Conceptualizing Enterprise Dynamic Systems Control For Run-Time Business Transactions

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CONCEPTUALIZING ENTERPRISE DYNAMIC SYSTEMS CONTROL FOR RUN-TIME BUSINESS TRANSACTIONS

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Abstract

Business transaction models prescribe the design freedom restrictions of a process-based organization and are useful to share a common understanding between the stakeholders that have a diverse interpretation of it. However, business transaction models do not guarantee that the business actors perform them accordingly. Business actors, individually and/or collectively, operate the organization and also administrate and control (steer and transform) it, by means of observing the state of the world and then acting with purpose to change its state. Therefore, a business actor is simultaneous a controller agent and a controlled agent within an enterprise. Classical dynamic system control theories alone are not applicable in a straightforward way to an enterprise because of the prohibitive complexity needed for the comprehensive definition of the business transactions’ dynamics. This paper conceptualizes the alignment of business transactions models with operations performed at run-time by the business actors, grounded on the emerging field of Enterprise Engineering and well-known Dynamic Systems Control theory, to elicit purposeful design requirements for a full enterprise dynamic systems control solution. A preliminary Markov chain simulation aids in clarifying the design requirements intent for the observation concept. In this simulation, the business transactions are observed considering three distinct variables: state space, transition space and actor roles.

Keywords: Actuation, Business transaction, Control, Model, Observation, Operation, Organization.
1 INTRODUCTION

Actually, the operation of an organization is demanding more and more optimizations to improve its efficiency and guarantee effectiveness (Porter, 1985). Besides the efficiency and effectiveness challenges, endogenous and exogenous unexpected situations are continuously occurring in organizations, e.g., requirement changes, legal changes, social changes, etc. While the organizations operate, the roles of management and control are the ones responsible for the run time resources usage optimization. These roles must also comply with the predefined restrictions and with the individually and collectively run time observations. Control concerns could be encountered in many scientific efforts, such as, the General Systems Theory (Bertalanffy, 1969), the Viable System Model (Beer, 1979, 1981) and the recent Enterprise Governance proposals (Hoogervorst, 2009). In general, organizational control is related with the ability to steer, within a bounded effort, the operation of the enterprise towards a desired prescription whenever changes or perturbations occur. However, control is most of the time considered as an independent, isolated organizational add-on component that reacts according with the behavior of the part of the organization that it is supposed to control. In practice, due to the organizational complexity, these approaches are insufficient because it is impractical to completely specify the dynamics of the system to be controlled. Moreover, many organizational points of view, in the scope of different domains of knowledge, refer to control, e.g., business strategy (Laudon and Laudon, 2012), psychology, organizational culture or IT Governance (COBIT, 2012) (Fahy et al., 2005). Some practical examples are, business processes run-time compliance verification (Governatori and Rotolo, 2010), e.g., financial audit control; or organizational access control models to govern the user’s access to the artifacts of an organization, e.g., fine-grained task-based security enforcement for complex WfMS (Kuhn et al., 2010). Keeping in line with the scientific contributions of (Beer, 1979, 1981) (Bertalanffy, 1969) an organization is a huge non deterministic state machine, i.e. non mechanic, composed by a set of systems that play a complex intertwined orchestration, played fundamentally by the actors, humans and computers. Besides the machinery used by the organizations, actors are humans with action freedom and act accordingly with their purposes and orchestrations (Winograd, 1986), organized in a social system. The organization existence is revealed while this social system performs actions. We consider that the orchestration between the actors is mediated by the concept of business transaction. A business transaction is a model representation of a given organizational reality that is valid within a specific timeframe. Business transaction models prescribe the design freedom restrictions prescribed for an organization, and share an established common understanding between the stakeholders that have a diverse interpretation of it, in a process-based organization (Op’t Land, 2009). However, during operation, the prescribed business transaction models, per se, do not guarantee that actors perform them accordingly. Castela et al. (2012) explain exactly this problem in the scope of capturing the enacted run-time actions, to improve the design and operation of the business processes. To narrow this research, the recent advances offered by the Enterprise Engineering (EE) (Dietz and Hoogervorst, 2012) body of knowledge ground the solution. In this context, DEMO theory and methodology (Dietz, 2006) introduces capabilities to deal rigorously with the dynamic aspects of the process-based business transactions using an essential ontology that is compatible with the communication and production, acts and facts that occur in reality between actors in the different layers of the organization. Focusing in the DEMO Ψ-theory, the basic transaction pattern includes two distinct actor roles: the Customer and the Producer. The goal of performing such a transaction pattern is to obtain a new fact. The transactional pattern is performed by a sequence of coordination and production acts that leads to the production of the new fact. In detail, encompasses: (i) order phase that involves the acts of request, promise, decline and quit, (ii) execution phase that includes the production act of the new fact itself and (iii) result phase that includes the acts of state, reject, stop and
accept. Firstly, when a Customer desires a new product, he requests it. After the request for the production, a promise to produce the production is delivered by the Producer. Then, after the production, the Producer states that the production is available. Finally, the Customer accepts the new fact produced. DEMO basic transaction pattern aims at specifying the transition space of a system that is given by the set of allowable sequences of transitions. Every state transition is exclusively dependent from the current states of all surrounding transactions. There is no memory of previous states. On the other hand, we consider the dynamic systems control (DSC) theories, which are defined and used successfully in the Engineering fields for decades (Franklin et al., 2009) (Ribeiro, 2002). The aim of DSC is to gain efficiency in the operation of dynamic systems, thus achieving the same output results but with less resource usage. The stability of a system is related to its response to inputs or disturbance. A system that remains in a constant state unless affected by an external action, and that returns to a constant state when the external action is removed can be considered stable (Franklin et al., 2009). The integration of the DSC concepts with the DEMO concepts allows the understanding, designing and engineering implementation of the enterprise dynamic systems control (EDSC) (Guerreiro et al., 2012). This integration allows the design of a non-singular solution. Any business transaction designed in any business domain could benefit from this solution, and not only a particular subset of business domains. The contribution of this paper to the EE domain is a set of requirements that describe the design of the EDSC artifact for business transactions operating in a run-time organizational environment, taking in account the misalignments between operational conditions and the prescribed references. These requirements are implementation independent and offer an innovative pattern for enforcing organizational control in the business transactions. In short, this paper uses already known concepts but integrates them in an innovative way. It uses literature review from EE and DSC to ground the solution, and a simulation example helps in visualizing the EDSC artifact design proposal (Winter, 2010).

