DEVELOPING EXECUTABLE MODELS OF BUSINESS SYSTEMS

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Abstract: Traditionally, business processes models are based on graphical artifacts that do not lend to model checking or simulation, e.g., any Flow Chart like representation or UML diagrams. To check whether business process models are syntactically correct, the models are either translated to other diagrams with formal semantics or the validation is carried out manually. This approach poses two issues: first, models not lending to execution (simulation) will hardly allow thorough insight into the dynamic behavior of the system under consideration; second, when manual checking for small models may not be too difficult, it is almost impossible for complex models. In this paper we investigate two research questions that resulted in a method allowing to build executable business process models based on formal semantics of Petri net. The proposed method is theoretically based on the *Transaction Concept*. The two questions further studied in this paper concern graphical extension of Petri nets for business process modeling, and developing a framework (guidelines) applying the proposed method.

1 INTRODUCTION

As organizations evolve and so do business drivers, analysts use modeling as a multi-purpose tool from understanding the operations of an existing organization, to redesigning business processes, studying impacts of planned changes, and IT-Business alignment. An aspect that recently attracted attention of many researchers is how to build models that can be verified, validated, and checked using computer tools. In practice, mostly these are accomplished via simulation. But, in order to conduct computer simulation, one needs to build executable models based on well supported formalism and semantics. In this paper, we further explore the works resulted from the LAP (Language Action Perspective) by Dietz (1994, 2006).

As evidenced from the literature, the business process simulation area has attracted a huge interest among researchers from diverse perspectives (to name a few: Gladwin & Tumay, 1994; Hlupic & Robinson, 1998; Harrison, 2002; Paul & Serrano, 2003; Vreede et al., 2003; Seila, 2005).

For a thorough analysis and study of business processes, both modeling and simulation should play in concert. Only modeling may not reveal sufficient information about the processes. For significant benefits and results with certain accuracy, business process modeling should be complemented with simulation. On the other hand, despite the abundance of powerful simulation tools, simulation alone may provide little help without profound conceptual modeling preceding it. It would be like "expedition without a map". A valuable lesson extracted from the practice of modeling and simulation suggests, like expedition without a map, simulation without a profound concept (conceptual model) is possible, but it would be very hard, if not impossible, to achieve accurate and precise results.

1.1 Business Systems as Social Systems

A distinctive and important feature of business processes is their social nature – systems encompassing human actors interacting and collaborating to carry out tasks and fulfill the mission of an organization. As such, business processes are not merely a sequence of tasks, or flow of physical materials, but a complex, collaborative, and interactive phenomena, involving actors communicating, negotiating, coordinating, and agreeing upon certain tasks. The social nature of business processes entails a fundamentally different

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perspective to perceive the reality of an organization and the role (responsibility and authority) of its members rather than the approaches used by conventional methods. One such new perspective was introduced in a framework referred to as the Language Action Perspective (Winograd & Flores, 1986). The LAP perspective and its philosophical stance inspired emergence of a number of modeling methodologies and techniques such as SAMPO (Lehtinen & Lyytinen, 1986; Auramäki et al., 1988), Action Workflow model (Medina-Mora et al., 1992), DEMO (Dietz, 1994), BAT (Goldkuhl, 1996), and others. Since the main focus in these methodologies is put on capturing communication acts and building business process models, their underlying modeling techniques do not result in models ready for simulation (Rittgen, 2005). In order to simulate these models, either an additional mapping schema is developed or the models are translated into other state-transition like diagrams, e.g., Petri net. In order to develop simulation ready business process models, this paper introduces a method and discusses the *business transaction concept* as a suitable framework for constructing business process models of an organization. We have adopted Petri net's formal semantics and graphical notations from the very beginning to avoid further translation that had place in (Dietz & Barjis 1999; Dietz & Barjis 2000).

