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Towards a Formal Definition of Goal-Oriented Business Process Patterns

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Abstract. Organizations of today are becoming ever more focused on their business processes. This has resulted in an increasing interest in using best practices for business process reengineering. Two problems arise in connection to using best practices: how to find a best practice that suits particular purposes, and how to ensure that the process from the best practice has the same nature as the process under reengineering. The paper suggests using business process patterns, i.e. relatively high level business process models, for making near formal comparison of business processes. The paper analyzes widespread modeling techniques to find out which of them suits the task of building patterns for comparison. Based on this analysis, the state-flow modeling technique is chosen and first steps towards formal definition of business process patterns based on this technique are suggested. A pattern is defined based on the notions of state space, goal, as a surface in the state space, and valid movements towards the goal. A thinkable procedure of constructing patterns is demonstrated on two real-life examples. A hypothetical procedure for comparing process is suggested but it still needs to be verified in practice.

Keywords: business process pattern, business process modeling, BPR, best practice

1. Introduction

Much of the work that is being done in the field of business process management has one purpose: to make business processes more effective and efficient, e.g. by cutting costs, and increasing quality of goods and services. One widely accepted approach for improving the performance of processes is to reengineer them based on best practices, which can also include adoption of information systems used in these best practices.

Borrowing a best practice from another organization cannot be done literally. We need to abstract from details in order to introduce the best practice in a new environment. Furthermore, before trying to take over somebody else's best practice, we need to be sure that we are borrowing from the process that has the same nature as the one we want to substitute with the best practice. Borrowing based on a wrong ("shallow") analogy may lead to catastrophic results as demonstrated in the following example.

In the middle of 1990th, the Swedish parliament passed a law that completely changed the state pension system. A new authority was established to handle the pensions, and a new IT system was purchased to support the work of this authority. When choosing the system, the new authority drew a conclusion based on an invalid analogy. They asked: "Who works with private pensions?", and got the obvious answer: "insurance companies". As the result, one of the most wide spread pension-handling systems was purchased from a well-known vendor who promised to adjust it to fit the needs of the new authority. It turned out that the system could never be adjusted to fit the authority's needs because their business was not similar to the one of insurance companies. An invalid analogy lead to a two year delay in the introduction of the new pension system, and a loss of money paid for the adjustment of the wrong system.

Suppose we have built a database with business processes taken from best practices. Assume we have an unsatisfactory functioning process that we want to substitute with a better one from the database. The question arises how we can find a suitable process in the database. If the database is relatively small, we can manually compare all processes with the one we want to substitute. However, when the database grows and becomes large, some formal means to narrow the area of manual comparison is required.

To narrow the area of search we need a general way to annotate business processes. The annotating mechanism should be of such nature that it allows establishing whether two processes are similar or not based on comparing their annotations. We believe that for annotating mechanism to be suitable for searching in the best practices database the following criteria should be observed:

1. The annotation should be formulated in a neutral terminology independent of the language and methodology used in the process descriptions. This neutral terminology would enable searches resulting in a minimization of false hits and a maximization of good hits.
2. The annotation, in one way or another, should represent the goal of the process, as naturally, the processes we are looking for should have the same goal as the one we want to substitute.
3. The annotation, as long as possible, should not refer to the order of activities in the process. The process we want to substitute may be unsatisfactory just because it has a "wrong" order of activities.
4. The annotation, as long as possible, should not refer to in what way and by whom the activities are performed in the process. The process we want to substitute may be unsatisfactory just because a "wrong" way of performing some activities is used, or/and "wrong" actors are assigned to perform some activities.
5. There should be a way to make annotations and comparison completely formal so that an automated retrieval could be introduced at some stage.

We believe that for an annotation to fulfil the criteria listed above, especially the first one, it should represent a kind of a model of the business process to which it refers. Consider detailed process descriptions as being at one extreme of a model scale and business process meta-models at the other. Between these extremes may exist a type of "language agnostic" model on a level of details suitable for our task.

