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BPM TECHNOLOGIES FOR MANAGING DYNAMIC HEALTHCARE PROCESSES FLEXIBLY

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Abstract. *Healthcare processes in hospitals are very complex and difficult to define precisely in advance. Furthermore, a detailed process for the same disease can be variable or dynamically determined according to the intermediate care results or characteristics of a patient. In this paper, we present a dynamic business process management system for variable healthcare processes. At first, a business process modeler based on business process change patterns is presented. An actual runtime process for a patient can be determined and designed dynamically considering intermediate results of the clinical care process. Also, an innovative runtime process execution mechanism for implementing the care process is described. The proposed dynamic BPM (Business Process Management) system can provide effective and flexible healthcare services to patients considering current situations at runtime.*

Keywords: BPM (Business Process Management), Change pattern, Healthcare process, Dynamic process

1. **Introduction.** Due to the complexity and variability of healthcare processes it is very difficult to apply conventional BPM (Business Process Management) technologies to the healthcare domain [1,9]. In many cases, healthcare processes cannot be defined precisely at design time and they may change dynamically according to the runtime situation of a patient. Although there may exist standard clinical practice guidelines, healthcare professionals tend to depend on their own decision makings rather than they follow strictly pre-defined procedures [2]. In order to resolve these issues in the healthcare domain, it is required to adopt dynamic business process management technologies such as runtime encapsulation, process version management, and pattern-based change management [3,4].

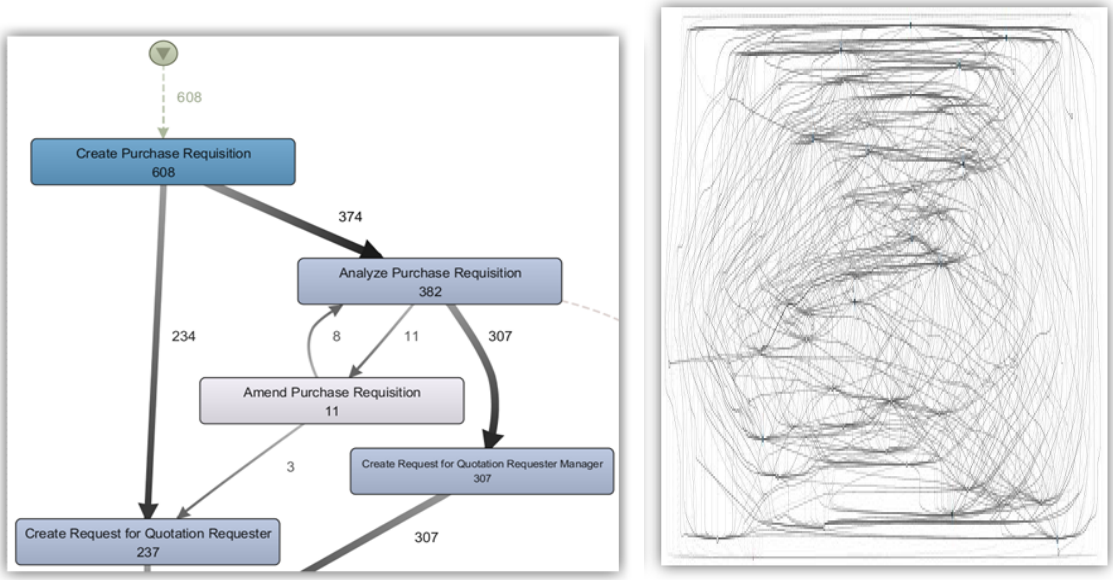
In this paper, we present a dynamic business process management system for complex and variable healthcare processes for effectively supporting context aware and personalized healthcare services. At first, a business process modeler based on business process change patterns is presented. An actual runtime process for a patient can be determined and designed dynamically considering intermediate results of the clinical care process. Also, an innovative runtime process execution mechanism for implementing the care process is described. The proposed dynamic BPM (Business Process Management) system can provide effective personalized healthcare services to patients by detecting the current health status of the patient at runtime.

The remainder of this paper is organized as follows. Section 2 describes characteristics of healthcare BPM and reviews related work. Section 3 presents the technology components of the proposed BPM system. Section 4 introduces an application case of the dynamic BPM system in the healthcare domain. Finally, Section 5 offers conclusions.

2. **Healthcare BPM.** BPM systems can model, execute, and control clinical healthcare processes in hospitals. However, many cases of applying BPM systems to the healthcare domain usually have focused on well-defined administrative processes rather than clinical processes for patient treatments [8].

This paper proposes innovative and effective BPM technologies for managing core healthcare processes considering the following characteristics of the clinical processes in hospitals.