1.2 Contributions

In summary, our research and findings of this paper provide the following contributions:

1) *Executable models* of business processes based on the transaction concept derived from the Language Action Perspective by Dietz. These original works are mostly focused on producing well defined and more detailed business process models, so called, *atoms*, *molecules* and *matter* of organizations. Our contribution is to make the resulting models executable to help analysts with model checking, validation, and studying impacts of changes by testing different scenarios.

2) *Compact models* of complex processes using the business transaction concept. Often in business process modeling, analysts are either not interested in all details, the process under study is too large to be depicted at a detailed level, or the analysts may spotlight part of the process and leaving other parts concealed. In these situations, compact modeling where certain activities are compressed into one well defined component would be of highest interest.

3) The knowledge, generated as a result, contributes to business process modeling, simulation, modeling methodology, application of modeling and simulation, and advancing the discipline of modeling and simulation in an organizational context.

2 EVALUATION OF THE PROPOSED METHOD

Hevner et al. (2004) and Seila (2005) suggest that graphical representation should be very simple, intuitive and easily understandable, at the same time, the accuracy and adequacy of such a representation should not be compromised. Furthermore, Hevner et al. (2004) suggest that methods deploying artefacts should be evaluated using *observational* (e.g., cases study) and *experimental* (e.g., simulation) methods.

In light of these recommendations, the proposed method has been tested on both observational and experimental bases. A dozen case studies have been conducted using the proposed method. Some of them purposefully were conducted with the involvement of undergraduate students to not only evaluate the method, but also its complexity and mastering by only lightly trained analysts and system designers. Then, each of the models was simulated to check the correctness of the models. One such case study is presented in this paper. To complete the proposed method evaluation and its capability to produce executable models for system development, a simulation experiment will be discussed towards the end of this paper.

As for the comparison of the proposed method and its performance against widely accepted conventional methods such as UML, EPC and other Flowchart methods, the main distinction that should be made is the fact that this method takes into account social actors involved in the business process – interaction of these actors through communication and exchange of utterances (conversation). It is a fully business process oriented modeling method incorporating the social character of organizations. Furthermore, in practice, most of the business process models are checked via translation to some sort of executable models. For instance, UML activity diagrams are often translated to Petri nets for checking (e.g., see Eichner et al., 2005; Eshuis, 2006). Also a number of tools are developed to translate UML diagrams to Petri net for further simulation (e.g., P-UMLaut tool converts UML 2 Activity and Sequence diagrams into high-level Petri nets for further simulation and 3-D animation). In this regard, the superior advantage of the proposed method is its direct adaptation of Petri net notations as a modeling technique. Thus analysts do not need any translation and translation schema that may, in turn, compromise the accuracy and adequacy of modeling, or cause further sophistication through the development of certain procedures.

As for the modeling notations that compete with Petri net, e.g. BPMN, EPCs, Role-Activity-Diagrams, IDEF, UML, RIVA etc., the reason for selecting Petri net is not only in its well-defined semantics, logics and formalism, but also its widespread use among researchers, practitioners and academic disciplines. In addition, Petri net is supported by a large number of tools for its analysis and is extended for solving a variety of problems (one such tool is used in this paper). As mentioned, many of the models developed using the other methods and techniques are eventually translated into Petri nets for model checking or validation and verification purposes.

3 BUSINESS TRANSACTIONS

In the proposed method, the core concept is of the business transaction concept introduced within the DEMO methodology (Dietz, 1994) and further developed and discussed in (Dietz, 2006). What follows is an illustrative introduction to the transaction concept using artifacts and constructs adapted by the authors. Readers, interested in more in-depth study about the transaction concept, are referred to the above cited original works by Dietz. We have adapted the Petri net notations and extended them as modeling constructs. Assuming that readers are familiar with the basic concepts of Petri nets that are widely used in systems analysis and design, we skip their introduction. Interested in Petri nets readers are referred to (e.g., Peterson, 1981; Reisig, 1985; Murata, 1989).

