# Translating Novelty of Business Model into Terms of Modal Logics

Hiroshi Kawakami[1], Ryosuke Akinaga[2], Hidetsugu Suto[3], and Osamu Katai[1]

[1] Graduate School of Informatics, Kyoto University
Sakyo-ku, Kyoto, 606-8501, Japan
{kawakami,katai}@i.kyoto-u.ac.jp
http://www.symlab.sys.i.kyoto-u.ac.jp/

[2] Matsushita Electric, Kadoma, Osaka, 1006, Japan

[3] Department of Industrial Design, Akita Municipal Junior College of Arts and Craft
12-3 Okawamachi, Araya, Akita, 010-1632, Japan

**Abstract.** By employing some modalities as bases for modeling business processes, the present paper shows that a conventional way of analyzing *Petri nets* also turns out to be a method for specifying the novelty of business processes. This novelty is translated into terms of *modal logics*. Most conventional methods for modeling business processes represent "structures" of their processes, which do not show directly their "novelty." The proposed method, on the other hand, enables us to specify their novelty. From the viewpoint of alethic, deontic and temporal modalities, business processes are modeled by interactions among three layers, i.e., top, main and base layers. The possible actions and states represented by using Petri nets in the main layer are controlled by designers' intentions represented in the top layer, and by what we call *social causalities* represented in the base layer. It is well known that a conventional method for checking the reachabilities of Petri nets results in a *coverability tree* of the net. We show that the coverability tree of the net in the main layer can be interpreted as a transition tree of *possible worlds* in terms of the modal logic, and that the type of tree specifies some kind of novelty of a business process.

**Keywords:** Modal Logic, Petri Nets, Business Process Model, Novelty, Modality

## 1 Introduction

The ban on obtaining patents for business processes has been removed [1]. Superficially, some of these processes seem to be trivial (not novel). In other words, some conventional business processes may now be monopolized. Most conventional tools for modeling business processes [2, 3] represent "structures" of their processes, which do not directly show their "novelty". In order to specify the novelty of a business process, we have to analyze its patent claim, which details the novelty in various ways. The present paper proposes a method for modeling

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business processes based on several modalities, which enables us to specify their novelty in a uniform manner, i.e., in terms of the modal logic.

In section 2 of this paper, we propose a method for modeling business processes that represents the process of business models and relevant social constraints by the use of interactions among three layers, i.e., top, main and base layers. By focusing on the modalities of processes and states of actors in business models, the contents of those three layers are strictly defined. In the top layer, deontic and temporal logic formulae represent designers' intentions. In the main layer, Petri nets represent possible actions and states of actors in a business process. In the base layer, what we call *social causalities* are represented. The three layers are closely related with each other, and the interactions among the layers show the relationship between a business model and its surroundings.

In section 3, the proposed model is applied to a method for specifying the novelty of a business model. The method is based on a conventional way of checking the reachability of Petri nets.

## 2 A Model for Representing Business Processes

### 2.1 Modalities in Business Processes

We discuss several modalities in business processes and their surroundings, e.g., technologies, cultures, social criteria and so on.

**A Viewpoint of Alethic Modality ($\Box$: necessity v.s. $\Diamond$: possibility)** Considering *possibility* and *necessity* on business processes, actors (seller, buyer, broker, distributor and so on) are to act to satisfy their own desires [8], and there are several *possibilities* for their actions. However, from the viewpoint of the designer of a business model, it is *necessary* to restrict actors' choices in order to organize the whole business process. Actors cannot widely deviate from a designed sequence of processes. Generally, necessity is either teleological or causal. This kind of restriction can be interpreted as the result of *teleological necessities*.

Actors are also restricted by causalities that we call social causalities. Their actions cause certain results governed by social constraints, e.g., legal restraints, contracts, ethical restraints and so on. For example, after a buyer notifies his/her decision to purchase to a seller, the only party who reserves the right to cancel it is the buyer. This type of constraint can be interpreted as *causal necessities*.

