Research on Improving Dynamic Business Processes in HIS

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Abstract

Dynamic patient treatment processes are usually human-centric and often unique. So if you want to model the different processes of the patient treatment, system must be capable to dynamically change process components, for example activities and business rules at runtime. The problem of process dynamics has been actively investigated over the last few years but there are still problems to be solved. This paper presents related literature analysis of the dynamic business processes. The analysis shows that there is no unified view of dynamic business processes - the formulated problems and proposed approaches to implement dynamic processes are very different. The analysed approaches cannot fully implement dynamic processes because they do not fully confirm needed dynamic process requirements. In the paper new dynamic process model is presented and realised. Dynamic patient treatment process model was developed and realised.

Keywords: process automation, dynamic processes, rules, hospital information systems, treatment schemas.

1. Introduction

Business processes in hospital are changing due to changes in the environment of business systems, new treatment methods and new law enforcement. These changes must be implemented very fast because it is necessary to adapt in fast changing environment, maintain competitiveness and improve quality. Usually it requires a lot of resources (time, people, and finance) to implement new changes because usually it is needed not only to reprogram the software but also to change the business process components: activities (their contents, consistency and executors), business rules, decision nodes. It is desirable that the changes were implemented at the business processes runtime in order to execute dynamic business processes.

Analysis of dynamic business process definitions is made. Also associated problems and general architectures are presented. Moreover, dynamic business process requirements and an improved definition of dynamic business process based on the requirements are introduced.

After the development of theoretical model of dynamic business processes, the proposed method was applied in practice in hospital information system (HIS). One of the main problems in hospital is that it is very difficult and time consuming for doctor to prescribe proper medication treatment to patient according to various patient characteristics like sex, age, weight, height, allergies, used medications, pathological, radiological and laboratory results. The goal of the experiment was to improve, accelerate and make auditable the process of patient treatment HIS by using dynamic processes and rules.

2. Dynamic business process

Research related to dynamic business processes is becoming increasingly important for the past several years, however concept of dynamic business processes still has no clear unified definition and authors propose different definitions of dynamic business processes. For example, Zeng et al. [1] propose that dynamic processes can be non-deterministic and they have an ability to flexibly adapt to changing business environment, Gartner organization [2] in the definition of dynamic business process management state that the dynamic processes are those which have the ability to support process changes by any role at any time with very low latency, Hermosillo et al. [3] propose that the process must be able to dynamically adapt in order to respond to different scenarios, Pucher et al. [5] propose the dynamics of the process as an opportunity to make changes to the process execution on the fly, Rajabi et al. [6] propose that the processes must have flexible and adaptive execution which can evolve according to specific situations and Aalst et al. [7] propose that dynamic business processes are processes which are changed regularly and changes are irreversible.

The analysis of related literature shows that there is no single definitions of dynamic business processes, because the authors emphasize different properties of the business process, which dynamic business process possess. Based on previous definitions, we identified three main properties that dynamic business processes must possess and in the Table 1 present which papers identify those properties.

Table 1 The dynamic properties of the business process
("+" – the authors think, that dynamic business process is characterized by this properties,
"-" – the authors think, that dynamic business process is not characterized by this properties))

Authors	**Business process is predefined sequence of activities**			**Business process is no predefined sequence of activities**
	Support change of activity at runtime	**Support change of conditions at runtime**	**Support change of context at runtime**	
Adams et. al. 2006 [1]	-	-	+	-
Hermosillo et al. 2010 [3]	+	-	+	-
Pucher et. al. 2010 [5]	-	-	+	-
Rajabi et. al. 2010 [6]	+	-	-	+
Weber et. al. 2008 [8]	+	+	-	-
Wörzberger et. al. 2011 [9]	-	+	-	-
Yoo et. al. 2008 [10]	-	+	-	-
Zeng et. al. 2002 [11]	-	-	-	+

The table of the dynamic business process properties clearly shows that the dynamic business processes are not commonly understood as having identical properties. Authors view them in their own way, the problems they solve are from different perspectives also the problems they attempt to solve is presented in the next section.

