ANALYSIS OF BUSINESS PROCESS FLEXIBILITY AT DIFFERENT LEVELS OF ABSTRACTION

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Abstract: Business process flexibility is understood as capability of the process to be changed without replacing it completely. This implies that there should be one part of the process that may be changed and another part of the process (process core) that should not be changed. The challenge of business process analysis is the detection and separation of these process subparts. One of the possible ways to meet this challenge is through use of topological functional modeling and utilization of graph theory methods, such as paths and cycle detection in a digraph at different levels of abstraction. The cycles that are found at several levels of abstraction may help detecting the core of the business process while other cycles may point to the changeable parts of the process.

1 INTRODUCTION

Today's organizations are generally operating in an increasingly turbulent environment (Cao et al., 2003). Business process flexibility is one of the possible responses to the challenges posed by these conditions. For instance, organizational theory views individual modern organizations as members of an inter-organizational network (Hatch, 1997); hence, changes occurring in other network members may require a matching adjustment in the particular organization. Such adjustments may affect various sub-systems of the organization, say, goals sub-system, process sub-system, structure or resource sub-systems (Sprice and Kirikova, 2005). The focus of this paper is on business processes adjustments. We will examine this topic from a process flexibility point of view.

For the purposes of this paper flexibility will be defined as the ability to attain the stated results of a business process even where the environment in which the business process is occurring has changed. At the same time there are constraints on how flexible a particular business process may become before it turns into an entirely different one (Regev et al., 2006). From a systems theory point of view a flexible business process features feedback capability ensuring that when the process result differs from what is expected due to changes in the environment, the process is adjusted until the expected result is attained. In this paper we will apply topological functional modeling for analysis of business process flexibility at different levels of abstractions. The purpose of this analysis is to reveal the most important part of the process which may constitute the non-changeable core. Identification of process core could provide means for effective decision making with respect to enterprise information systems development.

The paper is structured as follows: Section 2 briefly illustrates the state of the art in business process flexibility analysis performed by different researchers; in Section 3 the basics of topological functioning model development and cycle oriented interpretation of flexibility are discussed; in Section 4 the approach discussed in Section 3 is applied to a business sub-process analysis at different levels of abstraction (the application is illustrated by a small industrial example); and in Section 5 we discuss implications of our approach to enterprise

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information systems development and point to intended further research questions.

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The main purpose of every information system is supporting a range of particular business processes. As business processes should be capable of adjusting reasonably swiftly to changes in the external environment, such processes ought to, by definition, be flexible (Regev et al., 2006). That also means that if an information system is to support specific business processes continuously it should be flexible as well. Developing flexible information systems has been the subject of extensive research (Daoudi and Nurcan, 2006); however, an unambiguous definition of a flexible business process has not been provided so far. As a consequence, developing information systems supporting such processes is a non-trivial task.

There are different definitions of flexibility; however most of them focus on the ability to respond to external changes in an appropriate period of time using a reasonable amount of resources (Regev et al.,(2006), Daoudi and Nurcan, (2006), (Snowdon, et al., (2006)). For instance, according to Regev (Regev et al., 2006), since flexibility is the capability to change, it can be classified with respect to the types of changes it enables. Snowdon et al. (Snowdon, et al., 2006) writes that flexibility is the 'ability of a firm's processes and systems to respond quickly to changes in the business environment. It includes the capacity to accommodate shifts in consumer demand, in competitors' strategies, in rate of growth, and in suppliers' deals and shipment problems'.

