An Event-Driven Modeling Approach for Dynamic Human-Intensive Business Processes

Nancy Alexopoulou[1], Mara Nikolaidou[2], Dimosthenis Anagnostopoulos[2], Drakoulis Martakos[1]

[1]Department of Informatics & Telecommunications, University of Athens, Athens, Greece

[2]Department of Informatics & Telematics, Harokopio University of Athens, Athens, Greece

Abstract. One of the most challenging business process categories in terms of agility are those exhibiting dynamic behaviour and involving intense human decision. Any effort to automate such processes may constrain their agility, which constitutes an intrinsic requirement for this process category. Therefore, these two factors, i.e. intense human involvement and dynamic behaviour, pose a challenge regarding the role of a BPMS for such processes. In this paper, we explore the role of BPMS for dynamic, human-intensive processes and propose an event-driven modeling approach that efficiently supports modeling requirements of such processes. To validate our approach we provided a case study from the medical arena concerning medical treatment, which is a typical example of dynamic, human-intensive processes. While the focus of this paper is to introduce the modeling concepts, enactment aspects of the proposed approach are also discussed.

Keywords: dynamic business processes, human-intensive business processes, event-driven model

1 Introduction

Nowadays, business process automation is usually accomplished through the utilization of process-aware information systems [1] based on BPMS (Business Process Management System) technology and explicit process models that follow a strict action sequence. Such a sequence dictated by the most traditional approaches [2], [3] is suitable for well structured processes whose objective is to impose this sequence to the involved actors. However, there are processes in which activities performed are strongly based upon human decision influenced by the circumstances as well as unpredicted contingencies. Such processes are characterized by dynamic behaviour and intense human involvement and cannot be described through a specific order of actions, since such a description would hinder significantly the agility

required by the nature of these processes. Therefore an approach is required permeated by a different logic from that governing traditional action-driven approaches.

To this end, we adopted the event-driven paradigm for the development of a business process modeling approach eligible for the design of dynamic, human-intensive processes. Though the event-driven paradigm is well-established for the execution of business processes (e.g. ECA model [4]), the potential of applying events as a core concept (as opposed to the complementary fashion appearing in modeling approaches such as Aris [3]) for the design of business processes has not been explored. We show in this paper that events can be effectively used to promote agility in the design of dynamic, human-intensive processes.

An event represents something that happens that is meaningful for the enterprise. As such, it can express in a more abstract manner the conditions under which an action should be initiated. Such conditions may arise from data modifications, human decisions, timing states or anything that could lead to a situation that should be handled, which can even be of an unknown source. An event of unknown source may be defined in a model in case it is meaningful for the organization, which means that its occurrence should be handled somehow, e.g. the sudden fall of the stock market may initiate a number of actions despite the fact that what caused the fall may be unknown. The event-driven paradigm inherently supports the description of processes that are affected by unexpected contingencies, since contingencies may be regarded unexpected events. The proposed event-driven modeling approach is called 'Notify and Register' (N&R).

The objective of this paper is to introduce the N&R approach and delineate how dynamic human-intensive processes can be efficiently modeled using this approach. For this purpose, a case study from the medical arena is provided. While the focus of this paper is to introduce the N&R modeling concepts, enactment aspects of N&R models are also discussed in the paper. This paper is organized as follows. The role of automation in dynamic, human-intensive business processes is discussed in section 2. In section 3, the 'Notify & Register' approach is analytically presented. A case study from the medical arena is provided in Section 4 in order to demonstrate the proposed modeling approach. Section 5 includes a discussion concerning enactment issues and implementation aspects of the approach. Conclusions and future work lie in section 6.

2 The role of BPMS in Dynamic, Human-Intensive Business Processes

In most cases, when considering business process automation through a Business Process Management System (BPMS), what comes to one's mind is the automated coordination of specific actions that must be accomplished in a predetermined order. Indeed, business process automation has been mainly associated with action-driven processes [2], [3]. In such processes, actors perform specific tasks according to the order imposed by the BPMS. In this respect, the role of BPMS is to appropriately distribute work and ensure that process execution is realized according to a predefined flow.

