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UML Activity Diagrams as a Workflow Specification Language

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Abstract. If UML activity diagrams are to succeed as a standard in the area of organisational process modeling, they need to compare well to alternative languages such as those provided by commercial Workflow Management Systems. This paper examines the expressiveness and the adequacy of activity diagrams for workflow specification, by systematically evaluating their ability to capture a collection of workflow patterns. This analysis provides insights into the relative strengths and weaknesses of activity diagrams. In particular, it is shown that, given an appropriate clarification of their semantics, activity diagrams are able to capture situations arising in practice, which cannot be captured by most commercial Workflow Management Systems. On the other hand, the study shows that activity diagrams fail to capture some useful situations, thereby suggesting directions for improvement.

1 Introduction

UML activity diagrams are intended to model both computational and organisational processes (i.e. workflows) [14, 15]. However, if activity diagrams are to succeed as a standard in the area of organisational process modeling, they should compare favorably to the languages currently used for this purpose, that is, those supported by existing Workflow Management Systems (WFMS).

In this paper, we investigate the expressiveness and adequacy of the activity diagrams notation for workflow specification, by systematically confronting it with a set of *control-flow workflow patterns*, i.e. abstracted forms of recurring situations related to the ordering of activities in a workflow, and the flow of execution between them. Many of these patterns are documented in [3, 4], and a comparison of several WFMS based on these patterns is provided in [4].

Our evaluation demonstrates that activity diagrams support the majority of the patterns considered, including some which are typically not supported by commercial WFMS. This is essentially due to the fact that activity diagrams integrate signal sending and processing at the conceptual level, whereas most commercial WFMS only support them as a low-level implementation mechanism.

While activity diagrams compare well to existing WFMS in this respect, they exhibit the major drawback that their syntax and semantics are not fully de-

fined in the standard's documentation[1]. Indeed, while the features inherited from Harel's statecharts [9] have a formal operational semantics, the features specific to activity diagrams are only partially formalised in the standard (through OCL statements), and their description in natural language leaves room for some ambiguities that we point out throughout the paper. We hope that some of these ambiguities will be clarified in future releases of the standard.

The rest of the paper is structured as follows. Section 2 discusses some semantical issues of the activity diagrams notation, focusing on control-flow aspects. Sections 3, 4, and 5 evaluate the capabilities of activity diagrams against different families of workflow patterns. The patterns considered in sections 3 and 4 are extracted from [4], while those discussed in section 5 are variants of the well-known producer-consumer pattern. Finally, section 6 points to related work, and section 7 discusses directions for improving the activity diagrams notation.

2 Overview of activity diagrams

The aims of the following overview are (i) to discuss the semantics and properties of critical constructs used in the rest of the paper, (ii) to identify some ambiguities in the standard, and (iii) to explain how this paper deals with these ambiguities. It is not intended as an introductory overview. Readers not familiar with activity diagrams may refer to e.g. [8].

2.1 States and transitions

UML activity diagrams are special cases of UML *state diagrams*, which in turn are graphical representations of *state machines*. The *state machine* formalism as defined in the UML, is a variant of Harel's statecharts [9].

State machines are transition systems whose arcs are labeled by ECA (Event-Condition-Action) rules. The occurrence of an event fires a transition if (i) the machine is in the source state of the transition, (ii) the type of the event occurrence matches the event description of the transition, and (iii) the condition of the transition holds. The event (also called trigger), condition (also called guard), and action parts of a transition are all optional. A transition without an event is said to be *triggerless*. Triggerless transitions are enabled when the action or activity attached to their source state is completed.

A state can contain an entire state machine within it, leading to the concept of *compound state*. Compound states come in two flavours: OR and AND. An OR-state contains a single statechart, while an AND-state contains several statecharts (separated by dashed lines) which are intended to be executed concurrently. Each of these statecharts is called a *concurrent region*. When a compound state is entered, its initial transition(s) are taken. The execution of a compound state is considered to be complete when it reaches (all) its final state(s). Initial states are denoted by filled circles, while final states are denoted by two concentric circles: one filled and one unfilled (see figure 1).

[1] When discussing the syntax and semantics of activity diagrams, we take as sole reference the final draft delivered by the UML Revision Task Force 1.4 [14].

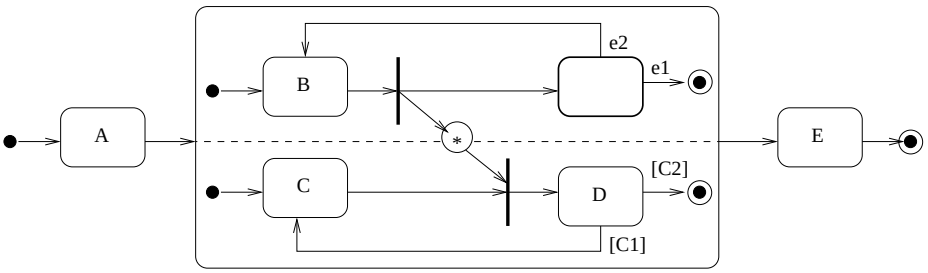


Fig. 1. An example of an activity diagram.

