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O. D. Smoktii, PhD in Physics and Mathematics, Associate Professor of the Information Technologies Departament, Vasyl' Stus Donetsk National University
K. V. Smoktii, PhD in Economics, Associate Professor of the Information Technologies Departament, Vasyl' Stus Donetsk National University
L. V. Kabak, PhD of Technical Sciences, Associate Professor of the Software providing computer systems, Dnipro University of Technology

HISTOPATHOLOGY TEST WORKFLOW MODELING IN BOUNDS OF LABORATORY INFORMATION SYSTEMS

Лабораторна інформаційна система як частина системи обміну інформації є головним елементом електронного обігу клінічних даних та зберігання медичної документації. Наразі лабораторна інформаційна система є основним ресурсом діагностичних даних для лікарів. Розробляючи таку систему для лабораторій, особливо генетичних, часто потрібно задовольняти потреби відділень тестування для диагностіки патологій та хірургічних дослідів. Також потрібно враховувати, що лабораторії, що проводять тести для диагностіки патологій, працюють з різними біоматеріалами, хірургічними зразками, вилученими з організму, рідин і тканин організму. Під час аналізу патологи використовують обладнання, яке може отримувати та надсилати дані тестування до шнформаційної системи.

Мета цієї статті - побудувати модель бізнес-процесу тестування в лабораторіях патологічних досліджень у випадку гістопатологічного тестування. Розглянуто випадок використання панельних тестів з гістопатології, включаючи можливість інтеграції з лабораторним устаткуванням (інструментами), та побудувано математичну модель даних загального тестового бізнес-процесу, що використовується для розробки лабораторних інформаційних систем. В роботі наведена bpmn-діаграма гісторпатологічного тестування в загальному вигляді, а також формалізовано змінні, що описують математичну модель бізнес-процесу, стани системи і перехід з одного в інший. Синтезована модель може бути використана в процесі

розробки лабораторних інформаційних систем. До побудованої моделі застосовано кінцевий автомат згідно з машиною Тьюринга, що проходить можливі стани системи, в яких вона може знаходитися в процесі гістопатологічного тестування.

Розроблена в ротобі модель дозволяє здійснити попереднє налаштування та адаптацію бізнес-процесу до конкретних лабораторних потреб під час розробки лабораторної системи. Подальшим розвитком цієї моделі може стати синтез оптимізаційної моделі для ефективного використання ресурсів обладнання та реагентів у лабораторіях.

Ключові слова: *лабораторна інформаційна система, діагностична патологія, бізнес-процес гістопатологічного тестування, модель машини Тьюрінга.*

Лабораторная информационная система как часть системы обмена информацией является главным элементом электронного обращения клинических данных и хранения медицинской документации. Цель этой статьи - построить модель бизнес-процесса тестирования в лабораториях патологических исследований в случае гистопатологического тестирования. Созданная в этой работе модель может быть использована в процессе разработки лабораторных информационных систем. Дальнейшим развитием этой модели может стать синтез оптимизационной задачи для эффективного использования ресурсов оборудования и реагентов в лабораториях.

Ключевые слова: *лабораторная информационная система, диагностическая патология, бизнес-процесс гистологического тестирования, модель машины Тьюринга.*

Laboratory information system (LIS) as a part of information delivery system is a main element in electronic clinical data circulation and medical record storing. The purpose of this article is to build a model of pathology testing workflow in a case of histopathology testing. Created in this paper model could be used in LIS development process. Further development of this model could be integration with the optimization methods to optimize using expensive environments and reagents in laboratories. A state machine is applied to the built model according to the Turing machine, which goes through possible states of the system in which it can be dring histopathological testing process.

Keywords*: laboratory information system, diagnosis pathology, histology test workflow, Turing machine model*

The problem formulation. Laboratory information is a foundation stone of the electronic medical record, representing the majority of the nondemographic,

nonfinancial clinical data present in most healthcare institutions' information systems [1]. Laboratory Information Systems (LIS) as a delivery system of laboratory information are widely being developed to meet the specialized needs of medical laboratories for example genetic, pathology and others.

LIS is critical for the functioning of clinical laboratory centers. It is developed for digital performing of tests working with biological specimens collected from patients and storing information about their test results, diseases, diagnosis, prescriptions, and doctors' consultations results. Nowadays, LIS performs as a source of diagnostic data for doctors in all clinics and hospital departments [2].

When designing LIS and preparing it to use in laboratories particularly in genetic ones it might be necessary to meet the needs of diagnosis pathology testing department and surgical researchers. Ordering of pathology tests varies across hospitals and generally increased [6]. Diagnosis pathology as a study of diseases and a group of LIS processes involve examining the cause of illness, how it develops and what effect on cells it makes. A bunch of tests related to anatomical, clinical, or molecular pathology should be included into the LIS digital space. It should also allow to use required instruments and inventories and get the analytical data from them if needed.