However, there are processes for which task sequence cannot be prescribed, since what will be executed and when is strongly based upon human decision. In such human-intensive processes [5], execution is efficient if actors are free to decide what to do and when, depending on the specific case and unexpected events that may occur. Patient treatment and crisis management are typical examples of such processes. In such processes, what would be the role of a BPMS? Let us consider the example of patient treatment. While treating a patient, all data concerning, for example, diagnoses, examinations scheduled, medication provided, results of clinical and paraclinical examinations, etc., are registered in the patient record created when a patient is admitted to the hospital. Thus, information included in the patient record is formed by activities carried out by actors, such as physicians and nurses. Essentially, this information depicts how each patient case was handled. The way a patient's case is handled can be affected by special characteristics exhibited by the specific patient (e.g. a patient may be allergic to a specified medication) or unexpected conditions that may arise (e.g. a patient may suffer a heart attack). The information is included in patient record and used by the doctors that collaboratively treat the patient, nurses and the rest personnel involved in the treatment process. Involvement in treatment occurs after notification either in a regular or in an ad hoc manner. For example, microbiologists in the laboratory department are daily notified to perform blood examinations for each patient. Radiologists, on the other hand, are notified less regularly, i.e. whenever an imaging examination is required. Ad hoc notifications may also take place, for example, to a physician to examine a patient who suddenly complained for an intense chest pain or to doctors of the Intensive Care Unit, if a patient that has suffered a heart attack needs to be immediately transferred there.

Obviously, employing a typical BPMS to automate the treatment process and impose a specific sequence of actions would not only be inappropriate, but in addition would hinder agility. In alignment with the actual process, what would be required is a BPMS that would "sense" the events occurring in the real world and in response to them perform the required notifications as well as the registrations in patients' records. Likewise, in crisis management, when meaningful events occur, the BPMS should register information associated with these events and notify the relevant parties that something should be done to deal with the crisis encountered. In this respect, the BPMS responds to events, which are proactively generated by actors. The latter is in contrast to the traditional BPMS approach, where actors adopt a rather reactive attitude, since they wait for the tasks indicated by the BPMS in their task list. In summary, we state that *for dynamic, human-intensive business processes, the role of a BPMS should be to handle events, which are proactively generated by actors, by registering information related to these events and/or performing the required notifications to the actors that need to be involved in the process.*

It follows that for a BPMS to function in such a way, an appropriate executable model is needed. To this end, we propose in the following a modeling approach which produces executable models that serve event handling through registrations and notifications, being thus eligible for the description of dynamic human-intensive business processes.

3 Introducing the 'Notify & Register' Modeling Approach

The objective of the proposed modeling approach, called 'Notify & Register' (N&R), is to depict the events that occur in the real world specifying thus when registration and notification actions should be performed. Thus, the central concept of N&R approach is that of event. More specifically, business events of instantaneous and permanent occurrence are used in N&R approach to represent traces of real world activities performed by humans that are of significance to the business process model. In dynamic human-intensive processes, activities do not take place in a strict predetermined order. While there may be cases of activities carried out in a regular fashion, most often, they are performed whenever required, following human decision. Clinical examinations, for example, are performed every morning as well as whenever an unexpected symptom occurs. Therefore, N&R does not focus on the order of activities performed by humans, instead depicts, using events, 'stamps' of activities that have been accomplished, which signify the need for registering relevant information and/or notifying specific actors that need to be involved in the process. How an activity will be carried out is left to the actor and thus does not fall within the scope of a N&R model. This makes sense in human-intensive processes, as in these processes most tasks cannot be automated. Consequently, s*tamp events*, as they are named, imply activities performed by humans either regularly or in an ad hoc manner. The latter case indicates that dynamic behavior is inherently accommodated in a N&R model.

A stamp event is generated by the actor category responsible to indicate that the corresponding non-automated activity has been accomplished. Usually, the generator of a stamp event coincides with the performer of the corresponding activity. However, this is not always necessary. As such, a stamp event in a N&R model, is always associated with a role that denotes the actor category responsible for its generation.

A stamp event, as described above, denotes that an activity has been accomplished. However, apart from confirmation, a stamp event may imply a request or a reply. The former case holds when an activity accomplishment causes the need for someone else to do something. The latter gives notice that the requested activity has been performed through a reply stamp event.

Apart from stamp events, N&R supports also time events. Time events can serve the need for sending reminders to the relative actors, in case they have not performed an activity that was meant to be performed. However, even in this case, the actors may not perform the activity, if they do not find it necessary. In general, through time events, N&R may support the description of routine activities that are performed in a regular basis and not because of human decision. Obviously, time evens are automatically generated and thus they are not related to roles.