The rest of the paper is organised by the following sequence. Firstly, the internal and external environment where the enterprise operates is studied. Then, the control requirements that should be enforced in an enterprise are elicited. After that, section 4 proposes a first approach towards the design of the solution and a preliminary simulation of business transactions for producing and selling goods is used to illustrate the concepts. Lastly, the conclusions and future work points are briefly identified. The first author would like to state that this work was supported by PTDC/CCICOM/115897/2009, MOBSERV, Sistemas Facilitadores da Utilização de Serviços por Dispositivos Móveis, Fundação para a Ciência e a Tecnologia, Ministério da Ciência, Tecnologia e Ensino Superior, Portugal.

2 ENTERPRISE AS A COMPLEX SYSTEM: THE CONCEPTS

This section identifies and characterizes the primitive concepts, regarding the internal and external environment where the enterprise operate and specifies its core elements using a textual description. A separation of concepts, where each concept presents a single concern regarding the dynamic of the business transactions is used. For the goal of artifact construction transparency, business transactions follow the generic system definition (Bertalanffy, 1969) encompassing: a state space and a transition space. 

Actors, Concept #1: The actors, human or machine, are part of the enterprise and are organised in a network where the individual and collective views of the enterprise coexist (Dietz and Hoogervorst, 2012). Actors have action freedom and act accordingly with their purposes and orchestrations (Winograd, 1986), organized in a social system. Some portions of the enterprise tasks can be automated by software systems while others are performed by humans. An actor executes different activities over time. For performing an activity, an actor should fulfil tacitly or explicitly, an actor role. An actor is autonomous in deciding what to do next. A user differs from the actor concept because it represents the corresponding access of a given actor role for a given software system. Typically, a relation between user and actor role exists in the organization. Actor role is thus a dimension that is added at the same layer as state space and transition are. 