3. Proposed implementation solutions

There were identified a few proposed solutions, which implement dynamism of the system. Proposed solutions are CEVICHE framework [3], DYPROTO tool [9], a rule-based dynamic schema modification and adaptation method to support dynamic business service integration [10], PLMflow tool [11] et al. The architectural and implementation solutions are provided in detail in this section.

Zeng et al. proposed PLMflow tool [11] which is able to flexibly adapt to the changing business environment and is capable of determining the sequence of activities at business process runtime. This solution provides flexibility to systems.

In order to implement business process changes at runtime when processes are not determined at runtime Yoo et al. [10] proposed a rule-based dynamic schema modification and adaptation method to support dynamic business service integration. This method supports modification of schemas based on a set of user-definable rules and running instances' migration to the modified schemas at run-time. However the two proposed solutions also does not have a contextual processing component, which provides information about changes in the context.

Hermosillo et al. [3] proposed the use of CEVICHE (Complex Event processing for Context-adaptive processes in pervasive and Heterogeneous Environments) system framework which combines the processing of complex events and events activated by changes in business processes. CEVICHE is composed of three main parts: a user interface to create the SBPL files, a translation framework to manage the plug-ins for each CEP engine, and an aspect manager to deal with the process adaptation. The system uses aspect-oriented approach, so it can add or remove functionality at runtime [3]. However, the authors do not provide information about any real-life implementation.

Another solution is DYPROTO tool. This tool can delete old activities, insert new activities or dynamically implement activity loops. The tool has been developed on the ground of submitted Weber dynamic model. However the main attention is to solve the correctness of problems which arise due to the dynamics [9].

The model of dynamic implementation solutions analysis showed that no one has proposed a solution, which would support the change of any business process component (a set of conditions, a set of activities, a content of activity, a set of activity sequences, a set of decision nodes, the participants) with low latency at run time due to changes of the context (external or internal factors). So we structure and combine components proposed by other authors proposed and present a general architecture (“Fig. 1”).

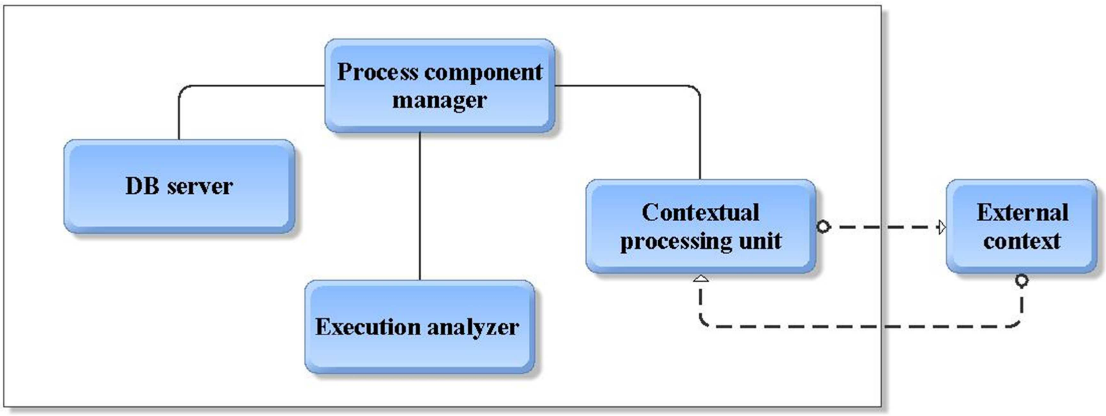

Fig. 1 General architecture of dynamic business process model

Architecture is composed of four components:

- **DB server** – this component saves information about conditions, decision nodes, activities, activity sequences definitions, contents of activities.

- **Process component manager** – this component is responsible for process component (conditions, decision nodes, activities, an activity sequences definitions, contents of activities) changes saved and process component information of new presentation enforcement.
- **Contextual processing unit** – this component is responsible for working with external context – analyzes and processes external events and messages.
- **External context** – it is mechanisms or sensors, which provide the most relevant information for the business process execution.
- **Execution analyzer** – this component is responsible for dynamic business process execution. Because sequence of activities is not defined before runtime, so first component receives process component information from “Process component manager” component and only then implement activity.

