PETRI NET BASED VERIFICATION AND RECONFIGURATION OF BPMN REPRESENTED CONFIGURED CONSTRUCTION PROCESSES

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Abstract: Verification of the completeness and consistency system network and validation of the intended purposes of the configured process models are important problems of the Business Process Configuration (BPC) environment. The same situation holds also for the construction processes, which consist of very complex and detailed processes and are not easy to model or to integrate with each other. Moreover, process modeling tools must support the process configuration with verification knowledge, which supports the end users to identify and to avoid system errors like deadlocks, infinite loops, logical errors, etc. and determines the model coherence according to the real world. This paper represents (1) the conceptually structured verification rules with knowledge acquisition for improving the Configured Construction Processes (CCP) and (2) a prototype tool, which is developed for the automated verification of CCP using Petri Nets (PN).

Keywords: Petri Nets, Verification, Process Configuration, BPMN, Transformation.

1. Introduction

Business Process Modeling (BPM) is a method for the managers or analysts to model their own business processes and to analyze or to improve their systems' performances (Kog et al., 2012). The main purpose of BPM is the representation and analysis of alternative process designs by formal or semiformal process models (Betz et al., 2006). BPM is the key point of the managers and analysts in the life cycle of Business Process Management (zur Muehlen, 2004). BPC, which is a method to integrate several business process variants into a single model, helps to omit unnecessary process parts and represents a family of process models. It provides flexible solutions to the modeled business process. In the construction industry, process modeling and configuration are used more and more to support simulation, estimate and plan required resources and costs (Benevolenskiy et al., 2012).

Business Process Modeling Notation (BPMN), which is a technique for modeling and analyzing business processes, has underlying capabilities such as simulation that helps business managers and analysts to understand the complex processes and to quantify the system's performance. BPMN is defined as a new standard for modeling business processes and web service processes by Business Process Management Initiative (White, 2004). It is used to support a nonredundant, flexible, integrable and adjustable visual environment for the business processes and it provides a graphical language with Business Process Diagrams, which is based on flowchart, activity diagrams and UML techniques.

2. Problem

Process configuration in the construction industry is different from general process configuration because it offers not only process sequence variants, but should support the construction process at all stages (Benevolenskiy et al., 2012). Moreover, construction projects consist of very complex and detailed processes, which are not easy to model or to integrate with each other. Even if there is a configured process model or configured reference process model (Rosemann et al., 2007) for a construction process, verification of the completeness and consistency system network is still a problem because of the complexity. Process modeling tools must support the process configuration with verification knowledge, which supports the end users to identify and to avoid system errors like deadlocks, infinite loops, logical errors, etc. and determines the model coherence according to the real world. BPMN is one of the most common and effective tools of BPM. In spite of BPMN's innovative approaches for business sectors, existing tools are not enough to model and simulate the construction projects because construction sector needs more sophisticated facilities to design and to control inherent uncertainties of their production systems due to one of kind product, production and project organization, due to the high complexity of the projects and due to the short lead time.

3. Objective

The main focus of our research is structuring a knowledge base, which includes mapping templates, transformation and verification rules, validation knowledge, and modification patterns for the business process reengineering (Guha et al., 1993) cycle using PN. PN, which was invented by Carl Adam Petri in 1962, is a mathematical and computational modeling language (Petri, 1962). It gives system designers a capability of analyzing the models with matrix representations, and it allows modeling of concurrency, synchronization, and resource sharing behavior of a system. It provides a uniform environment for modeling, formal analysis and meanwhile also verification and the design of discrete event simulation systems (Scherer and Kog, 2010). Several types of PN (timed, colored, hierarchy, attributed, etc.) were developed in order to satisfy the requirements of analysis and simulation of real world systems. Detailed information about PN can be found e.g. in (Murata, 1989).

The illustration of the main focus of this research is given as a lifecycle in Figure 1. Phase 1 indicates the configured process model, which is represented in BPMN. Phase 2 is the implementation level of transformation rules and mapping templates to the configured process model. BPMN model will be transformed into the PN model, which is represented in PN Mark-up Language (PNML, Jüngel et al., 2000). PNML will be used in existing and modified PN tools to verify the properties (phase 3) and to validate the structure (phase 4) of the model. Phase 5, which is the evaluation phase, indicates the consequence level for the checked process model. If a model has failed in the verification or validation phases it is handed over to the reconfiguration phases, which are Decomposition (6) and Recomposition (7) phases. Finally, phase 8 indicates the storage of the reconfigured process model in the knowledge repository. According to the requirements and alterations of the system these phases can be repeated many times for further changes.