Transition space and state space, Concept #2: An enterprise is a highly complex system of which large parts, like the state of mind of the people in organization, are fundamentally unknowable. In (Bertalanffy, 1969) two distinct
spaces are proposed: (i) state space and (ii) transition space. The state space is the set of allowable states of a system. The transition space is the set of allowable sequences of transitions of a system. Every state transition is only dependent on the actual state. Model and instance, Concept #3: In the scope of business transactions, a difference exists between the model definition and its instances. A model restricts the design freedom and is relevant to share a common understanding between the different stakeholders of an organization (Op’t Land, 2009). However, they are not sufficient to be operated by the actors. A model implementation is required, and that implementation is instantiated exactly while the actors perform their activities. Moreover, instances are of cornerstone importance in an organization because its existence is revealed while actors perform actions. Referring to concept #1, an actor role is hard defined in the model, but a user is the one that instantiates the model. Many instances of a model are executed at the same time in an organization. Run-time, Concept #4: Instances (Concept #3) exist while the actors perform their activities. When an instance is executing, at a single instant in time, it is called run-time. When the models are designed is called design-time. Moreover, the concept of time is always present in the dynamic of the enterprise. Hence, time should also be considered in the enforcement of a solution for controlling the enterprise. The transition space and state space of an instance evolve via events that are produced at run-time. Business transaction, Concept #5: Referring to Concept #3, a business transaction is a model representation of a given organizational reality that is valid within a specific timeframe. As proposed in Enterprise Ontology (Dietz, 2006), a business transaction involves (i) actor role definitions, in order to specify who is responsible for each part of the transaction, who initiates it and who executes it, (ii) a transition space definition, and (iii) a state space definition. These three control variables guide the design of the EDSC solution in the section 4 of this paper. When we refer to run-time business transactions, we are referring to the instances of the business transactions model that are executing at a precise and single instant in time. An enterprise has a set of transactions that are arranged by the composition axiom, as presented in (Dietz, 2006): ‘a business process is a collection of causally related transaction types, such as the starting step is either a request performed by an actor role in the environment (external activation) or a request by an internal actor to itself (self-activation)’.

3 ENTERPRISE CONTROL: THE CONCEPTS

The enterprise control design is firstly grounded in the concepts presented in the previous section. The object to be controlled are the run-time business transactions and the variables to be controlled are state space, transition space and actor roles. Business transactions models represent the design freedom restrictions; hence, they do not exist in the enterprise operation. Only business transaction instances could be identified. As explained in Viable System Model (Beer, 1979, 1981) multiple layers of control granularity exists within the organizational control. Each cycle have observation, decision and control. A textual discussion is presented herein. Next section describes the competencies, responsibilities and main information flows to be included in an enterprise control implementation.

Ex-ante and ex-post, Concept #6: In the scope of a run-time business transaction, two phases are identified: (i) what happens before the execution, called ex-ante; is related, for example, to the predefined design given for a business transaction model, and (ii) what happens after the execution of the instances, called ex-post. These are related, for example, to the actions that are taken in reaction to something that happens unexpectedly. In a fraud attempt, for example, it would be the actor access revocation, in order to deny other activities attempted by the actor. Ex-ante endorses the forecast of already known or estimated situations, while ex-post reacts to those situations of which an enterprise is already aware. Observable / unobservable, Concept #7: There are control variables of an enterprise system that are observable, while others are unobservable. Hence, not all the state space and transition space of the enterprise is observable directly in the operation of an enterprise. Dynamic systems control (Franklin et al., 2009) (Ribeiro, 2002) states: ‘...a system is completely observable if every state variable of the system affects some of the outputs... if any one of the states cannot be observed from the measurements of the outputs, the state is said to be unobservable and the system is not completely observable or simply unobservable’. Observation/non-observation is included in our
organizational control solution. This concept implies that an organization does not observe everything about the world. Where, world is considered the enterprise (concept #2) and the entire surrounding environment. When a control variable is not observed then a control decision and actuation could not be performed. **Controllable / uncontrollable, Concept #8:** Two types of control variables exist in a system, those that are controllable and those that are uncontrollable. In line, DSC (Franklin et al., 2009) (Ribeiro, 2002) states: ‘...a process is said to be completely controllable if every state variable of the process can be controlled to reach a certain objective in finite time by some unconstrained control \( u(t) \). If any one of the state variables is independent of the control \( u(t) \), there would be no way of driving this particular state variable to a desired state in finite time by means of a control effort. Therefore, this particular state is said to be uncontrollable, and as long as there is at least one uncontrollable state, the system is said not to be completely controllable or simple uncontrollable’. The control action results in changes in the prescribed business transactions models (negative control) or changes in the business rules (positive control). It is a continuously process running in the enterprise. In the negative control, the prescribed business transactions are changed to avoid the recurrence of unintended operations. In the positive control, innovation is recognized as positive and the deviations from the prescribed transactions models are incorporated in the new prescription. In other words, the observed misalignment is valued as being a more innovative way of operating the organization and thus it is used to define a new organizational prescription, in what constitutes in fact continuous organizational learning. Organizational control appears in different forms and acts at different levels throughout the distributed enterprise, e.g., actor’s qualification or business rules implementation, but in all cases, repeating the classic pattern of observation, deciding and acting.