Transactions are patterns of interactions and actions, as illustrated in Figure 1a. In the figure, “action” and “interaction” are distinguished by different colors. An *action* is the core of a business transaction and represents an activity that brings about a new result, changing the state of the world. An *interaction* is a communicative act involving two actors (actor roles) to coordinate or negotiate. An example of an interaction could be “requesting a new insurance policy”, clicking “apply” or “submit” buttons in an electronic form, inserting a debit card into an ATM to withdraw cash, or pushing an elevator’s summon button. While replying to the interacting actor or fulfilling their requests is an action, e.g., “issuing a new policy” or “moving an elevator to the corresponding floor.”

Each business transaction is carried out in three distinct phases, the *Order phase*, the *Execution phase*, and the *Result phase*. These phases are abbreviated as O, E and R correspondingly (see Figure 1b), and constitute the OER paradigm (Dietz, 1994). The figure illustrates a business transaction in detailed OER form and compact transaction form (T). Note that the order (O) and result (R) phases are interactions and the execution (E) phase is an action, therefore they are illustrated using different colors (the Execution phase is represented by a rectangle colored in blue (or gray in grayscale printout)). These three phases are a distinct feature that entails the discussed method as a *business process* modeling technique versus just a *process* modeling. Also, these three phases not only allow for the boundary of an actor (or business unit) to be clearly defined, but also to depict interaction and action as a generic pattern involving (social) actors. Compared to UML, Flowchart, EPC and other conventional approaches, the transaction pattern clearly identifies the actors involved as it is discussed below. In other words, in all other conventional methods, a transaction would be reduced to only one execution phase omitting information about the relevant actors and their role (authority and responsibility).

a) b)

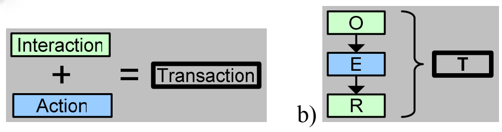


Figure 1: Transaction: a) pattern of action and interaction; b) sequence of three phases (detailed and compact).

Now, we try to introduce the further notions of the transaction concept along with the Petri net notations we adapted. In general, as depicted in Figure 2, Petri net structure consists of places (graphically illustrated by circles and representing outcome of an activity or process), transitions (graphically illustrated by rectangles and representing an activity or process), and directed arcs (graphically illustrated by arrows and representing flow sequence).

Another notion of the transaction concept is the role of actors involved in a transaction. Each business transaction is carried out by exactly two actors (or actor roles), see Figure 2a. The actor that initiates the transaction is called the *initiator* of the transaction, while the actor that executes the transaction is called the *executor* of the transaction. Since the Order (O) and Result (R) phases are interactions between the two actors, their corresponding transitions are positioned between the two actors. The Execution (E) phase is an activity solely carried out by the executor and, therefore, its corresponding transition is positioned within the confines (boundaries) of the executor. In case of multiple actors, they will be conveniently denoted by the letter A and numbered (A1, A2, A#).

In the figure, interactions between the two actors are illustrated at a high level. In effect, each of the two phases (O and R) may involve a series of back and forth interactions (request, offer, counter offer, negotiation, decline, etc.). A complete state-transition schema for the "conversation for action" can be found in (Winograd & Flores, 1986, p. 65) and a "business transaction" in (Dietz, 2006, Chapter 10).

A transaction diagram should also represent how the created result (outcome) is recorded. Since each transaction brings about a new result, the Result phase of a transaction is linked to an oval-shaped element representing the new result created. For simplicity sake, the depiction of the oval representing a transaction result maybe omitted in the models studied later. If a business transaction is a simple one (not nesting further transactions), it is better to compress its three phases into a compact notation, see Figure 2b. In this case, the transaction is placed within the boundary of the executing actor, while the initiation and ending points are placed within the boundary of the initiating actor.

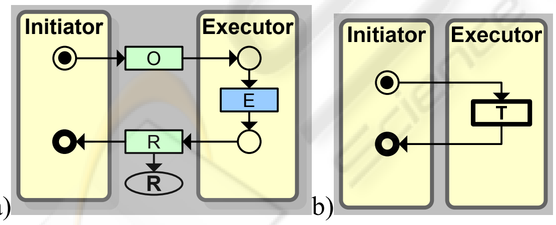
a)  b)

Figure 2: A transaction diagram: a) detailed; b) compact.