Even so, the meaning of the term 'flexibility' varies from research to research. A taxonomy of business process flexibility has been developed in an attempt to decrease this ambiguity (Regev et al., 2006). The taxonomy includes three dimensions: The abstraction level of change (business process type and process instances); the subject of change (functional perspective, operational perspective, behavioral perspective, informational perspective, organizational perspective); and the properties of change (the extent, the duration, the swiftness and the anticipation of change). On the other hand there are authors who believe business process flexibility can be examined from three points of view that differ from those listed in Regev's (Regev et al., 2006) taxonomy: Characteristics of the stimulus that generates the requirements for business process flexibility; business process flexibility itself; and the strategies and tactics employed to achieve business process flexibility (Regev et al., 2006). Snowdon et al. (Snowdon, et al., 2006) defines that flexibility can be categorized in terms of three factors: Type of flexibility (arising from the variety of different information types); volume flexibility (arising from the amount of information types to be dealt with); and structural flexibility (arising from the need to operate in different ways).

Summarizing the different approaches described above we come to the conclusion that business process flexibility should be considered from two aspects: The external dimension containing factors that define the necessity for such flexibility and the need to apply it; and the internal dimension which defines the subject of change, the extent of change, and the strategy for achieving such changes.

Several researchers (Regev et al., (2006), Snowdon, et al., (2006), Kumar and Narasipuram, 2006)) conclude that business process changes may be related to the structure of the particular process, data processed, resources and technologies used, and legal aspects.

An analysis was carried out by other authors on the extent of change with the following results: Business process flexibility suffers from the dilemma that whenever some part of a process is made flexible, some other part is made inflexible (Regev and Wegmann, 2006). The key point to flexibility, therefore, is to know when and what to change and when and what not to change (Regev and Wegmann, 2006).

The purpose of our paper is to contribute to better understanding of the abovementioned dilemma and to solve the problem of identification of that part of business process which "is not to be changed" (Regev and Wegmann, 2006).

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As it was discussed in the previous section, the key point to flexibility is to know when and what to change and when and what not to change (Regev and Wegmann, 2006). At the moment there are no other suggestions how to resolve this dilemma than agreeing on this issue by using some consensus-building methods, for instance Enterprise Knowledge Development method (Bubenko, et al., (2001), Kirikova, (2000)). However, due to the fact that such decisions have an effect not only on the strategic level of the enterprise but indirectly pose requirements for changes in enterprise information systems it is necessary to find more formal approaches of flexibility analysis to check the impact of strategic level decisions on the business processes and hence to the enterprise information systems development. Further in this paper we present our first findings in an attempt to apply topological functional modeling to analysis of business process flexibility with the purpose to detect core (non-changeable) and changeable parts of business processes under consideration.

Topological Functioning Model (TFM) can be viewed as a business model that abstracts details which are abundantly specific for the given viewpoint. A TFM is an expressive and powerful instrument for clear presentation and formal analysis of system operating and an environment the system operates within.

The TFM has a rigorous mathematical foundation. It is represented in the form of a topological space (X, Θ), where X is a finite set of functional features of the system under consideration, and Θ is a topology that satisfies the axioms of topological structures and is represented in the form of a directed graph. A necessary condition for topological space construction is a meaningful and exhaustive verbal, graphical, or mathematical system description. The adequacy of the model describing functioning of a particular system can be achieved by analyzing the mathematical properties of such an abstract object (Osis, (1969), Osis, (2006)).

A TFM has topological (connectedness, closure, neighborhood, and continuous mapping) and functional (cause-effect relations, cycle structure, and inputs and outputs) characteristics. In accordance with systems theory every business and technical system is a subsystem of the environment. Besides that the common thing for all systems' (technical, business, or biological) operations should be the main feedback which can be visualized as an oriented cycle. Therefore, it is stated that at least one directed closed loop must be present in every topological model of system functioning. It visualizes the "main" functionality that has vital importance for the system life. Usually it is even an expanded hierarchy of cycles. Therefore, proper cycle analysis is necessary in a TFM construction because it makes thorough analysis of system operations and communication with the environment possible.