**A Viewpoint of Deontic Modality ($\Box$: obligation v.s. $\Diamond$: permission)** There are several types of business processes in which actors take actions governed by the designers' intentions. That is, several restrictions fixed by designers from the viewpoint of teleological necessities turn out to be *obligations* for actors. On the other hand, possible alternatives of actions for actors are interpreted as designers' *permission*. For example, if a buyer wants to buy something, it is obliged to follow the purchase process designed by the designer, but as long as

**Table 1.** Relations between Modalities and Contents to be Represented

| | Alethic modality | Teleological -Causal | contents | Deontic modality | Temporal modality |
|---|---|---|---|---|---|
| Top layer | Necessity | Teleological | intention | Obligation | ○ |
| Main layer | Possibility | Free | process | Permission | ○ |
| Base layer | Necessity | Causal | social causality | n.a. | × |

he/she follows the obligations, he/she is permitted to buy anything anytime. In this paper, we use two symbols $\mathcal{O}(=\Box)$ and $\mathcal{P}(=\Diamond)$ to denote deontic modes.

Table 1 shows the relation between alethic and deontic modalities, and what we use to represent those modes.

**A Viewpoint of Temporal Modality ($\Box$: $\mathcal{F}$ v.s. $\Diamond$: $\mathcal{G}$)** When designing business processes, it is essential to consider temporal modalities. In the case where business processes are called "business flows," fragmentary processes are linked to form a chain. This is the most rigid case from the viewpoint of temporal modalities. Even if the temporal constraints are set up as loosely as possible, the process will be at most quasi-ordered. Actions (operations), their pre-state and post-state are also temporally ordered in nature. Therefore, in business processes, temporal modalities have to be taken into account when designers' intentions, actions and state transitions are represented, as shown by open circles in Table 1.

Sometimes, causalities are also discussed with the notion of temporal order. It has been said that "it is obvious that each causal relation involves a time sequence in nature" [9]. However, several problems arise when setting the temporal order as the reason for distinction between "cause" and "result." For example, even though an event A causes event B, A might continue longer than B. In this case, we cannot say that A precedes B. Of course, if A did not exist in this world, neither would B, but this fact is irrelevant to the temporal order [10]. Therefore, as indicated by a symbol "×" in Table 1, social causalities do not always involve temporal modalities.

Employing an axiom system "$K_T$," the following modal operators ($\mathcal{T}$, $\mathcal{G}$, $\mathcal{F}$, $\mathcal{U}$) are introduced:

$\mathcal{T}A$ : $A$ will be true at the next moment,
$\mathcal{G}A$ : $A$ will be true forever, i.e., at any future time point,
$\mathcal{F}A$ : $A$ will be true at some time in the future,
$A\mathcal{U}B$ : $B$ is true at the current moment or $A$ will be true at all times until the first moment when $B$ will be the case,

where $A$, $B$ denote atomic formulae.

Regarding state transitions in the future, there are two aspects, i.e.,$b$ (branching) and $l$ (linear), thus the modes $\mathcal{G}$, $\mathcal{F}$ are more precisely defined as [6]:

$$\mathcal{G}_b A : A \text{ will be necessarily persistent in the future,}$$
$$\mathcal{G}_l A : A \text{ will be possibly persistent in the future,}$$
$$\mathcal{F}_b A : A \text{ will be possibly the case in the future,}$$
$$\mathcal{F}_l A : A \text{ will be necessarily the case in the future,}$$

as shown in Figure 1. In the figure, each circle denotes a state, each arc denotes a state transition, and the letter $A$ means that $A$ is true in that state.

### 2.2 Three-Layered Model for Representing Business Processes

Based on the discussions of alethic, deontic and temporal modalities in business processes, we propose three layers (i.e., main, top and base layers) to represent a business process and its surroundings.

**Main Layer** In the *main layer*, actors' possible actions and their pre-state and post-state are represented by Petri nets. Since many actors are involved in a business model, their actions and state transitions are concurrent and distributed.

A set of local states represents the conditions of an event. Events occur either by actions or by causalities when their conditions are satisfied. Each condition has a binary value, i.e., true or false. Employing Petri nets, each local state and event are represented by a `place` and a `transition`, respectively. Therefore, the Petri nets we use are 1-bounded, i.e., the upper limit of the number of tokens in each `place` is 1. When a token is in a `place`, the business process is in the state denoted by the `place`. Each arc from a `place` to a `transition` means that the `place` denotes one of the necessary conditions of an event denoted by the `transition`. Firing of a `transition` means the occurrence of an event, while each arc from a `transition` to a specific `place` means that firing the `transition` alters the local state into what the `place` denotes. Markings of Petri nets show the state of a business process as a whole.