Actions or sequences of actions can be attached to basic (i.e. non-compound) states. In this respect, one can distinguish the following kinds of *basic* states:

- Wait state: no action or activity is performed. A state of this kind is exited when one of its outgoing transitions fires due to an event occurrence. The unlabeled state with a thick border in figure 1 is an example of a wait state.
- Action state: a single action is attached to a state. The execution of an action is non-interruptible, so that the transitions emanating from such a state cannot fire until the action is completed. The states labeled A through E in figure 1 are examples of action states (their labels are action names).
- Activity-in-state: an activity (expressed as a sequence of actions) is attached to the state. The execution of this activity can be aborted prior to its completion if one of the state's outgoing transitions fires. We found no definition of the term "activity abortion" in the standard, so it is not clear if an activity abortion means that no more actions in the sequence are executed (interruption semantics), or if it means that the system's state before the activity's commencement is restored (abortion semantics of ACID transactions).

A *subactivity state* is recursively defined as a compound state whose decomposition contains exclusively action and subactivity states. In [14] page 3-161, it is said that "an activity diagram is a special case of a state diagram in which all (or at least most) of the states are either action or subactivity states, and all (or at least most) of the transitions are [triggerless]". Unfortunately, no definition of "at least most" is given. Does it mean at least 50% of the states and transitions? In this paper, we assume that there is no quota on the percentage of action, subactivity states, and triggerless transitions, within an activity diagram. Indeed, wait states, activity-in-states, and transitions with triggers, are extremely useful features when it comes to model workflows, since they naturally capture exception handling and inter-process communication as pointed out in [16, 1].

2.2 Forks and joins

AND-states provide a means to express that a number of activities are intended to be executed concurrently. Still, activity diagrams also offer two other constructs for expressing concurrency, namely forks and joins. A fork (represented

by a heavy bar as in figure 1) is a special transition with one source state and several target states. When this transition fires, the target states are all simultaneously entered, resulting in an increase in the number of concurrent *threads*. A join (represented by a heavy bar as well) is a transition with several source states and one target state, which reduces the number of concurrent threads.

An activity diagram with forks and joins must fulfill some *well-formedness* criteria. These criteria state that it must be possible to replace all forks and joins with AND-states. In particular, for every fork there should be a corresponding join, the delicate point being to define what is meant by "corresponding".

The well-formedness of activity diagrams is partially defined as OCL and natural language statements in the standard ([14] pp. 2-161 through 2-169). This definition however does not take into account the case where choice and junction vertices are used within the paths leading from a fork to a join, thereby permitting deadlocking situations which would not occur if forks and joins were replaced with AND-states. We argue that if activity diagrams are to be used as a workflow specification language, a precise definition of their well-formedness is crucial, as it prevents several kinds of deadlocks. In a different context than activity diagrams, [10] provides a formalisation of these well-formedness rules.

In this paper, we avoid the use of forks and joins, and use AND-states instead. Forks and joins are only used in conjunction with *synch state* as discussed below.

2.3 Synch states

A synch state is a synchronisation point between two threads. In its simplest form, a synch state has one incoming transition emanating from a fork in one thread, and one outgoing transition leading to a join in another thread. A fork (join) connected to a synch state is called a *synchronising fork* (*join*).

Synch states differ from normal states in that they are not boolean. Using Petri net terminology, this means that a synch state may hold several tokens simultaneously. The number of tokens that a synch state can hold is constrained to be lower than, or equal to a given bound (the special symbol * denotes that there is no bound). Figure 1 shows an example of an unbounded synch state. In this diagram, one instance of activity D is executed each time that one instance of activity B *and* one instance of activity C are completed. This diagram shows that the use of synch states may lead to deadlocks. Indeed, in the given example, a deadlock occurs if B is performed only once, while C is performed twice.

2.4 Dynamic invocations

Within an activity diagram, it is possible to specify that multiple *invocations* of an action or subactivity execute concurrently: a feature called *dynamic invocation*. The *dynamic multiplicity* of a state, is the maximum permitted number of invocations of its action or subactivity. It is indicated as a string on its upper right corner (a star indicates that there is no bound). At run time, the state receives a set of *dynamic arguments*, and performs one invocation of its action or subactivity for each of these arguments, up to the limit fixed by its multiplicity.