4. Dynamic process model

The analysis shows that there is no unified view of dynamic business processes - the formulated problems and proposed approaches to implement dynamic processes are very different. Therefore, assessment of the proposed definitions and based on our understanding of dynamic business processes, we compose a set of requirements for dynamic business processes:

1. The process supports changes to any process component (M) in the instance of the process.
   - M is a business process component which can be any element from a set of conditions (C), activities (A), activity sequences (S), decision nodes (H), participants (P), i.e. $M \in \{C, A, S, H, P\}$.
2. S is formed at runtime and should not be predefined.
3. A process model is only a reference but executed instances may be different.
4. Process context is a set $K = E \cup I$, where
   - K is process context.
   - E is a set of external factors, i.e. $E \in \{e_j\}, where\ j = 1 \dots N$.
   - I is a set of internal factors, i.e. $I \in \{i_j\}, where\ j = 1 \dots N$.
5. The term (T_K) of alteration of K is much shorter than the whole duration of the process (T_P), i.e.$T_K << T_P$.
   - T_K is the term of alteration of context.
   - T_P is the term of the process.
6. The process changes can be initiated by any performer role, at any time, with very low latency ($T_1 + T_2$) compared with process term.
   - T_1 is an interval from a moment in time when the necessity to perform a change in a process instance occurs until the implementation of the change is started.
   - T_2 is time taken to implement the change.

According to the requirements, we propose to define dynamic business processes as processes that implement a business process models whose components (a set of conditions, a set of activities, a content of activity, a set of activity sequences, a set of decision nodes, the participants) may vary and if necessary change with low latency at run time due to changes of the context (Fig. 2).

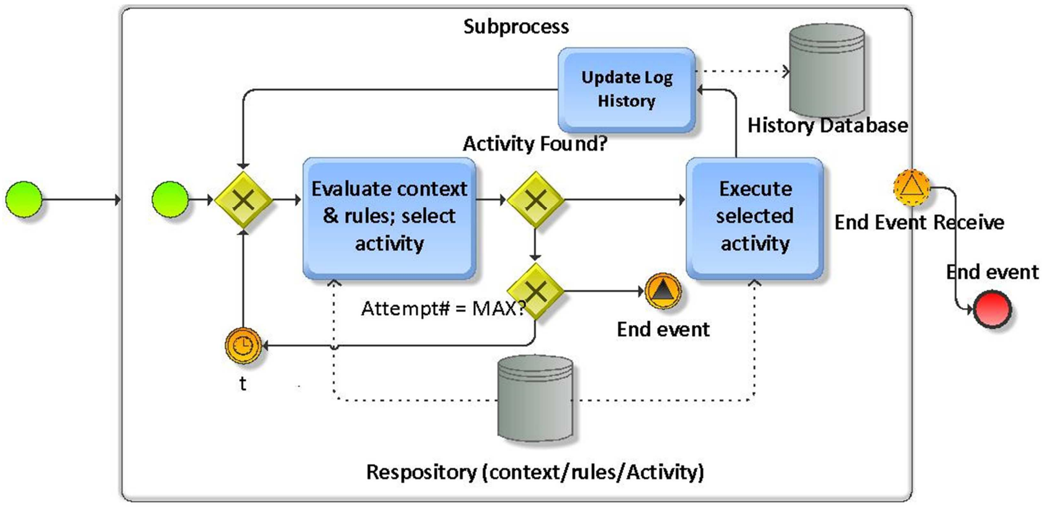

Fig. 2 Dynamic business process model

Dynamic business process model must consist of databases:

- Repository (context/rules/activity) – this database contains all the most topical C, A, S, H, P, K information.
- History Database - this database save activities of perform.

Primarily before starting to operate, it must evaluate K (context) and C (condition) for selection of A (activities) which is to be performed and execute the selected A. When A is executed it is saved in the history database. The steps are repeated again (evaluate K when C when select A which to be carried out…) until no A is found to be executed. If there was no A found for some time, then the process is counted as completed.

In the next chapter development of dynamic treatment processes in the hospital is described.

