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Modeling and Verification of Workflow Systems by Colored Petri Nets

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In this thesis, we discuss modeling and verification of workflow systems based on Colored Petri Nets, which are one of extended Petri Nets. A workflow system describes directed flows between steps in a business process. So it allows us to work effectively by using this framework. More precisely, after three steps in a business process, i.e., “Business process flow”, “Authority of official position” and “Content of ledger sheets” are analyzed, these steps are defined as components of a workflow system. “Business process flow” is defined by the process definition tool. Nodes of the process definition tool are defined for various contents of processing. In this tool, there are “Initial node”, “End node”, “Work node”, “Branch node”, “Arrival node”, “Division of labor node” and “Wait node”, and based on these nodes, the business flow is defined. “Authority of official position” is defined on the data base, and sections and official positions in the company correspond to these nodes. The above data is referred when the ledger sheets are carried out, and used to check the execution authority of the ledger sheets. “Content of ledger sheets” is constructed as an application for each client, and each item of those ledger sheets is related on the data base. A workflow system is driven by combining these components. However, the obtained system includes some errors, e.g. a definition error occurred by designer or programmers. It is difficult to find and solve these

technical problems, because workflow systems are a kind of distributed systems in which it is not easy to understand all operations. In this thesis, to overcome this technical difficulty, Colored Petri Nets is used. Colored Petri Nets are one of extended Petri Nets, and are well known one of theoretical computing models. Petri Nets are one of several mathematical representations of discrete distributed systems. As a modeling language, it graphically depicts the structure of a distributed system as a directed bipartite graph with annotations. Petri Nets consists of two types nodes, i.e., places and transitions, where an arc is either from a place to a transition or from a transition to a place. The current state is expressed by the token on the place. The places from which an arc runs to a transition are called the input places of the transition. Also, the places to which arcs run from a transition are called the output places of the transition. Each place may contain any number of tokens. Transitions act on tokens of input places by a process known as firing. By firing, tokens of input places transit to output places. In particular, Colored Petri Nets differentiate tokens by colors, i.e., each token can be defined some attributes. So attribute information on the token can be independently controlled by the transition. In this thesis, the CPN TOOLS is used to express Colored Petri Nets. The CPN TOOLS can use HCPN (Hierarchy Colored Petri Nets), which can define each component hierarchically. As a result, Colored Petri Nets allow us to model complex systems and data flows, and can treat various elements on business processes. The entire workflow system is modeled by using the CPN TOOLS. The CPN TOOLS is a tool for editing, simulating and analyzing Colored Petri Nets. The GUI is based on advanced interaction techniques, such as toolglasses, marking menus, and bi-manual interaction. Feedback facilities provide contextual error messages and indicate dependency relationships between net elements. So by using the CPN TOOLS, we can construct an appropriate environment to model business processes based on Colored Petri Nets. However, in the existing research, the CPN TOOLS models only a business process flow. So the entire system including a process definition tool, the database and a client application (Web Browser) is not modeled.

In this thesis, as one of practical applications, the business process of the sales task is modeled in detail and is verified by using the CPN TOOLS.

Also, the Cosminexus workflow system made in Hitachi, Ltd. is used in this thesis, because many companies widely use this system. In this thesis, first, the sales task is modeled as a workflow system. The sales process is composed of “Estimate”, “Order”, “Demand”, “Deliver” and “Payment”. To model the sales process, we consider actual affairs, e.g. “Made of the ledger sheets junior staff”, “The superior’s confirmation” and “Cancellation processing”. So the obtained model is useful from the practical viewpoint. Next, for transforming a workflow system into a model on the CPN TOOLS, some components of a workflow system are analyzed. Here, we analyze “Each element on the process definition tool”, “A peculiar processing element (log in and logout) to the workflow system”, “Ledger sheets (content of each item)” and “Data base (person information)”. These components are important to drive the workflow system. Also, these components are hierarchized such as “Flow definition process” $\rightarrow$ “Ledger sheets generation condition definition process” $\rightarrow$ “Reporting process”. Furthermore, this thesis proposes a new type called a WDF (Workflow Definition Format), which can be formally changed into the model. A formal model transformation is enabled by defining the transformation rule in this type. Finally, the business process of the sales task is verified. The CPN TOOLS has a simulator and a state space generation tool for the verification. The behavior of the business process can be easily confirmed by using the simulator. In this thesis, for technical problems, which are found by using the simulator of the CPN TOOLS, solving methods are proposed. In addition, we display various data by the following functions of the state space generation tool: reachability test, firability test, output of list of transitions that cannot fire, and upper and lower bounds of the number of tokens which enter each output place. By checking the above data, we can verify the business process of the sales task easily. From these results, we point out that the technical difficulties of an analysis of complex business process are overcome by using the proposed framework based on Colored Petri Nets. Also, the proposed framework gives various benefits to the future e-society.