**Time, Concept #9:** Between the ex-ante and the ex-post a time delay exists. The controller requires one or more observations \( y(t) \) before deciding upon a control \( u(t) \); consequently, the issued control \( u(t) \) is based on past observations \( y(t-1), y(t-2), \ldots, y(t-n) \). This consideration means that the control \( u(t) \) that is issued may no longer be valid for the actual reality of the controlled system. The control decision process also takes the ex-ante models definition to decide upon the \( u(t) \).

## 4 ENTERPRISE DYNAMIC SYSTEMS CONTROL

Figure 1 presents two control diagrams that have the previous presented concepts in mind. The top part designs a non-formal specification. The aim is to share the idea of feedback loops in the scope of the organization operation. Informal blocks and arrows depict the control components and information flow. The solution controls the activity of the actors, checking misalignments between the prescribed models and observations. The observed control variables are used to trigger the EDSC. Using a metaphor of the Human central nervous system (CNS) and peripheral nervous system (PNS), PNS grounds on the ability to control using a systemic view of the business transactions operations, checking if complies with the ex-ante business transactions and access control models. The result obtained is one control action: (i) a grant or revoke access to the activities that are currently attempted and/or (ii) a change to the prescribed models. CNS grounds in the ability to control using a systemic view of the historical transactions, checking if complies with the ex-ante business rules. The result is one of the following control actions: (i) a change in the business rules, (ii) a change in the business transaction model or (iii) a change in the access control model. When needed PNS is able to send an order directly to PNS. For instance, new government laws demanding immediate effect. The bottom part of Figure 1 details the DEMO Organization Construction Diagram (OCD) for EDSC. An OCD diagram designs the ontology of a given solution regarding the actors, the production banks, the coordination banks, the boundary and the information flow. The proposed control variables of section 2 and 3 are enforced by the competence of the transactions specified on Table 1.

<table>
<thead>
<tr>
<th>Control variable</th>
<th>Definition &amp; management of organizational models</th>
<th>Run-time control</th>
</tr>
</thead>
<tbody>
<tr>
<td>State space</td>
<td>T02, T12</td>
<td>T07, T04, T05</td>
</tr>
<tr>
<td>Transition space</td>
<td>T02, T12</td>
<td>T07, T04, T05</td>
</tr>
<tr>
<td>Actor roles</td>
<td>T03, T13</td>
<td>T06</td>
</tr>
</tbody>
</table>

Table 1. Control variables enforcement in the EDSC ontology
Observations (concept #7) of business transactions instances (concepts #3) are enforced by T04. T03 and T13, specify and change, the involved actor roles (concept #1). T02 and T12 specify and change the state space and transition space (concept #2) of business transactions model. An information link exists between A12 and T13 to obtain the access configuration from the business transactions models during the configuration phase of the references. The A07 (concept #4) has three information links to the T11, T12 and T13. They correspond to the control action of changing a model and are taken when any misalignment occur. T11 corresponds to a self-change in a business rule, T12 corresponds to a change in the business transaction model to be controlled, and the model manager performs it. T13 corresponds to a change in the access management. T05 enforces control (concept #8) by the mean of the business rules. CPB16 refers to the Period that the EG is being considered, by other words, a period where control is valid, hence an information link exists with EDSC boundary.

For clarifying EDSC observation requirement elicitation, a preliminary example is presented using a pizzeria case study broadly used in EE. The left part of Figure 2 represents the business transactions prescriptions regarding the control variables: state space, transition space and actor roles. Firstly, the customer requests a pizza by phone (T01), then it is prepared (T02), delivered to the customer’s home (T03) and, when the payment is done (T04), the pizza request is ended. The right part of Figure 2 simulates, in Matlab®, a set of run-time misalignments using a Markov chain simulation with a probability of 20% misalignment in relation to the prescription.
5 CONCLUSIONS AND FUTURE WORK

This paper addresses the problem of misalignments between the operation of the organization (as-is) and the previously defined models that are supposed to correctly describe what the actors should follow (to-be). Business transactions models establish the design freedom restrictions of organization but per se do not guarantee that the actors perform according to them. While in operation, actors are autonomous in their activity and act with the surrounding environment, changing the environment. A conceptualization of run-time business transactions control is presented to elicit requirements for a future implementation. Three control variables are observed in business transactions instances to illustrate observation concept: state space, transition space and actor roles. Any business transaction designed in any business domain could benefit from this solution, provided that the organization in question standardizes its processes (or part of its processes). The advantages of using such a conceptual approach: independent from the technological issues; facilitate the communication between the audiences in the information systems; a pattern for business transactions governance design and implementation; and to increase the organizational awareness related with the actions that each actor do and its impact in the overall activity of the organization.

References