Intelligent Agents that Span the Process Management Spectrum

John Debenham & Simeon Simoff

Abstract—The process management spectrum extends from conventional workflow processes to emergent processes. Three categories of process are identified. Activity-driven processes that are managed by a single reactive agent architecture. Goal-driven processes that are managed by a multiagent system of deliberative agents. Knowledge-driven processes that are managed by augmenting the multiagent system from the goal-driven system with an approach based on task types. The idea behind task types is that if the system knows what sort of task is being worked on by the (human) users then appropriate support may be provided. Three general purpose agent architectures are described, one for each category of process. The business of process management is generally limited to the management of the processes themselves — this is appropriate for production workflows. Goal-driven and knowledge-driven processes both rely on the management of the collaboration between the human players. Collaboration management is seen here to be an important component of process management, and an agent architecture, founded on concepts from information theory, is described for it.

Index Terms—Intelligent agents, process management.

I. INTRODUCTION

Business process management is an established application area for multiagent systems [1]. The term business process here covers the spectrum from production workflow to emergent process [2]. Production workflows are well-defined and highly repetitive processes. Emergent processes are processes that are not necessarily pre-defined, that may not be of a routine nature and that may rely on some level of initiative from the system to bring them to a conclusion. The automated aspects of a business process are managed by a process management system that applies a sequence of activity instances to each process instance.

Processes across the process spectrum have differing management requirements. A categorisation of processes is given into three categories each of which is associated with a particular agent architecture. These three categories are activity-driven, goal-driven and knowledge-driven processes. The management of activity-driven processes is achieved with a single reactive agent architecture. The management of goal-driven processes is achieved with a deliberative multiagent system. The management of knowledge-driven processes is partially achieved by augmenting the goal-driven system with a knowledge management approach based on task types. Of equal importance to the management of the processes per se is the management of the collaboration between the human players. A novel agent architecture, founded on information theory, is described for this purpose in [13].

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TABLE I

Properties of the three categories of process

II. THE PROCESS MANAGEMENT SPECTRUM

The terms “production workflow” and “emergent process” are types of business process and are usually defined in loose terms. An alternative categorisation of business process is given here by defining three categories of process in terms of their process management requirements. These three categories are: activity-driven process, goal-driven process and knowledge-driven process.

Following [3] a business process is “a set of one or more linked procedures or activities which collectively realise a business objective or policy goal, normally within the context of an organisational structure defining functional roles and relationships”. Implicit in this definition is the idea that a process may be repeatedly decomposed into linked sub-processes until those sub-processes are activities that are atomic pieces of work. Each process and sub-process has a process patron who is responsible for that process — responsibility may be delegated. Each process has a goal that is a state that the process aims to achieve. Each process has a termination condition that determines when that process should cease; the termination condition may be related to the process’ goal.

The three categories of business process are:

• An activity-driven process can be associated with a — possibly conditional — sequence of activities such that each of these activities has a goal, and is associated with a task.

\(^3\)viz. (op.cit) "An activity is a description of a piece of work that forms one logical step within a process," and "An activity typically generates one or more work items which together constitute the task to be undertaken by the user."
that on its termination "always" achieves this goal. Production workflows are activity-driven processes.

- A goal-driven process has a process goal, and can be associated with a — possibly conditional — sequence of sub-goals such that achievement of this sequence "always" achieves the process goal. Achievement of a sub-process goal is the termination condition for that sub-process. Each of these sub-goals is associated with at least one activity and so with at least one task. Some of these tasks may work better than others, and there may be no way of knowing which is best. Unpredictable task failure is a feature of goal-driven processes.

- A knowledge-driven process may have a process goal, but the goal may be vague and may mutate (Dourish, 1998). Mutations are determined by knowledge generated during the process. The termination condition for a knowledge-driven sub-process is not necessarily related to the achievement of the sub-process goal. At each stage in a knowledge-driven process instance the "next goal" is chosen by the process patron; this choice is made using general knowledge [4] about the context of the process — called the process knowledge. In so far as the process goal gives direction to goal-driven — and activity-driven — processes, the process knowledge gives direction to knowledge-driven processes. Knowledge-driven processes are "not all bad" — they typically have goal-driven sub-processes.

Properties of the three categories of process are shown in Table I.