After a thorough search through [14], we found that there are no indications as to how multiple invocations of an action or activity synchronise once their execution is completed. Assuming that these invocations are not required to synchronise upon completion, inconsistencies may arise when a "dynamic" state is followed by a "non-dynamic" one. Consider for example the diagram in figure 2, where an action state A with dynamic multiplicity 2 is followed by an action state B with no dynamic multiplicity. Suppose that two invocations of A are made, and that the first invocation finishes before the second. If the two invocations are not required to synchronise, state B can be entered at this point. Now, what will happen when the second invocation of A finishes? Will it trigger activity B again (in which case two instances of B will run simultaneously)? Because of this semantical conflict, we consider in this paper that a dynamic state can only be exited when all its associated invocations are completed. In particular, if one invocation is aborted due to some external event, all the other invocations are aborted too. This is in line with the interpretation suggested in [8].

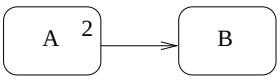


Fig. 2. An example of the use of dynamic invocation.

Another point regarding dynamic invocation which is left open by the standard, is whether each invocation runs in its own memory space, or if it shares the same memory space as the others. If two subactivities run in the same space, chances are that this could lead to write-write conflicts over shared variables.

3 Capturing synchronisation patterns

This and the following two sections, present a series of workflow patterns and their description using UML activity diagrams. For each pattern we provide:

- A description of the context, scope and intent of the pattern.
- A concrete example illustrating this description.
- A paragraph indicating to what extent the pattern is supported by WFMS.
- A discussion on how the pattern can be captured using activity diagrams.

The patterns in this section correspond to situations where one or several concurrent activities need to be completed before another activity is initiated.

3.1 The discriminator[2]

Description. The discriminator is a point in a workflow that waits for one of its incoming branches to complete before activating the subsequent activity. From

[2] The term discriminator here, refers to a special kind of synchronisation. It should not be mistaken with the use of the term discriminator in UML class diagrams, where it refers to a "dimension of specialisation within a class hierarchy".

that moment on, it waits for the other branches to complete and "ignores" them. When the last incoming branch completes, the discriminator resets itself so that it can be triggered again (in case it is embedded in a loop).

Example. To improve query response time, a complex search is sent to two different databases over the Internet. As soon as the one of the databases comes up with a result, the execution flow proceeds. The second result is ignored.

Degree of support offered by commercial WFMS. In all but a few WFMS, the discriminator cannot be captured at the conceptual level [4]. A notable exception is Verve[3], which offers a specific construct for this pattern. In the SAP R/3 Workflow[4], for each AND-split/AND-join combination, it is possible to specify for how many of the parallel branches started by the split, does the join need to wait. One can be thus be tempted to capture the discriminator by specifying that the AND-join only needs to wait for one of the branches started by the AND-split. However, the branches that are still running when the first branch finishes, will be marked as "logically deleted" by the SAP R/3 Workflow, whereas in the discriminator pattern these branches should proceed normally.

A solution using UML activity diagrams Figure 3 shows how to express the discriminator as a set of concurrent regions communicating through signals. Specifically, the incoming branches of the discriminator, as well as the outgoing branch, are placed in separate regions of a single subactivity state. When this subactivity state is entered, the regions corresponding to the incoming branches of the discriminator are executed, while the region corresponding to the outgoing branch "sits" in a wait state. When one of the incoming branches terminates, it produces a signal which causes the outgoing branch to start its execution.