5. Description of automated medication dispense system

Vilnius University Hospital Santariskiu Clinics is one of the major hospitals in Lithuania encompassing the provision of medical care in almost all key areas covering practical and scientific medicine, education of students, residents and physicians (www.santa.lt). The institution has developed hospital information system, which integrates electronic health record, laboratory, images and signals archives, staff and resource management, document management, and many other systems that are necessary for effective health care services.

One of the goal of Santariskiu clinics is to develop paperless HIS while improving automation of all dynamic business processes. One of the following steps is to develop dynamic medication dispense system which is described in the following chapters.

This paragraph briefly describes the dynamic treatment process. The process starts from an encounter (see definition http://hl7.org/fhir/). An encounter could be:

inpatient - the patient is hospitalized and stays overnight,
outpatient – the patient is not hospitalized overnight,
ambulatory - the patient visits the practitioner in hospital,
virtual encounter - the patient gets health services without a visit.

After the encounter the doctor assess the health status of the patient, if needed performs laboratory, radiological, instrumental, pathological and other investigations, if needed consults with other specialists and prescribes the medical treatment while patient is monitored at all the times. The treatment process is not the static one and has all dynamic characteristics. However in most hospital information systems only static processes are realized which causes many difficulties for the hospital personnel to achieve good results.

In the figure 3 the simplified model of dynamic treatment process is shown:

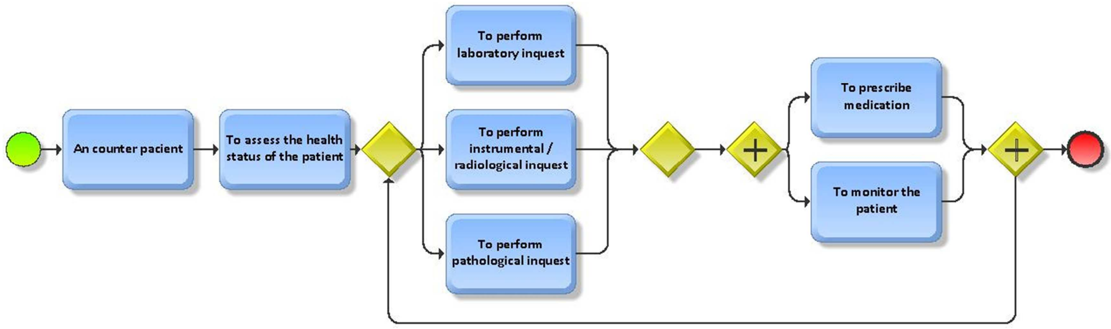

Fig. 3 The model of treatment process

SANTA-HIS (SANTA hospital information system) is composed of subsystems listed below. The main architecture of SANTA-HIS is described in figures 4 and 5:

- SANTA-HIS core system (encounter, health records, orders, resources, documents, statistics, planning etc.),
- Automated medication dispense system,
- Instrumental, radiology, nuclear and other medicine investigation system,
- Laboratory system (haematology and general cytology, biochemistry, microbiology, clinical immunology, blood transfusion and molecular diagnostic laboratories),
- Pathology system,
- E-prescription system,
- Medication warehouse system.

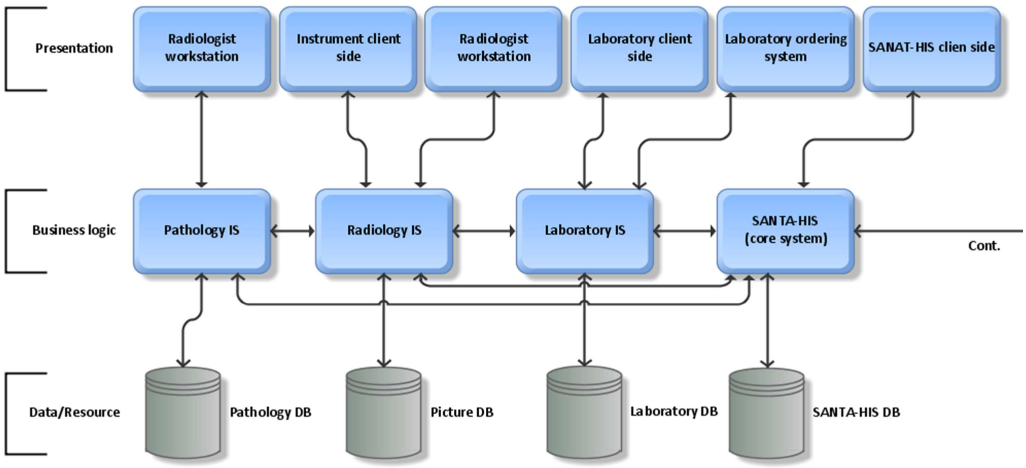

Fig. 4 Architecture of SANTA HIS (a)

