BUSINESS PROCESSES MANAGEMENT USING PROCESS ALGEBRA AND RELATIONAL DATABASE MODEL

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Abstract: Integrating information systems with tools that manage workflows and business processes is not always a simple task. This difficulty becomes more accentuated when the execution control assumes countless business processes. This work presents *NavigationPlanTool* (NPTool), a tool to control the execution of business processes that can be easily integrated into the information systems. NPTool is supported by *Navigation Plan Definition Language* (NPDL), a language for business processes specification that uses process algebra as formal foundation. NPTool implements the NPDL language as a SQL extension and offers two other important services: processes instantiation and process instances execution monitor. This paper describes the NPTool showing how the process algebra features combined with a relational database model can be used to provide a scalable and reliable control in the execution of business processes.

1 INTRODUCTION

Business Processes Management (BPM) involves methods, techniques and tools to support the project, the execution, the management and the operational analysis of business processes (Leymann et al., 2002). While the traditional definitions of workflow place emphasis on the execution of operational processes, BPM also gives support to the diagnosis phase, allowing the processes to be analyzed in order to detect flaws and possible improvements to the project.

In this context, associating formal frameworks with the process project phase is valuable since they provide non-ambiguous models, improve the diagnosis capability and enable a reliable execution control of the process.

Although there are a number of tools based on formal frameworks directed to the management of workflows and business processes, integrating these tools with other applications isn't always easy. Some of these tools are exclusively developed for modeling and simulation of processes, as occurs in CPN/Tools (Beaudouin-lafon et al., 2000). In other cases, the tools effectively carry out the execution control of business processes, but they do not provide mechanisms that allow them to be easily used within the information systems that manage business processes.

This work presents the *NavigationPlanTool* (NPTool), a tool that offers mechanisms for the representation and execution control of business processes supported by a process algebra formalism (Fokkink, 2000). NPTool uses the *Navigation Plan Definition Language* (NPDL) (Braghetto et al., 2007) and a relational database to specify business processes and to control their instantiations and executions. NPTool implements NPDL as an extension of SQL; this implementation allows an easy integration with traditional information systems, which generally already have mechanisms that facilitate the access to RDBMSs. The storage of the processes data in a relational database adds scalability to the execution control provided by NPTool. Moreover, the processes definitions can be reused in different applications. In this context, the database maintained by NPTool can be viewed as a common repository of processes.

Section 2 presents a summary of the related works and the reasoning behind the use of NPDL. Section 3 describes the services offered by the *NavigationPlanTool*; in particular, Section 3.1 describes the

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data structures in the relational database model to represent the processes, and Section 3.2 explains the mechanism for execution control. Using a real application as example, Section 4 illustrates the execution control applied to an instance of a process. Finally, Section 5 discusses the contributions of this work.

2 RELATED WORK

Management technologies for business processes were developed to meet the following needs: (1) to promote the separation between the specification of the process and its implementation; and (2) to take away from the applications the responsibility of the execution control of business processes. Among the various existing languages to define business processes, it is not easy to see a formal pattern as a representation basis, one that is capable of expressing in a non-ambiguous way the semantics associated to the existing constructions in these languages. The formalisms regarded as natural candidates for this role are the Petri nets and the process algebras. Works such as (Aalst, 1998), (Puhlmann and Weske, 2005) describe the use of these formalisms in the specification of business processes.

The *Yet Another Workflow Language* (YAWL) (Aalst and Hofstede, 2005) is the most well succeeded approach for business process specification based on Petri nets. It was developed intending to provide means for defining all the original control-flow patterns described in (Aalst et al., 2003). Also with the intention of representing business processes with a formal basis, *Navigation Plan Definition Language* (NPDL) (Braghetto et al., 2007) was created. NPDL is based on the concept of *navigation plan* of *RiverFish* architecture (Ferreira et al., 2005) as well as in the operators of ACP (Fokkink, 2000), a member of the family of process algebras. The navigation plan was formalized in (Ferreira et al., 2006) as a set of all business processes demanded from an application in order to achieve business goals. Like in processes algebras, processes in NPDL are defined by algebraic expressions. The expression of a process is built based on NPDL operators and steps (atomic actions or processes); the operators indicate the execution order of the steps. For completeness, we will provide an overview of NPDL operators.

2.1 NPDL Operators

The basic control-flow patterns described in (Aalst et al., 2003) can be easily represented with three basic operators of NPDL:

- ***Sequential Composition*** ("**.**")**.** the process term $A.B$ means that the activity B will be enabled for execution after the completion of the activity A. An activity can be an atomic action or a subprocess;
- ***Alternative Composition*** ("**+**")**.** the process term $A+B$ means that initially both activities A and B will be enabled for execution, but only one of them can be executed;
- ***Parallel Composition*** ("$||$")**.** the process term $A||B$ means that the activities A and B can be executed parallelly.