The generation of a stamp event leads to registrations and/or notifications. As already mentioned, these activities should be automated by a BPMS. The rest, i.e. the human-intensive activities, are made known to the BMPS through the respective stamp events. Apparently, if a stamp event is a request or a reply, it definitely causes a notification action, while it may also cause a registration.

Every N&R model comprises a data folder composed of a unit hierarchy. Atomic units, i.e. units at the lowest level of the hierarchy, comprise data fields that specify the actual data. The data for each atomic unit are provided by the role that generates the stamp event and are registered to this unit by the BPMS. Registration is always associated with a specific atomic unit. Access policies may be defined, specifying the

data fields that each role can alter. Alteration of an atomic unit can take place only if a stamp event occurs signifying that an activity was performed. The outcome of this activity is depicted through the data inserted in the corresponding data unit. As such, the N&R approach concerns only insertion of additional information. Updates or deletions of existing data are regarded as exceptional situations required as a result of human error.

Notification is related to roles indicating that respective actors playing these roles should be involved in the process when the corresponding event occurs. Notification informs the notified actors that a specific event has and indicates him/her the data folder in concern.

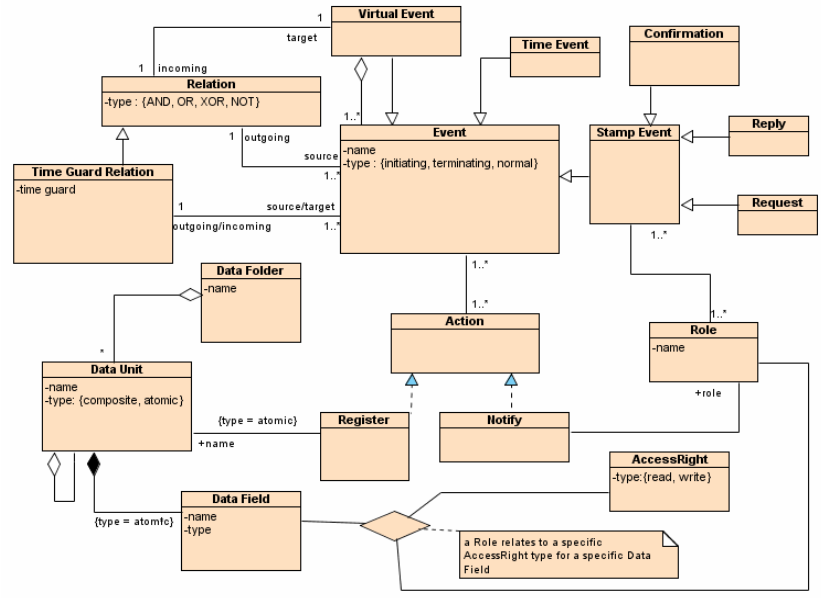

Fig. 1. The metamodel of the N&R business process modeling approach

Registration and notification can be triggered by a combination of events. For modeling efficiency, instead of directly connecting the combined events with the registration or notification actions, a virtual event can be defined aggregating the combined real events (stamp and/or time events) [6]. Then, the defined virtual event may be related with the corresponding registration or notification. Through virtual events, complexity is hidden within events. Registration or notification actions do not need to be aware of complicated event combinations that cause their execution. They only sense the produced conceptual event. A virtual event may also be defined through a simple causality relation, “aggregating” only one event if this serves the modeling purposes.

Stamp events can also be interrelated through timing guard relations. The latter impose that the occurrence of an event will follow the occurrence of another event within a specific time interval. A typical use of timing guards is to denote a temporal

constraint between a request and a reply event, although timing guards may also be defined between two confirmation events.

It should be noted that every event defined in a N&R model is either directly or indirectly (through a virtual event) associated with registration or notification. If for example events A and B cause the event C, all of them are stamps of actions (i.e. no virtual) and only event C leads to registration or notification then the causality relation (A and B) → C is not defined in a N&R model, as events A and B are meaningless for the model. Meaningful events are only those causing registrations and/or notifications.

Lastly, it should be also noted that according to the N&R approach, a process is triggered by an event defined as initiating and ends because of the occurrence of an event defined as terminating. All the concepts described in the previous section are included in the metamodel of N&R approach depicted in Fig. 1.