Analysis of recent research and publications. Testing workflow modeling has been researched and reported in a variety of papers and is being investigating by scientists for now.

Walter H. Henricks [1] examined laboratory information management in the LIS as integrated delivery systems (IDSs), showed different aspects for information system support of integrating operations and reviewed functional requirements for outreach.

Jiraporn Gatedee, Somphon Phraephan and others [2] described the implementation process of LIS at the Medical Technology Clinic. In this paper there was founded the necessity of planning LIS development with concern of separate stages corresponding to specific objectives, time limits, resources and good organized contract. Well trained staff and provision of appropriate corresponding solution by contractor are concluded to be important values in LIS implementation success.

Xuequn Pan and James J. Cimino [3] proposed a method to make outside unspecific laboratory data available for further use based on appropriate codes

and standards terms for the LOINC. C. F. Quo, B. Wu, M. D. Wang [4] and Cutting E.M., Overby C.L., Banchero M. et al. [8] presented workflow models and LISs implemented in university and medical center.

General modeling for laboratory testing has being investigated with the purpose to create a universal framework for LIS. Wendl M.C., Smith S., Pohl C.S. et al. [5] described a general modeling framework for laboratory data and its implementation as LIS. Pardo Ingrid-Durley and Luna, Francisco Jaime and Moreno [7] discovered the semantic model which allowed storing, searching and recovering lab workflows in civil engineering. Tarkan S, Plaisant C et al. [9] presented a workflow and prototype application for laboratory testing, gave ideas how to reduce data missing in LIS.

Statistical methods were used for assessing clinical data of different nature. Li L., Vecellio E., Xiong J., Georgiou A. et al, [6] used diagnosis-related groups (DRG) to examine pathology test volumes and variation between hospitals.

The purpose of the article. The purpose of this article is to build a model of pathology testing workflow in a case of histopathology testing. We have studied the case of using histopathology panel tests including the possibility of integration with instruments and have built a mathematical data model of a common test workflow to be used in LIS development.

Created in this paper workflow could be treated as a case of abstract workflow in a common architecture of the LIS functional model [7].

The main material representation. Diagnosis pathology laboratory business process consists of four main stages: Ordering, Specimen Processing, Resulting, Reporting. We considered a case of surgical histopathology testing process every stage of which has specific list of actions made by different laboratory specialists (figure 1).

Ordering (block 1 on figure 1) is a process of patient identification (create or find existing patient in a database, block 1.1 on figure 1), visit creation (block 1.2 on figure 1) and order creation (block 1.3 on figure 1). All these instances have a unique identificator in database, and also a visit number is used to make billing that includes all patient charges within a certain visit. Each order contains patient data, a list of specimens collected from a patient and a list of tests should be done under specimens. It can also contain doctor’s data, insurance, family data etc.

Laboratories making pathology tests work with surgical specimens removed from the body, whole bodies, body fluids and tissues. During analyzing

pathologists use instruments and inventories that may obtain and send some testing data by manually entering or automatically.

After technician registered an order it transfers to a laboratory for processing (block 2 on figure 1). Depends on specimens were collected the specific tests were ordered, based on them a processing of order may have all following actions or skip some of them. Specimen grossing (block 2.1 on figure 1) and microtomy (block 2.2 on figure 1) should be done in any case under any specimen. Grossing is a process of specimen description based on pathologist visual assessment, it may be dictated as an audio track or written as a text data.