A distinction is made between simple and composite transactions. A complex collaboration typically consists of numerous transactions that are chained together and nested into each other. *Simple* transactions do not involve, i.e. trigger or cause, other transactions during their execution (like the above figure). In *composite* transactions, on the other hand, one or more phases will trigger further, nested, transactions. For instance, think if actor A1 contacts actor A2 to reserve a hotel room (we denote this request as Transaction 1, or T1). Actor A2 receives the request and checks the room availability, but in order to complete the request, it has to request for a payment guarantee (we denote this second request as Transaction 2, or T2). For actor A2 to complete the reservation task, first the payment transaction should be completed. This process is represented in Figure 3a in the form of a nested transaction. Notice that the Execution phase of T1 now has several sub-phases or interactions, where each of the sub-phases is distinguished with a letter of the alphabet attached to the transaction number (e.g., T1a/E denotes "first sub-phase of the Execution phase of Transaction T1"). The process illustrated in the figure starts with the receiving of a reservation request and checking the room availability, then it waits for the payment transaction to get completed, only then the Execution phase gets completed, let say, by conveying a confirmation number to the first actor. The process involves three actors (or actor roles): A1 (customer or guest), A2 (hotel receptionist) and A3 (credit card company).

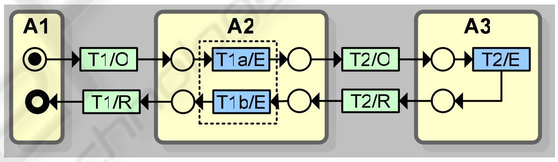


Figure 3: Nested transactions.

Another notion is of probability of some activities – optional transactions. For indication of optional transaction, a small decision symbol (diamond shape) is attached to its initiation (connection) point as illustrated in Figure 4a. In order to transform this optional transaction construct into standard Petri net, a traditional XOR-split that could be modeled by one place that leads to two transitions is used. It requires addition of a skip (or dummy) transition as demonstrated in the figure (tiny rectangle with no labels). A dummy transition is meant that it has zero duration and no resources.

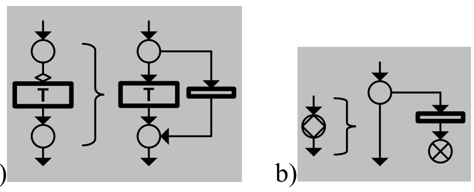
a)  b)

Figure 4: Standard Petri net representation of: a) an optional transaction; b) a decision state.

Finally, there are situations that a process may halt and result in a termination. For example, if there is no room available, then the payment transaction is not initiated at all. This situation is modeled through a place identified as “decision state” graphically represented via a circle with decision symbol (diamond shape) within it, see Figure 4b. As it is seen, for the transformation of a decision state into standard Petri net semantics, a traditional XOR-split that could be modeled by one place that leads to *proceed* or *stop* is used. Depending on the value of the state, the process either proceeds or terminates as indicated by a place filled with a cross.

Through these few simplified constructs and mini-models, we aimed to introduce how the proposed method can capture typical situations in business processes, provide sound concept based on communication, and ultimately contribute towards more accurate Business Process Modeling and consequently more adequate IS Design, since the models can be executed a number of times before it is finalized.

Now that the basic ideas and constructs are introduced, we discuss the underlying framework (guidelines) deploying the proposed method, and then we illustrate how this method can be applied to a real world business system.

4 APPLICATION GUIDELINE

Based on practice and application experiments, the following framework (guidelines) was developed. This framework is diagrammatically illustrated in Figure 5, in which both the process flow (block arrows) and feedback loop (circled block arrow) between the phases are depicted. As seen, this is an iterative process where after each simulation and output analysis, the model is refined, some parameters are modified and the experiment is repeated. It may be also required to return to earlier phases (phase I or phase II) for missing pieces of information, if the analysis reveals any flaws or doubts. This is especially important when changes occur for the system under consideration, modifications must be made to the model, and the change impact has to be studied. The entire process consists of the following major phases.