4 Case Study

In order to test our modeling approach, we decided to apply it in medical treatment. The relevant information was collected from the personnel of a Greek hospital. Based on this information, we developed a N&R model. The main portion of this model is illustrated in Figures 2 and 3. When a patient is admitted to a clinic, data related to patient's personal details (name, address, etc.) as well as his/her medical history should be registered to the patient's record. Also, the doctors of the clinic should be notified that a new patient has been admitted. Apparently event "Patient Admitted" (Fig. 2 (b)) is the one initiating the medical treatment process while, the process ends when event "Patient Discharged" occurs (Fig. 3 (d)). During a patient's treatment in a clinic, he/she is regularly submitted to clinical examinations, laboratory and imaging.

Let us discuss the case of laboratory examinations. As shown in Fig. 2 (c), event "Laboratory Examination Decided", which signifies that a Physician has scheduled a laboratory examination, causes the registration of the scheduled test along with the respective date to the corresponding data unit, as well as the notification of the microbiologist and the nurse for drawing the blood sample. "Laboratory Examination Decided" is a request event (illustrated using a circle with an arrow inside pointing up). The corresponding reply event (illustrated using a circle with an arrow inside pointing down) is shown in Fig. 2 (d). According to Fig. 2 (d), when the examinations are ready, the microbiologist will generate the respective reply event which will lead to the registration of the results in the data unit "Laboratory Findings" as well as to the notification of the Physician that the results are ready.

As already mentioned, a registration or a notification can be initiated by more than one events. As presented in Fig. 3 (c), the registration of data related to the medication provided is initiated when the medication is specified or whenever the medication is adjusted (e.g. in case a patient manifests an allergy to the current medication) or even when ad hoc medication is provided. The latter concerns the case a nurse gives, for example, an analgesic pill to a patient suffering from a headache. Even this slight intervention is important to be registered in the patient's record, as the provided pill may counteract with the medication provided and produce adverse

reactions. In Fig. 3 (c), a virtual event could have been alternatively defined aggregating through an OR relationship events "Medication Specified" and "Medication Updated". Then the virtual event would have been related to Medication unit and Nurse. However, as this was a simple OR relationship, the definition of a virtual event was not deemed necessary. Events of Fig. 3 (c) are confirmation events and are depicted using a double-lined circle.

Fig. 2 (f) and 3 (g) show causality relations with a time guard. Fig. 2 (f), for example, denotes that events "Laboratory Examinations Decided" and "Laboratory Findings Ready" are request and reply events respectively that must occur within a time interval. Time guard has been defined in the model in a parametric manner so that it can be instantiated with a specific value during run time.

Fig. 3 (b) presents a time event called "Time is 8 a.m.", using a circle with the clock hands inside it, which causes the virtual event "Clinical Examination Decided" This event is virtual in the sense that it is not a stamp event of a human activity, i.e. the clinical examination has not been decided in reality. The event is created to express the case of the routine clinical examination that takes place every morning. According to Fig. 3 (i), the daily morning clinical examination for each patient has to be performed between 8:00 and 13:00 o'clock. In case the event "Clinical Examination has been Performed" does not occur for a patient within the specific time interval, then a relative reminder is generated, which may or may not be taken into consideration by the physician.

In the medical example, patient record represents the data folder that is managed during the process execution. Its structure is presented in Fig. 4. Patient record, as deduced from Fig. 2 and 3, comprises the following units: Personal Details, Medical History, Diagnosis, Discharge Note, Medication, Specialist Evaluation, Examinations and Examination Findings. As opposed to the rest, the last two units are not atomic. Examinations is further decomposed to the atomic units Imaging Examinations, Laboratory Examinations and Special Examinations, while Examination Findings include the atomic units Clinical Findings, Imaging Findings and Laboratory Findings. Each of the atomic units comprises specific data fields.

As revealed by the medical case study, there is no process flow defined. Instead, for each event identified, the actors that should be notified and/or the data that need to be registered are defined through a notify or register action respectively. This is done for each event independently. In addition, as confirmed by the treatment process, stamp events denoting both regular (e.g. event "Laboratory Examination Decided" in Fig. 2 (c)) as well as ad hoc activities (e.g. event "Emergent Surgery Decided" in Fig. 2 (g)) are modeled in a unified fashion. Event "Evaluation by Specialist Decided" may be generated by a physician that needs consultation in the interpretation of a symptom, while another physician capable of interpreting the symptom on his own may not need a specialist's consultation. It depends, thus, on human decision whether event "Evaluation by Specialist Decided" will be generated or not. It follows that N&R offers a simple, yet efficient way to model functionality of dynamic, human-intensive processes. Apart from agility, N&R offers another advantage. It enables a consistent evolution of the data folder aiding in the production of high quality data. Such data can be explored using data mining technologies and lead to the extraction of valuable information. In case of medical treatment, patient data produced can be used in short or long term studies for the extraction of valuable information that may

contribute in the formation of international medical guidelines [7].