When it is possible for multiple `transitions` to fire, Petri nets *permits* any of the `transitions` to fire. In other words, it is *possible* to take any of the actions denoted by the `transitions`.

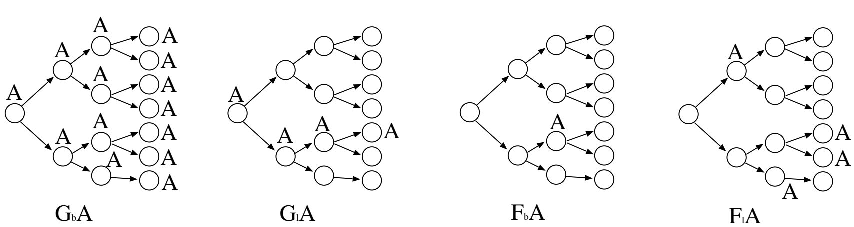


**Fig. 1.** World Transition Trees

**Table 2.** The Claim of US Patent 5,794,207

| | |
|---|---|
| 0. | inputting into the computer a conditional purchase offer which includes an offer price |
| 1. | inputting into the computer a payment identifier specifying a credit card account, the payment identifier being associated with the conditional purchase offer |
| 2. | outputting the conditional purchase offer to the plurality of sellers after receiving the payment identifier |
| 3. | inputting into the computer an acceptance from a seller, the acceptance being responsive to the conditional purchase offer |
| 4. | providing a payment to the seller by using the payment identifier |

**Top Layer** In the top layer, designers' requests are represented by combinations of temporal and deontic logic formulae. For example,

$$\begin{aligned} \mathcal{OF}A &\cdots \text{ it is obligatory that } A \text{ will be true in the future} \\ \mathcal{PG}A &\cdots \text{ it is permitted that } A \text{ is always true in the future} \\ \mathcal{O}(A\mathcal{U}B) &\cdots \ A \text{ must always be true before } B \text{ can be true} \end{aligned}$$

We have confirmed that each combination of temporal and deontic operators can be translated into extended Petri nets that we call "task unit graphs" [11]. By translating logic formulae into Petri nets, the top layer and the main layer can be connected in a natural manner.

"Business model patent claim" is a kind of design specification of business processes, which represents designers' intentions. Table 2 shows an example of patent claim (A portion of US Patent 5,794,207 [12]). Designers' (inventors') intentions are implied by means of a sequence of processes, which can be represented by modal logic formulae and then translated into extended Petri nets in the top layer.

**Base Layer** In the base layer, what we call social causalities are represented. When a certain action is taken in a business process, the corresponding `transition` fires in the main layer, which affects the surrounding of the business process. As a result, governed by social causalities, some actions become enabled or disabled. Social causalities are governed by legal, physical, political, cultural, or technical restrictions and so on.

Social causalities are represented by networks, as shown in Fig. 2. In the figure, an event "buyer received response" enables "the buyer cancels it" or "his/her deputy cancels it" and disables "other people cancels it," governed by contracts.

### 2.3 Interactions between layers

Figure 3 shows an overview of the main, top and base layers and the interactions between layers. These interactions represent relations between business processes, designers' intentions and social causalities.

