INTELLIGENT PATIENT MANAGEMENT FOR IMPROVING QUALITY OF MEDICAL SERVICES

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The paper is in line with the development of applications specific to the digitization of medical services in order to improve their quality. The proposed application was designed in compliance with the established methodological principles regarding the quality assessment and oriented on a maturity model for the management of clinical data, in particular regarding the preparation, maintenance and transmission of medical records. The validation by simulation of the application proved the usefulness of the solution, the technical quality of the operator interface, the friendly handling, as well as the inclusion in a maturity model that certifies the improvement of the quality of medical services provided through Hospital Information Systems.

Keywords: Hospital Information Systems, Intelligent Patient Management, Medical Services, Maturity Model, Quality Assessment

1. Introduction

The field of healthcare is under enormous pressure to cope with the growing needs of a growing population (not only in global numbers, but also through longevity). Deficiencies in the organization of health systems have become evident in crisis situations, including the pandemic caused by the new coronavirus. The need to provide integrated, good quality and efficient care services that meet the healthcare needs of patients is hampered primarily by the exponential growth of health data. This increase in the volume of clinical data is due not only to the accumulation of information resulting from analyzes performed at the individual level, but especially to the emergence of new technologies based on genetic information, which circulate huge amounts of data. For this reason what until only a few years earlier was called medical data processing is now the object of two areas that are separated primarily by the tools used. These areas are Data Management (DM) and DA (Data Analytics) respectively. DM includes collection processes and technologies, by storage, preparation (formatting, validation) and retrieval (completion, corrections) of the data to be provided for analysis. DA refers to the techniques used to explore data

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analytics and to extract knowledge from data sets, hence the current name of Big Data Analytics (BDA).

This paper refers only to the topic of DM, considered essential for the identification and activation of some models of health services that can contribute in addition to improving patient safety and quality of life, to a convergent policy of prevention and cure of diseases, being mostly the goal and prerogative of a Hospital Information System (HIS). HIS is a constituent element of e-Health systems that focuses mainly on managing all operational aspects of a hospital, i.e. medical, administrative, financial and legal issues, but also the proper processing of services, which is why it is also known under the name Hospital Management Software (HMS) - or, with the same acronym, Hospital Management System. HIS is also the name of a standard that sets out the architectural principles and characteristics of a range of digital services needed for the electronic description, planning and development of health systems [1]. This standard is also intended to facilitate the transition from DM to DA that capitalizes on the experience gained through practice through a special category of health models, called maturity models (MM) [2]. With the help of maturity models, hospital managers can respond more effectively to the requirements of creating new products and services, reducing costs and at the same time improving the quality of medical services. By incorporating in MM the formalism in improving the mentioned activities, an evolutionary process is realized that adapts more easily to the changes that are often unpredictable in the context.

This paper proposes an intelligent management application in the DM area based on a model compatible with the methodological principles of MM development, in order to guarantee its efficiency and relevance. In this sense, the application describes the necessary steps in the successful integration of usability in a medical organization, being a typical form of management of an information system (IS) and implicitly of HIS, able to cope with the increase in the volume of clinical data by structurally organizing the resources of health units and improving processing capacity for the simultaneous improvement of clinical and financial efficiency and quality of care.

2. Related work

The literature on quality management is very rich, but is focused more on the quality of products resulting from industrial processes and less on the quality of services. By this we mean not the generic term Quality of Services (QoS) which is a standard parameter in characterizing traffic in information networks, but the quality of how to meet the requirements and desires of users by running specialized applications.

Of course, references to already established quality assessment methodologies cannot be omitted, especially to Six Sigma, which in fact are used in this paper as a starting point in establishing the application design requirements ([3], [4]), but also recent data procedures, adapted to the facilities offered by progress in information technologies, such as the method for qualimetric evaluation of the quality of production process which offers a powerfull criterion to select solutions appropriate to improve efficiency and performance [5]. We are also pleased to report a state-of-the-art paper [6] dedicated to quality assessment in the field of health, a study of great scientific value in which more than 30 medical informatics experts collaborated to identify main technologies features that prove the quality of digitalization of medical services. .