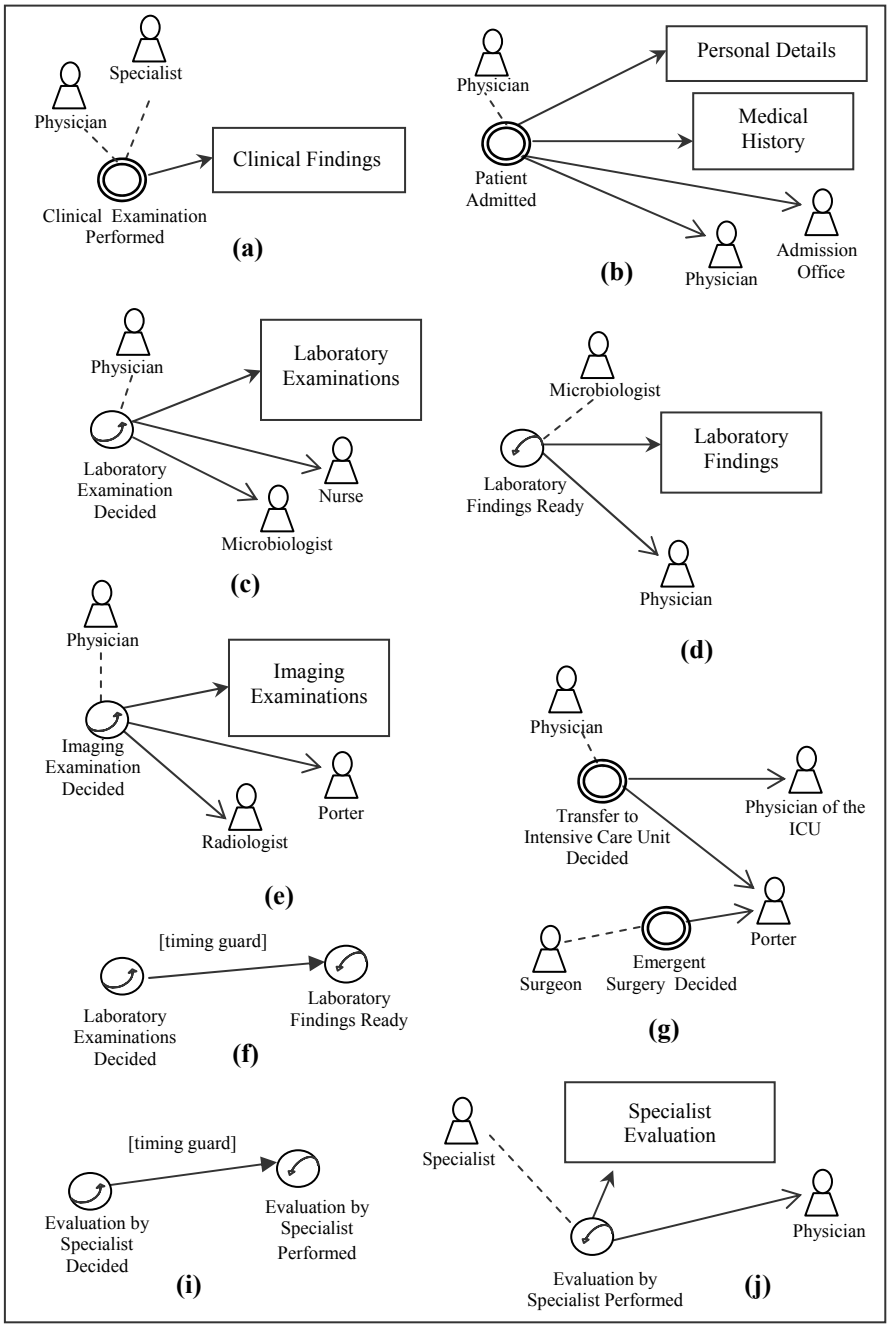

Fig. 2. Modeling the medical treatment process using the 'Notify & Register" approach