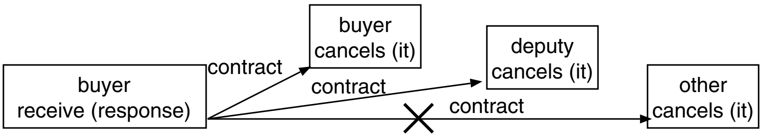


**Fig. 2.** An Example of Social Causality

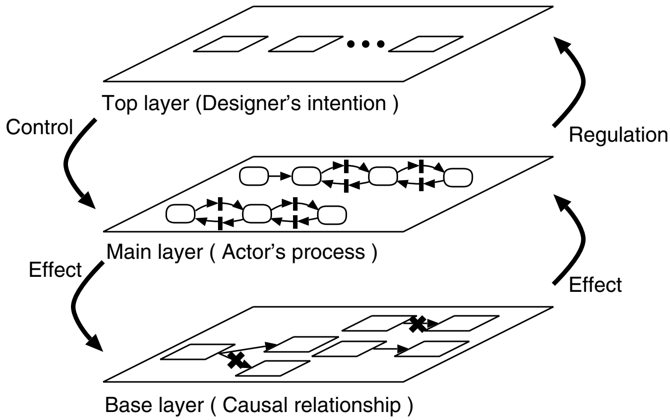


**Fig. 3.** Overview of Three-Layered Model

**Main and Top Layers** Actors involved in a business model are permitted to take actions, but the designers' intentions (patent claims) limit the alternatives of these actions. In the three-layered model, the main layer notifies the current state to the top layer, and the top layer forbids or forces certain `transition`s to fire in the main layer according to the current state.

**Main and Base Layers** Some local states denoted by `place`s in the main layer are unified with some "cause events" in the base layer. When the `place` receives a token in the main layer, social causalities derive "result events" in the base layer. Each "result event" enables and/or disables certain `transition`s to fire in the main layer.

## 3 A Method for Specifying Novelty of Patent Claim

In this section, an example of business model patent (US Patent 5,794,207) is represented by the three-layered model, and analyzed for its novelty by comparing it with a conventional "reverse-auction business model."

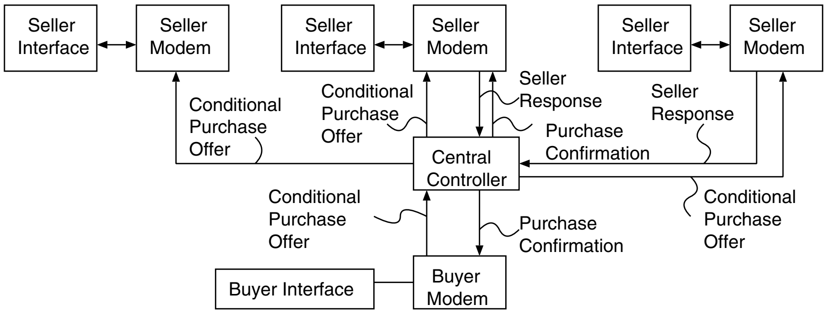


**Fig. 4.** The Structure of Reverse-Auction Business Process [12]

### 3.1 Representing Patent Claim by Three-Layered Model

**Conventional Reverse-Auction** Generally, an auction means that buyers propose the prices of an article presented by a seller, but the reverse-auction requires presentation of an article that a buyer wants in the first place, then sellers propose the prices.

Figure 4 shows the static structure of an internet auction [12], which is common to normal and reverse-auction except for exchanging the "seller" and the "buyer". From this structure, possible actions and local states can be derived, which are encoded into Petri nets and represented in the main layer.

**An Example of Patent Reverse-Auction** The main part of the patent claim, shown in table 2, is a sequence of processes. The temporal order of these processes is represented by modal logic formulae, then translated into extended Petri nets.

Figure 5 shows the "patent reverse-auction process" represented by the three-layered model. The upper part of the figure shows a modal logic formula represented by extended Petri nets[1]. The middle part of the figure shows that this business model involves a buyer, a broker, sellers and credit cards, while the lower part of the figure shows some social causal relations.

Note that the top layer (designer's intention) forces the transition "`notice_proof`" (the buyer notifies a payment identifier to the broker) to fire just after the transition "`offer`" (the buyer offers purchase) fires. When comparing with the normal reverse-auction processes represented by the three-layered model, the difference between normal and patent processes comes to light.

### 3.2 Analyzing Reachability to Goal State

Analyzing the Petri nets represented in the main layer enables us to examine the novelty of the business process. In this section, we focus on the process from the

[1] There are more temporal constraints that are derived from the patent claim, but they are omitted in the figure.