III. ACTIVITY-DRIVEN PROCESS

Activity-driven processes, or production workflows, are well understood [3]: they are briefly described for the sake of completeness. The underlying assumption for activity driven process management is that these processes can be associated with a — possibly conditional — sequence of activities such that execution of the corresponding sequence of tasks "always" achieves the process goal [5]. This assumption means that process failure will not happen. In practice, even production workflow applications can fail — there are always exceptions to any rule [6].

To model an activity-driven process, construct a node labelled with the activity that creates that process. From that node directed arcs lead to other nodes labelled with activities so that every possible sequence of activities that leads to a node that describes the process is represented. If more than one arc follows a node then those arcs are labelled with the condition under which each arc should be followed. No arcs lead from a node that terminates a process. Then re-label the arcs as a(C)/D where a is the event "that the activity that precedes the arc has terminated", C is the arc condition if any, and D is the set of actions that the management system should perform prior to the activity that follows the arc. In this way activity-driven processes are represented as statecharts see Fig. 1. Some of what a web-based process management system has to do is to add or delete pointers to virtual documents. Operations of this sort are represented as actions D on the state chart. For example, Fig. 2 shows part of a statechart for a loan application where the primitives "remove" and "enter" add and delete pointers in this way. For an activity-driven process, the only way that a process instance will not progress is if its activity instance is aborted for some reason such as time constraints. In Fig. 2 the event "assessment timed out" deals with such an eventuality.

We now convert the statechart to a reactive agent implementation as event-condition-action state-transition rules of the form:

if in state A and event a occurs and condition C is T then perform action D and enter state B

So activity-driven process management can be effected using a single reactive agent, or expert system, containing rules of this form.

Activity-driven processes can be made to do fairly smart things by using complex state labels. For example, a state label for a process that involves a virtual document that is to be circulated amongst n people, two at a time, until some event occurs can be represented as an n x 2 matrix; an example is shown in Table II.

IV. GOAL-DRIVEN PROCESS

A goal-driven process has a process goal, and can be associated with a — possibly conditional — sequence of sub-goals such that achievement of this sequence "always" achieves the process goal. Goal-driven process is like activity-driven process in that for each activity each task is intended to realise the sub-goal of that activity. Goal-driven processes are unlike activity-driven processes in that tasks may fail to achieve their goal, and the reason for failure may lie outside the understanding of the system.

Goal-driven processes may be modelled as state and activity charts [7]. The primitives of that model are activities and states. An activity chart specifies the data flow between activities. An activity chart is a directed graph in which the arcs are annotated with data items. A state chart is a representation of a finite state machine in which the transitions annotated with event-condition-action rules; see Fig. 1. [7] show that the state and activity chart representation may be decomposed to pre-empt a distributed implementation. Each event on a state chart may be associated
with a goal to achieve that event, and so a state chart may be converted to a plan whose nodes are labelled with such goals. Unlike activity-driven processes, the success of execution of a plan for a goal-driven process is not necessarily equated to the achievement of its goal. To represent goal-driven processes, a form of plan is used (see Fig. 4) that can manage failure.

A. Goal-Driven Architecture

The goal-driven architecture consists of one agent for each (human) user; the role of each agent is that of an assistant to its user. The user interacts with a virtual work area and a virtual diary. The work area contains three components which are: the process instances awaiting the attention of the user, the process instances for which the user has delegated responsibility to another agent, and the process instances that the agent does not understand. The diary contains the scheduled commitments of the user. The agent manages the work area and may also interact with the diary [8].

The conceptual architecture of these agents belongs to a well-documented class. Wooldridge describes a variety of architectures [9]. One class of hybrid architectures is the three-layer, BDI agent architecture. One member of this class is the IntelRaP architecture [10], which has its origins in the work of [11]. The conceptual architecture shown in Fig. 3 differs slightly from the IntelRaP conceptual architecture. It consists of a two-pass, three-layer BDI architecture together with a message area. A message manager manages the message area. Access to the message area is available to other agents in the system who may post messages there and, if they wish, may remove messages that they have posted. The idea behind the message area is to establish a persistent part of the agent to which the other agents have access. This avoids other agents tampering directly with an agent’s beliefs, and enables agents to freely remove their messages from a receiving agents message board if they wish. The message area is rather like a person’s office “in-tray” into which agents may place documents, and from which they may remove those documents if they wish. The agent’s world beliefs are derived either from reading messages received from a user, or from reading the documents involved in a process instance, or from reading messages in the message area. Beliefs play two roles. First, they may be partly or wholly responsible activating a local or cooperative trigger that leads to the agent committing to a goal, and may thus initiate an intention (e.g., a plan to achieve what a message asks, such as “please do xyz”). This is part of the deliberative reasoning mechanism. Second, they can be partly or wholly responsible for activating a reactive procedure trigger that, for example, enables the execution of an active plan to progress. This is part of the reactive reasoning mechanism.