These basic operators were directly extracted from ACP (*Algebra of Communicating Processes*) and have their semantics formally defined by a set of transition rules that will be presented in the Section 3.2. In order to represent all control-flow patterns identified by Aalst *et al* in (Aalst et al., 2003), the NPDL was improved with additional operators:

- ***Interleaved Parallel Composition*** (**"$|*$"**)**.** the process term $A|*B$ means that the activities A and B can be executed in any order (e.g., $A.B+B.A$), but not in parallel;
- ***Multi Merge Composition*** (**"&"**)**.** the process term $A\&B$ means that the activity B will be enabled for execution after the completion of each thread of control of activity A;
- ***Discriminator Composition*** (**"$\wedge$"**)**.** the process term $A\wedge B$ means that the activity B will be enabled for execution after the completion of the first thread of control of activity A;
- ***Unlimited Repetition*** (**"$?*$"**)**.** the process term $A?*$ means that the activity A can be executed an unrestricted number of times;
- ***Number Limited Repetition*** (**"$?n$"**, where n is a positive integer number)**.** the process term $A?5$ means that the activity A must be executed five times;
- ***Function Limited Repetition*** (**"$?f$"**, where f is a function that returns a positive integer number)**.** the process term $A?f_1$ means that the activity A must be executed the number of times calculated by function f_1 at execution time;
- ***Conditional Execution*** (**"$\%r$"**, where r is a rule, e.g. a boolean function)**.** the process term $\%r_1A$ means that the activity A will be enabled for execution if the return value of the rule r_1 is *true* at execution time;
- ***Negative Conditional Execution*** (**"$\%!r$"**, where r is a rule, e.g. a boolean function)**.** the process term $\%!r_1A$ means that the activity A will be enabled for execution if the return value of the rule r_1 is *false* at execution time.

Providing more details about NPDL is beyond the scope of this paper; the definition of the language and the specification in NPDL of each one of the 20 control-flow patterns described in (Aalst et al., 2003) can be seen in (Braghetto et al., 2007).

3 *NavigationPlanTool*

NavigationPlanTool (NPTool) provides methods for storing actions and processes in a relational database and for controlling the instantiation and execution of these processes. The tool offers operations like creation/removal of instances and services for monitoring the navigation plan execution. These services are also responsible for storing logs of the execution of navigation plans in the database and for recovering executions that have been interrupted before completion.

The programming language used in the implementation of NPTool was Java (*Java 2 Platform Standard Edition - J2SE 5.0*). NPTool extends JDBC API - *Java DataBase Conectivity Application Programming Interface*. JDBC enables Java programs to execute SQL commands and to interact with databases that are compatible with SQL standard. The usage of JDBC turns NPTool into a RDBMS independent tool. Since it was developed as a library of functions, the NPTool can be easily integrated into other Java applications.

NPTool is composed of three services:

• ***NPDL Interpreter.*** receives an input command and makes the lexical, syntactic and semantical analysis. There are two possible situations: (1) the command is a NPDL valid command, and (2) the command is not a NPDL valid command. In the former case, the interpreter will translate the command to pure SQL commands before the submission to the RDBMS. In the latter case, the command will be directly passed to the RDBMS. The translated SQL commands will be executed over a relational database environment whose tables are created by the interpreter to store processes, actions and instances data;

• ***Process Instantiation Service.*** provides functions for creating process instances. A process instance represents a request to a specific process. All the instance data, as well as process definition data associated with the instance, are stored in a database;

• ***Process Instance Execution Monitor.*** is responsible for linking a process instance to its execution data (navigation plan). This service contains the functions that control the execution of the navigation plan of a process instance.

3.1 The Relational Data Structures Created by NPDL Interpreter

The relational data model does not have appropriate structures for representing processes and, therefore, it requires an additional data structure to achieve this task.

In (Braghetto et al., 2007), the NPDL syntax was defined as an extension of the SQL syntax. The main goal of implementing NPDL as a SQL extension was to enable a RDBMS to create and handle business processes, providing to information systems an easy access to these features. The data structure kept stored in a database by NPTool is represented in the extended entity-relationship diagram shown in Figure 1. The diagram shows the data structures needed for representing business processes and for controlling their instantiations and executions.

In NPDL, the navigation plan of a process is defined by an algebraic expression formed by steps composed by operators that indicate the execution order of these steps. The relationship-set `NAVIGATION_PLAN_REL` between the entities-set `PROCESS` and `STEP` represents this definition. The specialization of `STEP` is total and disjoint, i.e., each entity in `STEP` is a process, or an action, or an operator, or a rule, or a function or a number. As described in Section 2.1, rules are always associated with the operators "%" and "%!", whereas functions and numbers are associated with operator "?". The entity-set `PROCESS_INSTANCE` and the relationship `INSTANCE_LOG_REL` are associated with the instantiation and control of process execution. An entity of `PROCESS_INSTANCE` is always associated with an entity of `PROCESS`, as the relationship `PROCESS_INSTANCE_REL` shows; an instance represents a process request. The relationship `INSTANCE_LOG_REL` represents the data related to execution status of the steps that compose the navigation plan of a process instance. Each entity of `INSTANCE_LOG_REL` represents the execution of a step in a specific process instance.

In Section 3.2, the implementation of the service *Process Instance Execution Monitor* will be detailed to show how process algebra properties and this relational database model were used for developing a scalable and reliable engine that controls the business processes execution.

