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Change Management in Business Process Modeling Based on Object Oriented Petri Net

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***Abstract*—** Business Process Modeling (BPM) is the first and most important step in business process management lifecycle. Graph based formalism and rule based formalism are the two most predominant formalisms on which process modeling languages are developed. BPM technology continues to face challenges in coping with dynamic business environments where requirements and goals are constantly changing at the execution time. Graph based formalisms incur problems to react to dynamic changes in Business Process (BP) at the runtime instances. In this research, an adaptive and flexible framework based on the integration between Object Oriented diagramming technique and Petri Net modeling language is proposed in order to support change management techniques for BPM and increase the representation capability for Object Oriented modeling for the dynamic changes in the runtime instances. The proposed framework is applied in a higher education environment to achieve flexible, updatable and dynamic BP.

***Keywords*—**Business Process Modeling, Change Management, Graph Based Modeling, Rule Based Modeling, Object Oriented Petri Net.

I. Introduction

ENTERPRISE infrastructure and organization require the support of critical BP. Since BP are the fundamental building blocks of an organization's success, information technology that focus on process management and improvement has been a good candidate to help organizations to fulfill their corporate visions and to improve their competitive positions[1].

BPM is the first and most important step in BP management lifecycle [2][3]. It provides high level specification independent from the implementation of such specification [4]. It is used to support a variety of business and information technology initiatives including process documentation, improvement, simulation, cost analysis, enterprise architectures and workflow management [5]. There are two most predominant formalisms on which Business Process Modeling Language (BPML) are developed: graph based formalism that has its root in graph theory or its variants, and rule based formalism that is based on formal logic [4].

Graph based languages have the visual appeal of being intuitive and explicit, even for those who have little or no technical background. However, rule based modeling languages require good understanding of propositional logic and the syntax of logical expressions thus are less attractive from the usability point of view. For this reason, most commercial business process management systems endorse the graph based formalism as the process definition language [6].

Examples for the graph based modeling languages are: UML 2.0 Activity Diagram (AD) [7][8] which is designed for modeling BP and flows in software systems; Business Process Definition Meta-model (BPDM) [7] which is specified as a UML 2.0 profile to define a generic meta-model in order to support the mapping between different tools and languages, where as Business Process Modeling Notation (BPMN) [9] is designed for modeling BP and their transformation into an execution language, namely the Business Process Modeling Language (BPML) [10].

Rule Based Language is often referred to as Business Rule Management System (BRMS). The common objective of BRMS is to integrate complex process logic into a process model as rules to support dynamic changes [4][11]. There are several classifications schemas for business rules. According to [12], there are four kinds of business rules: constraint rule, action enabler, computation rule, and inference rule. Fuzzy business rules added later as described in [13].

Examples for the rule based modeling languages are: Event Driven Process Chain (EPC) [14][15] (the basic elements of it are functions to model the activities of a BP, and events are created by processing functions or by actors outside of the model); PLMflow [16] which provides a set of business inference rules which is designed to dynamically generate and execute workflows; and ADEPT system [17] which specifies services that give the agents sufficient freedom to take alternative execution paths at run-time to complete the process goal).

Common BPMS distinguish between building time (design time) and run time. The most important criteria for characterize the functionality of control flow capabilities, considering the runtime (execution) requirements are [4]:

- Flexibility: The ability of the business process to execute on the basis of a loosely, or partially specified model, where the full specification is made at runtime [6] [18].
- Adaptability: The ability of the workflow processes to react to exceptional circumstances, which may or may not be foreseen, and generally would affect one or a few process instances [18].
- Dynamic: The ability of the workflow process to change when the BP evolves. This evolution may be slight as for process improvements or drastic as

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for process innovation or process reengineering [18].

Software change management is an essential discipline for enterprise IT organizations. In modern enterprises, software automates a wide variety of BP. Changes made to software are, in effect, changes made to the BP themselves. Software change thus requires careful management, without proper software change management, enterprises lack a full understanding of how software running in production automates their BP [19].

Business process management technology continues to face challenges in coping with dynamic business environments where requirements and goals are constantly changing and thus business users are demanding adaptive and flexible frameworks for process management [2] [6]. The rigidity in graph based models incur problems of lack of flexibility, dynamic and adaptability, which compromise the ability of the graph based processes to react to dynamic changes in BP and exceptional circumstances.

In this paper, an adaptive and flexible framework based on the integration between Object Oriented (OO) diagramming technique as a graph based modeling language and Petri Net (PN) as a rule based modeling language is proposed to support change management technique for BPM during execution and increase the representation capability for graph based modeling in the runtime instances. PN is a powerful instrument for modeling, analyzing, and simulating dynamic systems with concurrent and non-deterministic behavior. Techniques for OO analysis and design primarily support the representation and integration of static system properties from a function and data perspective, dynamic properties is only partially supported from a process perspective. The framework will be applied in a higher education environment to achieve flexible, updatable and dynamic BPM.