Phase I – *Big Picture:* during this phase, an organizational chart, profile and major business processes are identified. Identification of the major business processes virtually forms the *“big picture”* of an organization. Also during this phase, scope estimation is conducted – a major business process (or processes) is selected where the main focus will be directed. The perspective taken in this phase considers an organization as a network of business processes (BP). Methods used in this phase are mainly the review of the corporate documents and interview with the business manager if such documentation is missing or they are presented in a vague manner.

Phase II – *Detailed Picture:* During this phase, each major business process of interest is described to fill in the details of the “big picture” identified in phase one and draw boundaries of organizational units and rules. As a result, an analyst may describe a series of interrelated business processes (BP1, BP2, etc.). Methods used in this phase are mainly based on interviews, observations and review of the documented procedures.

Phase III – *Modeling:* For each specific major business process of interest:

Step 1: Identification of business transactions. For the elicitation of potential business transaction, in this step, the Transaction Concept is used.

Step 2: Description of business transactions (actors and results). For the description of business transactions, in this step, the Transaction Concept is used

Step 3: Construction of a model using artifacts (graphical notations). In this part the proposed notations are used to construct models of business processes under study.

Phase IV – *Simulation (Validation):* Using the business manager’s feedback and input combined with (animated) simulation the model(s) is validated. Once the model is validated, its behavior is studied through the simulation runs. In this phase, simulation tools are used to execute the models constructed, and the results as well as the animated models are validated with the business owners.

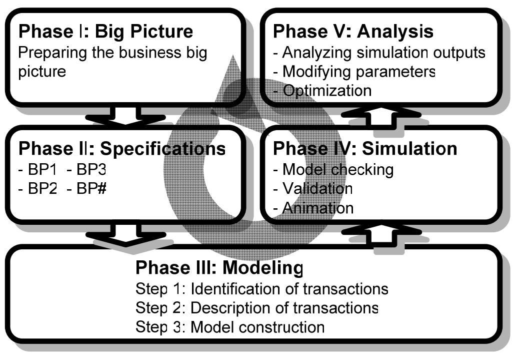


Figure 5: An application framework (guidelines).

Phase V – *Analysis & Improvement:* Based on the results of simulation, the model is analyzed in respect to alternative scenarios (statistical analysis). At this stage analysts may suggest improvements in the form of redesigning business processes. In this phase, using the statistical analysis methods, the simulation outcomes are analyzed and compared with alternative scenarios.

In the following section, we follow this framework to report on a case study.

5 CASE STUDY: PHARMACY

The case study reported here is not intended to be exhaustive, it is a simplified version. It is aimed to demonstrate how the proposed method is capable of capturing the dynamic behavior of business processes and serve as an input for simulation. This case study was conducted at a time when a Pharmacy was planning to acquire and implement a new system and extend its business with e-commerce. This case study was assumed to provide an insight and help to understand the Pharmacy's operations and requirements for a new system.

5.1 Prescription Filling Process

Upon arrival at the Pharmacy a patient proceeds to the pharmacy counter and requests prescription refilling by submitting their prescription to the pharmacists or technician. The technician asks if the patient is an existing customer to access their profile information which should be already in the QuickScrip's database. If it is a new patient, the technician asks the patient to fill out a short information sheet (name, address, insurance or medicine coverage). After selecting the correct medicine, the software automatically checks the current medicine for interactions with prescriptions the patient is currently taking. The user is alerted if any interactions are found and the patient or the patient's doctor can be informed. The user is then asked by the software if they would like to transmit a claim to the patient's insurance company, if one has been provided to the database. If a patient has no insurance coverage, a cash price is assigned to the prescription. Once a claim has been transmitted to the patient's insurance company via the internet, a price is assigned to the prescription based upon the company's response. The computer generates a label and sends the information to the 'robot' for automatic filling. The medicine is dispensed into a pre-selected bottle and counted using a laser and gear system which places the medicine into the bottle. A conveyer belt sends the prescription out for a final check by a pharmacist. Once verified, the prescription is bagged and then sent out to the cashier for pick-up by the patient. The entire process normally takes no more than 10-15 minutes. At the pick-up counter, the patient signs for their prescription and pays the cashier or charges the cost of the medicine to a personal charge account which is part of QuickScrip's billing function. The end of this process is related to inventory control that must be accurately maintained because QuickScrip uses an automated ordering system. We skip the details of this process due to space restrictions.

