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PROCESS MODELLING AND AI PLANNING TECHNIQUES: A NEW APPROACH.

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ABSTRACT

Nowadays the efficiency of the internal workings of organisations strongly depends on company processes. Over the past few decades, Business Process Reengineering has become fashionable among medium and big enterprises due to its capacity to present solutions that improve their processes. Although there have already been many approaches to the computer-aided design of processes, very few have concentrated on the automatic generation of process models. In this paper we present an initial overview of an approach to this type of solution. We describe how the integration of a process modelling tool, SHAMASH, with Artificial Intelligence (AI) planning techniques might be performed in order to automatically generate useful process models.

The AI community has been working over the last decades in different and complex domains like robotics, satellites or military logistics. AI has proven its maturity in planning and scheduling problems. All the research, experience and effort that this community has accumulated to solve problems could serve to solve other problems within the Workflow community. Workflow technology is a relatively new technology compared to AI. These two areas could have a positive influence on the modelling of processes and building of workflow engine. Some researchers have seen the advantages of this integration and there are already some papers written about points common to both fields, but very few tools have incorporated these ideas.

SHAMASH is a tool that allows simulation, modelling and optimisation processes taking into account a realistic model of the organisation, including interaction models between people. To make the work even easier for the user, who designs the processes, the tool generates automatically the models that the user could modify at will. This aspect combined to the features that the tool embodies make SHAMASH a powerful tool for the Business Process Reengineering.

INTRODUCTION

Due to the competitive nature of businesses and the strong pressure of the market, quality initiatives and the gradual improvement of processes are not enough for the continuous and dynamic changes that current organisations need. Nowadays organisations do not look for incremental percentage of improvement of say 10%, but multiplicative improvement of, for example, 15*X or more. Levels of changes so radical need new and powerful tools that can allow the redesign of the work. This is the main objective of Business Process Reengineering (BPR) [12].

In the last few years an increasing development of graphical documentation tools and/or process modelling techniques have emerged to capture the knowledge of the current processes. These business processes (BP) are represented as *workflow,* that is, computerised models within which all the parameters needed for the completion of the processes can be defined: orders, tasks, conditions, the information flow to support the tasks, resources involved, etc. Workflow Management Systems (WFMSs) have been widely deployed in sectors like insurance, banking, accounting, manufacturing, telecommunications, administration and customer service [18,27].

Workflow systems hold the promise of facilitating the everyday operation of many enterprises and work environments. Despite the popularity of these products, there is still a lack of maturity in some respect, that could be overcome using techniques coming from other fields such as AI. For several years, the AI community and in particular the planning and scheduling field, has been applying such techniques in different and complex domains like robotics, satellites or military logistics. We believe that all the research, experience and effort that this community has shown to solve problems could now be useful to solve other types of problem within the Workflow community.

Most workflow tools allow the user to define a model of one process of an organisation, potentially simulate it, and finally enact it within the organisation. As we have pointed out in some other work [5], very few tools allow more complex behaviour to be defined, such as: more detailed modelling than just having activities and attributes of those activities, automatic validation and optimisation of the models, or generation of HTML output, that allows people from the organisation to freely browse the processes in which they intervene.

SHAMASH is a tool that allows modelling, simulation, and optimisation of processes using a more realistic detailed model of the organisation. However, in its current form, the user is required to introduce the model into the system by defining: how activities relate to each other, and how they link. To help the user, who designs the processes, it would be very useful to have tools that automatically generate the models. Our hypothesis is that AI planning and scheduling tools and techniques could be used for this purpose, given that they have been applied successfully to other similar domains, such as, space missions [23,24] in which sequences of activities must be linked together to achieve given goals. Other researchers have seen the advantages of the integration of this approach, as it shown by the existence of a Technical Co-ordination Unit of the European research network on planning and scheduling, PLANET [19], on applications of planning and scheduling to workflow. This has lead to some exploratory work reflected in a roadmap [20] and some published papers [11,16,17]. However, to date few tools have been developed using these ideas.