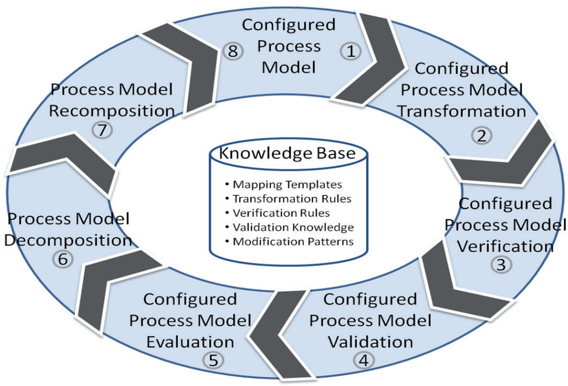

Figure 1. Knowledge based Reengineering Lifecycle of Configured Process Models

This paper represents the conceptually structured verification rules with knowledge acquisition for improving the BPMN represented CCP. In addition a prototype tool, which is developed for the verification of BPMN represented CCP, is proposed with an illustrative case. Phases between 4 and 8 are not included in the context of this study.

4. Related Work

A configurable process model represents a family of process models, that is, a model that through configuration can be customized for a particular setting (Van Der Aalst et al., 2010a). Configuration is achieved by hiding (i. e., bypassing) or blocking (i. e., inhibiting) certain fragments of the configurable process model (Gottschalk et al., 2007).

In recent years, process configuration acquires an importance in business industry and enterprise systems (Dreiling et el., 2005), furthermore in construction industry. Main process configuration methodologies in construction industry, which are based on knowledge based environment (Fischer and Aalami, 1995), graph theory (Huhnt, 2005), constraint/strategy-based methods (Beißert et al., 2007), ontology-based process modeling (Benevolenskiy et al., 2012), etc., are mostly focused on planning and scheduling activities. Even though the general objective of these researches is developing formal high level models for construction processes, verification and validation of the process models are not well examined.

According to the Macal (2005), verification ensures that the specification is complete and mistakes have not been made in implementing the model and validation ensures that the model meets its intended requirements in terms of the methods employed and the results obtained. Van der Aalst et al. (2010b), have been focused on the verification of configurable executable process models to examine behavioral anomalies such as deadlocks and livelocks in the instances of a configured model. They stated that the verification of configurable process models is challenging and only few researchers have worked on this. Moreover, existing results impose restrictions on the structure of the configurable process model and fail to provide insights into the complex dependencies among different process model configuration decisions.

There are several methodologies in order to improve or formalize existing tools. In this study, PN based process verification model (Kog et al., 2012) is used to improve deficiencies of existing tools.

5. Approach

A suggested approach for PN based Verification of BPMN represented CCP model, which is derived from the PN based model verification for BPMs (Kog et al., 2012), is given in Fig. 2. The main idea is transforming BPMN represented CCP models to the PNML, which are both in eXtensible Mark-up Language (XML) format (Kog et al., 2012).

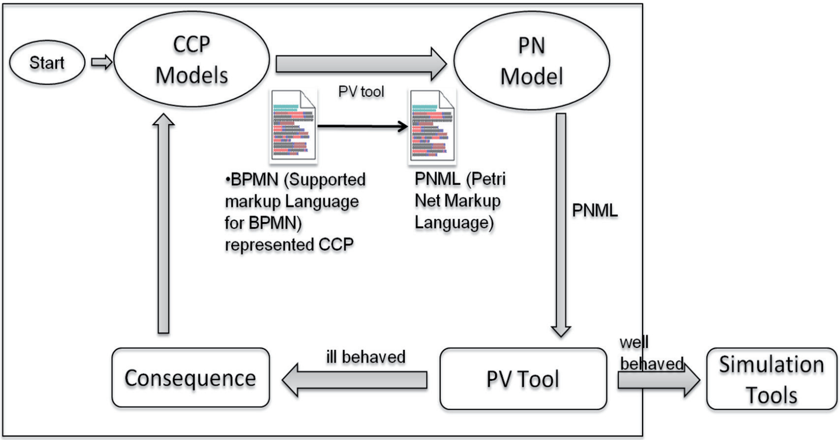

Figure 2. Suggested Approach for PN based Verification of BPMN represented CCP Model.