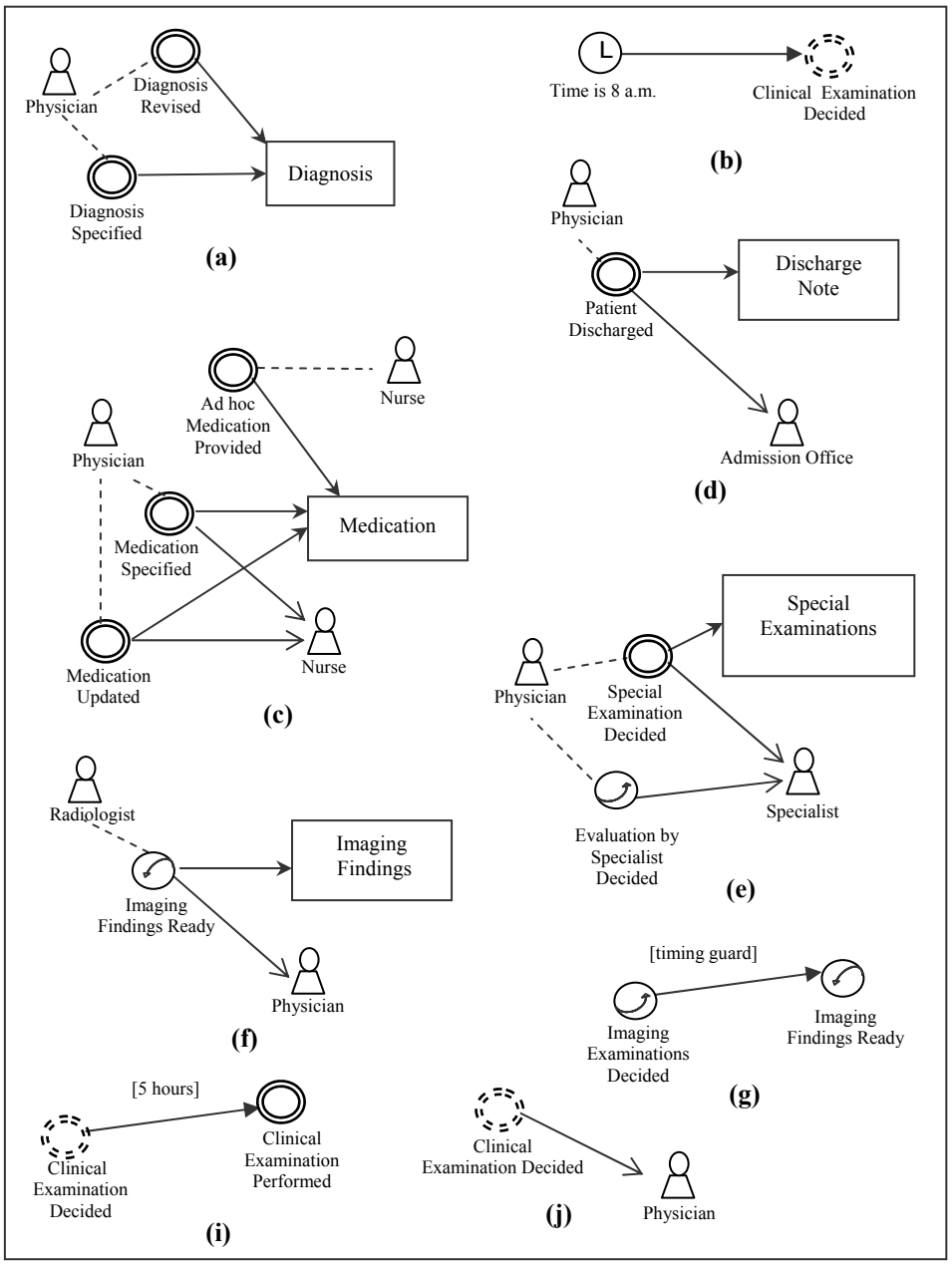

Fig. 3. Modeling the medical treatment process using the 'Notify & Register" approach

(continued)