This article is structured as follows. First, a general overview of the process modelling tool SHAMASH is given and the basic concepts of a workflow model are described. Then, the AI planning techniques and the analogy with the workflow model is explained. Later the integration between both fields is shown. Finally, conclusions are drawn and future research outlined.

THE SHAMASH SYSTEM

In this section an overview of the SHAMASH architecture is given. For a more detailed description, the reader can refer to [1,5]. Basically the SHAMASH tool consists of four subsystems:

- **Author subsystem:** this module provides a user-friendly interface that enables definitions of three types of knowledge: on standards, on processes and on the organisation. The standards, or norms, constrain how processes should behave. The interface allows the user to create their structure, related standards or processes, or organisation resources to be used. Processes are computational “units” within the organisations. The user can describe the sequence of steps to be completed to accomplish some goal. Each step or activity has pre- and post-conditions that define its behaviour. Once the user has defined his/her processes, the tool allows connection of the related process so they can be simulated and optimised. SHAMASH also allows the user to define libraries of processes to be used in other modelling applications.

- **Simulation and optimisation subsystem:** this is an important part of the modelling tool. The simulator can check the behaviour of the process that the user has created. SHAMASH also helps in detecting static problems (using validation expert heuristics) and spotting problems that can only be detected when the model is running (as underused resources or bottlenecks). Also, the tool is able to automatically perform an optimisation phase by which new optimised models are generated. The user can decide whether to adopt the new models, or to continue with the old ones.

- **Text generation subsystem:** this subsystem is responsible for maintaining coherence between the graphical (defined by specific people in the organisation) and the text versions (the ones seen by most people in the organisation). Sometimes we could need a graphical representation of the processes, sometimes we will need plain text, and in other cases we could need it in a mixed format. If there is a change in the graphical representation, SHAMASH allows to automatically generate a new HTML version in accordance with the changes made.

- **Workflow interface subsystem:** SHAMASH cannot directly be used as a workflow engine. An interface is needed to automatically translate the defined process models into the input of a workflow engine. As a result, a WPDL (Workflow Process Description Language) can be generated as output of the process representation.

The tool also allows the user to create and maintain knowledge about the organisation through a friendly interface. The behaviour of the model is defined through objects and rules with a well-defined and easy-to-use syntax. This allows detailed specification of how activities are performed, what inputs they take and in what format, how the outputs are generated from the inputs, etc. The next section describes in more detail the knowledge model of the tool related to activities. Given that SHAMASH is still under development to become and will eventually become a commercial tool, we cannot provide detailed description of the internals of the tool. However, we do supply the needed information to understand how the integration of workflow modelling and AI planning and scheduling can be combined.

SHAMASH ONTOLOGY ON ACTIVITIES

The SHAMASH ontology on processes adopts an activity-centred modelling viewpoint [11]. The activities use resources to satisfy the process requirements defined by the user. Every activity has a set of pre-conditions that must be true to execute an activity or a process. Figure 1 shows an example of the current SHAMASH interface with respect to the definition of an activity.

