranged. Installation involves making the connection at the DP (connecting a drop wire to the pair of wires that lead back to the exchange).

Then, someone must:

- contact the customer to arrange a visit to the house to fit new NTE (network terminating equipment, that is, the box on the wall that the phone is plugged into);
- arrange for an engineer to turn up on the right day/time to test the line end to end and install the NTE;
- allocate a telephone number to the new line and configure the exchange;
- update the exchange, line plant and customer records;
- and of course, check with customer that he is happy with the service.

Figure 2 shows the plan that Cassandra builds for this particular example. The decision-steps in the plan and all possible outcomes of uncertainty are represented in same way that the authors of Cassandra use in [28]. This particular plan has three sources of uncertainty: the existence of a line, the existence of spare pair and the availability of a card spare.

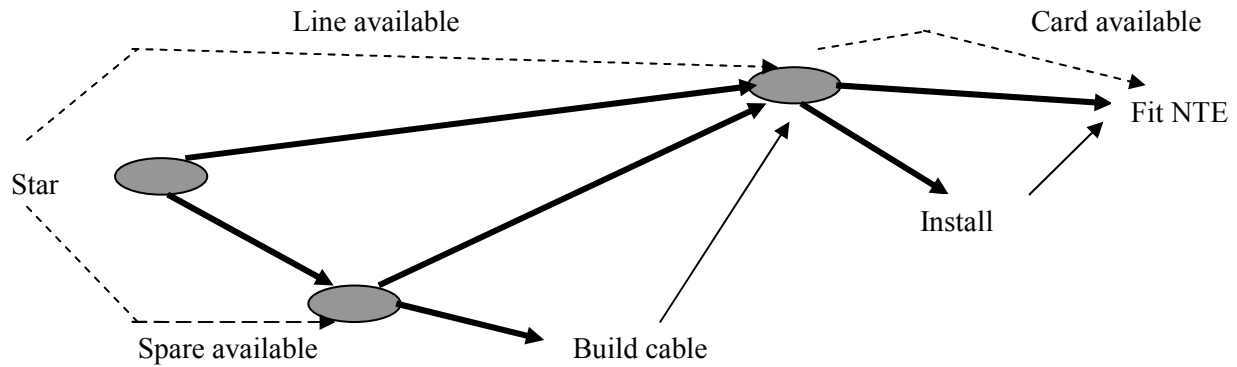


Figure 2. A plan for putting a new telephone line

Each of the possible actions/operators in Cassandra will be matched to a particular Activity Template in COSMOSS. Figure 3³ shows the Job template with its activities for the example of Figure 2.

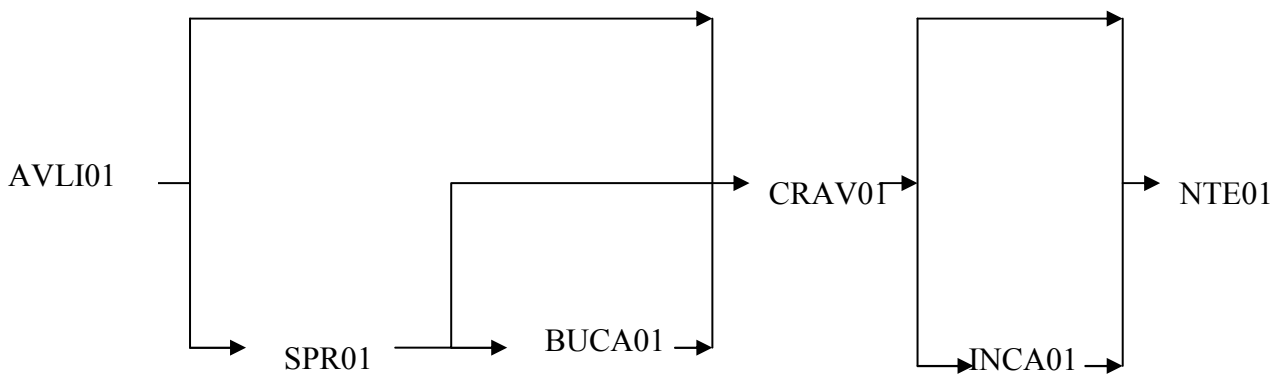


Figure 3. Job Template corresponding to the plan of Figure 2.

