Models and Algorithms for Business Value-Driven Adaptation of Business Processes and Software Infrastructure

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Abstract

This research investigates how to provide automated analysis and decision-making support for adaptation of business processes and underlying software infrastructure, in the way that both maximizes business value metrics (e.g., profit, return on investment) and maintains alignment between business strategies and adaptation decisions. Among its expected contributions are improved modeling of business value metrics and business strategies in business process models and novel business value-driven techniques and algorithms that support primarily automatic and dynamic (run-time) adaptations, but also manual and static (design-time) adaptations. The proposed solutions will be implemented in software prototypes to demonstrate feasibility. Their usefulness will be evaluated through realistic case studies.

1. Problem description

Business process management (BPM) [1] is a set of techniques, metrics, management best practices and software tools that help organizations model, execute, monitor and optimize their work activities. Despite the fast growing popularity of business process management software systems in the industry, they are significantly challenged by the need for constantly available and adaptable business processes. In a recent BPTrends survey [1], 56% of the surveyed companies (and 65% among the surveyed large companies) reported that the major driver for focusing on business process change is the need to save money by reducing costs or improving productivity. To this end, providing adaptation of business processes and underlying software infrastructure in a way that continually and transparently delivers value to business organizations is among the most important challenges with real influence on organizations’ financial performance.

The main objective of my research is to address this challenge through investigating how to provide novel automated analysis and decision-making techniques that improve adaptation of business processes and underlying software infrastructure (particularly service-oriented architectures – SOA). I want to provide adaptation that maximizes business value metrics (e.g., profit, return on investment – ROI) and also maintains alignment between business strategies and adaptation decisions. I am primarily interested in dynamic (run-time) adaptations that are automatic or autonomic [2] (i.e., with minimal human intervention). However, not all changes can be accomplished in this way, so I also want to support adaptations that are static (design-time) and manual (i.e., led by humans). I examine the following research questions:

a) How to integrate business value metrics and business strategies into business process models to improve automatic analysis and value-based decision-making techniques for adaptation?

b) How to automatically and dynamically (at run-time) analyze and choose the most suitable adaptation decisions, from N possible options, to maximize business value metrics and maintain alignment between business strategies and the performed adaptations?

c) How to feedback run-time execution information (including, but not limited to run-time business value measurements) to support design analysis and re-engineering decisions by humans?

I will primarily focus on tangible, financial business value metrics (e.g., profit) and less on intangible, non-financial metrics (e.g., customer satisfaction). This is because tangible financial metrics are easier to quantify. Annotation of business value metrics to business process elements (such activities, events and/or sub-processes) will provide a basis for the business value-
driven analysis and decision-making techniques at run-time. The analysis and decision-making techniques will utilize such financial information, in addition to other run-time information such measurements of technical metrics (e.g., response time and availability) and business policies, to derive decisions and their financial implications. Such decisions then can be fed into adaptation engines that will automatically execute them or into visualization systems used by humans (e.g., process analysts) who perform analysis and re-design of business processes or software infrastructure. My research will further investigate these steps and provide more detailed mechanisms on how to achieve them.

2. Background and related work

According to [3], most of the past software engineering research and practice was achieved in a business value-neutral way, in which the focus was only on technical issues such as availability. However, business-IT alignment is recognized as a critical success factor of information technology (IT) systems. For example, higher IT system availability and less response time do not necessarily increase customer satisfaction and/or business revenue. Consequently, business-driven IT management (BDIM) [4] and value-based software engineering (VBSE) [3] have recently emerged to bridge the gap between business strategies and IT systems. While BDIM aims at improving run-time IT service management activities in a way that maximizes business value metrics, VBSE explicitly addresses business value aspects during the whole software development lifecycle to improve the economic value of IT systems. VBSE is based on (but goes beyond) the work on software economics, e.g., the long-running series of Economics-Driven Software Engineering Research (EDSER) workshops. My research tries to link, at a high level, BDIM and VBSE solutions through providing a round-trip engineering loop that combines extended business process models with run-time business-driven management activities.

In the area of business value modeling, the e3-value [5] model is prominent. It is a new modeling notation for high-level description of economic value exchange between different interacting parties at the level of components and connectors. While my modeling of business value metrics will learn from the e3-value model, I will focus on specifying financial measures at the operational level (e.g., process elements such as activities and resources) and software implementation level (e.g., Web services), so that such models can provide precise financial measurements for run-time analysis and decision-making techniques. Furthermore, in contrast to e3-value, my solutions are extensions of widely used standards – the Unified Modeling Language (UML) and the Business Process Modeling Notation (BPMN) at design-time and popular Web service technologies (WS-* ) at run-time. This will facilitate their integration with existing BPM software systems and provide support to static and dynamic adaptations.

Regarding the analysis and decision-making support part of my research, some of the closest related works are rule-based techniques for dynamic adaptations [6, 7]. One problem with most of the existing rule-based techniques is that they focus on specifying technical quality of service (QoS) metrics only, i.e., they are value-neutral rules. Meanwhile, in my research I consider business value metrics and strategies, in addition to other essential QoS and IT infrastructure rules, as support for run-time analysis and decision-making techniques. Further, I examine automatic rule generation and creation when conflict between multiple rules occurs at run-time. The aim of my rules is to maximize business value metrics and ensure alignment of business strategies with automatically generated decisions.