The second category of reference works that we mention are those that refer concretely to the topic of our work, i.e. the management of clinical services performed with Hospital information Systems. Moreover, we referred to works that highlight the importance of users of maturity models (MM) as tools that facilitate the management of the organization, including their control through information systems, given that the application we proposed is based on a MM developed in a holistic conception. We will first point out the already cited seminal paper [2] developed by a team of researchers led by J. V. Carvalho, who showed for the first time the reasons why MM are indicated for the management of health information systems. However, we also pointed out the group of works that continue until now the concerns of the mentioned team in capitalizing on new methods of development and validation of MM characteristics based on comprehensive influencing factors ([7], [8]). The aspects related to the adaptation of MM to the facilities offered by digitization are also in the attention of recent data research, and focused on special aspects such as secondary medicine services [9], drug delivery and storage [10], cooperation of territorial medical units [11] and even development of a comprehensive framework that can capture uncertainties and avoid them through context-aware behavior [12].

3. Design principles

The main objective who fits with iPM.A1 is to develop a maturity model for improving cooperation both within hospital and between different healthcare units. In the same time, because improving quality has an very important impact in HIS, although our application need to implement a number of new safety practices, the possibilities of improving patient safety remain high.

Another important objective of the application is to improved resource efficiency by a performant Hospital Resource Management, including as well as information transmission and capability management. In this aim the maturity model must include a decision support system that improves the integration of

data into a data repository and facilitates to solve the issue of medical resources allocated to large health information systems.

As one of the main objectives of the application is to improve the quality of medical services, we used as a reference a well-established quality assessment methodology, namely Six Sigma [13]. A Six Sigma strategy aims to improve the quality of a product or service by identifying possible causes of defect and then eliminating them, to minimize their negative impact. For this purpose, a set of quality management methods is applied in a defined sequence of steps and has a specific final target. Two sets of methods are operational, one that applies to projects that aim to improve the quality of an existing process, product or service, the other that is used for projects that aim to create new product, process or services models. In our case, we appealed to the application of the principles of the second set, known by the acronym DMADV (Desire / Measure / Analyze / Design / Verify), which contains 5 actions that take place in a sequence of 5 stages:

(1) Define the goals that correspond to customer needs - in our case the main goal is to query and assign the availability of resources needed to solve cases of medical emergencies for patients.
(2) Measurement of the characteristics identified to be Critical To Quality, including, in our case, measurement of product capabilities, assignment of roles and assessment of risks.
(3) Analyze alternate solutions and available assets, in our case the available resources within a certain hospital.
(4) Design according to the best solution suited for analysis in the previous step. In our case this step consists in finding the person responsible for updating the resources available at each moment, in order to plan the optimal distribution of patients between different specialized departments that have hospitalization availability.
(5) Verify the validity of the design, first by simulation, then by tests in real environment using pilot runs, in our case monitoring the occupation of available bed-type resources.

4. Development of IPM-A1 support system

The main function of the application is to query and assign in the case of medical emergencies the availability of resources needed to solve cases of medical emergencies for patients.

In the developed application, in order to highlight the repetitive structure within the programmed algorithms, the key resource is the *Beds* resource, as a constraint to use the primary resource, if this resource is available in a hospital,

the user of the application can use by occupying a bed, by registering the patient in that clinic.

The available resources within each hospital (regional / county / municipal) are accessed, messages being sent through collaborative nodes, the responsible persons within each hospital who are responsible for updating the resources available at each moment.

Upon renewal of the patient's record, SA monitors the occupation of available bed-type assets and can redirect the patient to another clinic with available resources.

The hospital is one of the available resources, capable of handling the situation, or if the patient's condition is complex and the hospital is unable to cope, the "regional hospital" is accessed. There will then be a responsible person to find another hospital so the application will cross the agents in the levels until the necessary resources are found. If resources are not available in the hospital being accessed, a responsible person is assigned to the next hospital.