CONCLUSIONS AND FUTURE RESEARCH

We believe that there is great potential for applying AI planning techniques within workflow management systems. This benefit will be realised as much by introducing workflow specialists and software engineers to planning concepts and representations as by direct application of planning software. Particular areas worthy of attention are: scheduling and

³ The template shown in the Figure has been created for this particular example, and does not exist as such in COSMOSS.

resource allocation, process design (generation of contingent plans), elaboration of process instances at instantiation and during execution, monitoring [20] for (and anticipation of) deviations from plans, and re-planning in the event of such exceptions. Learning techniques [21] could also be applied, allowing e.g. optimisation of processes over time. In this paper we have focussed on how the contingent planner, Cassandra, can help to automate the design of appropriate templates in a legacy system used to support the business processes at BT.

ACKNOWLEDGEMENTS

The first author wants to thank all the Intelligent Business System for their help and collaboration shown during the period of time at BT Adastral Park, specially Paul O'Brien, Jamie Stark and Simon Thomson. Also to Simon Martin and Daniel Ballin for their comments on this paper and Nigel Irons for all the support that he has given us with COSMOSS. We also want to thank Daniel Borrajo.

REFERENCES

- [1] Austin Tate, James Hendler, Mark Drummond. *A Review of AI Planning Techniques*. *Knowledge Engineering Review* Volume 1, Number 2, pages 4-17, June 1985.
- [2] Blum and M. Furst, *Fast Planning Through Planning Graph Analysis*. *Artificial Intelligence*, 90:281--300 (1997).
- [3] Bogia, D. and Kaplan, S. *Flexibility and Control for Dynamic Workflows in the Worlds Environment*. In: *Proceedings of the ACM Conference on Organisational Computing Systems*, pp 148-159. 1995. Milpitas California.
- [4] C. Mohan. *Recent Trends in Workflow Management Products, Standards and Research*. In *Proc. NATO Advanced Study Institute (ASI) on Workflow Management Systems and Interoperability*, Istanbul, August 1997, Springer Verlag, 1998. http://www.almaden.ibm.com/cs/exotica/exotica_papers.html
- [5] Chandler J. *Management of special services: designing for a changing world*. *BT Technol Journal*, Vol 15, No 1, January 1997.
- [6] Cickocki, A. Helal, A. Rusinkiewicz, M. and Woelk, D. *Workflow and Process Automation: Concepts and Technology*. Kluwer. 1998. Academic Publishers, ISBN 0-7923-8099-2
- [7] Davenport, T. and Short, J. *The New Industrial Engineering: Information Technology and Business Process Redesign*. *Sloan Management Review*, pp 11-27. 1990.
- [8] Dellen, B. Maurer, F. and Pews, G. *Knowledge Based Techniques to Increase the Flexibility of Workflow Management*. *Data and Knowledge Engineering*, North-Holland. 1997. <http://wwwagr.informatik.uni-kl.de/~comokit>
- [9] Drapper D., Hanks S., & Weld D. *A probabilistic model of action for least-commitment planning with information gathering*. In *Proceedings of the Tenth Conference on Uncertainty in Artificial Intelligence*, pp 178-186 Seattle, WA, Morgan Kaufmann.
- [10] Etzioni O., Hanks S., Weld D., Draper D., Lesh N. and Williamson M. *An approach to planning with incomplete information*. In *Proc 3rd International Conference on Knowledge Representation and Reasoning*, pp 115-125. Boston, MA. Morgan Kaufmann.
- [11] Fikes R. E, Nilsson N. J. *STRIPS: a new approach to the application of theorem proving to problem solving*. In *Artificial Intelligence*, 2:189-208.
- [12] G. Alonso, D. Agrawal, A. El Abbadi and C. Mohan. *Functionalities and Limitations of Current Workflow Systems*. *IEEE Expert*, 12(5), 1997.
- [13] Goldman R.P. and Boddy M.S. *Conditional Linear Planning*. In *Proc. 2nd International Conference AI Planning Systems*, pp 80-85. Chicago, IL. AAAI Press.