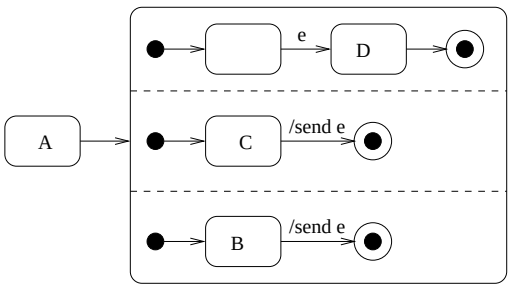


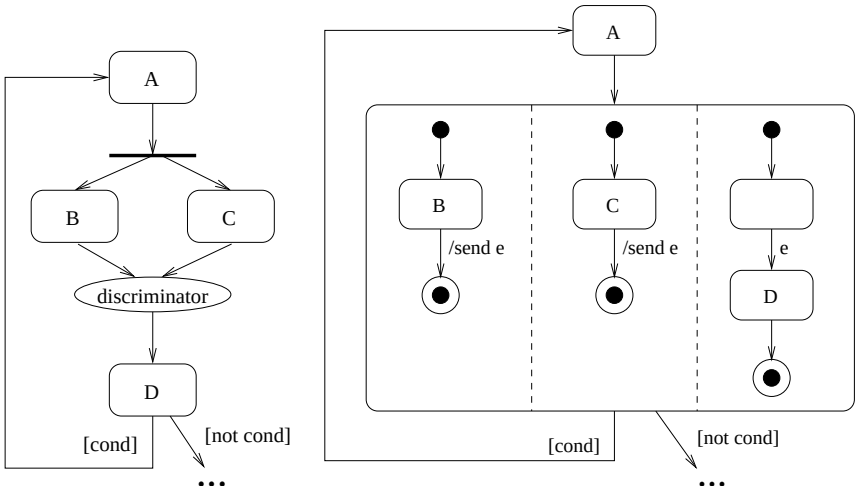
Fig. 3. Activity diagram capturing the discriminator pattern with 2 incoming branches.

This solution has a limitation when the discriminator is part of a loop. Consider for instance the situation depicted in figure 4(a), whose translation as an activity diagram is given in figure 4(b). This activity diagram forces an undesired synchronisation between activities B, C and D. Specifically, if B finishes before C, D is started immediately. Now, if D subsequently finishes before C, and con-

[3] http://www.verve.com or http://www.versata.com.
[4] http://www.sap.com.

dition cond holds, activity A cannot be started immediately: it has to wait for the completion of C. This is not in line with the semantics of the discriminator, which does not impose any synchronisation constraint besides the fact that one of its incoming transitions has to fire before firing the outgoing transition.

This example puts forward a limitation of activity diagrams inherited from statecharts. Unlike Petri nets whose places can hold several tokens, states in a statechart are boolean, in the sense that a state cannot be active several times simultaneously. In the example at hand, if A was started immediately after the completion of D, and if subsequently A finished before C, then the state labeled C would have to be entered (i.e. activated) again.



(a) Informal description (b) Expressed as an UML activity diagram

Fig. 4. A discriminator within a loop

3.2 N-out-of-M join

Description. The N-out-of-M Join is a point in a workflow where M parallel branches converge into one. The outgoing branch should be started once N incoming branches have completed. Completion of all remaining branches should be ignored. As with the discriminator, once all incoming branches have fired, the join resets itself. In fact, the discriminator is a 1-out-of-M join. The N-out-of-M join is identified in [6], where it is called *partial join*.
Example. A paper must be sent to three external reviewers. Upon receiving two reviews the paper can be processed. The third review can be ignored.
Degree of support offered by commercial WFMS. See previous pattern.
A solution using activity diagrams. This pattern can be treated in a similar way as the discriminator, except that a counter needs to be introduced, to keep

track of the number of termination signals generated by the incoming branches of the N-out-of-M join. The execution of the outgoing branch is started when a new termination signal arrives while the value of the counter is N - 1.

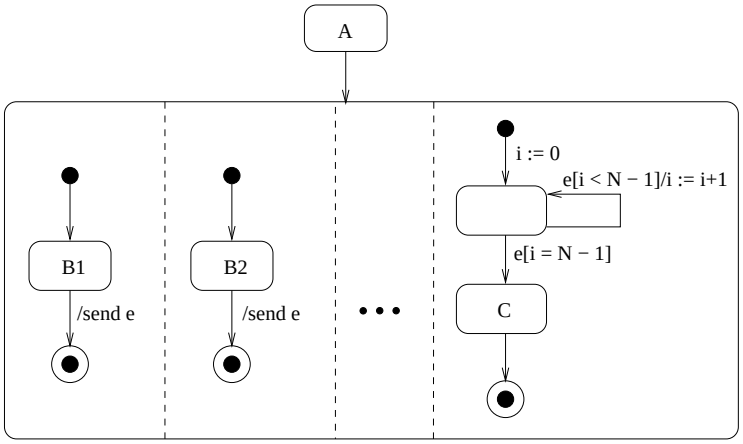


Fig. 5. Activity diagram corresponding to the N-out-of-M pattern.

When the N-out-of-M join is part of a loop, the above solution has the same limitation as the solution of the discriminator pattern presented in figure 4(b).

3.3 Multiple instances requiring synchronisation

Description. A point in a workflow where an activity A is enabled multiple times. The number of instances of A that need to be enabled is known only when the point is reached. After completing all the enabled instances of A, an instance of an activity B has to be executed.
Example. The requisition of 100 computers results in a number of (concurrent) deliveries. Once all deliveries are processed, the requisition has to be closed.
Degree of support offered by commercial WFMS. Many WFMS do not support the concept of "multiple instances of an activity" [4]. Systems that support multiple instances do not provide conceptual constructs to enforce the synchronisation of these instances. Interestingly, in UML the opposite holds : the synchronisation of multiple instances of an activity is imposed, so it is not possible to express (for example) that the activity B can be started as soon as one of the instances of A is completed (i.e. a discriminator-like synchronisation).
A solution using activity diagrams. Embed activity A within a subactivity state, and attach an unbounded dynamic multiplicity to it. Then, introduce a transition between this subactivity state and an action state labeled by B (as in figure 2). At run-time, provide one dynamic argument per required instance of activity A. Since UML does not provide a notation for passing dynamic arguments to a subactivity state, this has to be expressed in a programming language.