- Complexity: As shown in (b) of Figure 1, healthcare processes are very complex and tend to be determined at runtime. The spaghetti-type healthcare process discovered by Disco solution [6], a process mining tool, is too complex.
- Variability: Healthcare processes are variable according to intermediate results of care processes.
- Long-running property: Healthcare processes for treating chronic diseases tend to be long-running. This property should be reflected in the development of healthcare BPM systems.
- Dependency on the medical record of a patient: It is required to provide personalized treatment services according to the physical characteristics and current conditions of the patient treatment. Integration of BPM system and EMR (Electronic Medical Record) system is necessary.



(a) Lasagna-type business process (b) Spaghetti-type healthcare process

FIGURE 1. Lasagna and spaghetti processes

Lasagna-type processes are well-structured processes and handled in a planned manner [12]. On the contrary, spaghetti-type processes are less structured, and they are very complex and variable. Right hand side part of Figure 1 shows an actual clinical process model discovered from the event log of a real hospital information system by Disco (activity 100%, path 100%). It is a typical spaghetti-type process and it is too complex to understand it easily.

In order to support above-mentioned characteristics of healthcare processes, it is urgently required to provide runtime process change capabilities. We applied business process change patterns to the healthcare process design phase and execution phase.

A business process change pattern is defined as a transformation pattern between an existing process model and the changed version or new version of the process model [5].

Table 1. Business process change patterns [5,7]

Classification	Pattern number	Pattern name
Split patterns	CP01	Sequential Split Pattern
	CP02	AND Split Pattern
	CP03	XOR Split Pattern
	CP04	OR Split Pattern
	CP05	N-out-of-M OR Split Pattern
Merge patterns	CP06	Activity Content Change Pattern
	CP07	Activity Change Propagation Pattern
	CP08	Activity Position Adjustment Pattern
	CP09	Activity Parallelization Pattern
	CP10	Activity De-Parallelization Pattern
	CP11	Sequential Merge Pattern
	CP12	AND Merge Pattern
Extend/Delete patterns	CP13	Activity Delete/Detour Pattern
	CP14	Activity Sequential Insert/Propagation Pattern
	CP15	Activity Parallel Insert Pattern
	CP16	Activity Replace/Detour Pattern

Recurrently occurring process change patterns are summarized in Table 1. As shown in the table, the patterns are classified into 'Split patterns', 'Merge patterns', and 'Extend/Delete patterns'.

Although there have been many researches on healthcare BPM [10,11], BPM technologies have been adopted by very few healthcare institutions due to the limitations of the existing technologies. In order to overcome these limitations, we propose a dynamic process modeler based on business process change patterns at build-time and flexible execution mechanisms at runtime.

3. Technology Components for Managing Healthcare Process.

This section describes important technology components for dynamic and flexible BPM based on business process change patterns. Proper technology components for dynamic process modeling and flexible process execution are presented in detail.

3.1. Pattern templates and blocks.

Pattern templates are standard templates for 15 business process change patterns in the process library. These templates are utilized in the process modeling step at build-time. After you specify an activity or activity group, you can modify a process model easily by applying the pattern templates. By applying pattern templates, you can obtain the modified process model more conveniently than you change each individual activity without pattern templates.

Typically a set of related activities is changed by a single change factor. These activities can be grouped as a 'pattern block'. The aggregation of a series of pattern blocks is called as a 'pattern area', which has a possibility of dynamically selecting a proper process version. Other area excluding the pattern area is called as a 'common execution block' [7].

3.2. Abstract process execution with runtime encapsulation.

We applied the flexible process version management method based on the runtime encapsulation of a business process model proposed in [3]. The runtime encapsulation of process models extends a nested or embedded process model, separates the lower-level sub-process from the upper-level process and accordingly it can support dynamic and flexible healthcare process management.

3.3. **Dynamic healthcare process modeling and flexible execution.** Figure 2 shows dynamic process modeling and flexible runtime execution mechanism based on process change patterns. By applying change patterns such as sequential split, AND split, or activity content change pattern, you can easily modify the current business process model using the process designer.

At runtime, the BPM engine can select and execute a proper version of a process model flexibly by applying promotion or demotion execution mechanisms. In many situations within the healthcare environments, a proper process version can be determined dynamically at runtime. Dynamic process execution mechanism such as process promotion and demotion [5,7] can be applied to the dynamic healthcare process execution.

Figure 2 shows the dynamic healthcare execution mechanism based on the process change patterns. All the concepts in the previous sections such as pattern templates, pattern blocks, process promotion, and process demotion are applied to the dynamic healthcare process execution.