"Middle-scale" models are widespread in many practical fields under the name of patterns, e.g. pattern matching in AI, design patterns in the sense of (Gamma et al., 1995), analysis patterns in the sense of (Fowler, 1997). The ideas of analysis and design patterns have already started to be exploited in connection to business processes, see, for example, (Malone et al., 1999, Aalst et al., 2003). In this paper, we investigate another possible use of business process patterns, namely, as goal-oriented and terminology independent annotations for comparing business processes.

The paper suggests one possible procedure of constructing business process patterns that satisfies the above listed criteria and can be used as an annotation mechanism. The patterns are constructed based on the state-oriented approach to business process

modeling as described in (Khomyakov and Bider, 2001). In this approach, a business process is viewed not as sequence of activities, but as a trajectory in a specially constructed multidimensional state space. Based on this approach, a pattern is defined as a three component entity: state space, goal, and valid movements in state space.

The work presented in this paper is based on the analysis of literature and on our own experience in the field of business process identification and modeling. Our own experience lies in the field of administrative processes, such as bureaucratic decision-making, lobbying (influence decision of others), processing customer feedback, inquiries, funeral arrangements, etc., for examples, see (Andersson et al., 2002). This kind of processes has not received much attention in the literature where the standard examples concern production, sales, or insurance claims. The main characteristic feature of the administrative processes is their relatively loosely structure as far as the exact order of activities is concerned. Considering both well-structured and loosely-structured processes gave us a relatively broad basis for analysis.

The paper is structured in the following way. In section 2, we present a part of the factual material on which the suggested pattern definition approach is based. In section 3, we analyze the widespread approaches to business process modeling to see which one suits best for our task. In section 4, the state-oriented approach to business process modeling is presented and it is demonstrated how it can be used for a formal definition of patterns. In section 5, possible procedures for constructing and using patterns are described. Section 6 discusses related research. Section 7 summarizes the results achieved and discusses future research plans.

2. Informal examples

This section informally introduces two examples of business process patterns. The first one has been taken from literature, and it concerns a sales/collection process. The second has been taken from our practice and concerns a decision making process.

2.1 Example: Sales/collection

The idea of generalized description of business processes is not new. It appeared in several research works (Denna et al., 1995, Malone et al., 1999), but not always with explicit reference to the notion of pattern. For example, (Denna et al., 1995) identifies three most important business processes for industrial organizations: acquisition/payment, conversion, and sales/collection. Each such process is described in a sequence of activities, called business events in the terminology of (Denna et al., 1995). The events may be defined with more or less level of details. For example, the “sales/collection” process may be described as:

- Accept customer order
- Select, inspect, and package merchandise
- Ship merchandise
- Receive customer payment

The same process may be described in less detail as:

- Ship merchandise
- Receive payment

According to (Denna et al., 1995), the sequence of events may differ from organization to organization, and from customer to customer. Therefore, the generalized sales/collection process cannot be defined as a prescribed sequence of events, but rather as a set of business objectives. The objectives of the sales/collection process can be defined as achieving the state of the business world in which the following two propositions are true:

- The customer has the merchandise he ordered
- The organization received the payment agreed upon with the customer

2.2 Example: Decision making

The example of a decision making process described below was first discovered when analyzing a particular customer. Then it was abstracted from the customer-related details and checked with other customers having the same kind of business activity. Thus, the description below represents a generalized process, not a business process specific for a particular organization.

Consider a situation with a decision-making body, e.g., a company board, or political organ, constantly making decisions prepared by some service department/organization, like the company's head quarters, or administrative office. In such an organizational structure the decision-making process may be described in a uniform way independently of what kind of decisions are made by a particular decision-making body.

A decision-making process starts when a resolution is to be adopted by the decision-making body. A decision-making process usually originates in some document. This document can arrive from the external world, e.g., a proposal from a political party, information on a new regulation passed by a parliament, etc. Alternatively, it can be produced internally, e.g., a record from the previous meeting. This document may be considered as an "order" for a decision-making.