5.2 Identification of Business Transactions

The process of "Prescription Filling" starts when a patient presents a prescription to be filled. Thus, the first transaction (T1) is "prescription filling". Actually, this is a super transaction that nests many other transactions. This transaction is initiated by a "patient" and executed by the "pharmacist". The result of this transaction is a filled prescription. In this manner we identify all other transactions:

T1:	prescription filling
Initiator:	patient
Executor:	pharmacist
Result:	prescription is filled
T2:	creating profile
Initiator:	pharmacist
Executor:	patient
Result:	profile is created
T3:	checking medicine interaction
Initiator:	pharmacists (software agent)
Executor:	QuickScrip
Result:	interaction is checked
T4:	claim processing
Initiator:	pharmacist
Executor:	insurance company
Result:	claim is processed
T5:	automatic dispensing
Initiator:	pharmacist
Executor:	robot
Result:	medicine is dispensed into bottle
T6:	paying for the medicine
Initiator:	pharmacist
Executor:	patient
Result:	medicine is paid

Now, we build a detailed model as shown in Figure 6. By disclosing Transaction T1 (splitting its three phases), all other nested transactions are revealed. It also shows that once medicine is issued (T1/R), the inventory control process is activated. As the inventory control process is out of the scope, which itself is a network of transactions, we just illustrate it as a composite transaction (T#).

Within the scope of our model, only Transaction T1 is a composite transaction and, therefore, we decompose it. All other transactions (T2, T3, T4, T5 and T6) are simple transactions and, therefore, they are shown in a compact form.

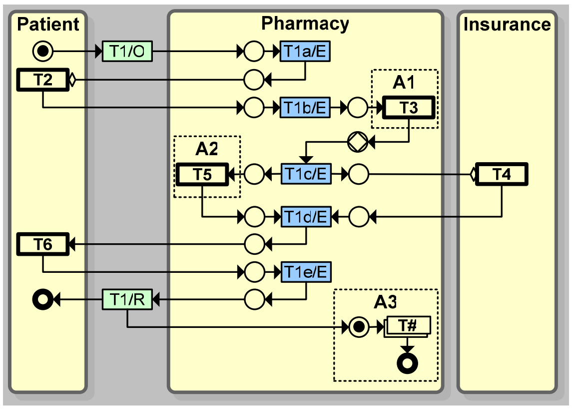


Figure 6: Pharmacy model (constructed with MS Visio).

In the above figure, the Pharmacy is considered as a composite actor delegating the role of a few other actors such as “pharmacist”, “technician”, “robot” and “software agent” for checking medicine interaction. In order to better understand the above figure, it should be read from left to right and from the top to down, just as the arrows indicate. It would be easier if the reader has a list of the transactions, previously identified, ready when reading the model: The patient requests prescription filling (T1/O) and with this request the execution by a pharmacist or technician starts (T1a/E). If it is a new patient, the technician requests them to fill in a form to create a new profile (T2). This is an optional transaction indicated with a small diamond-shape at the connection point. Then, within the pharmacy system (QuickScrip), a request is made to check the current medicine for any interaction (T3) (if an interaction is detected, the process terminates here). Through an online application, the claim for this medicine is transmitted to the patient’s insurance company to define the price of the medicine (T4), if the patient is covered by an insurance plan. Then the robot is instructed to fill in the prescription (T5). At this point the patient is requested to make their portion of the payment or arrange for later billing (T6), and only then the medicine is issued to the patient and the process is completed (T1/R). Notice, the completion of this process triggers a transaction in the inventory control process (T#) making sure the issued medicine is subtracted from the inventory and checks if this medicine should be ordered for restocking.