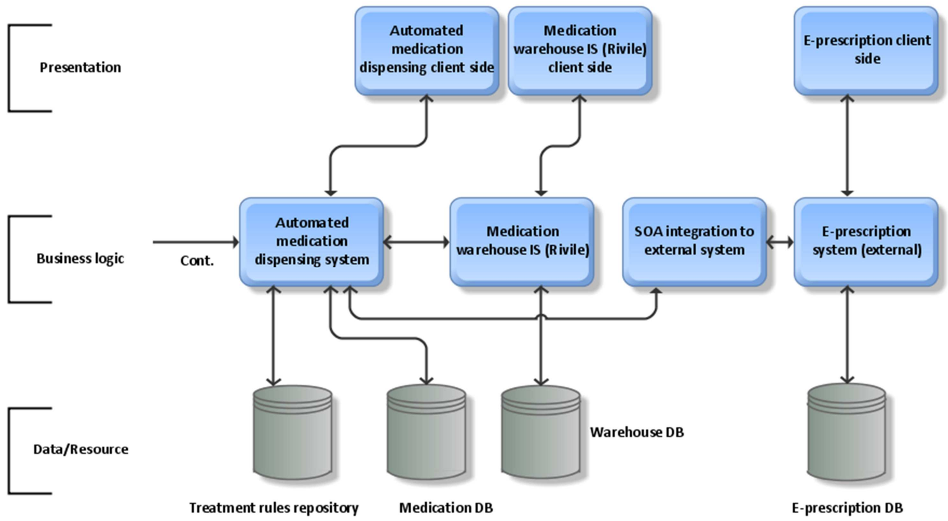

Fig. 5 Architecture of SANTA HIS (b)

In the following chapter automated medication dispense system is briefly described. Automated medication dispensing system is made of more than 300 treatment schemas and many different treatment rules. Treatment schemas and rules are configurable and saved in MS SQL server. The intelligent medication dispensing system dynamically provides list of medication, calculates doses of medication, date and time of medication dispenses according to patient data (age, sex, weight, height, laboratory results, stage of illness and other parameters) and provides other information for medical personnel.

Doctor needs to choose treatment schema, provide date when the treatment will begin and specify needed characteristics of the patient (look at the picture below):

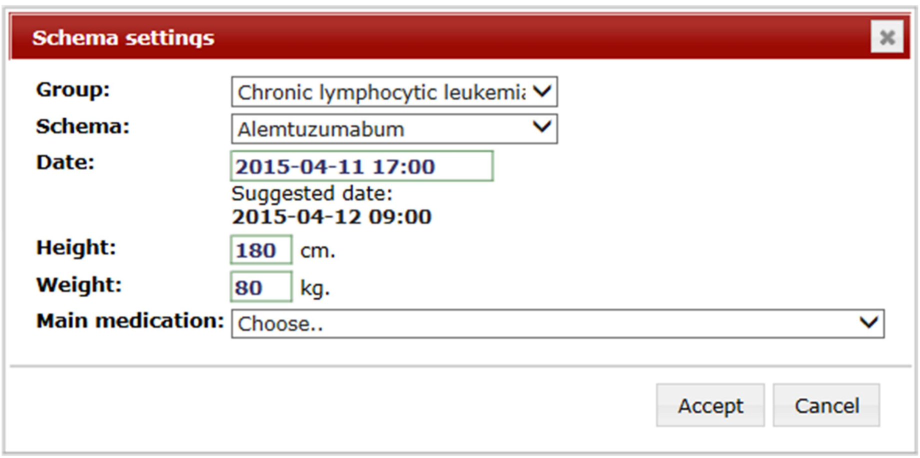

Fig. 6 Settings of treatment schema

In the picture below the dynamical treatment schema of the patient is shown. This schema is automatically made by the system according to the previously defined settings (the personal data of the patient is removed and is only visible for the doctor). In the first column of the table the list of medication is provided, in the next column - the dose of the medication, in the next columns dates and times of medication dispense is provided. The doctor can manually adapt treatment schema if needed according to the observation results of the patient.