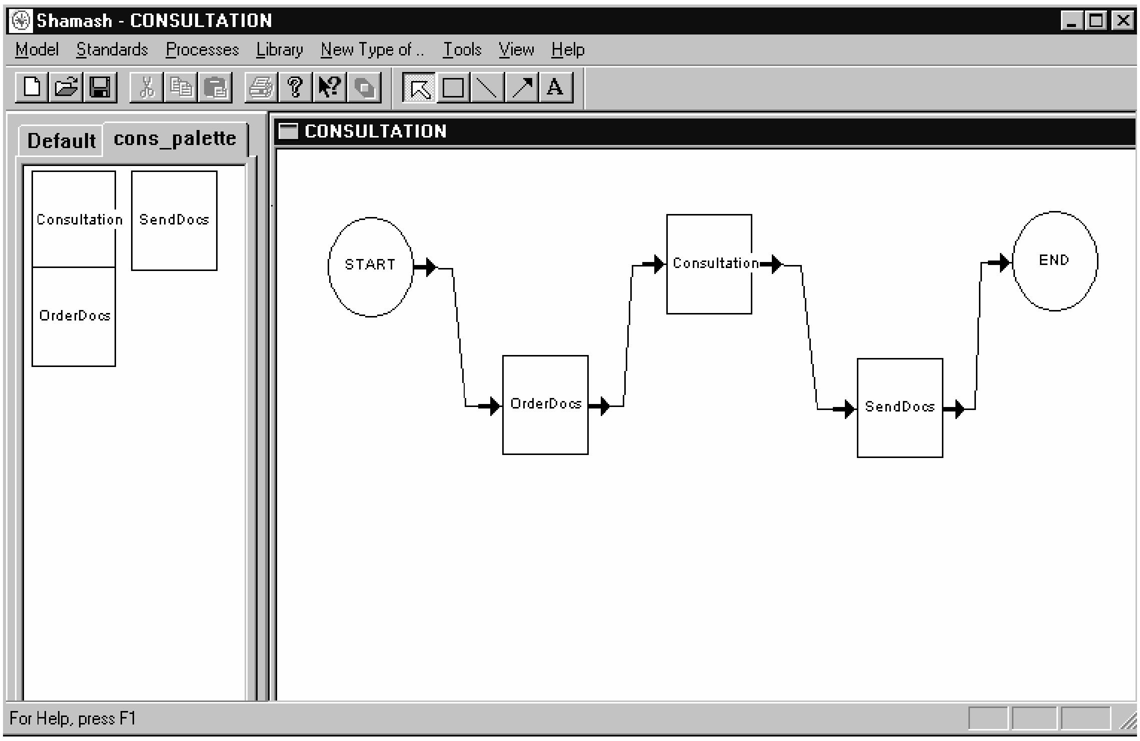

Figure 1. SHAMASH current interface

Rules can be used to define these conditions and to verify if an activity can be executed or not, or if it has achieved what it was supposed to. Rules are composed of two parts:

- The left part of the rule: defines the pre-conditions of the rule, i.e. when the right part of the rule can be executed.
- The right part of the rule: defines the actions to execute when pre-conditions are met.

An example of rule syntax in pseudocode is shown in Figure 2.

```
<Rule Consultation-activity>
     <Left-part>
        Check if there is a Consultation with the values
               Processing = Manual
               FoundResponse = No
               SentToUser = No
     <Right-part>
        Assign the new values to the Consultation
               FoundResponse = Yes
               SentToUser = Yes
```

Figure 2. Example of SHAMASH Rule.

This rule says that if there is a *Consultation* with attributes *Processing* equal to Manual, *FoundResponse* equal to *No* and *SentToUser* equal to *No*, then after the execution of the activity the field *FoundResponse* and *SentToUser* will be modified to *Yes*.

The activities need objects (e.g., data or information) that are created and modified within a process, along with their paths through a series of activities. In Figure 1, *Processing* and *Entry* are attributes of the data *Consultation*. The data *Consultation* will be modified by different activities depending on its initial values. The user will specify in each activity the input and output data. The activities also need resources to be performed and those are assigned according to the organisation structure. SHAMASH allows the user to define the type of resource that will be associated to each activity during the definition stage.

Once the user has defined all the data, activities and organisation structure that will be part of his/her process, he/she should specify the flow of control, i.e., the order in which activities are executed, and how they are linked. In the case of big processes, this stage is usually quite tedious for the user: draw all the activities, decision points and all the control connectors. The focus of our work is to automatically generate the model, avoiding going through all the drawing process, and making sure that the established connections among activities conform to a valid sequence of activities. After the model has been automatically generated, the user can simulate and optimise the process using SHAMASH, as it had been defined by him/her. If the model does not satisfy his/her expectations, he/she could modify it as required.