5.3 Simulating the Pharmacy Model

The model presented in the previous section was based on MS Visio software using a designed stencil. In order to execute this model, a vast majority of Petri net tools can be used, but, none of the tools, we have access, allows the import of MS Visio diagrams. Therefore, one needs to reproduce the model using the graphical editor of the tool used. We do this for two reasons: to check the model (detect deadlocks), and visualize its execution through *token game animation*.

We used HPSim tool (http://www.winpesim.de/, checked on November 25, 2006) that provides its own graphical editor to construct a model. A screenshot of the pharmacy model is shown in Figure 7. The diagram is identical to the one constructed with MS Visio except for three elements: T2 is an optional transaction that should be represented in a standard place-transition format using the equivalent we discussed and illustrated earlier; T3 is followed by a *decision state* which requires a place-transition equivalent, similar to the optional transaction schema; T4 is also an optional transaction which is substituted by its place-transition equivalent.

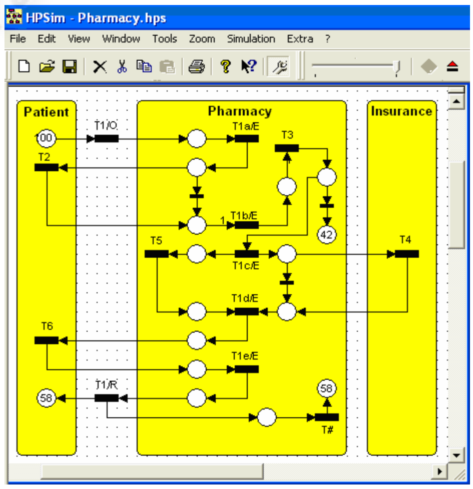


Figure 7: Screenshot of simulation modeling.

The screenshot is taken after a simulation experiment is conducted. The model generated 100 tokens each representing a patient (100 simulation runs) to check the model, to study if all the states are reached and all the transitions are executed, and if there is any deadlock. There are only three terminal places (when a medicine is issued, when the inventory is updated, and when a drug interaction is detected). The numbers in these three places show how many times each of the corresponding events has occurred. Actually these events together should make up the total number of generated entry tokens. Since the inventory is updated every time a medicine is issued, their corresponding places duplicate the same number of occurrences.

Our purpose in this paper was simply to demonstrate how executable models of an enterprise can be developed. It is just a starting point for many possible research directions and applications. For more complex investigations, analysts can use other Petri net tools such as CPN Tool widely used within the Petri net community. For more business or non-technical friendly representation, the Arena™ animated simulation tool can be used.

6 CONCLUSION

In this paper we have studied how business process models can be designed in a fashion easily lending to execution (simulation). By executing models, analysts can better conduct model validation and get insight into the dynamic behavior of systems. In addition, the paper outlined a framework that serves as a guideline to apply the proposed method as a step by step analysis, covering most of the phases involved in system study. It starts from a description of business process in a natural language, leads to the identification of business transactions and actors involved, and ends with executable models. This approach provides a tool for the optimization of processes via comparison of different scenarios.

However, when the method and the resulting models were discussed with users, it was established that Petri net based models seem challenging to understand. We found that this issue can be surmounted by using more animation. Even a token game (when in a Petri net model movement of token from input places to output places are animated) can ease understanding of the models and make them more attractive. But, using more advanced simulation tools that provide cartoons to illustrate entities would make the models more realistic for any group of users.

Finally, only complex real life systems study can prove how vigorous a method is. Thus, one of the objectives of our ongoing future research is to apply the method to more complex business systems with emphasis on inter-organizational interactions.

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