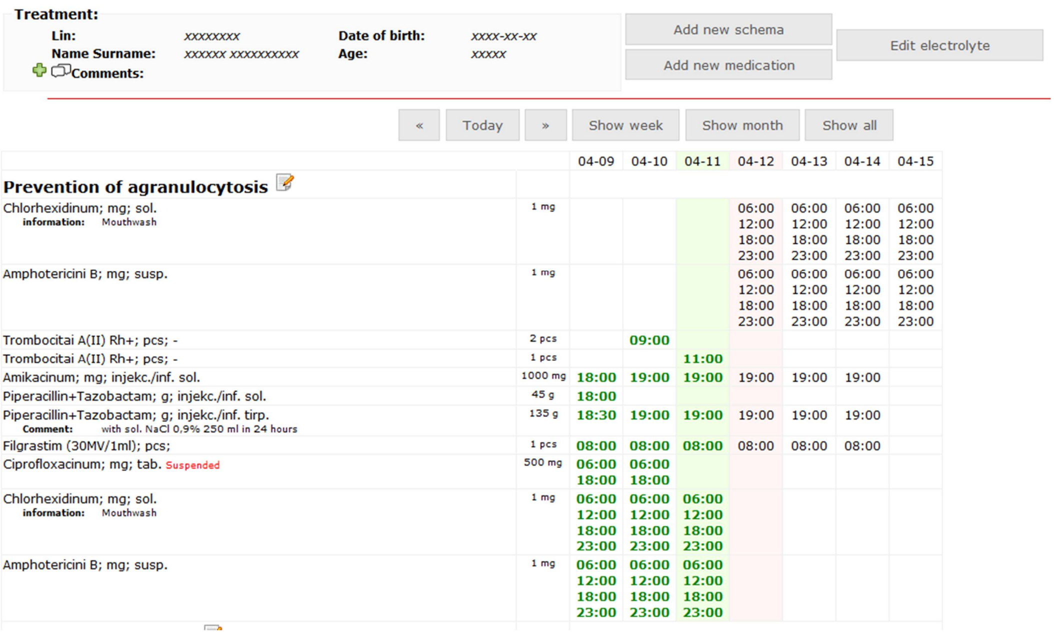

Fig. 7 Medication treatment schema

The list of criteria's used for the development of treatment process:

- additional signature (medication and dose must be confirmed by other doctor, other doctor can recommend not to use specific medication or propose different dose),
- age of the patient,
- course of cisplatin,
- creatinine clearance,
- creatinine serum weight,
- dose of ciclofosfamid,
- dose of melfalan,
- height of the patient,
- main and optional medications (doctor has several options for treatments, in case of allergy he can choose from the list of medications),
- sex of the patient.

Below several examples of self-explanatory formulas used for calculation of medication doses and development of dynamic treatment process are provided:

- if((Sqrt(height * weight/3600) * 1.4) > 2, "2", "Sqrt((height * weight)/3600) * 1.4")
- if(age <66,"90 * Sqrt((height * weight)/3600)", "60 * Sqrt((height * weight)/3600)")
- 5*((((140-age)*weight)*(if (sex = “male”, "1.23", "1.04"))/creatinineClearance)+25)
- if((5*(creatinineClearance +25)) > 420, 420, 5*(creatinineClearance +25))
- medication option 1|600*Sqrt((height * weight)/3600)
- medication option 2|if((Round(dose/0.5,0)/3) - Round((Round(dose/0.5,0)/3), 0) > 0.

When the doctor develops and confirms treatment schema, the nurses gives medication to the patient. The nurse has to check when and what medication was given to the patient according to schema provided in Figure 7.