On the other hand, from the point of view of systems theory process P is a set of related activities that transforms particular inputs I into particular outputs Y, to achieve a particular objective O (Skyttner, 1996). When the process under the consideration is a business process (BP) the objective O may be expressed in terms of process BP business mission. Business mission of a process is the reason why the process exists, i.e. the reason why the process is beneficial for other processes. This means that synergy between input given by the external process and capability of the BP under consideration brings a particular value to the external process and to the BP. The value generated by a repeatable BP must be substantial enough to ensure its ability to function, i.e. to attract inputs I and to provide corresponding outputs Y more than once. Thus each situation when Y produced by BP is such that it can cause new instance of I to arrive at the "gates" of BP is considered a productive output of BP. We will call the moment of this arrival an external return of instance i (Figure 1). An example of such return could be a satisfied customer coming back to the barber's shop, as well as customer appearance causing the arrival of another person. The main cycles (or hierarchy of cycles) in TMF are those that point to the activities that ensure the capability of the business process to handle and cause external returns of input instances.

The issue of flexibility of business process arises when it permits handling of inputs where at least one input instance is different concerning at least one property relevant to the process. The process is considered flexible if it can handle input instances that are not ideal with respect to the basic value creating method(s) of BP (see the bold path – the sequence of arcs and nodes of the digraph, in Figure 1). This means that the process has at least one extension that helps to not lose a non-ideal instance of input without providing value for it (see cycles – closed sequences of arcs and nodes, in Figure 1). A well known example of such extension is a procedure of repeated examination in the university process that gives another chance to students to enrich their knowledge. Thus internal return of instances may help to yield external return of instances. However, if a process is too busy with its extensions it may be a sign that either there is a need to switch to a different method of value creation where a currently non-ideal instance is considered as ideal or discover the reasons of wrong proportion between ideal and non ideal input instances.

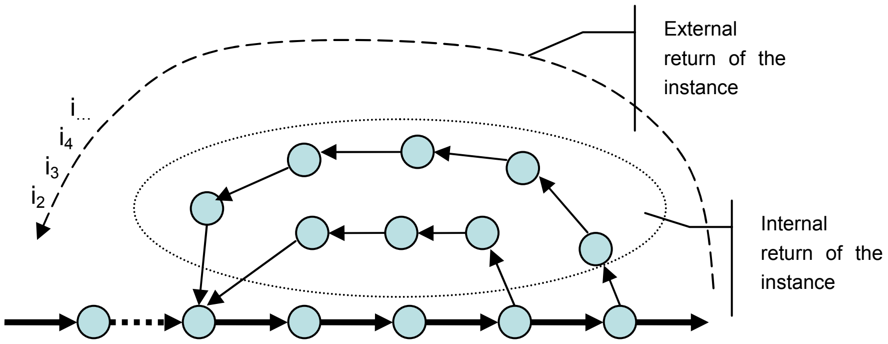

Figure 1: External and internal return of input instances.

It is essential to understand that the visibility of paths and cycles in the digraph depends on the level of abstraction and detail of systems analysis, as well as on the subsystems chosen for consideration. For instance, in Figure 1 the main method of value creation is depicted by the path; however, when changing the viewpoint of consideration, this path would be seen as a constituent of the main cycle of a particular business process BP. To investigate the applicability of TMF for business process flexibility analysis a field experiment was performed using business process models developed for an international telecommunications company. Part of the experiment is briefly discussed in the next section.

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For TMF to be suitable for business process flexibility analysis it should detect the same main cycle(s) at different levels of abstraction. We experimented at two levels of abstraction. At the higher level of abstraction only a story about a small sub-process told by a practitioner was used. On the lower level of abstraction the business process model of the same sub-process was utilized. Modeling at each abstraction level is discussed in Sections 4.1 and 4.2 accordingly. A comparison of modeling results is given in Section 4.3.

4.1 Topological Modeling on the Basis of the Process Description

At the higher level of abstraction the TFM of the sub-process receiving data from a multitude of sources and running a validity check on such data (see Figure 2a) was analyzed without imposing any predefined analysis framework on it. The analysis is described in Subsections 4.1.1-3.