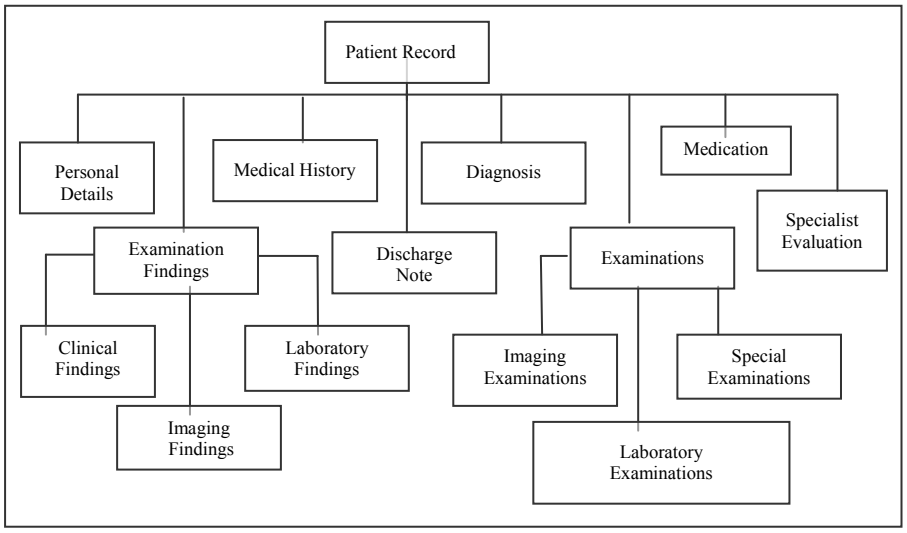

Fig. 4. The structure of Patient Record

5 Enactment Of "Notify & Register" Business Process Models

Enactment of event-driven models requires a BPMS that is based on an event-driven BPM engine. Two indicative event-driven BPM engines proposed in the literature are Yeast [8] and Eve [9]. Eve is based on the ECA model [4]. An ECA rule dictates that when an event occurs, a condition is evaluated. If the condition is satisfied, the respective action is executed. Yeast, on the other hand, uses EA (Event-Action) model also proposed in [10]. EA model is based on only two entity types (event-actions). A condition in EA model is expressed through two opposite events corresponding to the condition's true and false outcomes.

Fig. 5 presents a proposed conceptual architecture for the implementation of N&R approach. The N&R models are developed using the *N&R Specification Environment* presented at the upper part of Fig. 5. The developed models are stored into the *N&R Models* repository. Obviously these models have to be translated into executable event patterns and EA rules in order to be readable by the BPM engine. The EA rules, for example, for Fig. 3 (e) could be as follows:

EVENT Special_Examination_Decided(Patient_Record, Physician)
ACTION Register (Patient_Record, Special_Examinations) AND Notify (Specialist);

EVENT Evaluation_by_Specialist_Decided (Patient_Record, Physician)
ACTION Notify (Specialist);

Actors generate event instances through an appropriate *User Interface*. When an event instance is generated, it is received by the *Event Composer*, which is responsible for combining events to composite ones based on the information stored in the *Event Patterns* repository. The Event Composer examines whether the received event participates in any event combination using the event pattern definitions stored in the repository. If it does not, the Event Composer directly forwards it to the *BPM Engine*, while if it does, it also keeps it in a record until instances of the rest events

related to it occur. The Event Composer is also responsible to handle time guard relations also maintained in the Event Patterns repository. If the time interval specified by a time guard elapses before the occurrence of the respective reply event, the Event Composer forwards a message along with the required information (i.e. name of the reply event and identifier of the patient folder) to the BPM Engine, so that the latter can generate an alert message to the involved roles. The Engine can find the involved roles from the corresponding EA rule.

When the related event instances occur and the complex event is created based on the information stored on Event Patterns Repository, it is forwarded to the BPM Engine. In parallel, the Event Composer stores the occurring event instances into an *Event Log*, which includes additional information for each event occurrence such as a timestamp indicating the time it was generated, the identification data of the actor that generated it, etc. When the BPM engine receives an event instance from the Event Composer, it checks the *EA rules* repository and executes the respective EA rule. This means that it invokes the appropriate registration and/or notification services.