4 Capturing state-based patterns

In real workflows, where human and material resources are not always available, activities are more often in a waiting state than in a processing one [4]. This fact is central in the following two patterns, where a distinction is made between the moment when an activity is enabled, and that when it starts running. In the first pattern, the choice between two alternative enabled activities is delayed until an event occurs. In the second pattern, several enabled activities have to be processed, but at any point in time, at most one of them can be running.

4.1 Deferred choice

Description. A point in a workflow where one among several branches is chosen based on some external information which is not necessarily available when this point is reached. This differs from the "normal" choice, in that the choice is not made explicitly (based on existing data) but several alternatives are offered to the environment, and the choice between them is delayed until an external signal is received. Using the WFMS terminology, this means that the alternative activities are placed in the worklist, but as soon as one of them starts its execution, the others are withdrawn. This pattern is called implicit XOR-split in [2].
Example. When a contract is finalised, it has to be signed either by the director, or by both the deputy director and the secretary, whoever is/are available first.
Degree of support offered by commercial WFMS. Although all WFMS provide a construct capturing the "normal" choice, few of them support the deferred choice. A notable exception is COSA[5]. In some WFMS, the deferred choice can be handled at the implementation level using cancellation messages (i.e. both A and B are enabled and one of them is cancelled when the other starts), but this solution will not always work due to concurrency problems.
A solution using activity diagrams. The deferred choice can be expressed as a normal state which waits for an event from the environment, and chooses one of its outgoing branches accordingly (see figure 6).

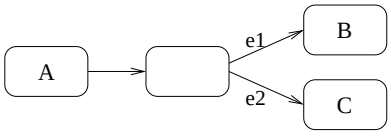


Fig. 6. Activity diagram corresponding to the deferred choice pattern.

4.2 Interleaved parallel routing

Description. A set of activities $\{A_1, A_2, \ldots, A_n\}$ need to be executed in an arbitrary order. Each activity in the set is executed exactly once. The order

[5] http://www.cosa.de and http://www.cosa.nl.

between the activities is decided at run-time: it is not until one activity is completed that the decision on what to do next is taken. In any case, no two activities among $A_1, \ldots, A_n$ can be active at the same time.

Example. The army requires every applicant to take 3 tests: an optical, a medical, and a mental. These tests can be conducted in any order but obviously not at the same time. When an applicant completes a test, the decision of which test to perform next is taken depending on the presence of the relevant doctors. If for example the doctor responsible for the optical test is present, while the doctor for the medical one is absent, the optical test is performed before the medical.

Degree of support offered by commercial WFMS. In many WFMS, this pattern cannot be expressed at the conceptual level. At the implementation level, it can be coded by introducing a resource shared by all activities $A_1, \ldots, A_n$. This shared resource acts as a semaphore, forcing a serialization of the activities.

Since this pattern can be expressed in terms of the deferred choice pattern (see below), it can be captured in those WFMS supporting the deferred choice [4].

Solutions using activity diagrams. This pattern can be expressed in terms of the deferred choice as follows. First, a deferred choice is made between n branches, such that the i^{th} branch starts with activity A_i ($1 \leq i \leq n$). In the branch that leads to activity A_1, another deferred choice is made (after A_1 is executed) between $n - 1$ branches respectively starting with $A_2, \ldots, A_n$. A similar nested deferred choice is also made in all the other branches of the first deferred choice. This process of nesting deferred choices is recursively repeated, until all the permutations of A_1, ..., A_n are enumerated. Clearly, for a large number of activities, this combinatorial explosion is undesirable.

A better alternative is to enforce the interleaving of activities by placing each activity in a separate concurrent region, and blocking their execution through synch states emanating from a single "blocking region" (this is the leftmost region in figure 7). A token is inserted into the synch state blocking an activity Ai, only after the processing of the event that enables the execution of Ai. When Ai starts its execution, the blocking region enters a state which defers the occurrences of events that may unblock the execution of other activities. For instance, in figure 7 events s1, s2 and s3 are used to indicate that activities A1, A2 and A3 respectively, can be executed. If one of these events occurs while one of the activities is being executed, the processing of this occurrence is deferred until the ongoing activity execution has completed.