AI PLANNING TECHNIQUES

AI planning consists of a set of techniques that enable efficient searching for solutions of problems. First, the user should supply a domain description that is composed of a set of operators that allow the planner to go from a defined initial state to a state in which a set of goals is fulfilled. For instance, if the domain is a travel planner, the operators would be `travel-by-airplane, travel-by-bus, book-hotel`, etc. A potential initial state would be someone willing to spend his/her holidays in Toledo (Spanish city very close to Madrid that does not have an airport) who lives in London. The planner should come up with an instantiated plan, that is, a plan formed by a sequence of grounded operators (variables of the operators such as `origin-city` or `target-city` bound to specific values). The plan in this case might contain a sequence such as:

```
travel-by-airplane(London,Madrid-Barajas,14,August,IB341)
travel-by-subway(Madrid-Barajas,Madrid-Atocha,14,August)
travel-by-train(Madrid-Atocha,Toledo,14,August)
```

This sequence might be followed by the return trip. Now we have to understand the relationships between planning and workflow, and try to find similarities and differences. An instance of a business process, (e.g. the accounting process) is analogous to a plan in AI. In Business Process Manager (BPM) terminology [3,6] a plan also includes allocation of resources and target start and end times, while in AI terminology this task is usually performed by scheduling techniques. AI planning and BPM are complementary disciplines with much to gain from collaboration. The ability to invoke AI components flexibly and dynamically from within the workflow framework would considerably enhance business productivity.

A process is a description that must be carried out in a pre-determined order to achieve some process goal. A plan is a description of actions that one or more agents execute for a given objective or goal, that is, an instantiated process. If planning is to be used for BPR problems, the first step would be to think at a high level of what inputs of a planner correspond to the knowledge that BPR tools use, as well as what outputs of the planner corresponds to what knowledge on BPR tools. At a high level, one could establish the following relations:

Inputs of a planner:

- **Domain theory**: the STRIPS representation originally proposed by Fikes and Nilsson is one of the most widely used alternatives [7]. It was introduced to overcome what were seen as computational difficulties in using states to construct plans. In the STRIPS representation, a world state is represented by a set of logical formulae, the conjunction of which is intended to describe the given state. For instance, in the case of the travel planner domain, if Maria wants to travel to Toledo and initially she is in London, a logical formula that represents the world state could be `at(Maria London).`

  Actions are represented by so-called operators. An operator consists of pre-conditions (conditions that must be true to allow the action execution), and post-conditions or effects (usually constituted of an add list and a delete list). The add list specifies the set of formulae that are true in the resulting state while the delete list specifies the set of formulae that are no longer true and must be deleted from the description of the state.

  Each BPR domain (e.g. the accounting domain in an organisation) can be defined in terms of a set of activities (they are also called tasks or even processes) that are performed by organisation agents (either human or software). Therefore, there is a strong relation between operators in planning and activities in BPR.
- **Problem**: is described in terms of an initial state and goals. Those states are represented by a logical formula that specifies a situation for which one is looking for a solution. For BPR, a problem might be described as a process that has to be designed (modelled) for a particular task to be performed within the organisation. For instance, modelling the purchasing of an organisation would be the problem that one has to solve.
- **Initial state**: in planning, one has to specify the starting situation of the posed problem. In the case of the BPR domain, the initial state would be all knowledge that the organisation has about itself and has to be modelled for a specific process within the organisation. Examples of initial states would be: the hierarchical and/or functional representation of the organisation, the resources that it uses, the documents that are generated, etc.
- **Goals**: are often viewed as specifications for a plan. They describe the successful behaviours that execution of the plan should produce: specify what one would like to be true at the end of the solution of the problem. In the case of BPR, this might be represented by the business goal of the organisation with respect to that process. For instance, a purchase process has to be completed, having in mind a set of time or cost constraints.

Outputs of a planner:

AI planners generate a plan or set of plans if a solution exists. A plan can be seen as a sequence of operator applications that can lead from the initial state to a state in which the goals are reached. In the case of BPR, most processes are sequences of activities, adding conditional branches.

