A Model for Medical Diagnostic Laboratory
Traditional and Multimedia Medical Database Approach

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Abstract: There are two main tendencies in Medical Informatics. One is the development of core theory in the information technology itself and the other one is the use of technologies in applications for health improving. In recent years, the deployment of Health Information Technology applications and deployed Laboratory Information System (LIS) in some large hospitals has enhanced the quality of administrative management and actively supported the diagnosis and treatment tasks of the physician. Currently, in this paper, we will present an architectural model of the Medical Diagnostic Laboratory (MDL) and some result.

Keywords: MDL, LIS, RIS, PACS, DICOM, HL7.

1. INTRODUCTION
Radiology Information Systems (RIS) using digital images (DICOM, JPEG) instead of the traditional method of using film. With the assistance of the computer program, doctors can easily interact, process image in the analysis process. It is important that the system will help to reduce the need of using the film in Diagnostic Imaging, saves the cost of buying film and the storage issues. RIS also help to reduce the number of medical imaging film when patient data is stored on the computer system.

All data related to patients diagnosis such as photographs, diagnosis, management reporting, a unified storage, synchronization and security. Therefore, doctors and even patients can view details about the medical history over time easily. This will be a great assistance in the examination and treatment of disease.

The system allows multiple access and fast response speed. Doctors can access data and images of patient quickly and accurately everytime, anywhere base on computing technology in the network allows the system.

It is extremely important in medicine, more than in any other field, that the accuracy is comparable to experts. Diagnoses that are incorrect, or other diagnoses which are missed, may result in serious consequences for the patients. HIS provide support to medical personnel improving the reliability and quality of treatment [1].

A Medical Diagnostic Laboratory (MDL) occupies a large part of the structure of diagnostic research, both in the quantity of research and the clinical importance of test results – which are an important source of diagnostic information for modern medical diagnostic processes. According to world statistics, in previous decades the quantity of performed clinical laboratory tests and their diagnostic importance exponentially increased – and continues to increase [2]. The use of Laboratory Information Systems (LIS) has now become the standard of MDL activity, with MDLs using a variety of automated information systems.

The incorporated between systems LIS - RIS (Radiology Information System) - Teleradiology form a perfect combination to meet the needs of professional work of physicians. This combination forms a closed system can replace the system using traditional medical record and needs good support consultation, counseling, through analysis of medical images and medical videos, the case of an emergency or difficult cases.

RIS and MDL system promises to bring a lot of economic efficiency and social networking in the work of community health, improve the quality of people's health care.

"... With approximately 90,000 cases per year can save about 25 % compared with the cost of the film in RIS " (Huang 2004) .

FirstHealth RIS system allows for film budget cuts over 37 %, from approximately $80,000 to $50,000, director of FirstHealth images - Mike McCarthy has told in Computerworld .

2. RELATED WORK
2.1 In Vietnam
With the strong development of the information technology industry in our Vietnam in recent years, most of the major hospitals in the country are finding the need to apply information technology in the health sector, particularly is the data management issues, medical imaging, video and medical needs of patients from remote consultation. Starting from practical needs, many hospitals have invested to build a software system and it has rekindled in shaping a RIS system.

Viet-Duc Hospital since 2003 has implemented construction projects consultant surgical system online. This is part of a project to build the satellite centers of Viet-Duc Hospital. With this model, Professionals of Viet-Duc Hospital can sit at his hospital to direct, experienced medical consultant, or to control a surgical case is done in other localities through the camera and radio screen.

Forseeing this need, present a number of IT companies in the Vietnam are concentrated investment in the development of systems related to the medical field, including RIS system with multiple different approaches. General research and development RIS system is still slow and not being invested properly while this is a core system and optical incredibly important.

As an institution, we have early access and learn about RIS system for many years. With its inherent experience from the development of other health systems and the knowledge learned from RIS systems in European
countries, America... we also had numerous monographs, reports on RIS and Telemereadiology at international conferences and seminars in Vietnam.

Transmission infrastructure in Vietnam is the next generation network NGN (Next Generation Network) with IP high quality backbone network by the Posts and Telecommunications Corporation provides fiber optic transmission as technological security virtual private network VPN (Virtual Private Network) is a very good support for telemedicine applications. In addition, at present, with the development of research and education network in Vietnam (VinaREN), have a high speed connection organizations, research centers and universities in Vietnam has opened up opportunities for the new applications require more bandwidth, there are large amounts of data need to exchange and computation. Combined with TEIN2 network (currently being upgraded to TEIN3 network), VinaREN can connect to the national potential in science and technology such as France, Hong Kong, Taiwan... This is the foundation network infrastructure to develop the ideal RIS and teleradiology system.