5 Producer-consumer patterns

The patterns in this section are variants of the producer-consumer pattern found in distributed systems design. They correspond to situations where several instances of an activity A (the producer) are executed sequentially, and the termination of each of these instances triggers the execution of an instance of another activity B (the consumer). The instances of A and B execute concurrently, but some asymetric inter-dependencies link them (a "B" is caused by an "A").

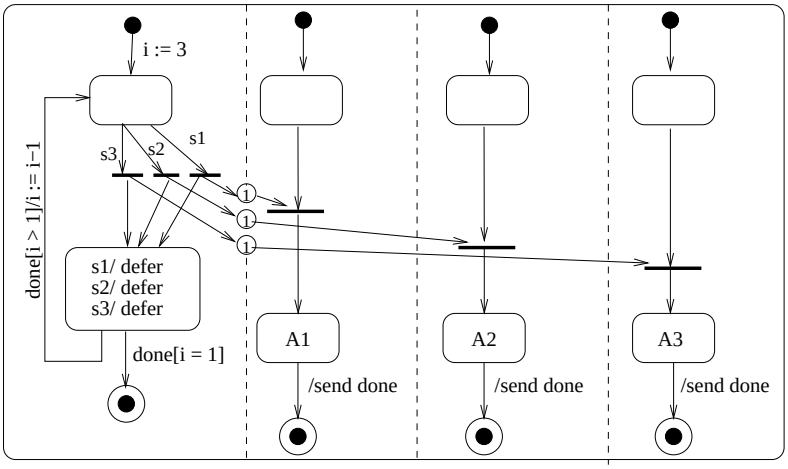


Fig. 7. Activity diagram for the interleaved parallel routing of 3 activities.

5.1 Producer-consumer pattern with termination activity

Description. This pattern involves three activities A, B and C. The process starts with the execution of an instance of A. When this execution completes, an instance of B is enabled. Concurrently, a second instance of A can be started. When this second instance of A completes, a second instance of B is enabled and a third instance of A can be started. This process continues in such a way that at any point in time, the following conditions hold: (i) at most one instance of A is running; (ii) the execution of the i^{th} instance of B does not start before the i^{th} instance of A is completed. When all the instances of A are completed, the system continues executing instances of B until the number of completed executions of B is equal to that of A. Finally, a terminating activity C is executed.

Example. A customer is shopping in a virtual mall aggregating several vendors. Every time that the customer orders an item, the system must trigger an activity which contacts the corresponding vendor to check the item's availability and expected delivery time. Once the customer states that (s)he does not want any other item, and once the availability of all the requested items is checked, a mail is sent to the customer with the list of available products and their delivery time.

Degree of support offered by commercial WFMS. We notice that in this pattern, an a priori unknown number of instances of B may run simultaneously, and these instances need to synchronise upon termination. Therefore, this pattern is not supported by those WFMS which do not support the pattern "Multiple instances with synchronisation". Now, if we restrict the description of the pattern to the case where at most one instance of B is executed at a time (i.e. the instances of B are executed sequentially), then it becomes possible to express this pattern using AND-splits, loops and counters. This is actually the approach that we adopt below to capture this pattern in UML activity diagrams.

Solution. The pattern is captured by the activity diagram shown in figure 8. Essentially, instances of activity A and B run in two concurrent regions of a compound state. Every time that an instance of activity A is completed, it puts a token in a synch state, and it increments a counter i. Each of the tokens generated by the completion of an instance of A, enables a transition leading to the execution of one instance of activity B. When the execution of an instance of activity B is completed, a token is put in a second synch state. Once all instances of A are completed, the tokens of this second synch state are "consumed" one after the other, and for each of these consumptions, the counter i is decremented. When the value of the counter is zero, it means that B was executed as many times as A was. The compound state is then exited and C is executed once.

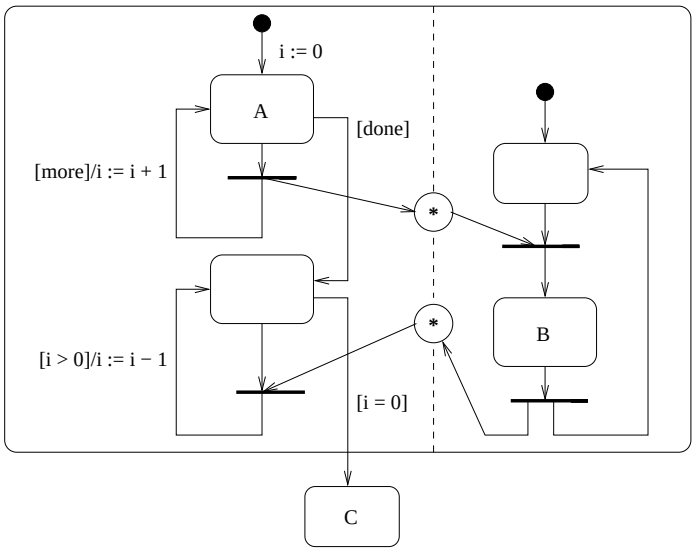


Fig. 8. Activity diagram for the producer-consumer pattern with termination activity.