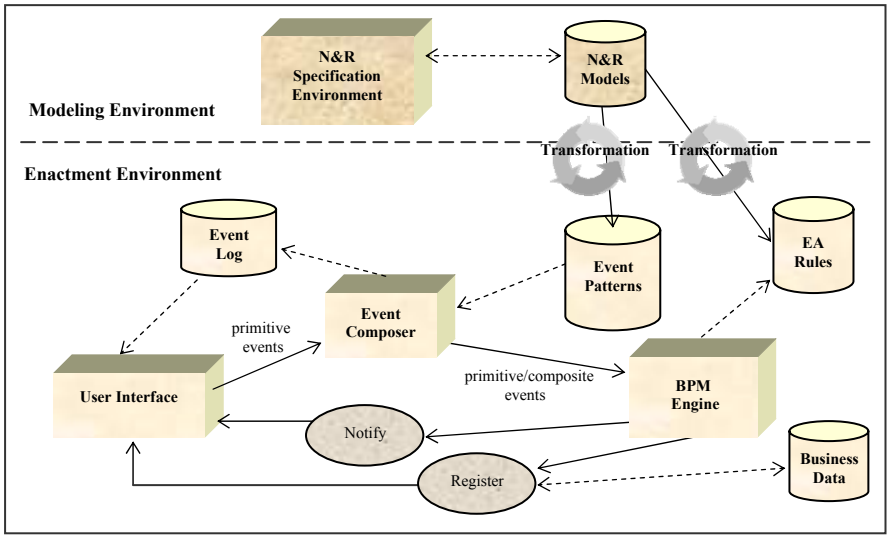

Fig. 5. A conceptual BPMS architecture for the implementation of N&R approach

N&R approach ensures agility in the execution of dynamic human-intensive processes as it allows the business process to dynamically evolve during execution time based on human decision and the circumstances that may arise. The order of the steps that will be followed is not known in advance. When a process ends, its structure can be traced by viewing the event log.

6 Conclusions – Future Work

In this paper, we presented an event-driven business process modeling approach called “Notify & Register’. The objective of this approach is not to describe how tasks

are carried out, as in traditional action-driven logic, but to depict the events that occur in the real world specifying thus when registrations and notifications should be performed. The event-driven paradigm guided our minds away from the conventional way of designing processes for automated execution and made us think in a totally different way for the development of an approach that does not hinder but promotes agility required by the dynamic, human-intensive processes. For the demonstration of the N&R approach we provided a case study from the medical arena that concerned medical treatment, which is a typical example of dynamic, human-intensive processes. Our future work involves applying the N&R approach in the design of other dynamic, human-intensive processes, as well as developing a prototype based on the proposed conceptual architecture, in order to test the enactment of N&R models. Currently, in an effort to formalize our modeling approach, we are exploring the UML extension mechanisms taking into considerations the concepts introduced in UML profiles for business process modeling, as BPMN[2].

Acknowledgments. This paper is part of the 03ED470 research project, implemented within the framework of the "Reinforcement Programme of Human Research Manpower" (PENED) and co-financed by National and Community Funds (25% from the Greek Ministry of Development-General Secretariat of Research and Technology and 75% from E.U.-European Social Fund.

References

1. Dumas M., Aalst W., Hofstede A., *Process-Aware Information Systems* (John Wiley & Sons INC, 2005).
2. OMG, Business Process Management Notation. Version 1.0,(OMG, 2006).
3. Scheer A.W., *ARIS-Business Process Modeling*. 2nd ed. Berlin (Springer 1999).
4. Dayal U., Hsu M., and Ladin R., Organizing Long-Running Activities with Triggers and Transactions in Proceedings of *ACM International Conference on Management of Data*, 1990, pp.204-214.
5. Swenson Keith and Farris Jim, Human-Centered Business Process Management in *Fujitsu Sci. Tech. J*., April, 2009, Vol. 45, No. 2, pp.160-170.
6. Luckham David, *The Power of Events* (Addison-Wesley, 2002).
7. Lenz Richard and Reichert Manfred, IT support for healthcare processes - premises, challenges, perspectives in *Data and Knowledge Engineering*, 2007, 61 pp. 39-58.
8. Krishnamurthy B. and Rosenblum S. D., Yeast: A General Purpose Event-Action System, *IEEE transactions on Software Engineering*, 1995, Vol. 21, No., 10.
9. Geppert A. and Tombros D., Event-based Distributed Workflow Execution with EVE, *Technical Report*, 1996, Department of Computer Science, University of Zurich.
10. Alexopoulou Nancy, Nikolaidou Mara, Chamodrakas Yannis, Martakos Drakoulis, Enabling On-the-fly Business Process Composition through an Event-based Approach in HICSS 2008.