3.2 The Execution Control of Business Processes in NPTool

When an execution of a process instance is started, the navigation plan associated with the instance is recovered from database. According to the algebraic

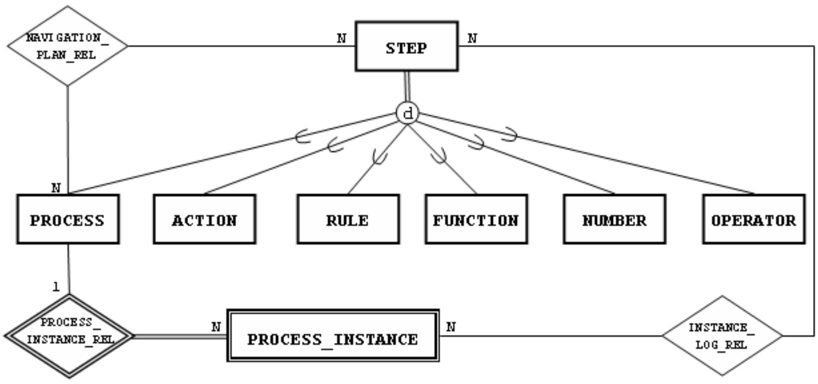


Figure 1: Extended entity-relationship diagram of process data.

expression that represents the navigation plan, an expression tree of the instance is built. Expression trees are used in the execution monitor service to determine the execution order of the steps in the navigation plan. In this work, the expression tree of a process instance was called *navigation tree*. A navigation tree node can represent one of these three elements: a NPDL operator, an action or a process. A navigation tree is a complete binary tree; its internal nodes represent binary operators of NPDL, whereas its leaf nodes represent actions or processes. As the navigation tree nodes represent the possible execution steps, an important attribute of a node is its current status. A node, in a specific point of the instance execution, can be in one of the following states: *not started* (N), *started* (S), *finished* (F) or *canceled* (C). The Figure 2 shows an hypothetical example of one of the possible navigation tree for an instance of process $P = (a+b).c.(d\|e).f$.

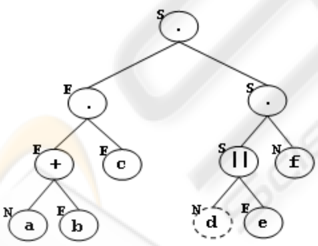


Figure 2: Navigation tree of an instance of process $P = (a+b).c.(d\|e).f$.

After creating the navigation tree, the execution monitor recovers the current state of the instance execution by consulting the execution instances log, that is stored in the database. This operation only is done for instances that have already started their execution, but have not finished it yet. When an instance execution is started, all nodes in its navigation tree will have the current status *not started*. If the instance execution have already been started in a previous execution of the monitor service, there will be records related to the instance in the log and they must be loaded to the navigation tree. This is made by updating the status of the tree nodes associated with the steps indicated as started, finished or canceled in the log. Each step performed in the navigation plan of an instance results in the insertion or update of a record in the log.

$$\frac{x \xrightarrow{v} \surd}{x+y \xrightarrow{v} \surd} \quad \frac{x \xrightarrow{v} x'}{x+y \xrightarrow{v} x'} \quad \frac{y \xrightarrow{v} \surd}{x+y \xrightarrow{v} \surd} \quad \frac{y \xrightarrow{v} y'}{x+y \xrightarrow{v} y'} \qquad (1)$$

$$\frac{x \xrightarrow{v} \surd}{x.y \xrightarrow{v} y} \quad \frac{x \xrightarrow{v} x'}{x.y \xrightarrow{v} x'.y} \qquad (2)$$

$$\frac{x \xrightarrow{v} \surd}{x\|y \xrightarrow{v} y} \quad \frac{x \xrightarrow{v} x'}{x\|y \xrightarrow{v} x'\|y} \quad \frac{y \xrightarrow{v} \surd}{x\|y \xrightarrow{v} x} \quad \frac{y \xrightarrow{v} y'}{x\|y \xrightarrow{v} x\|y'} \qquad (3)$$

Figure 3: Transition rules for basic operators of process algebra. The variables x and y in the rules range over basic process terms, while v ranges over the set of atomic actions.

The "navigation" through the tree of an instance determines the execution order of the steps of this instance. The algorithms of the monitor service of NPTool use the semantics of NPDL operators and the transition rules of process algebra to visit a navigation tree. Figure 3(1,2,3) shows the transition rules extracted from (Fokkink, 2000) that define the operational semantics of terms of basic process algebra and ACP. The operational semantics of a language describes how a valid sentence must be interpreted in sequential steps. Figures 4 to 6 show how the transition rules are applied on the navigation tree branches to guarantee that the instance status, after starting or finishing the execution of an action, will be consistent with the behavior specified by the algebraic expression of the process associated with the instance.

The four rules in Figure 3(1) states that the process defined by the term $x+y$ terminates successfully after executing x or y. Figure 4 shows how the *alter-*

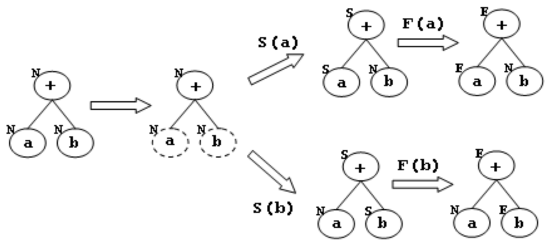


Figure 4: State transitions for a branch rooted at an operator of *alternative composition*.