4.1.1 Definition of Functional Characteristics

At the higher level of abstraction the first step on TFM construction is the definition of functional characteristics of the process. In our experiment the definition was based on word analysis and consisted of the following activities (Asnina and Osis, 2006): (1) Definition of objects and their properties from the problem domain description that is performed by noun analysis, i.e. by establishing meaningful nouns and their direct objects as handling synonyms and homonyms; (2) Identification of external systems (objects that are not subordinated to the system rules) and partially-dependent systems (objects that are partially subordinated to the system rules, e.g. system workers' roles); and (3) Definition of functional features performed by verb analysis in the problem domain description, i.e. by identifying meaningful verbs.

In the sub-process description (Figure 2a) nouns are shown in italic, verbs are shown in bold, and action pre- (or post-) conditions are underlined. The identified objects (or concepts) are as follows: (1) internal objects: the process (synonym: entire process), a script, a human operator (synonym: operator), the information transfer, the data download activity, (data) entirety, data validation (synonym: validation), the full set of data, consistency, contents, a manual download process, the possibility, an automated process, a manual one (process); (2) external objects – input objects: process; data at the locations (synonyms are: input data from certain sources, each input data location, all the input data, the downloaded data, such input data storage locations), data stored in an external system; (3) external object – output object: result – data matching in all locations.

Functional features identified from the fragment are the following (given in the form: action, object, (condition), and responsible entity):

1. Commencing the process by the script; 2. Entering of data at the locations; 3. Collecting data from the locations by the script; 4. Checking downloading of data at all locations by the script; 5. Checking completeness of data at the locations by a human operator; 6. Re-launching data download by the human operator; 7. Receiving the full set of data by the human operator; 8. Commencing validation by a script; 9. Entering of data stored in an external system by the script; 10. Downloading of data stored in an external system by the script; 11. Checking data at the locations with data stored in an external system for consistency by the script; 12. Checking data at the locations with data stored in an external system for contents by the script; 13. Establishing of a mismatch by the script; 14.Starting a manual download process for data at the locations with mismatch by the human operator; 15. Repeating the download process for data at the locations with mismatch by the human operator; 16. Checking the result – data matching in all locations by the human operator.

4.1.2 Introduction of the Topology

Introduction of topology Θ is the next step. This means establishing of cause and effect relations between functional features. Cause-and-effect relations are represented as arcs of a digraph that are orientated from a cause node to an effect node. The main properties of cause-and-effect relations are the following: a) a cause chronologically precedes an effect; b) a cause can be sufficient or necessary (complete or partial, correspondingly); it is assumed that there are necessary causes in the topological functioning model because risks of the system functioning can be unknown during the analysis; c) a cause not only precedes an effect and always is followed by it, it causes and is condition on an effect; d) the causality is universal, i.e. it exists in any problem domain even if it is not evident for a human. A structure of cause-and-effect relations can form a causal chain wherein each relation is important.

The cause-and-effect relations between the functional features identified from the sub-process description are illustrated by means of the TFM in Figure 2b.

Figure 2b clearly shows that cause-and-effect relations form functioning cycles. All cycles and subcycles should be carefully analyzed in order to completely identify existing functionality of the system. The main cycle of system functioning (i.e. functionality that is vitally necessary for system life) must be found and analyzed before starting further analysis. In the example, the main functional cycle is defined by the expert, and includes the following functional features “3, 4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 3” (bold lines in Figure 2b). As an example of the first order sub-cycle is a cycle that includes the functional features “3, 4, 5, 6, 3”.