The form of plan is slightly more elaborate than the form of agent plan described in [11] where plans are built from single-entry, triple-exit blocks. Those three exits represent success, failure and abort. Powerful though that approach is, it is inappropriate for process management where whether a plan has executed successfully is not necessarily related to whether that plan’s goal has been achieved.

A necessary sub-goal in every high-level plan body is a sub-goal called the success condition [12]. The success condition is a procedure whose goal is to determine whether the plan’s goal has been achieved. The success condition is the final sub-goal on every path through a plan. The success condition is a procedure; the execution of that procedure may succeed (✓), fail (✗) or abort (A). If the execution of the success condition fails then the overall success of the plan is unknown (?). So the four possible plan exits resulting from an attempt to execute a plan are as shown in Fig. 4.

A plan body is represented as a directed AND/OR graph, or state-transition diagram, in which some of the nodes are labelled with sub-goals. The plan body may contain the usual conditional constructs such as if...then, and iteration constructs such as while...do... The diagram of a plan body has one start state (activation condition [ac], and activation action a, and stop states either labelled as success states “✓” (success action σ), fail states “✗” (fail action ϕ), unknown states “?” (unknown action ν) or abort states “A” (abort condition [ac], and abort action ω).
A.1 Reactive Reasoning

Reactive reasoning play two roles: first, if a plan is aborted then its abort action is activated; second, if a procedure trigger fires then its procedure is activated — this includes hard wired procedure triggers that deal with urgent messages.

Reactive reasoning is achieved by rules of the form:

if < trigger state > and < belief state > then < action >

and < trigger state >

where the < trigger state > is a device to determine whether the trigger is active or not, and < belief state > is something that the agent may believe; < action > may be simply to transfer some value to a partly executed plan, or may be to abort a plan and decommit a goal.

Each plan contains an optional abort condition [ab] as shown in Fig. 4. These abort conditions are realised as procedural abort triggers that may be activated whilst their plan is active. If an agent A has an active plan P that requires input from its user or another agent B then a procedure sends a request message directly to B with a unique identifier #I, and a reactive procedure trigger is activated:

if active and believes B’s response to #I is Z then pass Z to P and not active

In this way data is passed to partly executed plans using reactive triggers. Reactive triggers of this form are associated with belief states of the form: “B’s response to #I is known”. Such a procedure trigger is active when its associated sub-goal is committed to, but has not been realised.

V. KNOWLEDGE-DRIVEN PROCESS

The complete representation, never mind the maintenance, of the process knowledge may be an enormous job [13]. In general, knowledge-driven processes can not be managed in the traditional sense [14]; one exception being when all the process knowledge is represented electronically as it may be in an e-Business application [15], or if a powerful workspace-based CSCW technology is employed. On the other hand, the collaboration between humans that is vital for most knowledge-based processes can be managed. The initial selection of the process goal, and its possible subsequent mutation, is performed by the patron, and so this action is completely unsupported by the system. Task selection is supported by the agent for certain “task types”.

The task type identifies what sort of thing the task is trying to achieve. Examples of task types are: marketing tasks, negotiation tasks, focussed discussion tasks and fishing-for-information tasks. The objective of a marketing task is to determine what a client is likely to purchase (or sell). The objective of a negotiation task is to determine the conditions of sale, including price, of an item, a service or some combination of these. The task parameters for a task in a knowledge-driven sub-process are its potential utility (even if on some very crude scale such as from “trivial” to “mission critical” [16]) and its budget (i.e. a cost above which the continued existence of the process will be questioned).

VI. CONCLUSION

The process management spectrum extends from conventional workflow processes to emergent processes. Three categories of process have been identified, and two agent architectures described for the first two. Beyond the management of the processes per se, process management is seen here to include the management of the collaboration between the players. An agent architecture, founded on ideas from information theory, has been described to support collaboration, and a strategy has been described that attempts to balance being equitable with utility optimisation.

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