native composition operator ("+") is treated in a navigation tree branch. As in figures 7 to 14, the nodes delimited by an ellipse with dashed line indicate the actions that are enabled for execution in the current instance state represented by the tree. The labeled arrows signalize the start or the end of the execution of an action[1]. So, $S(a)$ signalizes the start of the action a, while $F(a)$ signalizes the end of the same action. The start or finish of the execution of an action in an instance modifies the status of a leaf node in its navigation tree. Each modification in the status of a leaf node in a navigation tree requires the update of status of its predecessor nodes. To enable this operation, each node keeps a pointer to its parent node, besides the pointers to the left child and the right child nodes. The status node configuration in a navigation tree determines the current state of the instance; thus, a change in the instance state generates a new set of actions currently enabled for execution. The status of a node that represents an *alternative composition* operator is specified by the status of its child nodes in the following way:

• *Started*: if the left **or** the right child has status *started*;

• *Finished*: if the left **or** the right child has status *finished*;

• *Canceled*: if the left **and** the right child has status *canceled*.

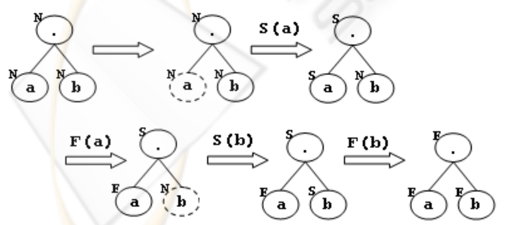


Figure 5: State transitions for a branch rooted at an operator of *sequential composition*.

In Figure 3(2), the rules state that the process represented by $x.y$ executes first x and, after x have been finished successfully, it starts the execution of y. Figure 5 shows the possible state changes in a branch rooted at a *sequential composition* (".") operator.

The status of a node with a *sequential composition* operator is specified by the status of its child nodes in the following way:

• *Started*: if the left child has status *started* **or** if the left child has the status *finished* and the right child has status *started*. The right child will never have status *started* while the left child does not have status *finished*;

• *Finished*: if the left **and** the right child has status *finished*;

• *Canceled*: if the left **and/or** the right child has status *canceled*.

The process term $x \| y$ indicates that the terms x and y will be executed parallelly, i.e., it is possible to execute an initial transition of x ($x \xrightarrow{v} \surd$ or $x \xrightarrow{v} x'$) or a initial transition of y. This behavior is formally specified by the rules in Figure 3(3). The set of all the possible states originated by an expression involving the *parallel composition* ("$\|$") operator is large, as Figure 6 shows. The status of a node that represents the *parallel composition* operator is specified by the status of its child nodes in the following way:

• *Started*: if the left **or** the right child has status *started*;

• *Finished*: if the left **and** the right child has status *finished*;

• *Canceled*: if the left **and/or** the right child has status *canceled*.

The *conditional execution*, *negative conditional execution*, *unlimited repetition*, *number limited repetition* and *function limited repetition* operators are not treated as nodes in the navigation tree. They are treated as attributes of nodes, since they influence the execution of the complete branch rooted at the node with which they are associated. If a node have a rule or a function associated with it, then it is necessary to execute this rule or function before "visiting" the node in the navigation algorithm. The execution of the rule or function, like in the case of atomic actions, is a responsibility of the applications that use the NPTool. When an action or a process term is delimited by some of the two conditional execution operators, the rule that conditionates the execution is attributed to the node that represents the delimited action or to the root node of the delimited process term.

In the example of Figure 7(a), the execution of action a is conditioned by the return value *true* of rule r_1, while the execution of b is conditioned by the return value *false*. In this example, the return value of r_1 was *true*; so, after finishing the execution of r_1, only

[1] In NPTool, the actions of a process may not have an instantaneous execution, i.e., the execution can be distinguished by a start event and by an ending event.

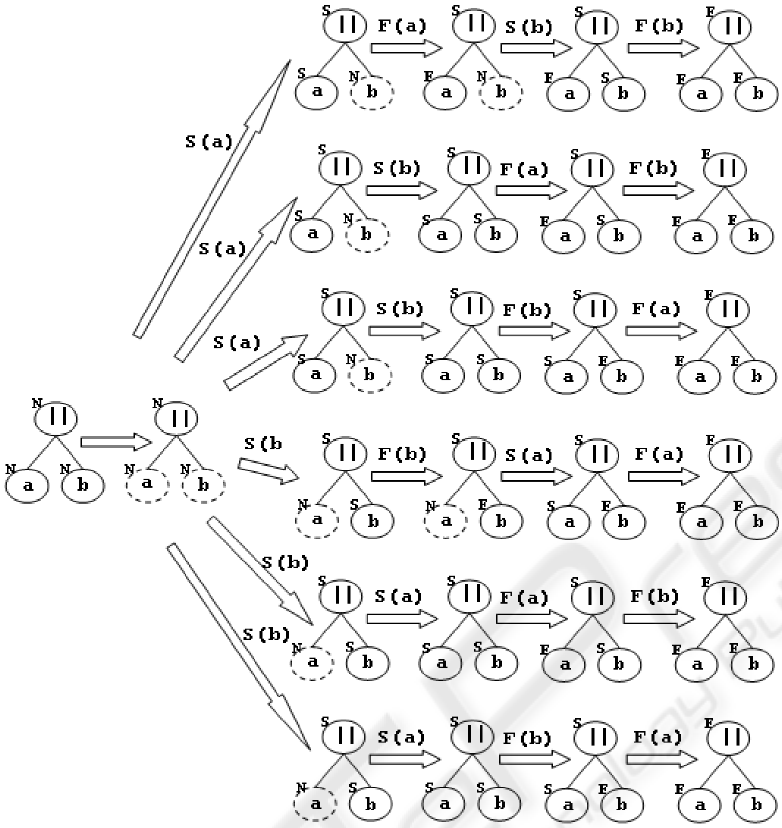
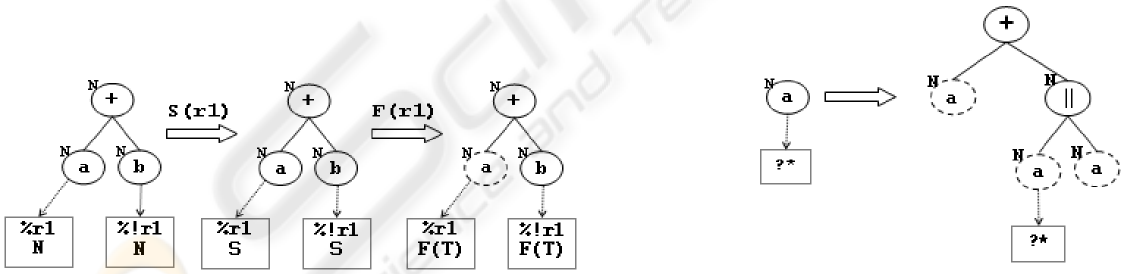