A prototype tool is implemented in Java to realize the transformation and verification purposes. It is called Process Verificator (PV). The XSLT templates are created for the different transformation procedures between CCP and PN models. In addition eXtensible Stylesheet Language (XSLT) templates are carried out for main business process pattern examples, which are derived from workflow patterns (van der Aalst, 2003). The interface eases the transformation for the users. After the transformation has carried out, several analysis methods or tools can be executed. For the PN verification the PN workflow analyzer tool WOFLAN, which was developed by van der Aalst (1999), is integrated in the program. The proposed methodology for the PN based verification of construction process models and detailed description of transformation model can be found in (Kog et al., 2012).

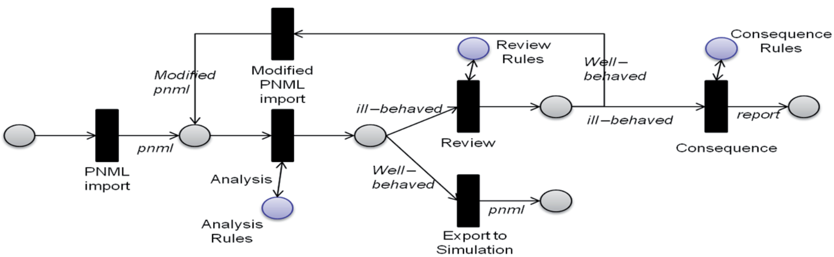

Figure 3. PN represented CCP Model Verification

Conceptual knowledge-base verification rules of CCP models is given Fig. 3., which is derived from the approach given in Fig 2. Verification rules consist of three main rules, which are analysis rules, review rules and consequence rules. Analysis rules are organizes the analysis methods in order to verify model syntax and semantics. In review rules comprises knowledge expertise to recompose ill-behaved models. As a result if there will be no possible condition to resolve the problem, consequence rules are defined to formulate report for model developers.

In this study, new analysis methods according to the verification rules are implemented to the PV. These are Logical Controller, Soundness Analyzer, Incidence Matrix Developer, Reachability Analyzer, and Loop Finder. Logical Controller is developed to capture syntax errors, which are caused by logical mismatching (for instance “Xor-And” errors). Soundness Analyzer is working with the same algorithm with tool WOFLAN to examine Soundness Analysis (Oanea, 2007) of models. Incidence Matrix Developer and Reachability Analyzer are important mathematical properties of PN. In order to utilize from this property in future implementation according to the requirement of CCP models, these features are also implemented in PV. Loop finder is developed for Soundness Analyzer; however it is also implemented externally for different kind of applications, which will be used in further researches.

6. Case Study

The first case example is about the construction of a wall (Ismail, 2012). The respective example model is given in Figure 4. This is the reference process model, which depends on the condition expressions of the construction type “in-situ concrete” and “precast”. The example model was represented in BPMN and exported as a BPMN 2.0 xml file.

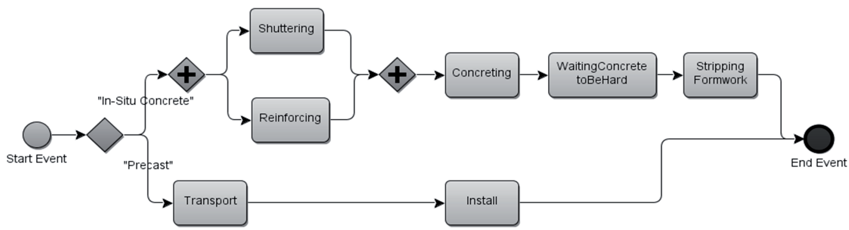

Figure 4. The instance BPMN represented CCP model of Wall Construction

This process model is transformed into the PN model with transformation part of the PV tool. The suitable XSLT template is chosen as a transformation method for BPMN source. At the time being this selection was made manual. The automatic selection of the mapping template with the recognition of source file is under development progress. The transformation procedure is completed with the execution of the transform command. The output file, which is a proper PNML file, is saved automatically to the user's folder. After that the PNML file is directly used in the verification part of the PV. In this part, Soundness Analyzer, Incidence Matrix Developer, Logical Controller and Loop Finder methods are chosen to verify the process model. These methods are executed in the verify command to show whether the process model has deadlocks, sinks or loops, i.e. whether is it a well or ill-structured model. Soundness Analyzer result shows that the model is ensured three conditions of soundness property, which are Workflow net property (van der Aalst, 1997), Boundness and Liveness (Murata, 1989). Hence the instance wall construction model is sound (Fig.5).