Before the decision-making body can pass a resolution, all relevant basic information should be gathered, and assessed. Assessment results in a proposal for a resolution prepared by the service organization. The basis for decision-making may be considered as a collection of ground documents, e.g., documents containing external or internal opinions on the matter, calculations, laws and other regulations that should be taken into consideration, etc. At the start of the decision-making process, some of these ground documents exist e.g., laws and regulations, others, e.g., internal or external opinions, are compiled during the process.

In short, a decision making process can be summarized in the following steps: defining which ground documents are needed to support a particular decision, acquiring each document, assessing them, preparing a proposal and finally passing a resolution. In a particular case, depending on the situation, the process may be much more complicated. The procedures of acquiring ground documents depend on the type of ground document in question. If it is an existing regulation, it should be found in an appropriate store (a

bookshelf, a database, etc.). If it is an internal opinion on the matter, the task of writing the ground document should be assigned to an appropriate member of staff of the service organization, e.g. a lawyer. If it is an external opinion from some interested party, it should be requested from this party, etc.

The objectives of the generalized decision making process may be described in the same way as for the generalized sales/collection process in section 2.1. Namely, achieving the state of the business world in which the following two propositions are true:

- All ground documents are defined, collected, and assessed
- The proposal is prepared and passed by a decision making body

The details of the project in which this process was analyzed are presented in (Andersson et al., 2002).

3. Analyzing approaches to business process modeling

According to the general definition of a business process, see, for example, (Hammer and Champy, 1993), a business process is a partially ordered set of activities performed to reach a well-defined goal of a kind illustrated in the examples from the previous section. A process is envisaged to engage a number of participants, which can be divided into two categories: passive and active participants. Passive participants are consumed, produced or changed through the execution of activities, for example, a document being written or an organization being reorganized. Active participants, or agents, are those participants that perform activities aimed at the passive participants.

There are many different methods of modeling business processes. Below, the most common ones are grouped in four categories based on the way they reflect the business process dynamics (details see in (Bider, 2002)):

1. *Input/output flows*. The focus is on passive participants that are being consumed, produced, or changed by the activities. A typical notation to represent this kind of flow is IDEF0 (IDEF0, 1993).
2. *Workflows*. The focus is on (partial) time ordering of activities performed by active participants. Typical notations to represent this kind of flow are IDEF3 diagrams (Mayer et al., 1995), Petri nets (Reisig, 1985), and activity diagrams of UML (Rumbaugh et al., 1999).
3. *Agent-related workflows*. The focus is on agent cooperation, i.e. order in which active participants get and perform their part of work. An agent-related workflow adds an agent dimension to the time dimension of an ordinary workflow. A typical notation to represent this kind of flow is Role-Activity Diagrams (Ould, 1995).
4. *State-flows*. The focus is on changes produced by activities executed in the frame of a given process instance. Some changes may concern the state of passive participants, e.g., their form, shape, or physical location. Other changes may concern the state of active participants, e.g. a state of the mind of a human agent trying to find a solution for a complex problem. An example of a state-flow notation is IDEF3 state-transition diagrams (Mayer et al., 1995); these diagrams are complementary to the IDEF 3 workflow diagrams. However, the state-transition diagrams exploit the state-flow

view only partially. For a more extensive exploitation of the state flow view see (Khomyakov and Bider, 2000, Andersson et al., 2002).

Consider which of the above categories is the most appropriate for our task of comparing business processes (see criteria listed in the introduction).

The input/output flows focuses on by what means the things are being done, as they require precise specification of what is consumed, produced or changed by each activity. This makes it difficult to compare the processes taking place in different organizations if they choose different means for achieving the same business objectives.

The workflow view is based on the idea of ordering activities in time. According to (Denna et. al., 1995), even for the sales/collection process, which is relatively well structured, the sequence of activities in one organization may be reversed to what is used in another organization. As far as loosely-structured processes, like decision-making, are concerned, a sequence of activities for such processes is difficult, or, sometimes impossible to establish even for one and the same organization. Therefore, we consider the workflow view as not particularly useful for our task

The agent-related workflows, which focus on the agent cooperation, do not easily allow comparisons of, for example, a sales/collection process in a one-man company with the sales/collection process in a large organization. In the first case, all activities are executed by one universal agent, whereas in the second case, different activities are executed by different specialized agents.