2.2 In the world:

In recent years, the term MDL, RIS and Telemedicine has appeared in more developed countries like the U.S., Canada, Switzerland, Japan... Telemedicine is the application of information technology to bring health services, health education to remote users a convenient, quick and effective. These systems have gradually proved necessary and appropriate life needs of the growing society.

First PACS Project titled "Installation Site for Digital Imaging Network and Picture Archiving and Communication System" was implemented in the U.S. in 1983 with an investment of U.S. Army and managed by The MITRE Corporation in 1986.

According to estimates predicted in 2001, the United States has a cost to the healthcare system to nearly $2 billion, not including the cost of equipment and other software applications.

In Asia, The First International Symposium on PACS and PHD (Personal Health Data), to be held in Japan (7/1982) by the Japan Association of Medical Imaging Technology. "Japan leading research and early development of PACS and consider this as a national project. The national resources are distributed to many manufacturers and hospitals, universities ".

In Europe, EuroPACS (Picture Archiving and Communication Systems in Europe) are held every year since 1983. National Health Service (NHS) in the UK is one of the leading organizations in the research and development of systems PACS in Europe and also had a lot of success. "According to the latest analysis from Frost and Sullivan indicates PACS market in Europe reached 535 million euros (679 million dollars) in 2009 and the figure is estimated to reach 1,065 million euros (1,353 million dollars ) in 2016".

"Due to the differences in operating conditions and environment, which PACS differences between North America, Europe and Asia. At first, the research and development of PACS in the U.S. Getting huge support by the government agencies and manufacturers. In European countries, the PACS was developed through the support of local organizations and multinationals. The European research team aims to partner with a major manufacturer, because most of the components of the PACS was developed in the U.S. and Japan, not many in Europe. These groups insist on modeling and simulation as well as PACS systems, survey components of PACS image processing " [3].

Existing RIS systems are very popular in European countries and America. RIS are widely deployed in most hospitals. And also there are many components of RIS has been developed as open source and is available to provide users learn and use. This is a favorable condition for us to learn and develop appropriate RIS, LIS and MDL systems in our Lab in Vietnam.

3. NEEDS OF LOCAL HOSPITAL

According of Viet-Duc hospital: "Every year over 1,000 cases transferred to hospital death. There are many cases if the initial emergency handling is good and in time then the patient can live. Meanwhile, local hospitals are lack of equipment and qualified doctor is limited, is not regularly updated". "So how should doctors in the central hospital and in the medical universities can support as well as consulting for remote medical station. Surgical teleconsultation system is an ideal solution".

Currently, almost all the general hospitals in Vietnam were equipped with diagnostic imaging equipment under the new technologies such as Computed Tomography (CT), magnetic resonance (MR), computed radiography (CR), ultrasound (US)... All devices are supported on the digital data standards (DICOM, JPEG, Video...). However, the hospital is still operating on the device and perform professional work through film images. Because it is not really optimal exploitation of the advanced capabilities that these devices can bring and still spend a part of budget for the purchase and storage of plastic film images.

The devices operate on independent and still not connected yet and still have not support the communication between rooms with different expertise. So that, it take so much time and effort to gather information of patient, data to perform a general diagnostic or consultations. This causes a significant reduction in speed, flexibility, accuracy and convenience in handling cases of emergency or urgent surgery. This is an essential requirement in order to improve the quality of health care for people.

The process of receiving and processing patient data in traditional medical records are still complex and time-consuming in the examination and treatment. The issue of cost to buy film, film storage and replication is always a burden for hospitals. The retrieve patient records on traditional record, film records and learn the medical history of patient is also a difficult issues for physicians. Therefore solutions LIS - RIS - Teleradiology will be a good remedy to help address all the above issues.

4. RIS SYSTEM ARCHITECTURE AT BINH DUONG GENERAL HOSPITAL

4.1 RIS System Architecture

Under the general architecture, RIS system is divided into three main classes: class imaging devices
(modalities), PACS_SERVER server class systems and workstation class applications.

The conventional imaging device is camera digital X-ray (CR), ultrasound (U.S.), magnetic resonance imaging machines (MR)... These devices must be able to give out some photos or video.

PACS Server is a core component of the system, responsible for three main functions:

- Collecting data from medical imaging devices an immediate right after patient admission photography pictures port (PACSGATEWAY).
- Organize storage and management of medical data and other relevant information of the patient.
- Provides, coordinates the application support the examination and treatment: information function to filter, display support functions, image processing and analysis, functional diagnosis support, functional support consultation...