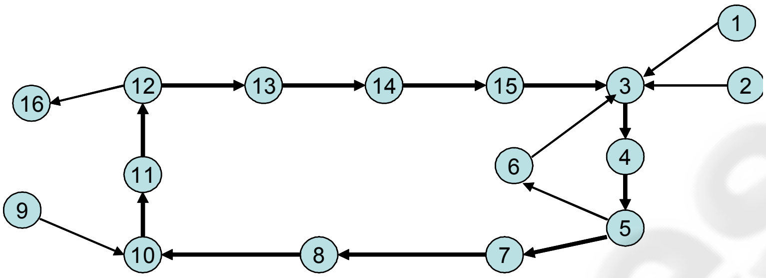
4.2 Business Process Model in GRAPES BM

In the approach demonstrated in the previous section there was no clear separation between such issues as data, activity, and performer. At the lower level of business process analysis we used business process representation in the business process modelling language GRAPES BM (Kalnins, 1996) which provides clear separation of mentioned issues. The business process model fragment in GRAPES BM corresponding to the description given in Figure 2a was cut out of the larger process model for the purposes of the experiment. A small part of this fragment is shown in Figure 3a.

The GRAPES BM business process model shows the cause-and-effect relationships between the tasks of business process to be performed. Thus the digraph corresponding to the business process model was obtained by following the inputs and outputs of the tasks and task-triggering conditions in the business process model. No distinction was made with respect to the contents of the information flows. All of them were considered as a flow of one substance (Grundspenkis, 1983). The digraph obtained by reflecting tasks as nodes of the digraph and information flows as links between them is reflected in Figure 3b. The graph contains the main cycle of systems functioning consisting of nodes “3, 4, 9, 10, 13, 14, 3”, and contains a sub-cycle “3, 4, 9, 11, 3”. Note: the numbers of nodes in digraphs reflected in Figure 2b and Figure 3b do not correspond each to other, because the graphs were made by different researchers and granularity of knowledge about the system reflected in each node differs considerably from one approach to another.

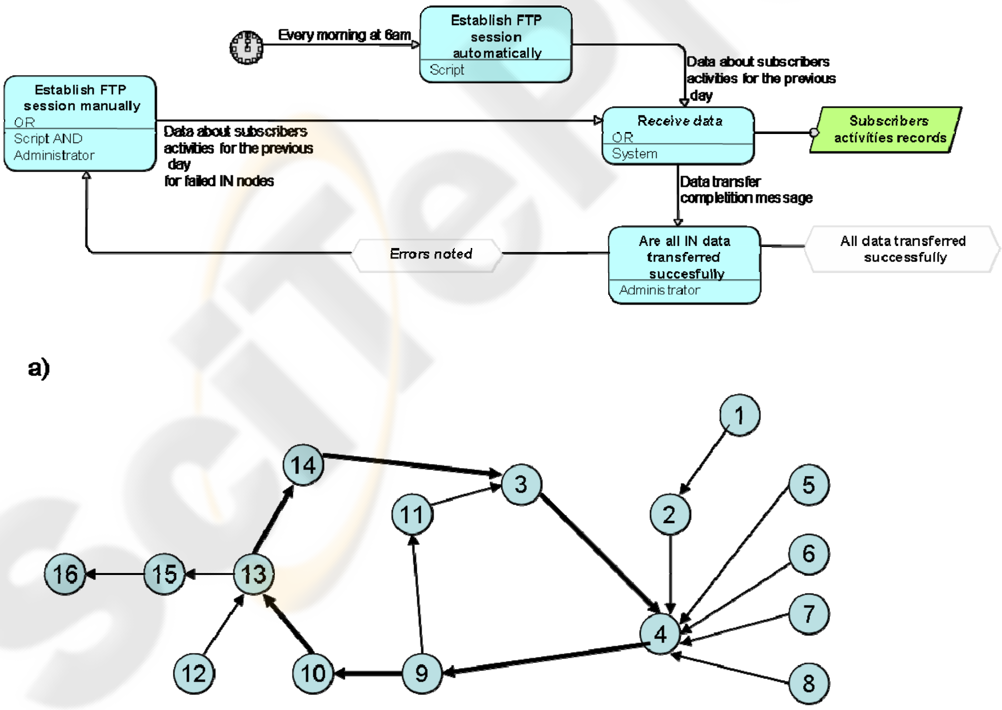
The process **commences** when *a script* **is launched** at a pre-defined time **collecting** *input* data from *a certain set of sources*. Once *the script* **has downloaded** *data from al the locations*, *a human operator* **checks** whether *the information transfer* was complete for *each input data location*. If it **turns out** to be incomplete *the data download activity* **is re-launched** manually as many times as is necessary for *the operator* **to verify** that *all the input data* **have been received** in their *entirety*. This *verification cycle* is the most important *component* of the process as *data validation* **cannot be commenced** unless *the full set of data* is received. Once all *the input data* has been downloaded, *validation* **checks commence**. *The downloaded data* **is checked** for *consistency* and *contents* with *data stored in an external system*. In *case* the *data* **do not coincide** in those two locations *a manual download process* **is repeated** for *such input data storage locations* where *a mismatch* **is identified**. *The process* **terminates** when *the downloaded data* and *the data stored in the external system* **coincide**. *Flexibility of the process* **is manifested** through *the possibility* of **changing** *an automated process* into *a manual one* and **repeating** *the entire process* if the expected *result – data matching in all locations –* **is not achieved**.