One unique feature that distinguishes my run-time analysis and decision support from the previously proposed approaches (e.g., in [8, 9, 10]) is that my solutions are based on business value metrics and strategy information that are associated with both design models and run-time execution engine. The run-time adaptation technique in [8] is basically based on the predefined QoS properties, as cross-cutting concerns using aspect-oriented programming, of composite Web service. The dynamic support for process instance adaptations [9] enables human to navigate, initiate and/or cope with activity changes (e.g., failure, suspension, retry, etc) during process run-time. In other words, it focuses on changes from the functionality perspective, and not business value information. The ontology-based modeling algorithms [10] allow users to initiate and construct process functional changes as ontology code sub-trees that can be embedded with corresponding business process. Contrary to [10], my work supports adaptation that can be triggered by various events, both technical (e.g., some computer fails) or business (e.g., there is a change in business strategy), and the changes need not be initiated by users.

One of the common features of BPM tools is that they focus on visualizing real-time activity changes in dashboards, so business analysts can use them for analysis decisions. However, automatic monitoring is not enough and autonomic control is more important because human reactions can be slow, not always precise and unreliable. For instance, a change in a business process that has hundreds of users in parallel should be quick and accurate, but business analysts are not always available and even if they are available the problem is often so complex that their adaptation deci-
3. Expected contributions and evaluation

Figure 1 highlights my expected research contributions in the business process (BP) implementation life cycle. The main expected contributions are in the boxes with continuous brown frame color. The non-continuous brown frame boxes indicate some, but not crucial, areas of my contribution. The yellow circles map the expected contributions to the corresponding research questions listed in Section 1. These contributions are elaborated in the following paragraphs.

**Assisted modeling of business processes with business value metrics (BVMs) and business strategies (BSs):** Business value metrics and business strategy information are modeled as annotations to business process elements. This annotation is done by humans, but assisted by software tools. The structure of annotated information is currently based on WS-Policy4MASC [11], but I plan to improve it. I work on automatic transformation of annotated business value metrics and business strategy information into policies used by a process execution engine, value-based analysis modules, and/or an adaptation engine. The related issue of automatic transformation of business processes into executable models used by process execution engines is not a central part of my research because it has already been researched in the literature.

**Automatic value-based analysis and decision-making techniques:** The main contribution will be improved quality (from the business viewpoint) of decision-making for adaptations, based on business value metrics and business strategies. My automated decision support algorithms will make decisions about which pattern of events and/or possible adaptation actions will have the minimal negative financial impact on that process (e.g., minimal costs), maximum positive financial impact (e.g., maximum profit generation) and/or best alignment of business strategy with the software infrastructure. They will use operations research techniques to determine the best outcome. I assume that there are a process engine executing business processes and performing policy-driven monitoring and an adaptation engine that can carry out the chosen adaptations (when they are needed, for all or only 1 process instance). Several research projects on such tools appeared recently, such as the MASC (Manageable and Adaptable Service Compositions) middleware [11].

**Automatic feedback of business value metrics and adaptation actions into assisted manual analysis and re-design:** If adaptation is needed, but it is too complex to be performed by the adaptation engine at run-time, the information about what happened during run-time can be annotated on corresponding business process models for business analysts for further design analysis and re-engineering at the level of the whole process. Automatic transformation rules can then be used to transform run-time adaptation decisions into business process model changes. I work on additional annotations that help humans make appropriate business value-driven adaptation decisions.

These contributions will be primarily evaluated through laboratory proof-of-concept prototype implementations. There will be at least one prototype for each research objective to demonstrate its feasibility. Furthermore, the resulting models, techniques and algorithms will be applied to laboratory experiments and case studies to evaluate their usefulness. In the experiments and case studies, the main criteria for success will be making decisions that maximize business value metrics and this will be compared with decisions made by existing tools that maximize technical metrics that lead to sub-optimal business value metrics. In addition, I will make at least 4 publications (3 at high-quality in-
ternational conferences and 1 in a journal) to receive expert and practitioners’ evaluation and feedback that will help improve the research outcomes.

4. Results so far

The results achieved so far belong to the objectives a) and c) listed in Section 1. A UML profile for annotating business value metrics and business strategies on business models has been developed and published in an international conference [12]. I extended the published work and implemented prototype tools:

- A prototype extension of Eclipse OMONDO UML plug-in tool with information analogous with WS-Policy4MASC policy assertions. The annotations are applicable to any UML diagram (e.g., class diagram, activity diagram – used for business processes, etc.).
- A prototype XSLT (Extensible Stylesheet Language Transformations) software for automatic transformation of annotated UML models into WS-PolicyAttachment and WS-Policy4MASC files that can be executed by the MASC middleware.
- A prototype for automatic feedback of run-time information and changes to corresponding UML diagrams to support human design analysis and re-engineering activities.

These prototypes represent a round-trip loop that combines models of business processes and underlying software infrastructure with run-time execution information and adaptations, as shown in Figure 2. A paper describing results of this work is accepted by the ICSE 2009 workshop PESOS (Principles of Engineering Service Oriented Systems) 2009. I am currently working on generalizing these results.

5. References