A. The operational structure of the IPM.A1 application

The iPM.A1 application consists of sections which in turn can contain sub-sections, as shown in the operational diagram of the application, Fig. 3.1.

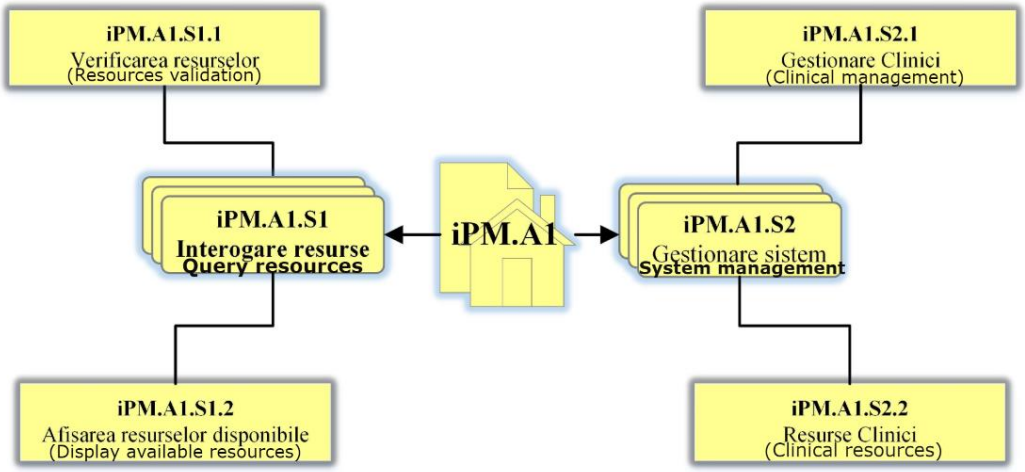


Fig. 1. Functional diagram iPM.A1

The iPM.A1 application was developed in a WEB editor based on the PHP programming language, collecting all the information within the application, using the MySQL database software to effectively store all the information in the application. Because the application displays the monitor views in Romanian, we kept the names in Romanian for sections, commands and buttons and added (in *Italics*) the equivalent of the name in English. iPM.A1 can be accessed from any WEB browser by calling the application's URL, for example:

http://localhost/ipm/public/, when accessing the application interface is loaded automatically.

The iPM.A1.S1 section is the section for querying the system and checking available resources, called " Interogare resurse (*Resource Query*)".

This section is also compiled from the subsection iPM.A1.S1.1, called "Verificare Resurse (*Resource Verification*)" where after selecting a resource and pressing "Verifica (*Check*)" button as shown in Fig. 2, the application activates sub-section iPM.A1.S1.2, called "Resurse disponibile (*Available Resources*)", displaying any available resources as shown in Fig. 3.

Fig. 2 Sub-section IPM.A1.S1.1

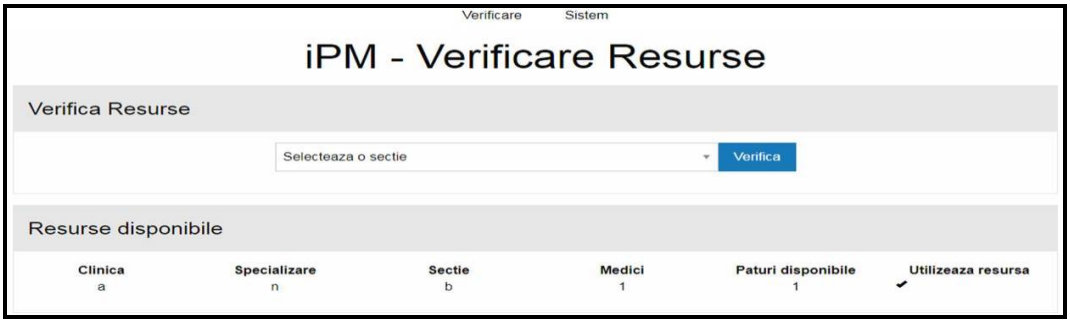


Fig. 3 Sub-section IPM.A1.S1.2

The sub-section of the iPM.A1.S2 application called "Gestionare Sistem (*System Management*)" is the administration section for system setup, i.e the resource input. In this section you can call the "Sistem (*System*)" button, see Fig. 4.