a)



b)

Figure 2: Topological modeling at a high level of abstraction: a) source text; b) TFM.



a)

b)

Figure 3: Modeling at abstraction level prescribed by GRAPES BM: a) part of the business process model fragment in GRAPES BM, b) obtained TMF.

4.3 Comparison of Modeling Results

The main result of the experiment is that at both levels of abstraction the main cycle and the sub-cycle of systems functioning were found. Theoretically the number of cycles at the lower level of abstraction could exceed the number of cycles at higher level of abstraction because, in general, it shows the business process at a higher level of detail. In our case the number of cycles was the same, probably because only a very small fragment of the business process model was considered. The meaning correspondence analysis of nodes in Figure 2b and Figure 3b was done to indicate whether both graphs refer to the same main cycle with respect to reality. The analysis confirmed that in both graphs the same main functionality of the business sub-process under the consideration was found.

The obtained results allow drawing a hypothesis that TMF at a higher level of abstraction may be used as a tool for detecting the unchangeable core of the process. The paths and the cycles that are outside the main cycle may be analyzed and designed to achieve the desired level of flexibility.

The sub-process discussed in Sections 4.1 and 4.2 is a flexibility provider for the system in a larger context containing the script which sometimes succeeds to get complete and correct information and sometimes does not. The business value of the sub-process is to provide trust for the script so that it could be useful for other processes in a larger systems context. All nodes of the main cycles are needed to provide the trust. If we wish to analyze the flexibility of the sub-process itself, the structure of the graph related to the main cycle must be considered and a deeper level of detail chosen for the nodes of the main cycle. This type of analysis is beyond the scope of this paper.

4 CONCLUSIONS

Possibility to identify the core processes in a business process model provides considerable opportunities with respect to enterprise information system development. Some of them are as follows:

- Reliability and security issues of core processes support may be considered at a higher level of detail than for non-core processes.
- Core processes may be considered as a high priority candidates in requirements prioritization.
- Different development methods can be used for core and non-core processes, e.g. more rigid methods for core processes and more agile ones for non-core processes.
- Not just business but also software core processes may be taken into consideration in making enterprise information systems development decisions.

One of the ways to determine which tasks or sub-processes belong to the core of the business process is through use of topological functioning model development at different levels of abstraction. The first steps of application of this approach show that it promises tangible results. However this modeling exercise involves a considerable amount of human knowledge and effort, therefore supporting tools such as business process model transformation to a digraph, digraph comparison methods for digraphs with different level of node granularity, digraph analysis methods taking into consideration several business input substances, business process visualization tools as well as appropriate consensus building methods could be useful in further development of the approach.

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