Figure 6: State transitions for a branch rooted at an operator of *parallel composition*.



(a) (b)

Figure 7: Treatment of (a) node associated with rules or functions and (b) nodes with *unlimited repetition*.

the action *a* was enabled to be executed.

In the case of repetitive actions or process terms, the node that represents the action or term is labeled as repetitive, and if this repetition is limited by a number or a function, this number or function will be associated with the node. Figure 7(b) shows how a repetitive node is treated by "expanding" it in an equivalent branch.

The inspection of a navigation tree in order to get enabled steps to execution in an instance is also controlled by the transition rules expressed in Figure 3; the rules are used to determine how the nodes of the tree should be visited. The execution monitor starts to visit the navigation tree from its root node. Accordingly the current status of the tree nodes, the navigation returns a set of steps currently enabled to be executed in the instance.

Only the basic operators of NPDL are kept in the navigation tree. The other operators are treated by a mapping algorithm that removes them of the navigation tree, replacing them by an equivalent branch containing only basic operators. Figures 8 and 9 show how nodes rooted at non-basic NPDL operators in the navigation tree can be replaced by other equivalent

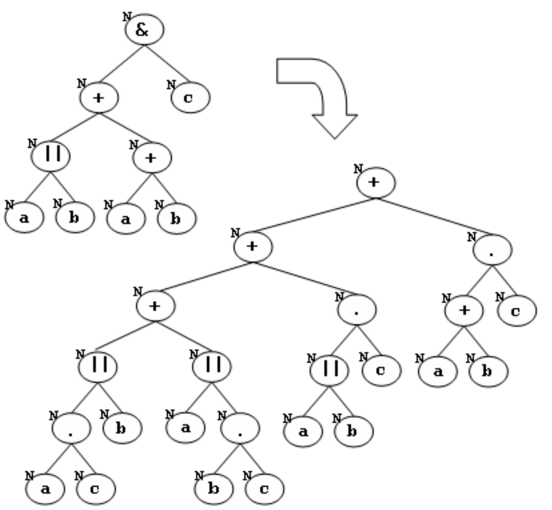


Figure 8: Treatment of a branch rooted at a *multi merge composition* operator.

branches.

Processes that involve in their definition a reference to other processes are treated by a simple substitution. The navigation tree for the referred process is created and "connected" to the navigation tree of the instance, replacing the node that represents the process. After the substitution of the process node by the tree that represents it, the algorithm for obtaining enabled steps is applied on the root node of the referred process.

The execution of an instance is considered successfully complete when the status of the root node of its navigation tree is set to *finished*.

4 EXAMPLE OF EXECUTION CONTROL

This section illustrates a simulated execution of a process instance. It shows how works the navigation that gets the enabled steps and updates the state of the navigation tree. The process used as example is a simplified version of a system developed for controlling the acquisition of items to a library collection.

Consider the set of rules and the set of actions belonging to the acquisition system that are defined, respectively, as $R = \{r_1\}$ and $A = \{a_1, a_2, a_3, a_4, a_5\}$, such that:

• r_1 checks the completeness of data from acquisition order and the availability of the budget for purchasing;

• a_1 sorts the order items according to some priority;

• a_2 gathers the prices of the order items;

• a_3 liberates the order for purchasing;

• a_4 registers the purchase receiving;

• a_5 registers a problem with the purchase.