The rest of the paper is organized as follows. In sections II and III we present the problem statement and motivation. In section IV the existing work related to change management techniques for BPM and Object Oriented Petri Net (OOPN) are described in brief. In section V the proposed system is discussed including the research plan. Finally, we conclude the paper and the future work.

II. Problem Statement

Current varying market opportunities are commented as "Change has become the only certainty" [10]. To stay efficient and effective in such a turbulent environment, organizations are required to adapt their structures and BP to new conditions continuously [3]. As a response, organizations should provide new technologies to manage their dynamic changes in the changing BP.

Many companies use BPMS for modeling and execution support of their BP. Many processes are highly dynamic and require changes even during execution. Common commercial BPMS fail to support such processes appropriately since they work in a rather static manner; they demand that the structure of a process is fixed before execution [20]. Also according to [21] most commercial BPMS support rapid adaptations of workflow definitions but prohibit dynamic changes in workflow instances, like adding missing activities. Thus, they cannot optimally support dynamic processes. The aim of the proposed research is to design and control the organizational structures in a very flexible way so they can rapidly adapt to changing environments [6]. Enterprise requirements highlight flexible and adaptive processes whose execution can evolve according to situations that cannot always be prescribed, and/or according to business changes (organizational, process improvement, strategic). In order to achieve flexible business process and make quick response to varying requirements, it is extremely important to propagate the change to the in progress instances [20].

Graph based process modeling is an answer to a requirement of presenting business process models to various stakeholders in as straightforward manner as possible [22]. But the rigidity in it incurs problems of lack of flexibility, dynamic and adaptability, which compromise the ability of the graph based processes to react to dynamic changes in BP and exceptional circumstances [4].

III. Motivation

BPM has been successfully introduced and implemented in several application fields such as Healthcare, Higher Education, Effective Customer Relationship Management (CRM), and Customizable Product Manufacturing. Therefore, its significance has increased dramatically.

Software systems are not static, and so the Business Process Management technology continues to face challenges in coping with dynamic business environments [2]. Software systems must change and adapt to the environment, or become progressively less useful.

Increasingly, today's software engineers need systematic and methodical approaches for change analysis and management.

Higher education is one of the application fields of BPM and change management in higher education BP is very important. BP changes in higher education institutions and various models of the change process are directed to organizational character, structural features and planning procedures. These key elements are considered as key individuals in the change process. Structural features of the institution that may affect receptivity to change include organization size and decentralized/centralized decision-making procedures. Characteristics that indicate openness to change include a consensus on operating goals, a spirit of self-examination, provision of resources for change, and widespread influence on decision-making [23].

IV. Related Work

A. Change Management Approaches for BPM

Integration of Fuzzy aspects in BP management was developed by [13]. It extends the process modeling through the consideration and processing of fuzziness using the fuzzy-set-theory. This fuzzy extension will be reproduced with the EPC. It was shown that many situations in business process management could be described more exactly through the modeling of vague knowledge with fuzzy logic. Therefore, rule based systems founded on fuzzy logic are well suited for controlling processes.

Flexible Modeling and Execution of Workflow Activities model [24] is based on the activity meta-model. The system supports the functionalities of flexibility, and dynamic changes such as add and delete activities. The weakness of this approach is there is no activity can be in state running during the change time.

ADEPTflex [25] is a graph based workflow model to support dynamic changes of running workflow instances and concentrate on structural changes and support the users to modifying the structure of a running workflow, while maintaining its structural correctness and consistency.

A special kind of dynamic change called compatible change based on Petri Net proposed in [26]. An algorithm is put forward to calculate the minimal region affected by the changes. Furthermore, it proves that the change regions can be used to check the compatibility of workflow changes (change can be applied without causing any structural errors or behavioral inconsistencies). It is applicable and efficient in terms of time and space for large-scale and complex systems.

Constraint-Based Flexible BP Management approach [2] based on the notion of process constraints was developed to demonstrated how the specification of selection and scheduling constraints can lead to increased flexibility in process execution, while maintaining a desired level of control. Also a number of aspects addressed in this approach including constraint modeling, specification and validation, as well as run time functions for supporting the evolution of BP.

Simulate Dynamics on a Static BPMS approach [21] extends the static BPMS in as much as dynamic changes of processes during execution. It described how support for run time dynamics can be realized by an additional dynamics layer based on existing static BPMS.