The state-flow view is focused on changes, which allow us to easier abstract from the means and agents used to produce these changes, and from the order in which they are applied, at least while the order is not dictated by some physical laws. We believe that the state-flow represents a promising for our task view on business processes.

4 Defining goal-oriented patterns

4.1 The state-flow view in more details

Creating a business process model based of the state flow view requires construction of a state space for a given business process type. A state space is considered as being multidimensional where each dimension represents some important parameter (and its possible values) of the business process. Each point in the state space represents a possible result of the development of the process. A trajectory (curve) in the state space represents a possible development of a process instance in time.

In Figure 1, the dimensions of the sales/collection process (see Section 2.1) are represented by the axes in a coordinate system. There are two dimensions for each product being sold: *ordered* and *delivered*. The number of such pairs of dimensions is not fixed but are less than or equal to the size of the company's assortment. The product dimensions are denoted as X_1, \dots, X_n (ordered) and Y_1, \dots, Y_n (delivered). Additionally there are two dimensions concerning payment; *invoiced* and *paid*; denoted as Z^{in} , and Z^{pa} .

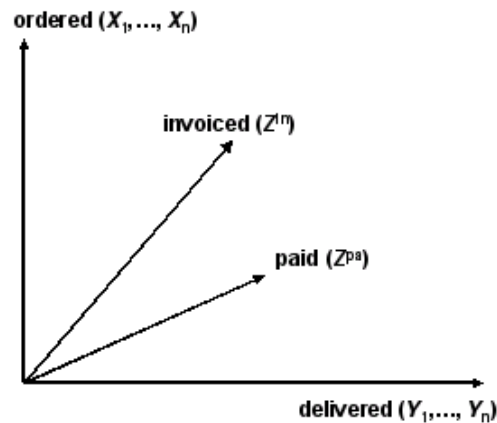


Figure 1. State space of the sales/collection process represented as axes

Figure 2 shows a software representation of the sales/collect process where the process parameters corresponding to the state-flow dimensions are highlighted.

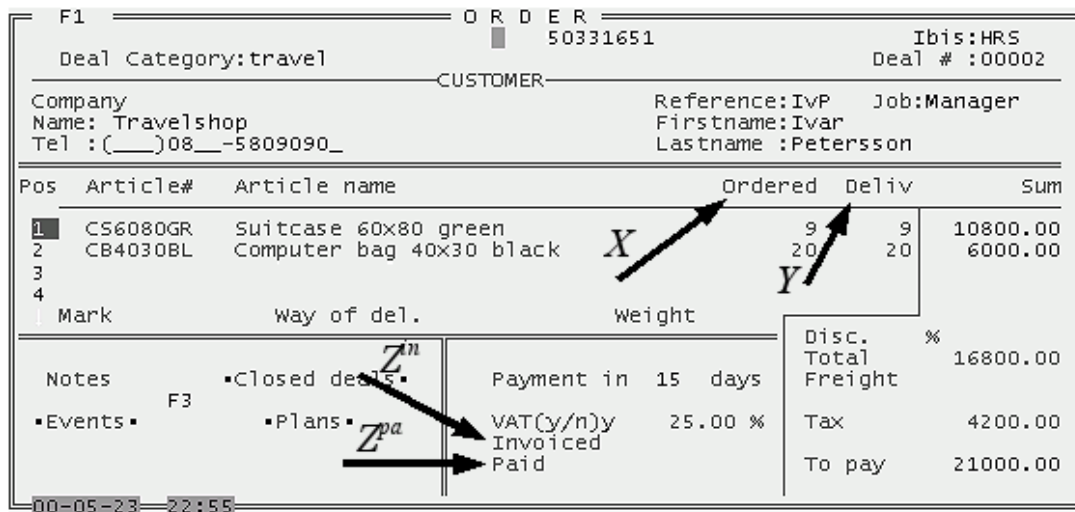


Figure 2. State space of the sales/collection process represented as a screen (from (Khomyakov&Bider, 2000))