The acquisition system can be specified by the process P defined in NPDL by the commands:

```
SET P1 = a1 |* a2 + (a1 |* a2).P1;
SET P = %r1 P1 . a3 . (a4 + a5?* . a4);
```

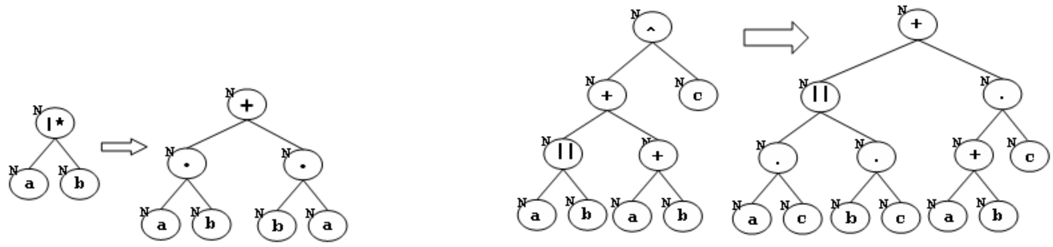
The check step of order data is treated as a rule (in the case, r_1). Thus, the execution of the activities involved in the acquisition system will only be enabled if the order data is valid and there is available budget for the purchase. The subprocess P_1 encapsulates the actions of sorting items (a_1) and gathering items price (a_2) . The actions are composed by the operator "$|*$", that indicates that they can be executed in any order, but not in parallel. Moreover, P_1 was defined in a recursive way. This indicates that these actions can be repeated an unrestricted number of times before the liberation of the order for purchasing. After the liberation of the order (action a_3), it is possible that problems occur in the purchase. These problems are registered in the acquisition process by the action a_5. The repetition operator "$?*$" was used associated with a_5, to represent the possibility of occurring more than one problem during the purchase.

The initial navigation tree of an instance of acquisition process is represented in Figure 10(a). Each node has, at the upper left side, a character that indicates one of the following states: "N" (not started), "S" (started) and "F" (finished). It is important to notice that, associated with the node that represents the process P_1 in the tree, exists the rule r_1. Such as the tree nodes, a rule has a status too. Associated with the node representing action a_5, exists the operator "$?*$", that indicates that the action can have its execution repeated.

In the beginning of the execution, the tree is visited starting on its root node (distinguished by a dashed line in Figure 10(a)). While the navigation algorithm is visiting the tree nodes, it comes across the rule r_1 and it adds the rule in the set of currently enabled steps to execution. Since the execution of the other steps depends on the execution of step conditioned by r_1, no other step can be executed at first.

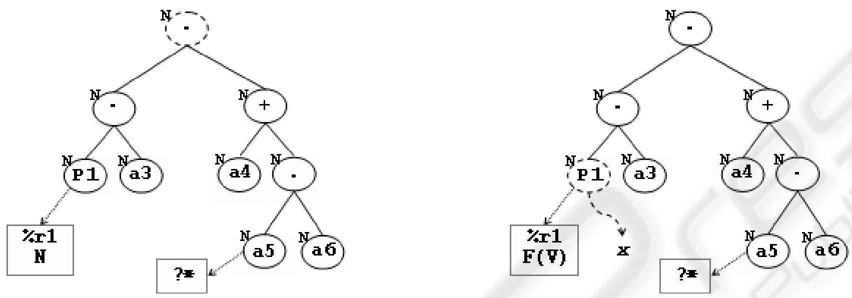
Considering now that r_1 have been executed and its return value was *true*, the algorithm for getting the currently enabled steps is applied on the node associated with r_1 in the tree and finds the node x in Figure 10(b). The node x represents the process P_1 and, as explained previously, it needs to be expanded by replacing the node by its navigation tree. Figure 11(a) shows the tree after the substitution.

Continuing the visitation to the tree nodes, the al-



(a) (b)

Figure 9: Treatment of a branch rooted at the operators (a) *interleaved parallel* and (b) *discriminator composition*.



(a) (b)

Figure 10: (a) Initial state of the tree for an instance of acquisition process. (b) Tree after the execution of the rule r_1.

gorithm detects the existence of the operator "$|*$" in two different places in the tree (nodes x and y in Figure 11(a)). Since the operator "$|*$" is not a NPDL basic operator, it requires a special treatment.

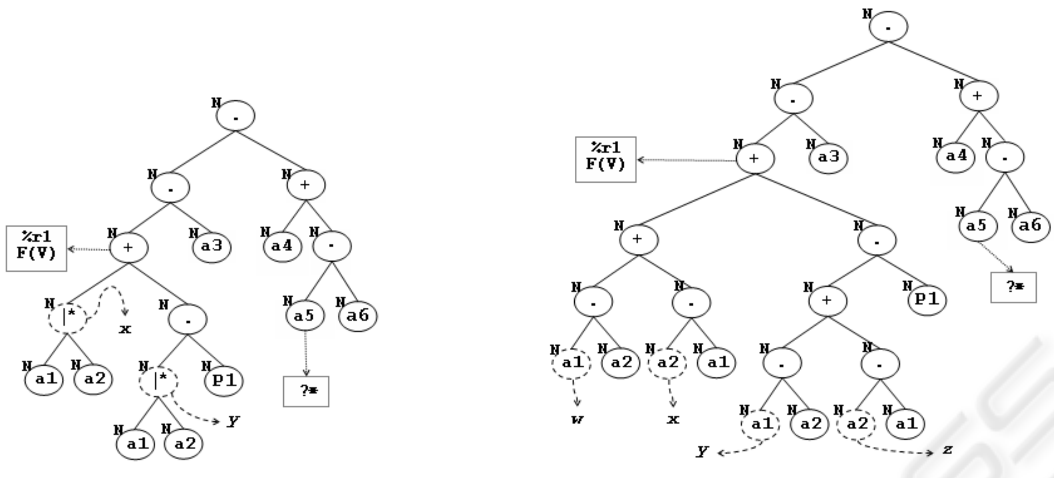
In NPDL, a process term like $a|*b$ is equivalent to $a.b+b.a$. Figure 11(b) shows the navigation tree after mapping the operators "$|*$". After the mapping, the visitation algorithm is able to identify the currently enabled steps to execution. As the distinguished nodes in Figure 11(b) shows, there are two enabled steps to execution in the navigation tree: actions a_1 and a_2.