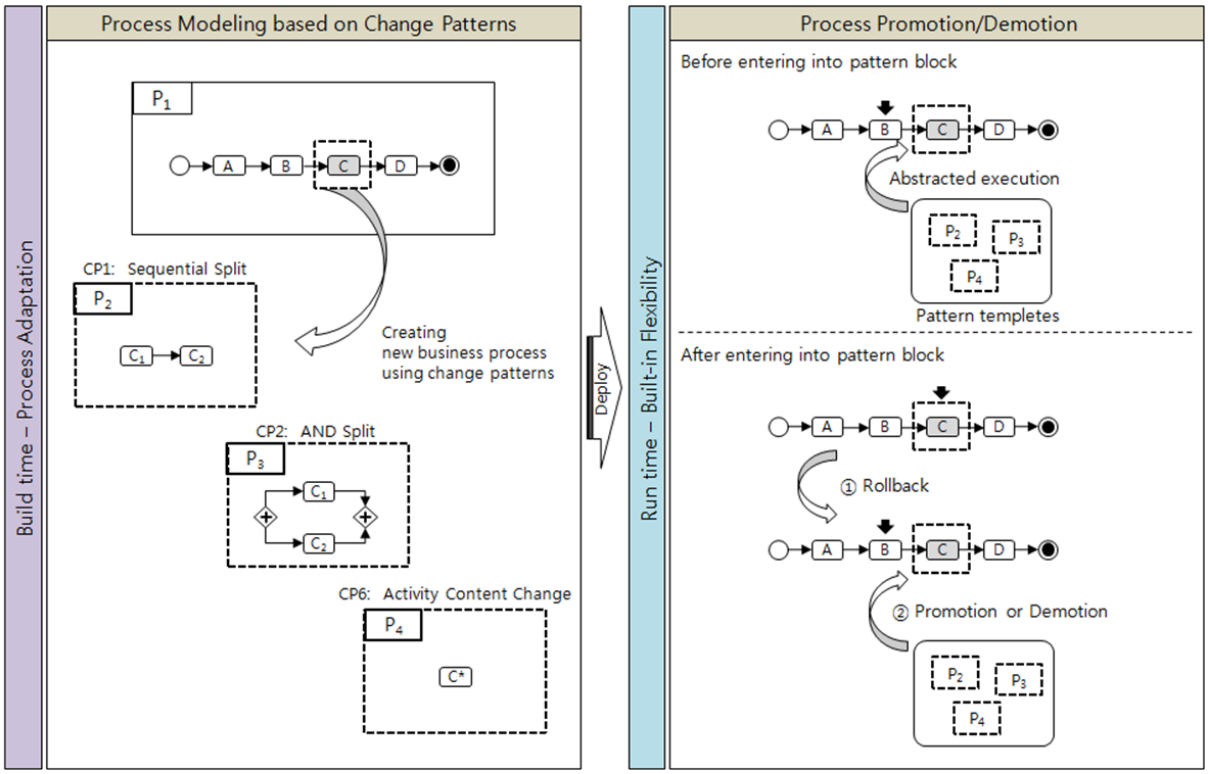


FIGURE 2. Dynamic process modeling and flexible execution

4. **Application Case.** This section introduces an application case of flexible clinical process management for the treatment of an epidemic disease MSRA (Methicillin Resistant Staphyloccus Aureus). Usually hospitals have policies and procedures for managing infectious diseases which require a proper quarantine measure.

Figure 3 shows the original MSRA treatment process composed of 8 sequential activities. If a situation change requires process modification, we can apply proper change patterns easily and acquire the new version of the process model.

As shown in Figure 4, by applying XOR split pattern to 'Kickoff' activity of the version 1 MSRA treatment process, we can easily decompose it into two exclusive activities ('Admission Kickoff' and 'Manual Kickoff'). In this way, a new version of MSRA treatment process can be designed very conveniently.

Figure 5 shows the final revised process after applying proper change patterns. In addition to application of CP03 (XOR Split Pattern) to the MSRA treatment process,