According to [27] business process management would greatly benefit from integration with business rule management. But there is still no established solution to this integration problem, and the leading BPML, BPMN, does not provide any explicit support for rules. Combination between rules and Activities for modeling Service-Based BP system is proposed to cover this problem. The approach investigates the extension of BPMN by adding rules (R2ML) as a modeling concept in the form of a new gateway type, using the principles of Model-Driven Engineering. The integration on the level of the meta-models of the involved languages, a new modeling language called rBPMN (Rule-based BPMN) can be changed during the runtime.

B. Object Oriented Petri Net

Object Oriented methods [28]: One of the main advantages of OO method is the effectiveness of the process to identify and refine objects. Unified Modeling Language (UML) is a language for specifying, visualizing, constructing and documenting the artifacts of software systems, as well as for business modeling and other non-software systems. UML uses OO methods for modeling [29][30].

Petri Net [28] is a directed graph that mainly consists of two different nodes, places and transitions. Places represent possible states of the system. Transitions are events or actions which cause the change of state [14][30]. Low Level PNs (LPN) [31] does not have data type and data processing mechanism. High Level PNs (HPN) supports abstract data type and state transition with data processing. HPN can express a system in a compact net, but, analysis of HPN is difficult.

Colored Petri Net (CPN) [28] incorporates both data structuring and hierarchical decomposition without compromising the qualities of the original PN. Timed PNs [32] introduced time in Petri nets, and Hybrid PNs [33] can model a system where discrete state transitions and continuous state transitions coexist. More information about PN theory and applications are provided in [34]

Nested Nets for Adaptive Systems proposed in [35] to model adaptive workflow in health care environment. Nested nets are PNs in which tokens can be PNs themselves. This means that processes are considered as objects that can be manipulated by other processes construct more flexible workflow management systems that can be modified during the execution.

An OOPN is defined on a collection of elements comprising constants, variables, net elements (places and transitions), class elements (object nets, method nets, synchronous ports, and message selectors), classes, object identifiers, and method net instance identifiers. An OOPN has its initial class and initial object identifier, as well. The so-called universe of an OOPN contains (nested) tuples of constants, classes, and object identifiers [36]. According to [37] three directions for integrating PNs and OO concepts are:

1. Integration of Object Oriented concepts into Petri Nets: PNs control the overall dynamic behavior of the system, while the tokens represent objects that model the system's static properties. These objects may be carried by the places of the net. Within the transitions, the attributes of the objects may be read, manipulated, or their methods may be executed.
2. Integration of Petri Nets into Object Oriented techniques: a system is structured with OO techniques. First, the relevant objects of the discourse world and their mutual relationships are identified. Then, the description of the object behavior and the communication between objects will be specified with the help of PNs [38].
3. Mutual integration of Object Oriented techniques and Petri Nets: objects will be initially used to determine the structure of a system. Subsequently, the behavior of the objects is modeled with the help of nets. Nets need not carry anonymous tokens but they may contain references towards other objects whose behavior is also modeled through nets and so on. This process of nesting facilitates multi-layer models with concurrent behavior [38].

Hierarchical Object Oriented Petri Net (HOOPN) designed in [39] to aid in the modeling and analysis of OO software systems and to bridge the gap between formal treatment of PNs and OO approach for the modeling, analysis, and prototyping of complex software systems. A HOOPN model is a variant PN representation that corresponds to a class in OO paradigm.

Integration of Object Oriented Design with Colored Petri Nets approach was developed by [29] [40] to check the correctness of the designed system. The approach integrates OO techniques at the design level and use of CPNs at the

verification and validation level. OO methodologies lack analysis and verification methods and PNs suitable for validation and verification of systems. The approach presents a technique to transform an OO design into hierarchical CPNs model.

Object Oriented Petri Nets with modularity (OOMPNets) model [41] is an advanced CPN that introduces CPNs into OO techniques. Based on the scenario, OOMPNets can be allowed to describe objects incrementally. The analysis techniques based on CPNs can be applied for that of OOMPNets to reduce the effects of specification errors. OOMPNets supports gradual progress on modeling software requirement with formal representation from actor, data views, control flow and data flow. The incomplete specifications are encapsulated in nodes with hierarchical presentation to support forward and backward traces. The flexibility for presenting incomplete specifications in a formal format can allow the analysis for these specifications by those techniques in CPN.