Fig. 4 Section iPM.A1.S2

This second section of the application consists of two subsections as follows:

iPM.A1.S2.1, called "Gestionare Clinici (*Clinics Management*)", a sub-section in which the clinical resources are entered into the system by filling in the "Denumire (*Name*)" and "Specializare (*Specialization*)" fields, and by activating the "Adauga (*Add*)" button, the database MySQL is updated with the new resource being imported, and it is saved automatically.

In the second subsection iPM.A1.S2.2, "Resurse Clinici (*Clinical Resources*)", resources in the sub-section iPM.A1.S2.1 may be assigned to other resources such as "Sectii (Sections)", "Medici (Physicians)", "Paturi (Beds)" by completing the fields and pressing the "Adauga (*Add*)" button as shown in Fig. 4. After entering these data, the resource sub-fields automatically update and save the information that is assigned.

B. Structure of the programmed algorithms

All attributes of the models in iPM.A1 are managed by two controllers: "Welcome controller" and "System controller". Welcome Controller, within the iPM.A1 application, through the "INDEX" function, searches the database for all sections of hospital clinics entered into the system, which are unique, data that is sent to the user interface in the "Resource" view. At the same time, it sends an information group, for each clinic it displays the respective section.

The repetitive structure is represented by the Welcome Controller by the "SEARCH" function. This feature selects all clinics and for each clinic with specialization registered, only selects clinics with available beds. It also makes a comparison between the defined beds and the occupied beds and a filter with the section name.

The Welcome Controller searches for the resources for each function and when the active button "Seen - ✔" is accessed, the resource is used, if the uniqueness constraint is fulfilled, only the occupied beds are registered, the available ones being calculated only without being recorded.

The MySQL database works with automatically generated migration, for example, creates the clinical table. There is a correlation between the table and the respective models. Advantages include high performance and scalability, increased availability, security, immediate recovery, server processing.

The "AP" function, for example, creates the clinic.

5. Experimental results of testing iPM.A1

The following resources are considered for testing and validating the iPM.A1 application as shown in Table 1. which will be recorded in the application by each clinician responsible. These resources are just some of the total resources

in a hospital. After declaring hospital and clinic type resources within subsection iPM.A1.S2.1, shown in Fig. 5 and recording related resources in subsection iPM.A1.S2.2, the application database is updated automatically, as shown in Fig. 6.

Table 1.

Available resources

Resources related to Hospitals entered in iPM.A1			
Available Resources / **Specialities/Sections**	**Number of available beds**		
	Hospital / Clinic A	**Hospital / Clinic B**	**Hospital / Clinic C**
Cardiology Section	5	5	5
Diabetes Section	5	5	5
Endocrinology Section	5	5	5
Hematology Section	5	5	5
Internal Medicine Section	5	5	5
Nephrology Section	5	5	5
Neonatology Section	5	5	5
Neurology Section	5	5	5
Oncology Section	5	5	5