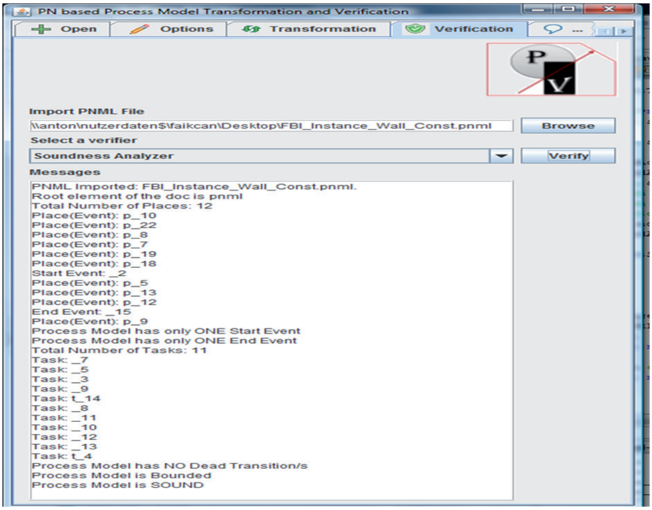

Figure 5. Analysis of the instance model with PV.

The second case example (Fig. 6) is about the logic of construction work inside a single work section, which is derived from the sample project "Mefisto Hochhaus" (Ismail and Benevolenskiy, 2011) in Mefisto Project (Scherer et al., 2010). This reference process model has been used as a part of the input data for the simulation model using the construction simulation toolkit (Ismail, 2012).

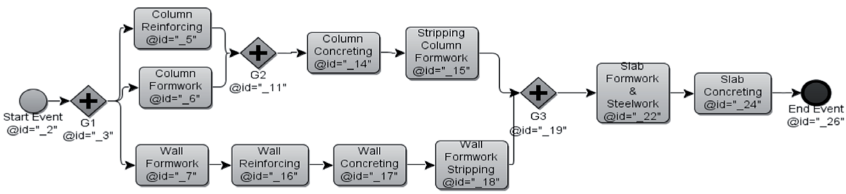

Figure 6. Instance BPMN represented CCP model of simple construction work.

The same procedures are applied as for case one. There are three parallel gateways in the model. Gateway “G3” is modified to exclusive gateway to examine the reliability of PV. Analysis results of Logical Controller method gives automatically that there is an AND-XOR Mismatch between parallel gateways and exclusive gateways (which are shown in GUI of PV’s graphical view with key id’s “_3”, “_11” and “_19” and are indicated with bold borders and lines in Fig. 7.), which damages the soundness of the model. This means, there is a conflict at the end of parallel column and wall works, before starting slab works.

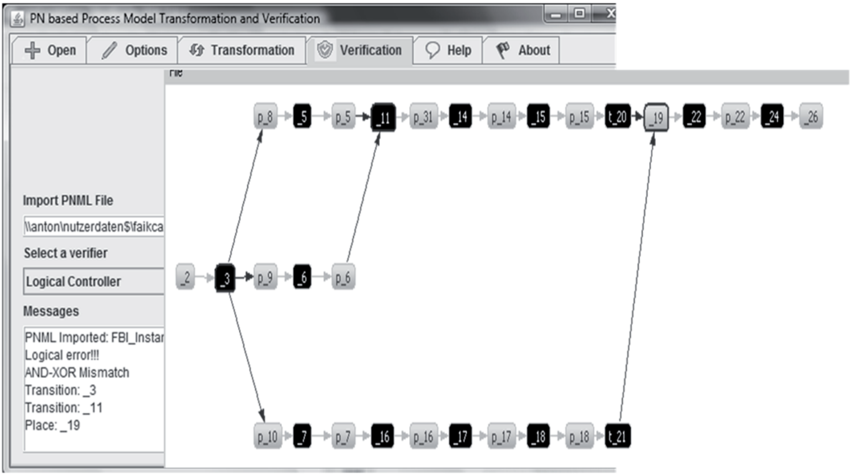

Figure 7. Analysis of the instance model with PV.

7. Conclusion

In this paper an approach of verification rules is suggested for the verification of the CCP with PN. PN was selected, because data losses are usually less compared to other modeling methods. PN gives excellent power to managers to design, control, simulate and analyze process systems. There is a strong mathematical background in PN that is still an attraction for researchers.

For the verification purpose, knowledge-base verification rules are defined conceptually and main rules are given. In further studies, these rules will be defined as patterns for business process reengineering. However this study is aimed to focus on verification purpose. Therefore validation, decomposition and recomposition parts of the reengineering cycle (given in Fig. 1) are not defined in the context. Nevertheless, decomposition and recomposion parts are mentioned briefly in approach part. Consequently, this work will be enlarged with the aim of validation in further works. Moreover, besides the existing methods, other methods and PN based analyzing techniques will be developed and implemented in the prototype.

8. Acknowledgement

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