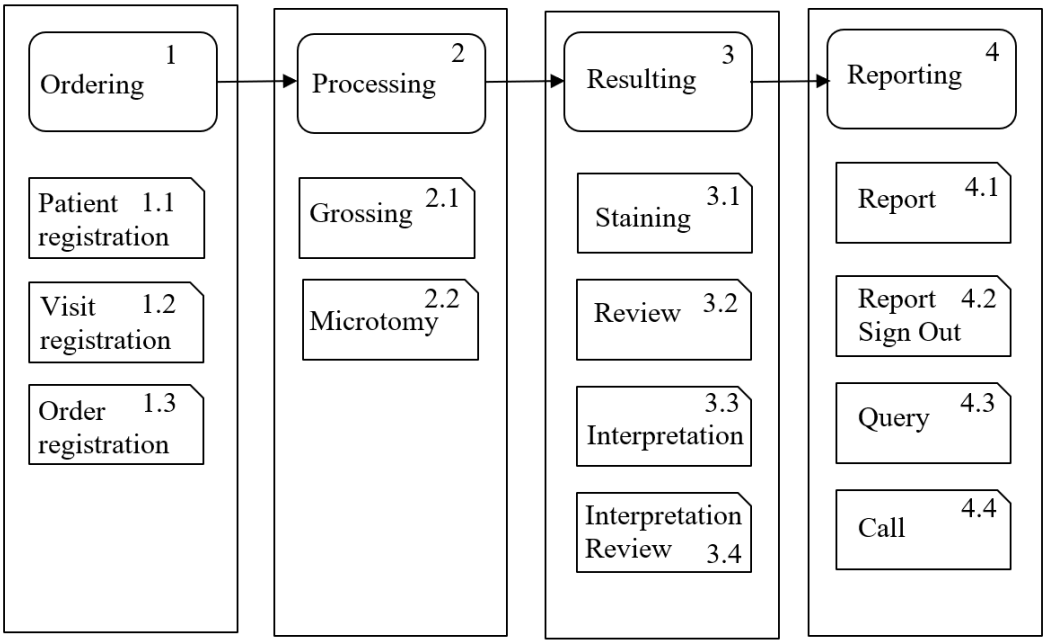

Figure 1. Diagnosis pathology laboratory general workflow of histopathology testing

After pathologist made microtomy the initial material becomes a set of slides to process and a portion of the initial specimen that got frozen and store in a fridge. Slides shall be stained by a single stain or a set of stains (block 3.1 on figure 1) and interpreted by a pathologist (block 3.3 on figure 1).

Staining, interpretation, and final reports are usually reviewed by another pathologists, sometimes it is needed a several persons to review each action (block 3.2 and 3.4 on figure 1).

A reporting stage (block 4 on figure 1) is usually present in a workflow but it is acceptable to process tests without reporting when the results are needed for another test or sent to external system. Reports (block 4.1 on figure 1) should be signed out by a pathologist (block 4.2 on figure 1) or could be auto signed out. Sometimes it is needed to have two or more signs on a report. After report is signed out order becomes inactive and could be viewed in read-only mode in LIS.

Querying (block 4.3 on figure 1) all patient previous tests and results is usually necessary to understand a clinical figure and make a right diagnosis. There is also one of the most important features to the end-user is the ability to efficiently navigate historical information [8]. When the report and diagnosis are made then it may be necessary to call or e-mail the patient or his doctor, this option should be scheduled or made automatically (block 4.4 on figure 1). Most of researches found out that a tool to generate and send result letters with predefined texts to patients via email is the highest-rated feature of a potential results management system [9].

Data model. Following entities are created to describe data flow from the LIS functioning point of view.

O - a set of orders registered in the system,
T - a set of tests that could be ordered, (1)
S - a set of specimens that could be collected from patients,
B - a set of material containers.

Following sets of states in which these entities could be at a particular moment are created.

$Q^O=\{q_i^O\}^5_{i=0}$ ={ not created, new, test added, specimen added, in process, completed} - states of order,

$Q^S=\{q_j^S\}^5_{j=0}$ = {not created, new, collected, received, in process, completed} - states of specimen,

$Q^B=\{q_k^B\}^3_{k=0}$ = {not created, new, in process, completed} - states of containers,

$Q^T=\{q_m^T\}^6_{m=0}$ = {not created, new, in process, QC passed/failed, pending for interpretation, pending for sign out, completed} - states of test.

Sets of actions for each of these entities are created. These actions are performed manually by technician or pathologist or could be made automatically

by an instrument.

$A^O = \{a_p^O\}^5_{p=1}$ = {create, add test, add specimen, add report, complete} - actions performed on order,

$A^S = \{a_t^S\}^6_{t=1}$ = {collect, receive, material prepare, gross, aliquot, material processing} - actions performed on specimen,

$A^B = \{a_l^B\}^4_{l=1}$ = {prepare for processing, tissue processing, embedding, microtomy} - actions performed on container,

$A^T = \{a_u^T\}^5_{u=1}$ = {slide staining, QC checking, panel interpretation, panel review, report sign out} - actions performed on test.

Action diagram of histopathology test processing is presented on figure 2 in terms of definitions given above and testing workflow.