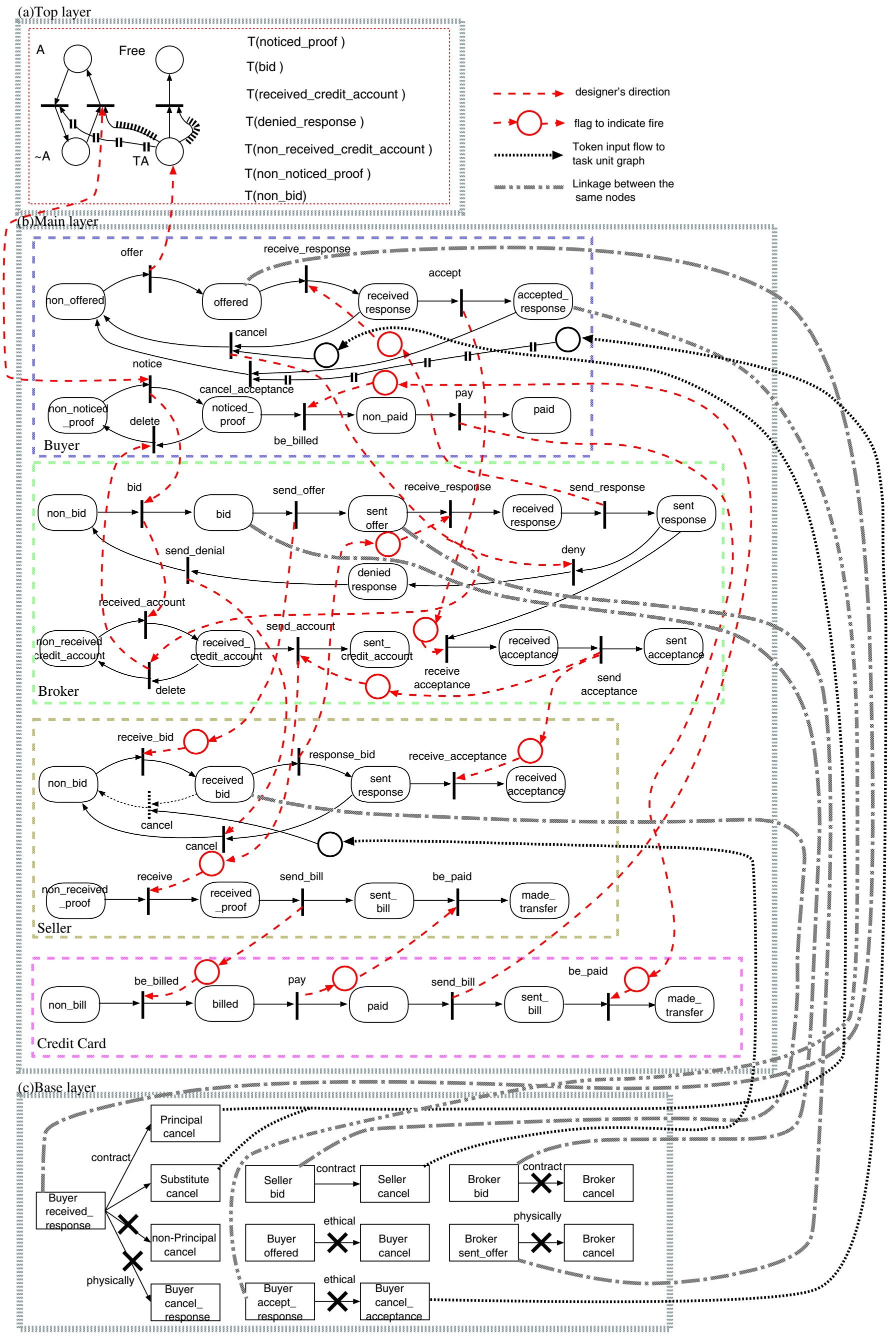


**Fig. 5.** An Example of Business Model Represented by the Three-Layered Model

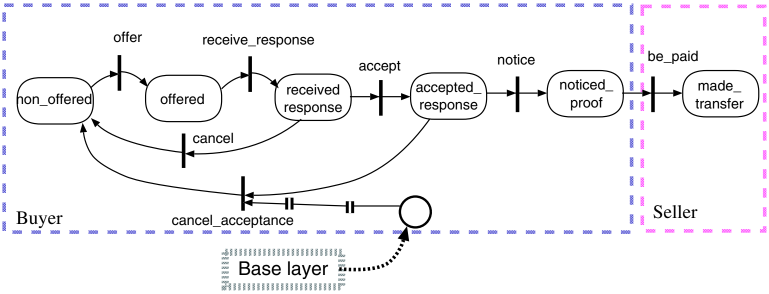


**Fig. 6.** A Portion of Petri Nets for Normal Process

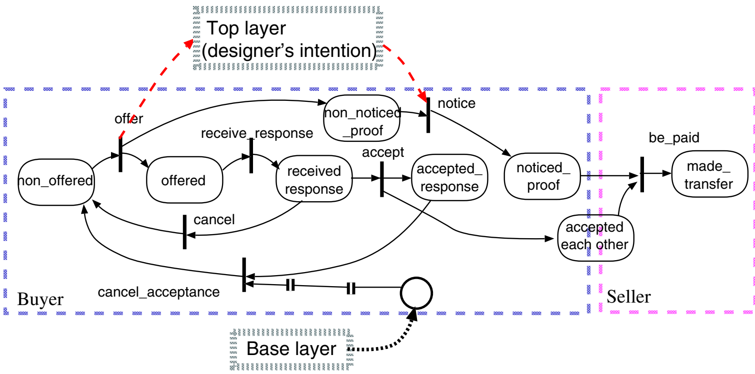


**Fig. 7.** A Portion of Petri Nets for Patent Process

action "`purchase_offer`" to the goal state "`paid`." Figure 6 shows Petri nets extracted from the main layer of the normal process model, and Fig. 7 shows the counterpart of the patent process model.

Generally, once the buyer notifies the broker of acceptance of purchase, ethical restraints inhibit the buyer from canceling. In Figs. 6 and 7, the arc from the place "`accepted_response`" to the transition "`cancel_acceptance`" exists because the patent claim does not explicitly forbid it. The special arc from the base layer to a blank place represents the ethical restraints.