The client application is the machine worked by doctors and other medical staff. At the client application will typically have high requirements on the display device (size, resolution, brightness...) will help health officers to exploit the functionality offered by the system.

![Fig.1 - Architectural model RIS system](image)

### 4.2 HIS-RIS-PACS Architecture

PACS is a system platform in the application system for the medical field. Typically, the PACS system will provide image data / video systems for medical rest. All three systems HIS, RIS and PACS need to be closely connected with each other, truly meet the requirements of the hospital and fully exploit the power that the number of medical devices bring.

Therefore PACS should be built as an open system interfaces are connected on the development of data standards in the field of medical standards like DICOM and HL7. This is useful when hospitals in developing countries are not synchronized three system HIS - RIS - PACS together. Some hospital systems development RIS - PACS or HIS, then continued development system remaining. This requires the system must be able to communicate with each other easily, flexibly through common data standards.

### 4.3 Data Standards used for communication and representation

Three data standard most commonly used in the system as DICOM and HL7 .

- Health Level 7 (HL7) : The computer can only exchange data with each patient when they have a common communication protocol (communication environment and common language). A group of computer systems used in health care began development in 1987 HL7 protocol. And HL7 has become a common protocol to be applied globally to share patient data.
- DICOM (The Digital Image and Communication in Medicine) is a standard that defines the format and rules of exchange of medical images and related information. Medical imaging is received from the receiving device different digital images such as CT (computed Tomography), MR (Magnetic Resonance), US (UltraSound), NM (Nuclear Medicine). It creates a common language for communication allows images and related information between medical devices and information systems in healthcare networks.
- LOINC (Logical Observation Identifiers Name And Codes), a codification for clinical laboratory values and common observation.

![Fig.2 - The links model between HIS-RIS-PACS](image)

### 4.4 Flowchart of Workflow when Deploying System

As a cross-cutting system in accordance with the examination and treatment of patients related to diagnostic imaging. PACS system was designed in conjunction with RIS to meet the work requirements of the medical staff from the stage of welcome patients, receiving and storing medical data (images, video,...) to the stage of support the display, processing, analysis and diagnosis of the health status of patients.

With a closed model in all stages in the process of examination and treatment. The PACS - RIS system is guaranteed to bring the convenient, fast processing for both medical staff and patients, along with historical information of patient is provided and telemedicine technology (Teleconsultation function by using the medical image and surgical video with the participation of many experts in the different places) will contribute to improve the efficiency of diagnosis and treatment. Accordingly helps to handle the emergencies promptly and complicated surgery.

The biggest advantage when deploying the RIS system is the rapid speed of the response, convenience and the ability to assess the medical history of patient. With this system, right after the hospital receive the patient, the doctor immediately can review the medical history of patient that this patient had been cared in hospital before.
Since then, the medical doctor give the order for the Diagnostic Imaging Department. After photographing finished, the patient does not have to wait for receiving film and confirmation by doctors at the Department of Diagnostic Imaging. Patients do not need to bring the film back to the clinic or emergency. At the clinic or emergency room, doctors can easily view, process and analyze images immediately after patients were taken. In particular, at this moment the doctors between the concerning departments can organize and conduct the diagnosis through remote consultation program. Soon there will be concluded for patients. This contributes to simplification of procedures for patients and shorten the process time and handle the medical emergencies.

Fig. 3 – Flowchart of workflow when deploying RIS systems

5. Medical Diagnosis Laboratory Model

To provide a basis for the development of LIS which really meet the requirements of health care workers, a domain analysis for EHRs has been undertaken in close cooperation of computer scientists with several domain experts [4].

Firstly, based on field studies in some Belarussian hospitals, a generic hospital laboratory structure is derived and the relevant entities for MDL are identified. Secondly, hospital specific laboratory workflow problems are discussed. Sources of the information for construction of information model are document circulation and experts of laboratory. As well as in any other organization, passage of documents through MDL is accompanied by the certain procedures of the coordination, the statement and signing of documents and the control over their origin [5].

A macro model of MDL functioning follows a certain sequence of events. First, during input, research orders and biomaterial samples are registered and brought into correspondence with each other. Next, analyses (a set of laboratory tests) are carried out automatically or manually. Then, the obtained results of these tests are passed to a requester. The following peculiarities can be outlined at this stage:

- Test results (and their dynamics) are of great diagnostic importance.
- There is significant document circulation between clinical departments and laboratories.
- There are a great number of tests to perform.
- There is an availability of efficient automatic analyzers, information from which can be transferred.
- There is a necessity to improve the reliability and quality of laboratory research.
- There is a great deal of routine work completed by laboratory employees.
- The necessity of laboratory operational statistics preparation and availability of scientific statistics.