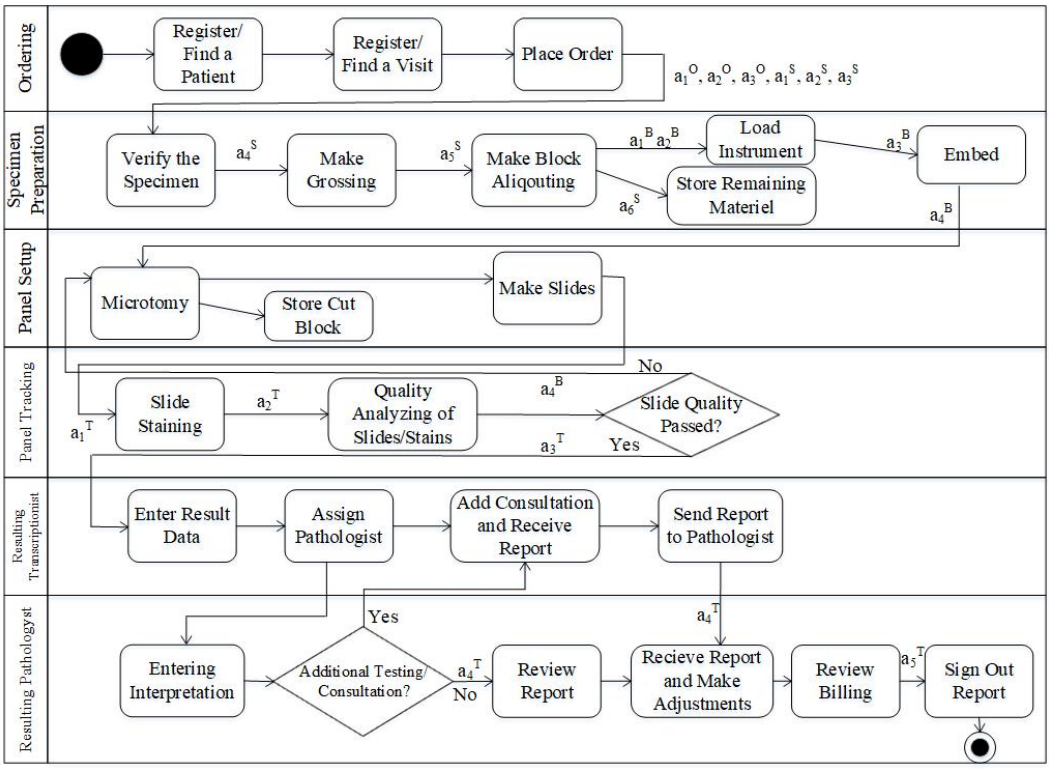

Figure 2. Action diagram (BPMN) of histopathology test processing

A set of rules will transfer entities (1) from one state to another depends on action performed on it. Rules are based on Turing machine model: actions are a set that contains alphabet, states of corresponding entities compose states of machine, an action performed by pathologist or instrument is an input symbol.

The system state is described by vector $Q(q^O,q^T,q^S,q^B)$ that depends on states of four entities - order, test, specimen and container, each of them could be switched by a rule. The fragment of rule's set representing order creation and specimen preparation processes is following.

$Q(q_0^O, q_0^T, q_0^S, q_0^B)$ - the initial state of the system.
r_1: $a_1^O Q(q_0^O, q_0^T, q_0^S, q_0^B) \rightarrow a_1^O Q(q_1^O, q_0^T, q_0^S, q_0^B)$
r_2: $a_2^O Q(q_1^O, q_0^T, q_0 S, q_0^B) \rightarrow a_2^O Q(q_2^O, q_1^T, q_0^S, q_0^B)$
r_3: $a_3^O Q(q_1^O, q_0^T, q_0^S, q_0^B) \rightarrow a_3^O Q(q_3^O, q_0^T, q_1^S, q_0^B)$
r_4: $a_3^O Q(q_2^O, q_1^T, q_0^S, q_0^B) \rightarrow a_3^O Q(q_4^O, q_1^T, q_1^S, q_0^B)$
r_5: $a_2^O Q(q_3^O, q_0^T, q_1^S, q_0^B) \rightarrow a_2^O Q(q_4^O, q_1^T, q_1^S, q_0^B)$
r_6: $a_1^S Q(q_4^O, q_1^T, q_1^S, q_0^B) \rightarrow a_1^S Q(q_4^O, q_1^T, q_2^S, q_0^B)$
r_7: $a_2^S Q(q_4^O, q_1^T, q_2^S, q_0^B) \rightarrow a_2^S Q(q_4^O, q_1^T, q_3^S, q_0^B)$
r_8: $a_3^S Q(q_4^O, q_1^T, q_3^S, q_0^B) \rightarrow a_3^S Q(q_4^O, q_1^T, q_3^S, q_0^B)$
r_9: $a_4^S Q(q_4^O, q_1^T, q_3^S, q_0^B) \rightarrow a_4^S Q(q_4^O, q_1^T, q_3^S, q_0^B)$
r_{10}: $a_5^S Q(q_4^O, q_1^T, q_3^S, q_0^B) \rightarrow a_5^S Q(q_4^O, q_1^T, q_3^S, q_1^B)$

This set of rules do not have shift variable as the classical Turing machine model has because we assume that shifting is always made into right.

Conclusions and further researches directions. Laboratory information system as a part of information delivery system is a main element in electronic clinical data circulation and medical record storing.

Created in this paper model could be used in LIS development process. Business process formalization gives a visualized instrument that allows effectively control and manage LIS functioning rules. This model allows to perform preliminary setup and adaptation of business process to a specific laboratory needs while developing LIS.

Further development of this model could be integration with the optimization methods to optimize using expensive environments and reagents in laboratories.

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