Consider that, after the execution of r_1, the action a_2 have been executed, and the algorithm for propagating the status update through the tree nodes is applied on the nodes x and z of Figure 11(b). In the resulted tree, only the action a_1 is enabled to execution; Figure 12(a) shows the tree after the execution of a_1.

In a navigation tree, branches rooted at a node whose status have already been defined as *finished* and which do not have enabled steps to execution can be removed from the tree. The goal of this removal is the optimization of the main memory occupied by the storage of the trees. Figure 12(b) illustrates the tree resulted by the removal of the inaccessible branches of the tree in Figure 12(a); the nodes distinguished by the background color gray are the nodes that had their children removed.

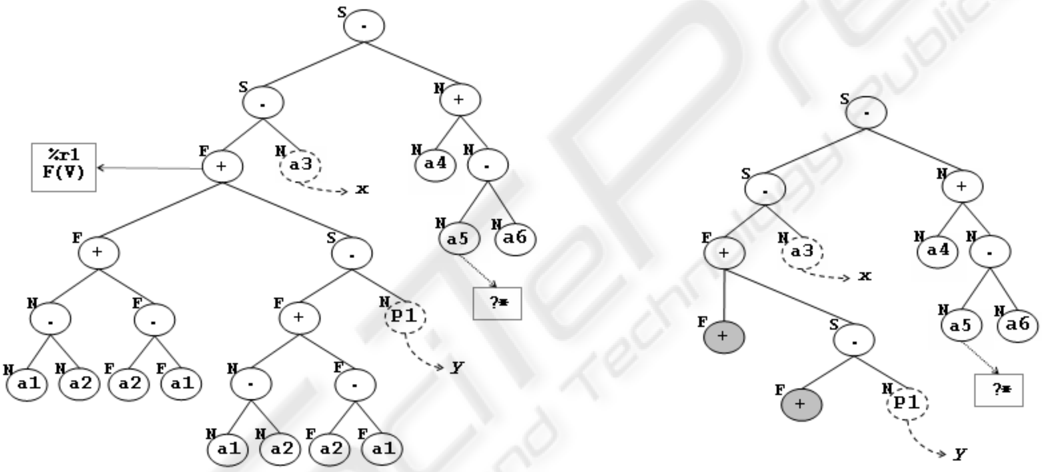
The navigation for getting the currently enabled steps to execution detects the node y in Figure 12(b), which once more represents the process P_1. The node is replaced by the navigation tree of process P_1, resulting the tree in Figure 13(a). In the tree in Figure 13(a), the nodes x and y represents the operators "$|*$", which must be mapped to basic operators, resulting the tree in Figure 13(b). In the tree in Figure 13(b), the enabled steps are the actions a_1 (nodes w and y), a_2 (nodes x and z) and a_3 (node v). If the chosen step for execution is the action a_3, the application of the algorithm for propagating the status update through the tree nodes over the node v in Figure 13(b) results in the tree in Figure 14(a).

When the algorithm of navigation finds the node y in the tree in Figure 14(a), it will apply the mapping of the operator "$?*$" associated with the action a_5, resulting the tree in Figure 14(b). In this tree, the currently enabled steps to execution are the actions a_4 and a_5. The tree in Figure 14(c) is obtained by executing the action a_4 and applying algorithm for propagating the status update over the node w in Figure 14(b). The root node of the tree in Figure 14(c) has the status *finished*, which indicates that the execution of the process instance was terminated successfully.



(a) (b)

Figure 11: (a) Navigation tree after the substitution of P_1 and, next, (b) after the substitution of operators "|∗".



(a) (b)

Figure 12: Navigation tree (a) after the execution of actions a_2 and a_1, and (b) after the removal of inaccessible branches.

5 CONCLUSIONS

NavigationPlanTool is a framework that uses NPDL and a relational database model to specify business processes and control their instantiations and executions. The NPDL language is based on the concept of *navigation plan* of the *RiverFish* architecture as well as in the operators of processes algebra.

The simplicity of the relational database model (used by NPTool for the storage of processes, instances and its executions) is consequence of the adoption of processes algebra as formal basis, due to its algebraic and textual form. Albeit simple, this model has proved to be quite flexible, since it allows the enrichment of the expressiveness of NPDL (by including new operators in the language) without causing impact to the data structure. This model also allows us to make reuse of the processes definition between different applications that use the *NPTool*, as it can be viewed as a common repository of processes. Moreover, the compositional characteristic of processes algebra makes the composition of great processes from smaller ones possible. This constitutes an important aspect for business processes, in which the reuse of definitions is a common occurrence.