- [14]J.S.Penberthy and D. Weld. UCPOP: *A sound, complete, partial order planner for ADL*. In Proc. 3rd Int. Conf. On Principles of Knowledge Representation and Reasoning, pages 103-114, Oct 1992.
- [15]Jarvis P, Stader J, Macintosh A, Moore J, & Chung P. *A Framework for Equipping Workflow Systems with Knowledge about Organisational Structure and Authority* .In Proceedings of the Workshop on Systems Modeling for Business Process Improvement (SMBPI-99), University of Ulster, County Antrim, Northern Ireland, UK, pp 205 - 219.
- [16]Jarvis P. et al. *What right do you have to do that?*. In ICEIS – 1st International Conference on Enterprise Information Systems. Portugal, 1999. <http://www.aiai.ed.ac.uk/project/tbpm/>
- [17]Karen L. Myers and Pauline M. Berry. *At the Boundary of Workflow and AI*. In AAAI-99 Workshop on agent-Based Systems in The Business Context. Brian Drabble and Peter Jarvis Cochairs.
- [18]Leymann. F., and Roller. D. *Business Process Management with FlowMark*. Proceedings of IEEE Comppcon, March 1994.
- [19]M.Hammer and J. Champy. *Reengineering the Corporation*. Harper Business Press, New York, 1993.
- [20]Manuela Veloso, M. E. Pollack, and M. T. Cox. *Rationale-based monitoring for planning in dynamic environments*. In Proceedings of the Fourth International Conference on AI Planning Systems, 1998.
- [21]Manuela Veloso. *Learning by Analogical Reasoning in General problem solving*. PhD thesis, Carnegie Mellon University, Pittsburgh, PA, 1992.
- [22]Markus Hannebaeur. *From formal Workflow models to Intelligent Agents*. In AAAI-99 Workshop on agent-Based Systems in The Business Context. Brian Drabble and Peter Jarvis Cochairs.
- [23]MD R-Moreno, D. Borrajo, D. Meziat. *Process modelling and AI planning techniques: A new approach*. 2nd International Workshop on Information Integration and Web-based Applications & Services. IIWAS2000. Yogyakarta.
- [24]Medina-Mora, R. Winograd, T. and Flores P. *Action Workflow as the Enterprise Integration Technology*. Bulletin of the Technical Committee on Data Engineering, 6(2), 1993. IEEE Computer Society.
- [25]Paul Kearney and Daniel Borrajo. *An {R&D} Agenda for AI Planning applied to Workflow. Management* Proceedings of the eBusiness and eWork Conference 2000.
- [26]Peot M.A and Smith D.E. *Conditional Nonlinear Planning*. In Proc. 1st International Conference AI Planning Systems, pp189-197. College Park, Maryland. Morgan Kaufmann.
- [27]PLANET: European Network of Excellence in AI Planning. <http://planet.dfki.de/>
- [28]Pryor L, Collins G. *Planning for Contingencies: A Decision-based Approach*. Journal of Artificial Intelligence Research 4 (1996) 287-339.
- [29]Sigrid Goldmann, Jürgen Munich, Harald Holz. *Distributed process planning support with MILOS*. To appear in Int. Journal of Software Engineering and Knowledge Engineering, October 2000.(y)
- [30]Stader J. *Results of the Enterprise Project*. Proc. 16th Int. Conference of the British Computer Society Specialist Group on Expert Systems. Cambridge, UK, 1996.
- [31]Weld D. *An Introduction to Least Commitment Planning*. Artificial Intelligence Magazine, Winter, 27-61. 1994.
- [32]Weld D., Anderson C, Smith D.E. *Extending Graphplan to Handle Uncertainty and Sensing Actions* . AAAI98. 1998.
- [33]Workflow Manage Coalition *Terminology & Glossary*. <http://www.wfmc.org/>