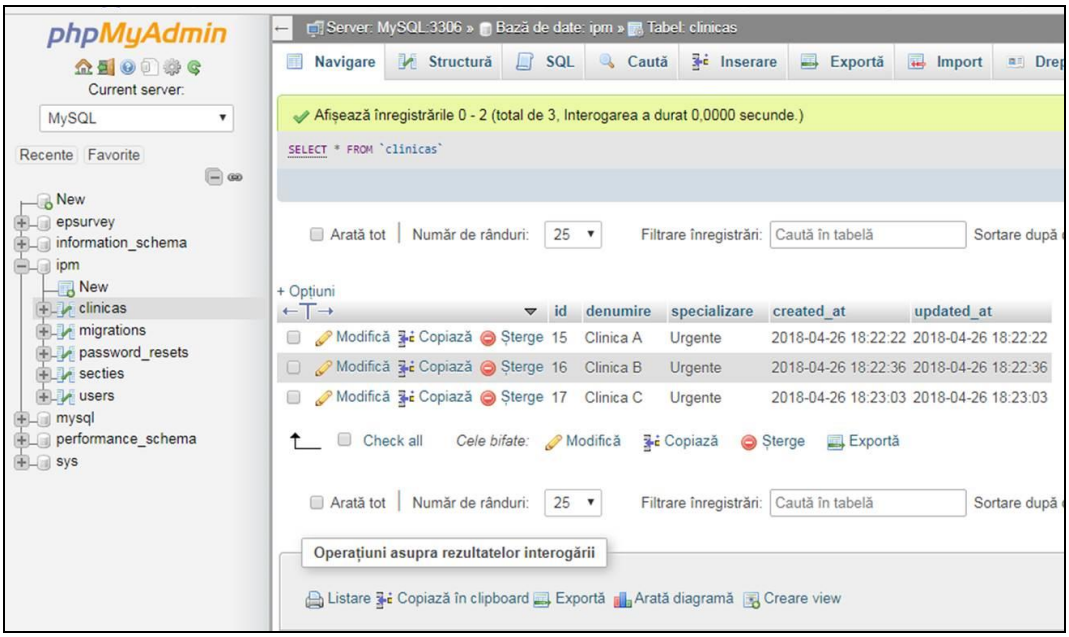


Fig.5 Declaring and registering Clinical resources in the MySQL database

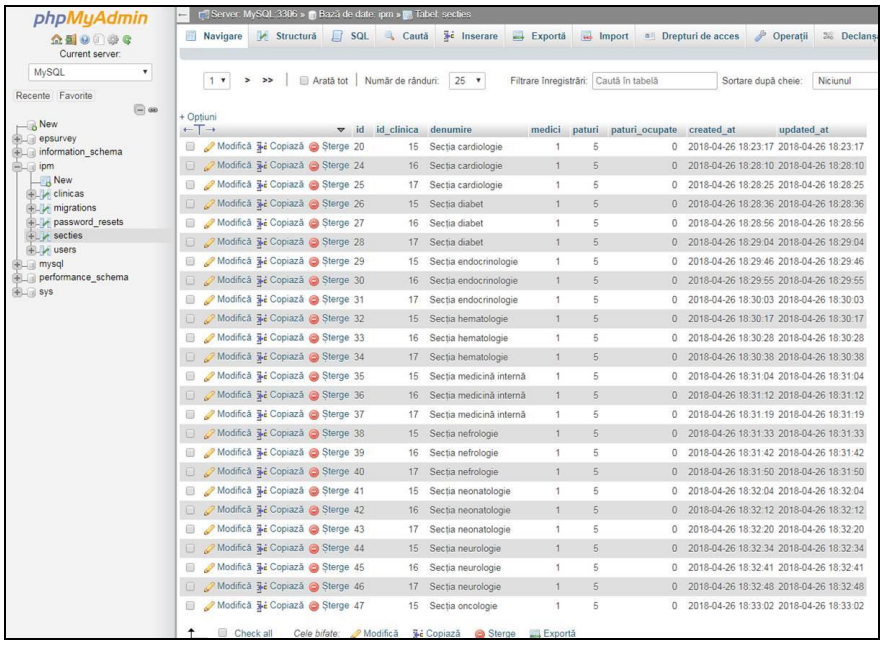


Fig.6 Registering Sections type resources and related attributes in the MySQL database

In section iPM.A1.S1, staff responsible for resource management, at the time of assignment of a medical case, checks the availability of sections by accessing the section name corresponding to the case, after selecting it, sub-section iPM.A1.S1.1 is displayed all the resources in all clinics registered in the database, as shown in Fig. 2.