V. Proposed Framework

The aim of the proposed framework is to provide a change management technique to improve the flexibility, adaptability, and the dynamic of the current BPM approaches. As we discussed before, the rigidity in graph based models incur problems of lack of flexibility, dynamic and adaptability, On the other hand, the rule based approach is to integrate complex process logic into process model as rules in order to support dynamic changes. This framework proposes an adaptive and flexible framework to integrate graph based and rule based modeling languages in order to increase the representation capability for graph based modeling to support the dynamic changes in the runtime instances. OO diagramming technique as a graph based modeling technique and PN as a rule based modeling techniques will be selected to be applied in this framework. The framework will be applied in a higher education environment to achieve flexible, updatable and dynamic BPM and make quick response to varying requirements in higher education systems.

A. Research Approach

The focus of the proposed system is on the value that a flexible, adaptable and dynamic BPM adds to higher education systems. In order to fulfill this, a new methodology for change management in the BPM will be developed. This research will be based on both exploratory and qualitative approach. While we tried to carry out empirical study and survey, we carried out deeper analysis albeit some qualitative to gain an in-depth knowledge of the value added by the proposed framework to higher education.

B. Research Question

- How can we increase the representation capability for OO modeling in the run time environment using PN modeling?
- How we can improve the flexibility to dynamic changes in the higher education environment?

C. Source of Data

- Primary Source of Data: Our research will rely on the questionnaire and interviews. Questionnaire in order to get responses that will enable us to analyze how change management techniques in BPM add value to higher education. And interviews contain some questions and or issues that the questionnaires are not able to cover.
- Theoretical Study: The theoretical study will base on materials that have been written on the BPM and its value to higher education.
- Empirical Study: We will use the qualitative approach in the interview section with some semi structured questions as guidelines. We will conduct the interview and questionnaire on some universities to get a comprehensive view from them to get information and compare the responses with our theoretical framework. The findings from the analysis are used to find answers to our research.
- Selection of Cases: We will choose two or more higher education systems.
- Analysis and Presentation of Empirical Findings: Both descriptive and quantitative means will be adopted to analyze our findings. We intend to use statistical diagrams such as graphs to present our findings.

D. Research Plan

The proposed system can be accomplished by the following major phases:

Phase 1. Background and Literature Survey: The initial work will consist of studying relevant literature sources in the field of BPM. In this phase we will discuss the following:

- Introduction about the concepts related to the business functions, BPM and application domain
- Reviewing the graph based and rule based modeling approaches, implementation issues, strengths and weaknesses.
- Review the approaches related to the change management techniques in BPM and its applications.
- Review the approaches related to the combination between OO and PN modeling techniques and their applications.

Phase 2. Framework Development, this includes:

- Graph Model Design: Abstract BP model definitions. And this will be based on OO modeling languages (UML modeling Language).
- Translation Technique: Translating the UML model to PN Rule to apply the dynamic changes. Places and transitions. Places represent possible states of the system. Transitions are events or actions which cause the change of state.
- Rule Design: Including reaction rules that can be added into process models. The important point is a place where rules should be used. And this will be based on PN modeling languages (PN state based (events or action)). High Level PNs (HPN) selected to implement rules; the rules implement the change in the process at the runtime. The type of changes the framework will support depend on the data collected through the questionnaire and interviews

- Integrating between graph model design and rule design this will include:
  - Determining type of rules (constraint rule, action enabler, computation rule and inference rule or Fuzzy condition) and this depend on the collected data
  - Determining how to integrate the rule through the design time and runtime.
  - Selecting the methodology to convert UML diagram to PN.
  - Determining the change management technique.
- Checking the Consistency, Reliability, Verification and Validation of the integration using PN techniques. And it's very important to determine how we will check it.

Phase 3. Analysis of findings: Both descriptive and quantitative means will be adopted to analyze our findings. We will intend to use statistical diagrams such as graphs to present our findings.

Phase 4. Evaluation of research: This will include determining the weak points, validity and reliability and correctness of the source analysis and results**.**

E. Expected Outcomes

- Short Term Outcomes:
  - New methodology to integrate OO and PN modeling languages.
  - New change management technique for dynamic changes in the runtime processes.
- Long Term Outcomes:
  - Effective change management technique for the dynamic BPM framework based on the combination of OO and PN modeling languages.
  - Increasing the representation capability for graph based modeling to support the run time environment criteria's (flexibility, adaptability and dynamic).
  - Applying the system in a higher education environment and increases the flexibility and adaptability of the processes.

VI. Summary and Future Work

Change management is very important to reduce risks and costs and maximizes the benefits of such major changes in business and IT. BPM technology continues to face challenges in coping with dynamic business environments where requirements and goals are constantly changing at the execution time.

In this paper we present a research proposal for the change management in BPM based on OOPN. We provide an overview about the change management techniques and the BPML approaches including graph based and rule based modeling. The future work is to apply this framework according to phases discussed in the research plan section.

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