Additionally electrolyte and nonelectrolyte solutions may be used for treatment as described in Figure 8.

Electrolyte and Nonelectrolyte Solutions		April		May			
		29d	30d	1d	2d	3d	4d
		→	→	→	→	→	→
NaCl 0,9%; ml; injekc./inf. sol.	**1000**	15:00	15:00	15:00	15:00	15:00	15:00
KCl 10%; ml; injekc./inf. sol.		10	10	10	10	10	10
MgSO4 25%; ml; injekc./inf. sol.		5	5	5	5	5	5
NaCl 10%; ml; injekc./inf.sol.		20	20	20	20	20	20
CaCl 10%; ml; injekc./inf.sol.		10	10	10	10	10	10
Glycophos; ml; injekc./inf.sol.		20	20	20	20	20	20

Fig. 8 Electrolyte and nonelectrolyte solutions

If the nurse decided not to dispense medications to the patient according to schema, the reason must be provided in the system so the doctor could update the process of the treatment. Communication between doctors and nurses is very important and all the changes should be tracked in the log files. Information system must make medication treatment process auditable. All changes made in the treatment process must be explicitly shows to the doctors and nurses.

For example dispense of specific medications from the list must be confirmed by two doctors. If the second doctor has different opinion he may propose to change the treatment. One of the real life examples why second doctor did not confirmed treatment because he thinks that medications doses are too big and he left a message in the system "it is sufficient dexamethasone 8 mg and 8 mg of ondansetron" for the patients treatment.

The other feature of the integrated process system is that system automatically makes a record in medication warehouse system that medication was used for a patient using ATC code. As a result of it person responsible for medication warehouse knows what medications will be used in near future, what medication exists in warehouse and what medication needs to be ordered. The main problem is that doctor prescribes generic medications to the patients but the nurse actually gives branded medication. To control such process without automated systems is nightmare for the hospitals personnel.

Medication	Dose	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30
Valaciclovirum; mg; tab.	**500mg**			+											
Omeprazolum; mg; tab.	**20mg**			+											
NaCl 0,9%; ml; injekc./inf. sol.	**1000ml**	+										+			
KCl 10%; ml; injekc./inf. sol.	**10ml**	↑										↑			
MgSO4 25%; ml; injekc./inf. sol.	**5ml**	↑										↑			
Furozemidum; mg; injekc./inf. sol.	**10mg**	+												+	
Filgrastim (30MV/1ml); pcs;	**1vnt**			+											
Amikacinum; mg; injekc./inf. sol.	**1000mg**														
Piperacillin+Tazobactam; g; injekc./inf. sol. Comment: with sol. NaCl 0,9% 250 ml in 24 hours	**135g**														
Chlorhexidinum; mg; sol. informacija: Mouthwash	**1mg**											+			
Amphotericini B; mg; susp.	**1mg**											+			

Fig. 9 Dispense of medication

The treatment greatly depends on reactions to the medications and patient condition. Temperature, pulse, blood pressure and other monitoring is used to check if treatment goes as expected. In the figure 10 and 11 temperature, pulse and blood monitoring of the patient is shown. If the results are not in the expected range, the doctors must be alerted and the medical treatment should be changed. In our experiment for 900 unique encounters the medication treatment was changed more than 2500 times. For these patients more than 45000 (35 different types) unique medical records were created.