After displaying available resources on the screen, the user can validate patient distribution by choosing a patch available by pressing the "Seen - ✔" active button, as shown in Fig. 3., at which time the programmed algorithm updates the database with the new remaining available resources that can be viewed at the next user check.

For example, after using the resources of clinics A and B and using a single resource in clinic C, the system displays the only remaining resources, as can be seen in Fig. 7.

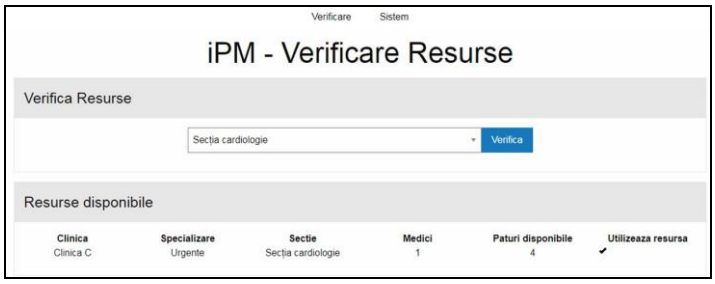
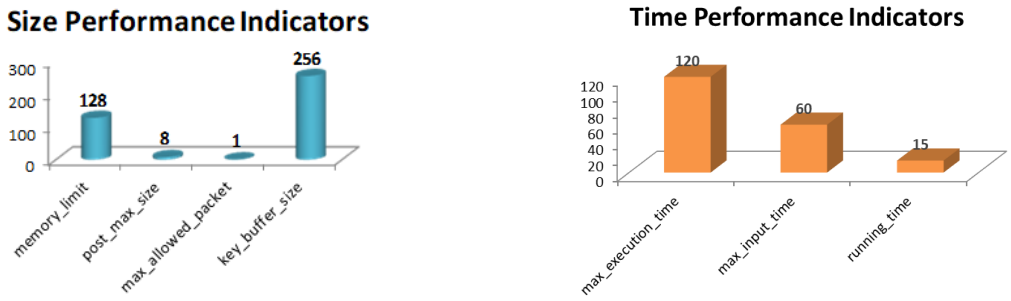


Fig.7 View remaining resources for Selected Section

The results obtained by testing the application by recording all related resources, assigning resources by validating them at the time they were used, as shown above, demonstrates that iPM.A1 is a complex hospital tool that can be used successfully in the patient distribution process by categories of medical emergencies available and using available resources from several hospital-type organizations, in turn, composed of available section and bed-type resources.

Regarding to the Key Performance Indicators, the program effectiveness is directly proportional to the real-time updating of the database or resource available. Regarding the effective duration for the running time, following the completion of the project, relevant results were recorded and compared with others obtained in parallel with iPM.A1 by using classical methods, Gantt charts and surveillance sheets. The results are illustrated in Fig.8.



a b

Fig. 8 Performance Indicators for iPM: a) Size; b) Time

In summary, the common features covered by our application which provide an integrated solution for an efficient management of the hospital are: Patient Registration; In-Patient Management; Out-Patient Management; Bed Management; Policy Management; Nursing Management System; Human Resource Module.

6. Conclusions

Among the various ways to assess the quality of health care services, the paper refers to a model that meets the facilities offered by digitization, focusing on the implementation of an application that ensures data management at the level of an entire hospital. With the primary goal of reducing response time within medical IT management processes and having real-time control for better HIS management, a new web application called iPM.A1 has been developed and tested. The tests demonstrated the feasibility and potential of the proposed Health Information Management method, used successfully in the process of patient selection and distribution by categories of medical emergencies according to an optimized allocation of available resources from several hospitals and clinical

units. The experimental results certify the possibility to reach through future developments an advanced level of digital maturity materialized through a defined set of stages associated with different technological capabilities.

For further work iPM.A1 should be conceptually developed to a web service but preserving the performance results obtained by the web-based application. As a webservice, it could be easily connected to the internal HIS that hospitals already have, and it could only implement the interface level for reservation and other specific issues among various healthcare infrastructures.

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