This solution is such that at any point on time, at most one instance of B is running. Although we do not have a proof, we believe that the version of this pattern where multiple instances of B may run concurrently, cannot be expressed as an activity diagram. Indeed, this would require a dynamic invocation operator in which not all of the dynamic arguments are available at once, but rather arrive one by one. Given such an operator, it would be possible to express that an instance of B needs to be triggered each time that an instance of A terminates, even if the previously generated instances of B have not yet completed.

5.2 Producer-consumer with bounded queue

Description. The description of this pattern is similar to that of section 5.1, except that at any time, the difference between the number of times that activity

A has been executed, and the number of times that activity B has been executed, is bounded by an integer called the *size of the queue*.

Example. To obtain an ID card, an applicant has to complete a form and present it to an officer for verification. Once the officer has checked the form, the applicant is sent to a photographer's room. However, the queue leading from the officer's counter to the photographer's room cannot contain more than 5 persons. Should the queue contain 5 persons, the officer would stop accepting applications until one of these persons enters the photographer's room.

Degree of support offered by commercial WFMS. See previous pattern.

Solution. The idea is to modify the diagram of figure 8, in such a way that two separate counters are kept: one counting the executions of A (na), and the other counting the executions of B (nb). Every time that activity A is completed, if the boolean variable "more" is true, a waiting state is entered, which is only exited when the condition $na - nb < s$ holds (where s is the size of the queue).

6 Related work

The suitability of statechart-based notations for workflow specification has been recognised by many studies. For instance, [12] argues that statecharts are perceived by practitioners as being more intuitive and easier to learn than alternative formal notations such as Petri nets (whose suitability for workflow specification is advocated in e.g. [2]), yet have an equally rigorous semantics. More recently, [16] and [1] illustrate through selected case studies, the adequacy and limitations of activity diagrams for business process modeling. None of these references however undertakes a systematic evaluation of the capabilities of statecharts/activity diagrams for workflow specification as in the present paper. Interestingly, [16] agrees with us in saying that wait states and activity-in-states are crucial for workflow modeling, thereby sustaining our position that no restrictions on their use should be imposed as currently suggested by the standard.

The issue of defining a precise semantics of UML is the subject of intensive investigations, as evidenced by the number of projects, forums, and workshops in this area (see [13] for a list of links). Unfortunately, within this stream of research, activity diagrams have received relatively little attention, despite the fact that they are "one of the most unexpected parts of the UML" [8]. Ongoing efforts such as those reported in [5] and [7] are attempting to fill this gap. [5] defines an algebraic semantics of the core constructs of activity diagrams. It does not deal however with features such as synch states, dynamic invocation and deferred events. In this regard, the formalisation given in [7] is more complete. Based on the STATEMATE semantics of statecharts [9], this formalisation covers all activity diagrams constructs (except synch states and swimlanes), and considers issues such as data manipulation. The authors however do not formalise syntactical constraints such as the well-formedness rules linking forks with joins, which are essential to avoid some deadlocking situations. These syntactical constraints and some of their expressive power implications are studied in [10].

To summarise, we can state that the formalisation of the activity diagrams notation, and the evaluation of its suitability for workflow specification, are still open issues. It is expected that the ongoing OMG RFP "UML extensions for workflow process definition" [17] will provide an occasion to address them.

7 Conclusion

This paper presented an evaluation of UML activity diagrams against a set of workflow patterns involving control-flow aspects. Some of these patterns are extracted from [4], while others are variants of the producer-consumer pattern. Actually, we have confronted activity diagrams against the 22 control-flow patterns in [4], although for space reasons we have just presented some of them.

From this systematic evaluation, we conclude that in the context of workflow specification, the strong points of activity diagrams with respect to alternative languages provided by commercial WFMS are essentially the followings:

- They support signal sending and receiving at the conceptual level.
- They support both *waiting states* and *processing states*.
- They provide a seamless mechanism for decomposing an activity specification into subactivities. The combination of this decomposition capability with signal sending yields a powerful approach to handling activity interruptions.

However, activity diagrams exhibit the following drawbacks:

- Some of their constructs lack a precise syntax and semantics. For instance, the well-formedness rules linking forks with joins are not fully defined, nor are the concepts of dynamic invocation and deferred events, among others.
- They do not fully capture important kinds of synchronisation such as the discriminator and the N-out-of-M join (see section 3). Similarly, to the best of our knowledge, they do not fully support the producer-consumer pattern with termination activity (see section 5.1).