With the dimensions set, a sales/collection process is represented as a point moving in the state space. The operational goal of this process may be expressed as reaching the surface in the state space defined by the equations:

$$x_n = y_n, z^{in} = k_1x_1 + \dots + k_nx_n, z^{pa} = z^{in}, \text{ where } k_1, \dots, k_n \text{ represent prices of the products ordered}$$

After defining the state space and the goal, we can investigate possible movements along the identified axes, see Figure 3. Moving along the X-axis means that the customer formulates or changes the order. Moving from the origin along Y-axis means a delivery. Moving towards the origin along Y-axis means a return of goods. Moving from the origin along Z^{in} -axis means an invoice being sent. Moving towards the origin along Z^{in} -axis

means crediting the customer. Moving from the origin along Z^{pa} -axes means that a payment has been received. Moving towards the origin along Z^{pa} -axes means paying back (for example, after a return of faulty goods).

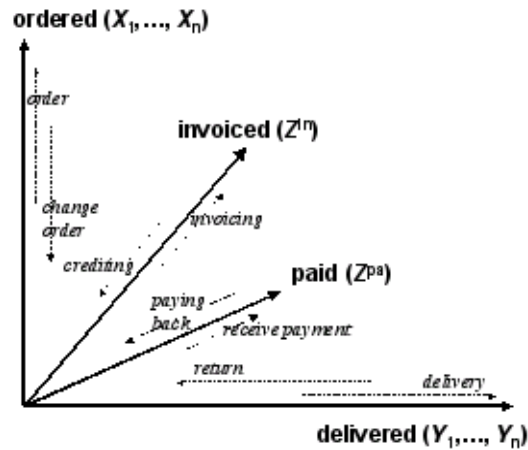


Figure 3. Classified movements along the axes in the sales/collection process' state space

Finishing a model for a particular business process requires setting some restrictions on the order in which valid movements can follow one another in the state space. For example, three kinds of orders can be considered for the sales/collection process dependent on the organization, or/and on the customer:

- (a) *Delivering* product first, *Receiving* money after that, i.e., *sell on credit* when seller has trust in *buyer*.
- (b) *Receiving* money first, *Delivering* product after that, i.e., *prepayment* when seller does not trust *buyer*, but *buyer* does trust *seller*.
- (c) Money and product change owners simultaneously through a third party, e.g., a *cash-on-delivery* parcel; neither *seller* nor *buyer* trust each other, but they trust the third party.

Note that a model based on the state-flow view has quite high level of abstraction; it says nothing about who is performing activities, and how things are done in the real world. It just shows how the position of a process instance is being changed in an abstract space state. As we can arbitrary name dimensions and their values, the model defined above is terminology neutral.

4.2 Pattern definition

The following procedure for checking similarity of two business processes based on their state-flow models can be suggested. Two business processes are considered as similar if:

1. Their state spaces have a similar topology (i.e. similar structure of dimensions). This means that there is a mapping m from one state space into another that possesses some kind of "morphism". Strong similarity of processes requires an isomorphic mapping, but other less strict types of mappings can be considered as well.

2. They have similar goals. Goals are defined as surfaces in the state space. Similarity of goals means that the goal of the second process can be obtained via mapping the goal of the first process by applying mapping m defined above.
3. They have the same kinds of valid movements in the state space towards the goal. Again, it means that valid movements of the second process can be obtained by applying mapping m to the valid movements of the first process.

Note that constraints on the order of movements are not included in the comparison procedure. In addition, it is allowed that the state spaces of the processes we compare are not exactly the same. A large common subspace may be enough to consider two processes as similar. We believe that thus defined similarity satisfies the task of searching in the best practices database formulated in the Introduction.

Based on the formulated above idea of similarity, a pattern for annotating business processes can be defined as a triple

$$P = \langle p\text{-state-space}, p\text{-goal}, p\text{-movements} \rangle$$

The state space of a pattern constructed for a particular business process does not need to be on the same level of details as the state-space of this process. Some less important axes may be omitted, as well as the set of possible values of the remaining axes may be reduced. Which axes and values should be omitted, and which ones should be left in the pattern definition is up to the person annotating a particular business process.