All of these factors work together to propel the necessity to solve the problems of transferring and storing data, as well as the need to act responsibly to ensure the reliability and quality of publicly available laboratory research results. Therefore, the best solution to these problems is the use of modern IT technologies and facilities in laboratory activities.

Relations between Hospital and Medical Diagnostic Laboratory based on Laboratory information systems and Radiology Information System are shown in Fig. 4.

Fig. 4 – Relations between Hospital and Medical Diagnostic Laboratory based on Laboratory information systems and Radiology Information System

6. The ER-diagram of MDL

The database of a MDL contains relevant information concerning entities and relationships in which the MDL is interested. A complete description of an entity or relationship may not be recorded in the database of an MDL. It is impossible (and, perhaps, unnecessary) to record every potentially available piece of information about entities and relationships [6]. From now on, we shall consider only the entities and relationships (and the information concerning them), which are to enter into the design of a database.

Entity Relationship Diagrams illustrate the logical structure of databases. An entity is an object or concept about which you want to store information. Relationships illustrate how two entities share information in the database structure.

On the basis of domain analysis, the high-level (not detailed) ER-diagram of MDL is presented in Fig. 5. This diagram incorporates some of the important semantic information about the MDL. Its components are rectangles – representing entity and diamonds – representing relationship.

An explanation of the model in Fig. 5 is given as follows. Analysis (entity ANALYSIS) is a set of the laboratory tests (entity TEST). For example, biochemical blood analysis includes whole protein, albumin, glucose, etc.
Reference range of the test depends on method of testing, patient’s gender and age.
Result values of some tests can be verbal. Verbal values are collected in the entity **TERM**.
In some cases, entities can be self-linked. For example, tests can include other tests (relationship **component**).
The entity **FORM** collects all information on analysis (patient ID, doctor, date of sampling, etc.). All patients’ analyses are contained in the entity **FORM**, which is linked to the entity **EHR** by relationship **form-EHR**. The entity **RESULT** is intended to store the results of laboratory tests. The list of laboratory employees is represented as the entity **LABORATORIAN**.
Representation of **TEST** as a separate entity lays in the basis of our approach [7]. According to this approach the database scheme does not depend on quantity and structure of laboratory subdivisions and tests in MDL.

**6. RIS system has been implemented at Binh Duong general hospital**

From the orientation of the system above, we want to introduce some typical functions of the system that we have developed and are being implemented effectively in a number of hospitals.

**Fig.5- The ER-diagram of Medical Diagnostic Laboratory**

**Fig.6- Program management examination and treatment at the Diagnosis Department**

Program management examination and treatment at the Department of Diagnostic Imaging (RIS) (Figure 6) connection and information flows between: patient reception area, Examination Department, Emergency Department, Finance and Accounting Department, Diagnostic Imaging department. Reception to meet the needs of patients, ordering, payment of hospital fees, conclusions and supports photos, video medical patients taken after [8].

**Fig.7- Program to filter and see the profile photos**

Program extracted patient information, search, view detailed photos / video of patient diagnosis (Figure 7). Moreover, the program also supports operations change the image size, image change direction, increase or decrease the contrast, changing the light / dark, HU factor analysis, measuring the distance damage, record results and conclusions...

Program management and tracking data system (Figure 8): the management of patient data related to diagnostic imaging, user management system, management information services diagnostic imaging and take over the function... monitoring and operations management systems.

**Fig.8- Program management and tracking data system**

The program supports activities at the Department of Diagnostic Ultrasound images (Figure 9): Allows the storage, management, display the ultrasound images and video.

**Fig.9- The program supports ultrasound work**
**Fig. 10- Remote consultation program through medical imaging**

Program organization and management of remote medical consultation medical images (Figure 10). Perform synchronization and coordination of activities in the consultation. The end of the consultation can communicate with each other through chat window, sound exchange, intuitively (image synchronization with the tools to create focal points, localize objects...).

5. CONCLUSION

Medical Imaging informatics is the rapidly evolving field combine biomedical Informatics and image, developing and adapting core methode in informatics to improve the usage and application of imaging in healthcare; and to derive new knowledge from image study.

LIS - RIS - Teleradiology System improve the use of imaging throughout the process of care while still being economic and social efficiency. Along with the strong development of science and technology, particularly the application of information technology in practice, it can be said that a true bitter and development needed. The application of this system in hospitals will contribute greatly to improving the quality of healthcare in the community.

User applications of information technology in the health sector is a key direction that the Government and the Ministry of Health is very interested. Accordingly we are continuing strong investment in research and development, further improve LIS – RIS - Teleradiology system.

6. REFERENCES

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