The implementation of NPDL as an extension of the SQL language provided by *NavigationPlanTool* allows its easy integration to traditional information systems, which already have mechanisms that facilitate the access to RDBMSs. In addition to that, the storage of the processes definition data, instances and its executions in a relational database makes the *Nav-*

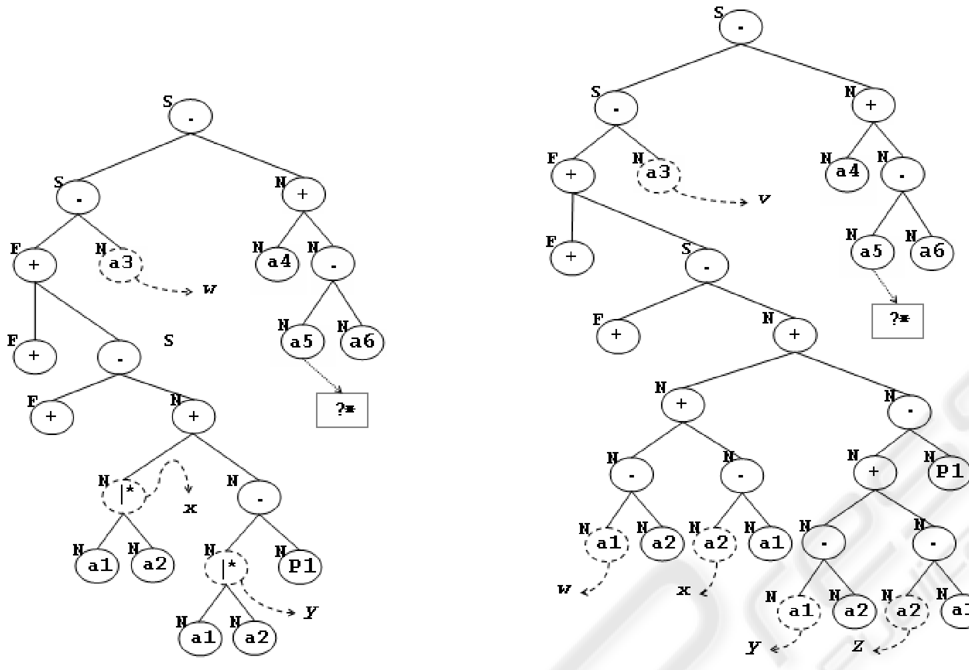


Figure 13: Navigation tree (a) after substituting P_1 and, next, (b) after the substitution of the operators "$|*$".

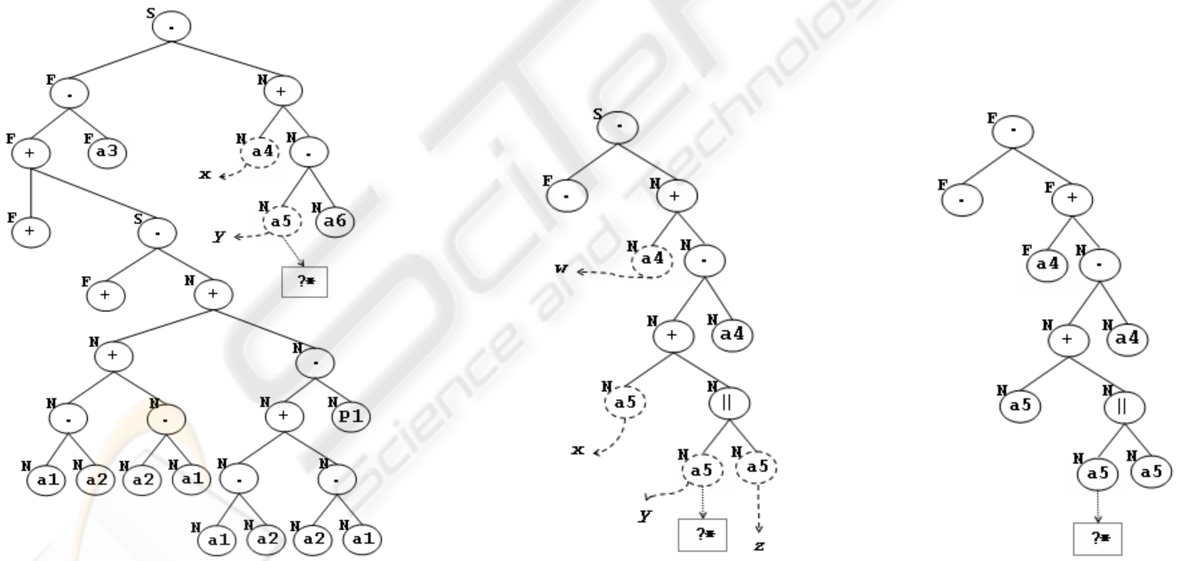


Figure 14: Navigation tree (a) after executing action a_3, (b) after the removal of inaccessible branches and mapping operator "?$*$"; next, (c) after executing action a_4.

igationPlanTool a tool that can be used by information systems that require scalable and reliable control to execute business processes. These reliability and scalability are assured by the use of a RDBMS.

Currently NPTool has been used in three important applications: controlling the acquisition and lending of library items at University of São Paulo (USP); managing of clinical exams in the Human Genoma Institute at USP, and the identification of HIV drug resistance. Details about the latter can be seen in (Araújo et al., 2008); the referred paper presents an alternative for mapping of genotypic drug resistance algorithms rules using NPDL expressions.

Our ongoing research topics include the identification and reuse of control-flow patterns in business processes, data flow management for business processes and automated generation of NPDL expressions from graphical representations.

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