The presented definition of patterns is more conceptual than formal. To make it formal, an understanding of what kinds of state spaces can be useful for representing business processes is needed. However, even now, this definition can be used in practice when analyzing and comparing state pictures of the type shown in Figure 2 (and Figure 4 below) without paying attention on the labels used in the screen shorts.

5. Constructing and using patterns

5.1 Constructing patterns

Based on the definition of business process pattern from the previous section, the construction of a pattern for a particular business process can be done according to the following three steps. Firstly, a state space suitable for representing the development of the process in time is defined. Secondly, the process's goal as a surface in the state space is defined. Finally, all possible valid movements towards the goal are defined.

An example of a pattern construction for a decision making process is given below. A picture of a state space, on Figure 4 (borrowed from (Andersson et al., 2001)), acts as the starting point for this example. Part of the state space for the decision-making process concerns ground documents. As there potentially can be any number of such documents, the state space is considered to have a variable number of dimensions.

Introduce for each ground document two dimensions X_i and Y_i , where X_i shows the progress of obtaining the document, Y_i shows the level of acceptance of the document.

Both dimensions have a finite number of values. For X_i , the values can be defined in general way as:

- *Suggested* – a suggestion has been made to include the document into the grounds (equivalent to zero)
- *Approved* – the document is included in the ground
- *Requested* – somebody was assigned to prepare a document, or a request to an external organization has been sent
- *Obtained* – the document has been prepared, received, or taken from a store, e.g. downloaded
- *Evaluated* – the document has been assessed by the person(s) who is (are) assigned to prepare a proposal.

	Type	Requested	Received	Satus	Document	Author
1	Review		Yes	Evaluated	98/KK0190 Review 1	Union of Retired
2	Review	Yes	Partly		98/KK0190 Review 2	Department of Cult
3	Review	Yes	No			Department of Eld
4	Review		Yes		98/KK0190 Review 3	Department of Plan
5	Opinion			Final	98/KK0190 Opinion 1	Municipality lawyer

Figure 4. The state of the decision-making process from (Andersson, et al. 2002).
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The axes Y_i show the value of acceptance of the ground document after evaluation. The following list of values would be enough for the first approximation:

- *Not accepted* – the document has not been obtained yet, or its content is totally unsatisfactory
- *Partially accepted* – some parts of the document are missing, i.e. appendixes, etc.
- *Accepted* – the document obtained has everything as expected

Besides the axes that concern ground documents, an axis concerning the status of the decision document is needed, denote it Z . For the first approximation, three values of Z are sufficient to represent the status of the decision:

- *Requested* – decision has been ordered
- *Proposed* – a proposal has been written

- *Passed* – a decision has been made

Using the state space as defined above, the goal of the decision-making process can be represented by the following equations:

$$x_i = \textit{Evaluated}, y_i = \textit{Accepted}, \text{ for } i = 1, \dots, n; z = \textit{Passed}.$$

Movements in the decision-making process can be quite complicated. For example, *return for revision* (after the decision body meeting) may result in moving to the position where $z = \textit{Requested}$ (return from $z = \textit{Proposed}$), and a new set of ground document dimensions X_j, Y_j , added with the values assigned to $x_j = \textit{Approved}, y_j = \textit{Not accepted}$. The meaning of such movement can be “We want to hear the opinion of Mr. Watson”.

5.2 Using patterns

Let us return to the task of searching in the best practices database formulated in the introduction. Assume that each time a new process description is added to the database, an associated pattern is constructed according to the rules above and added to the database along with the process description. Let us again have an unsatisfactory functioning process that we want to substitute. Then we can create a pattern for this process according to the same rules and search the database for processes with the same pattern assigned to them. Those that are found should be subjected to manual analysis of their adequacy to the process we want to substitute.