Assuming a world where ethical restraints have no power, let us compare the reachabilities between Figs. 6 and 7. For the initial marking, both Petri nets have a token in the place "`non_offered`", and no other places have tokens. The goal state is "`made_transfer`," which denotes the resultant state of payments.

It is well known that a conventional way for checking the reachabilities of a Petri nets results in a *coverability tree* of the nets. Figure 8 (a) shows coverability trees of the normal process, and (b) shows that of the patent process, with the sequences of actors' actions shown from left to right. The branches represent alternative actions. Each broken line from right to left denotes state regressions.

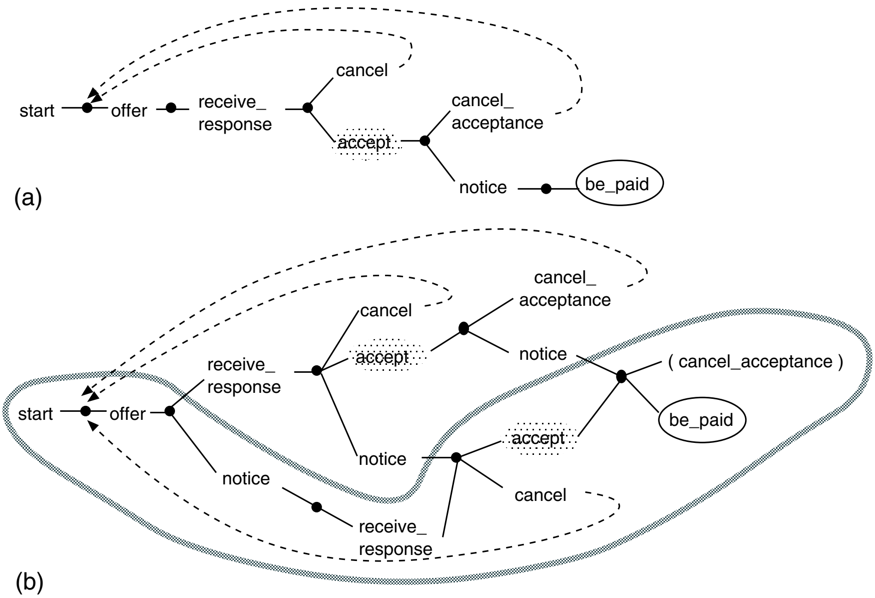


**Fig. 8.** Coverability Trees of Petri Nets

Comparing Fig. 8 (a) with (b) clarifies the *novelty* of the patent process. After accepting a purchase (denoted by the label "`accept`" in the figure), the buyer has a chance to cancel it (denoted by the label "`cancel`") in Fig. 8 (a), and the state regresses to an almost initial state.