In this study, we have used the Prodigy planner [13], given that we already built some tools that might be useful in the future, such as automatically learning control knowledge (heuristics) [4,21]. In the next section, we make the connection between AI planning and workflow tools more precise, by describing how to translate an organisation model described in terms of SHAMASH into a planning domain model for Prodigy, how Prodigy can produce the desired plan (model), and this is translated back into SHAMASH.

PRODIGY AND SHAMASH

To merge both fields we have chosen the PRODIGY 4.0 planner and the SHAMASH Workflow Modelling tool. PRODIGY is an integrated planning and learning system [13]. The system includes a planning algorithm and procedures for learning as well as case-based reasoning that

greatly increase the efficiency of the planner. It is a non-linear planner, domain-independent problem solver architecture [10,13].
To illustrate all the concepts described in the last section, let us consider the SHAMASH rule described in Figure 2. This rule activity could be transformed into the PRODIGY operator shown in Figure 3.

```
(OPERATOR
Consultation-activity
(params <e1>)
(preconds
     ((<e1> consultation))
     (and(Processing <e1> Manual)
         (FoundResponse <e1> No)
         (SentToUser  <e1> No)))
(effects
     ()
     (add(FoundResponse <e1> Yes))
     (add(SentToUser  <e1> Yes))
     (del(FoundResponse <e1>  No))
     (del(SentToUser  <e1>  No))))
```

Figure 3. Example of PRODIGY operator corresponding to Figure 2.

The name of the rule in a SHAMASH activity is used to give the name of the operator in PRODIGY. The operator's variable *e1* is a variable that is used to produce a fully-instantiated precondition, and represents an instance of a consultation.
The pre-conditions and post-conditions, as shown above, are represented by logical formulae. The way we have used to represent them into PRODIGY is:

Attribute Data Value

In the example, the data is represented by a variable of the consultation type and each attribute has the value dictated by the SHAMASH rule: the left part of the rule corresponds to the preconds part of the operator and the right part of the rule to the effects part.

The second input to the planner, the initial state, will contain all data and organisation structures that the process needs. For instance, there might be several *consultations*, but only in the case that the consultation has as attributes *Processing* equal to *Manual* and *FoundResponse* and *SentToUser* to *No*, the operator can be applied. The effect of the operator will be applied to the specific *consultation* (that is the planner binds the variables of the operators to obtain a grounded plan).

Finally, the user has to specify the goal or the process ending condition. In our example the user might specify as goal that the *consultation* the client has posed, has an answer and this answer is sent to the client. This could be translated as the logical formula:

```
(goal (and (FoundResponse consultation Yes)
          (SentToUser consultation Yes)))
```

Once the domain and problem inputs are defined, PRODIGY generates a sequence of steps with the operators' name representing the order the activities will follow in the process.

This translation presented here would serve to any planner that uses logical formulae.

CONCLUSIONS

In this paper, we have presented our work on developing a framework for fully integrating Workflow and AI planning. We have observed that both communities have a lot in common and that modelling business processes can take advantage of the experience that the AI community has shown to solve problems in different domains like military logistics or space missions. We have used the PRODIGY 4.0 planner and the SHAMASH modelling tool to show an example of merging between both fields.

FUTURE RESEARCH

Although use of this technique allows the user to save a lot of time in the modelling process, there is still much that can be done to improve it:

- Given that the SHAMASH grammar has been also translated into PDDL syntax [18], other planners like Graphplan [2], IPP [8] or UCPOP [9] that allow parallel plans could be used to obtain processes with activities that can be executed in parallel.
- The PRODIGY architecture can be modified to allow conditional plans that will create the decisions points in the process model.
- The user is interested in obtaining the order of the activities that minimise the time and cost of the process. Quality parameters can be introduced into the planner to obtain the best plan according to the parameters chosen [4].
- Efficient optimisation procedures could be learned using Machine Learning techniques or Case Based Reasoning [15].

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