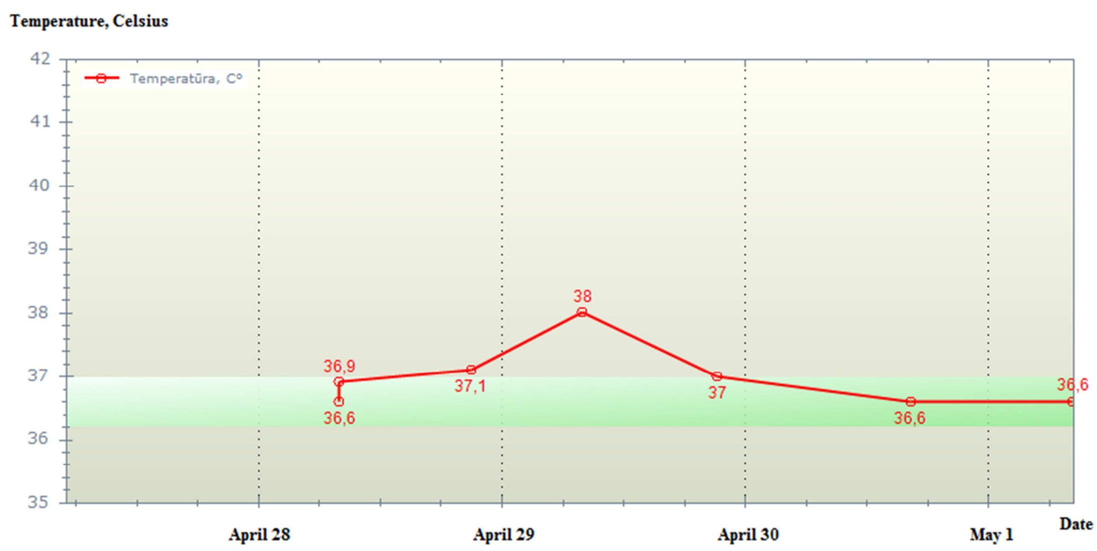

Fig. 10 Temperature monitoring

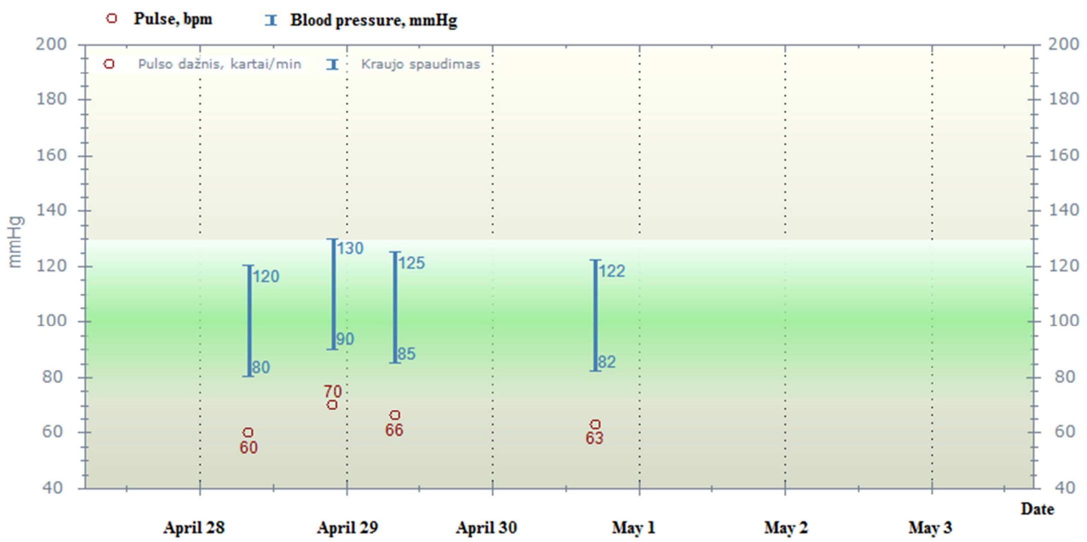

Fig. 11 Pulse and blood pressure monitoring

CONCLUSIONS AND FUTURE WORK

The literature's analysis shown that the problem of process dynamics has been actively investigated over the last few years. However these problems are still to be solved. This paper presented literature analysis related to the dynamic business processes definitions and dynamic business of process solutions. Also presented general architecture, proposed dynamic business process requirements and provided a dynamic model of its structure, which supports business process modification due to changes in the context.

Experiment was made in hospital where dynamic patient treatment process was developed and pilot testing of automated medication dispense system was accomplished. During these activities 12 treatment groups and more than 300 unique treatment schemas were developed, 2600 medication used in schemas (on average 8 medication per schema), 1400 settings for treatment schemas were configured, more than 900 unique patients were registered from the June of 2014 till the April of 2015, more than 90000 medications were given to the patients according to treatment schemas. After the analysis of experiment results we believe that automated dynamic medication dispense system will bring great benefit to doctors, nurses and patients of the hospital.

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