The procedure described above relies on the total match between the pattern we search and the patterns recorded in the database. Under the total match, we mean that one pattern could be transformed into another by renaming the axes, or/and the values that constitute the axes. To increase the number of potentially relevant processes, other types of matching can be considered. The less precise matching procedure could rely on relationships established between patterns. Intersection and inclusion can be considered as potentially useful relationships for matching rules. Intersection is defined as two patterns having a “common” subspace. Common means that the projections of the goal surfaces and the valid movements on this subspace coincide for both patterns. Inclusion means a special kind of intersection when the space of one pattern coincides with a subspace of another pattern.

As the procedure of constructing patterns is a manual one, it is entirely possible that two persons annotating process descriptions construct different patterns for the same process. This means that the annotators were focused on different aspects of the process when deciding which details could be omitted. Using several annotators may increase the recall ratio of information retrieval. In the case when several different patterns are constructed for the same process, all of them can be stored in the database together with the given process. A process is considered as relevant when a match occurs with any of the patterns assigned to it.

6. Related research

A literature on patterns is vast; for the lack of space, we consider here only two directions that are most relevant to the research reported in this work.

A formal approach to defining patterns for business processes is presented in (Aalst et al. 2003). This work is based on the workflow view on business processes. Patterns in (Aalst et al. 2003) define various ways of ordering activities in workflow, e.g., task sequencing, split parallelism, join synchronization, and iteration. It is similar to the approach suggested in the paper in that both approaches are language neutral. It differs from our approach in that it focuses on ordering of activities and thus does not satisfy the set of criteria formulated in the introduction. However, this approach can be quite useful for other tasks, like defining analysis and design patterns, or building and evaluating workflow management systems.

A practically useful methodology for defining and exploiting business process patterns is presented in (Malone et al., 1999). Here, a general process pattern is defined as a number of generalized activities of the type discussed in section 2. A large collection of general and specialized patterns has been built based on this approach, and it is in use for process improvement purposes, i.e. analysis and synthesis. When synthesis is performed, a general pattern is specialized by specializing each of its generalized activities and ordering them. The main aspect in which this approach differs from that of ours is that it is not totally language neutral. Although our movements in the state space correspond to the abstract activities from (Malone et al., 1999), they differ from the latter in two respects. In one respect, state space movements are more abstract as they refer only to the changes in the constructed state space, not to what happens in the real world. In another respect, they are more concrete as they are tied to concrete changes in the position in the state space. Therefore, the results of movements can be measured.

7. Conclusion

In the introduction, we formulated a task of annotating business processes in a way that the similarity between two business processes could be established based on comparing their annotations. A suggestion has been made that a business process pattern, i.e. a relatively high level business process model, could be used as such an annotation. Further, we analyzed widespread modeling techniques to find out which of them is the most suitable for our task. The analysis showed that the state-flow modeling technique is the most promising direction to take. Based on this technique, first steps towards formal definition of goal-oriented business processes patterns were suggested.

The definition of business process pattern is based on the notions of state space, goal, as a surface in the state space, and valid movements towards the goal. The description of valid movements is independent of the activities performed in the real world, e.g. how the activities are named, how they are performed, and in which order. The movements refer only to the changes in the constructed state space. The suggested approach affords a controlled abstraction from many details, without losing the essential nature of a particular business process, e.g. its goal. The suggested approach can be useful for the task of representing the nature of business processes in order to understand where from one can adopt best practices. So far, the suggested procedure for creating and exploiting patterns is hypothetical; an experiment is required to prove or disprove its validity for practical purposes.

We believe that the suggested approach to pattern definition can also be useful for other type of tasks, e.g. analysis, and synthesis (design). For example, synthesis (specialization

in terms of (Malone et al., 1999) from the goal-oriented pattern can be done by steps in two directions:

- Specializing valid movements by adding operational procedures of what should be done in the real world to move the process from one state to another. This corresponds to the external action of activity, discussed in (Bider, 1997, Andersson et al., 2002).
- Establishing constraints on the permissible trajectories of the process in the state space, i.e. introducing some order in activities. This can be done by rules of dynamic planning discussed in (Bider, 1997, Khomyakov and Bider, 2000).

Investigating possibility of other ways of using goal-oriented patterns is included in our future research plans.

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