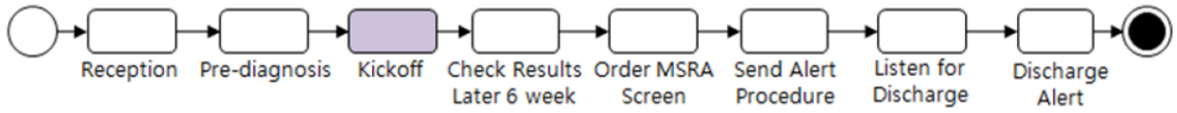


FIGURE 3. MSRA treatment process – version 1

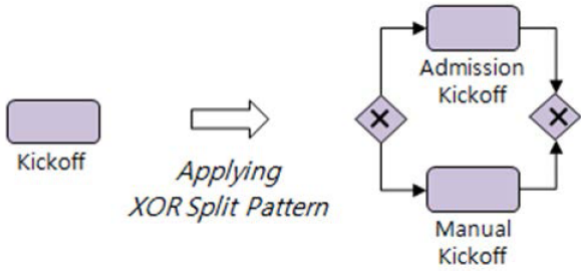


FIGURE 4. Applying XOR split pattern to MSRA treatment process

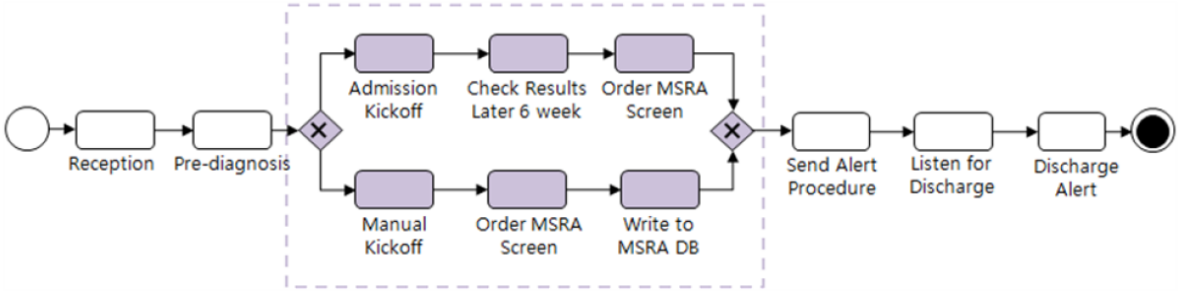


FIGURE 5. MSRA treatment process – version 2

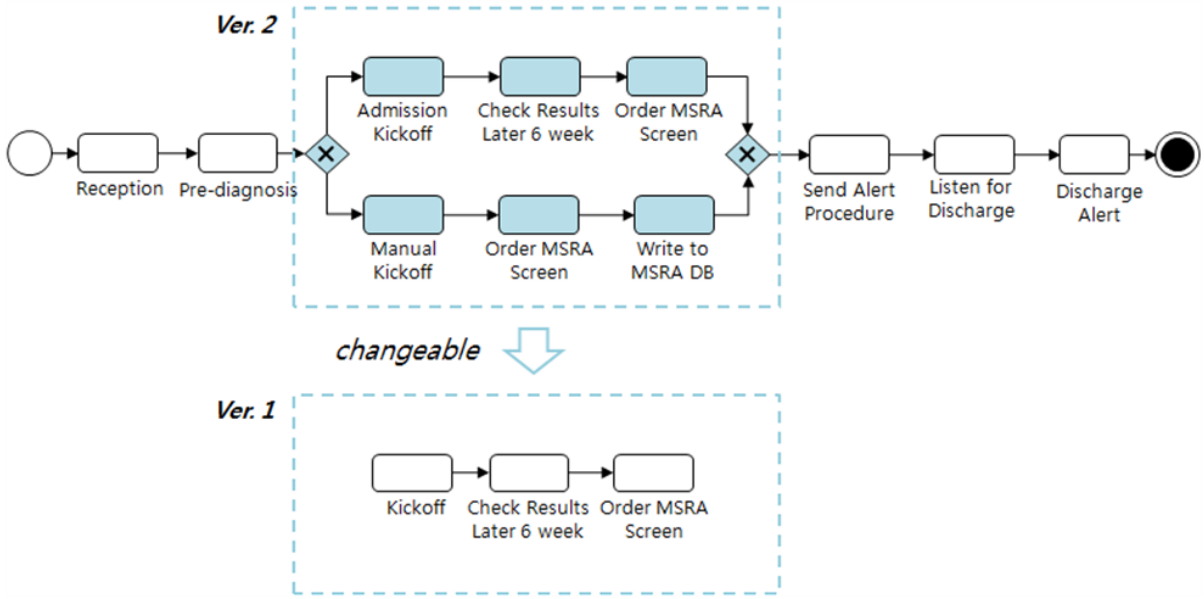


FIGURE 6. Flexible execution of MSRA treatment process

CP14 (Activity Sequential Insert/Propagation Pattern) was applied to the process. A dashed line box shows a pattern block.

Figure 6 shows a flexible process execution mechanism of process demotion. In this example, process instances of version 2 are created and executed currently. However, due to some reason process instance modification from version 2 to version 1 may be

necessary at runtime. Then the process demotion mechanism can be applied to this particular instance. We call the selection of lower version as demotion.

As mentioned in Section 2, healthcare processes are very complex and variable. The application case in this section illustrates not only how healthcare processes can be modeled dynamically, but also they can be executed flexibly considering runtime environments in hospitals.

5. **Conclusions.** In this paper, we presented a dynamic and flexible business process management system for variable healthcare processes in hospitals. Business process change pattern-based dynamic healthcare process modeling was proposed. In addition, runtime process execution mechanisms for clinical care processes were introduced. The proposed dynamic BPM system can contribute to the flexible and dynamic healthcare service management by reflecting the current health status of a patient and other situations at hand at runtime.

In the future, it is required to design and implement a context aware BPM system by integrating EMR system and BPM system in order to provide fully personalized healthcare process management to a patient.

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