We encourage the participants of the OMG RFP "UML extensions for workflow definition" [17], to consider these two points in their proposals. Actually, [17] mentions the issue of capturing the N-out-of-N join, although it does not discuss what is the expected behaviour of this pattern when embedded in a loop.

In this paper, we focused on the *control-flow perspective*. However, workflows can also be viewed from a *data* and from a *resource* perspective [11]. The data perspective relates to the flow of information between activities, while the resource perspective defines human and device roles responsible for handling activities. The data and resource perspectives may be captured through *object flows* and *swimlanes* respectively. Assessing the suitability of these constructs against appropriate workflow patterns is a perspective to our work.

Another perspective is to study how the concepts and constructs of UML activity diagrams compare to those of the Workflow Management Coalition's Reference Model [18]. Such an effort could trace the road towards defining mappings from activity diagrams into vendor-specific workflow specification languages.

References

1. J.Ø. Aagedal and Z. Milosevic. ODP enterprise language: An UML perspective. In *Proc. of The 3rd International Conference on Enterprise Distributed Object Computing*, Mannheim, Germany, 1999. IEEE Press.
2. W.M.P. van der Aalst. The application of Petri nets to workflow management. *The Journal of Circuits, Systems and Computers*, 8(1):21–66, 1998.
3. W.M.P. van der Aalst, A.P. Barros, A.H.M. ter Hofstede, and B. Kiepuszewski. Advanced workflow patterns. In *Proc. of the 5th IFCIS Int. Conference on Cooperative Information Systems*, Eilat, Israel, September 2000. Springer Verlag.
4. W.M.P. van der Aalst, A.H.M ter Hofstede, B. Kiepuszewski, and A. Barros. Workflow patterns. Technical Report WP 47, BETA Research Institute, 2000. Accessed March 2001 from `http://tmitwww.tm.tue.nl/research/patterns`.
5. E. Börger, A. Cavarra, and E. Riccobene. An ASM semantics for UML activity diagrams. In *Proc. of the International Conference on Algebraic Methodology and Software Technology (AMAST)*, Iowa City, IO, USA, May 2000. Springer Verlag.
6. F. Casati, S. Ceri, B. Pernici, and G. Pozzi. Conceptual modeling of workflows. In *Proc. of the 14th International Object-Oriented and Entity-Relationship Modelling Conference (OOER'95)*, pages 341–354. Springer Verlag, December 1995.
7. R. Eshuis and R. Wieringa. A formal semantics for UML activity diagrams – Formalising workflow models. Technical Report CTIT-01-04, University of Twente, Department of Computer Science, 2001.
8. M. Fowler and K. Scott. *UML Distilled: A Brief Guide to the Standard Object Modeling Language (Second Edition)*. Addison Wesley, Readings MA, USA, 2000.
9. D. Harel and A. Naamad. The STATEMATE semantics of statecharts. *ACM Transactions on Software Engineering and Methodology*, 5(4):293–333, October 1996.
10. B. Kiepuszewski, A.H.M. ter Hofstede, and C. Bussler. On structured workflow modelling. In *Proc. of the Int. Conference on Advanced Information Systems Engineering (CAiSE)*, Stockholm, Sweden, June 2000. Springer Verlag.
11. F. Leymann and D. Roller. *Production Workflow: Concepts and Techniques*. Prentice Hall, Upper Saddle River, NJ, USA, 2000.
12. P. Muth, D. Wodtke, J. Weissenfels, A.K. Dittrich, and G. Weikum. From centralized workflow specification to distributed workflow execution. *Journal of Intelligent Information Systems*, 10(2), March 1998.
13. The precise UML group. Home page. `http://www.cs.york.ac.uk/puml/`.
14. UML Revision Task Force. *OMG Unified Modeling Language Specification, Version 1.4 (final draft)*. February 2001.
15. J. Rumbaugh, I. Jacobson, and G. Booch. *The Unified Modeling Language Reference Manual*. Addison-Wesley, 1999.
16. M. Schader and A. Korthaus. Modeling business processes as part of the BOOSTER approach to business object-oriented systems development based on UML. In *Proc. of The Second International Enterprise Distributed Object Computing Workshop (EDOC)*. IEEE Press, 1998.
17. The Object Management Group. UML Extensions for Workflow Process Definition, RFP-bom/2000-12-11. Accessed on June 2001 from `ftp://ftp.omg.org/pub/docs/bom/00-12-11.pdf`.
18. The Workflow Management Coalition. The Workflow Reference Model. `http://www.aiim.org/wfmc/standards/docs/tc003v11.pdf`, accessed on January 2001.