On the other hand, Fig. 7 shows that the designer's intention represented in the top layer enforces the transition "`notice`" to fire just after firing the transition "`offer`." Consequently, the coverability tree shown in Fig. 8 (b) is confined to the area circled by a thick line. Within that area, after accepting a purchase, there are only two possible alternative actions: the buyer pays or the seller cancels it. In other words, the structure of the business process implicitly prevents "canceling after an acceptance by buyer" without support from ethical constraints.

### 3.3 Temporal Mode of State

A coverability tree shows all the possible state (marking) transitions, and all the possible world (in terms of modal logics) transitions can be represented by a tree as shown in Fig. 1. Each marking of Petri nets corresponds to a possible world of modal logics. Therefore, we can interpret coverability trees as world-transition trees.

The novelty implied by the structure of a business process is formulated into the structure of a coverability tree, which is then translated into temporal mode $\mathcal{F}_l$ shown in Fig. 1.

"Canceling after acceptance" is ethically inhibited, although sometimes buyers do so for fun or offer to purchase just for fun. In this case, sellers go to a lot of trouble for nothing, and brokers lose their attraction for sellers and ethical buyers. On the other hand, the patent process guarantees that sellers can get their money. The novelty of the patent process can be explained that way in natural language, but in terms of modal logics, the novelty can be explained in more formal manners, e.g., "$\mathcal{F}_l A$ is true" where $A$ denotes a goal state.

## 4 Discussions

### 4.1 Supporting Design Process of Business Model

The three-layered model represents the relation between business processes and their surroundings, and a conventional method for checking the reachability of Petri nets clarifies temporal modes of a certain state. Therefore, by modeling a business process with the use of three-layered model, we can check "what will happen if we change the flow of an existing business process" by altering the content of the top layer. Furthermore, we can check "what will happen if social common sense shifts" by altering the content of the base layer. There may also be more ways to support designers (inventors) of business processes.

### 4.2 Implementation and Limitation of the Proposed Model

The proposed method consists of an "extended Petri nets simulator (EPNS)," a "causal chain generator (CCG)" and their mediator.

The EPNS was implemented by modifying a common algorithm for generating coverability trees of Petri nets. The variation of "marking" of a normal 1-bounded Petri nets is at most $2^n$, where $n$ denotes the number of `place`s in the net. Forbiddance and enforcement by the main and the base layers can be either implemented as limitations of possible transitions from specific markings to others. Consequently, for the Petri nets in the main layer, the number of its marking, that is the number of nodes on its coverability tree, is finite (less than $2^n$). The CCG was implemented [14] based on CMS (Clause Management System).

When the "degree" of states (e.g., amount of stockpile, circulating rate of goods, etc.) plays a significant role in a business process, some difficulties arise in modeling it when the proposed method is used. To represent such a degree or quantity of states by schemes for discrete events, e.g., Petri nets, the states have to be divided into some "value fixed sub-states," which in turn explode the size of Petri nets. Removing the ban on the capacity of each `place`, on the other hand, seems to be one way to reduce the size of the net, but the coverability tree does not show how many tokens are in each place; i.e., each node of the tree shows only whether each `place` has tokens or not. Therefore, the "degree" of states, i.e., the number of tokens, cannot be taken into account.

## 5 Conclusions

In this paper, focusing on modalities of actions and states involved in business processes, we proposed a three-layered model for representing business processes and their surroundings.

Designers (inventors) implement their ideas into a sequence of processes, which is represented by the combination of temporal and deontic logic formulae. The static structure of a business process is broken down to possible actions and their pre-states and post-states, which are represented by Petri nets, and the arbitrality of transition firings corresponds to the possibility of actions permitted by designers. The temporal order of state transition is represented by a firing sequence, and the temporal modes of each local state can be analyzed with the reachability of the net.

In this paper, we only showed that $\mathcal{F}_l A$ exists in the case of representing novelties, but there may be other temporal characteristics of novelty. For example, when $\mathcal{G}_b A$ is the case, anytime actors are guaranteed to take an action, in which the only necessary condition is $A$. We are now investigating some other novelties that can be represented by temporal modes.

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