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ALGORITHMS AND TECHNOLOGY FOR BUILDING INTEGRATED MEDICAL INFORMATION SYSTEMS

Abstract

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The dissertation can be found in the Fundamental Library of the Belarusian State University.

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for the defense of dissertations
Candidate of phys.- math. sciences, associate professor E.S.Cheb

INTRODUCTION

Automated processing of medical images and signals in Medical Information System is currently an important issue in state policy of developing and also in develop country due to the fast develop of variety of imaging modalities, and computational facility based on current network technology in the hospitals. Diagnosis of doctor has the involvement of using the medical image and clinical data of the patient. But still, test samples and results related data are largely managed by non-standardized paper-based systems and manual entry methods. The treatment data of patients and diagnosed image in the hospital have been managed in the separated system and it still has not fully and timely provided to the physician in the hospital.

The Electronic Health Record (EHR) in the hospital in developing countries is still lacking although, we realized that 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 provides support to medical personnel to improve the reliability and quality of treatment

Laboratory Information System (LIS), dealing with the requirement of laboratory and pathology departments, provides interfaces to the various instruments used to assess chemistry, hematology, immunology, microbiology, genetic and other histopathologic markers. The use of LIS has now become the standard of Medical Diagnosis Laboratory (MDL) activity, with MDLs using a variety of automated information systems.

In particular, a focus on Medical Diagnosis Laboratory (MDL) and Picture Archiving and Communication System (PACS) has been developed for medical diagnosis. PACS which is an evolving health care technology for the short and long term storage, presentation and distribution of medical images. 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.

Specific functions attributed to RIS include scheduling, patient and imaging study management (e.g., study tracking), and reporting (e.g., dictation support, review or previous study results). A distinguishing aspect of RIS vs. PACS is that the former is typically constrained to non-imaging data, whereas PACS is primarily concerned with the storage and manipulating of the imaging data. The most

important role of PACS is to integrate imaging modalities and interfaces with hospital and departmental information systems to manage the storage and distribution of images to radiologists, physicians, specialists, clinics, and imaging centers. A crucial advantage in PACS is to provide an efficient search function to access desired images.

In this dissertation, comprehensive investigations were carried out in order to solve the above remained problems by using the theory of developing and integrating of the subsystem in the Medical Information System, theory for constructing the medical image database, Data mining of Knowledge Discovery in Database theory to supply the information support the decision and possibilities of modern software technologies.

GENERAL DESCRIPTION OF THE WORK

Communication of the work with scientific programs (projects), topics

The results of the dissertation are obtained within investigations carried out at the Department of Information Management Systems, Faculty of Applied Mathematics and Computer Science, Belarusian State University (BSU), in accordance with:

Scientific and Technical programs of the Republic of Belarus:

– Topic 1.7.04 “Development of theoretical foundations and technologies for building computer systems for data mining based on pattern recognition and image analysis”, State Program of Scientific Research “Computer science, space and security”, subprogram “Computer science and space research”, 2016–2018, State registration № 20161303.

– Topic 1.1.17 “Development of theoretical foundations and technologies for data mining based on machine learning and recognition methods” of the State program of scientific research “Informatics, space and security”, Subprogram “Informatics and space research”, 2019-2020, State registration № 20190683.

The purpose and objectives of the research

The purpose of the dissertation research is developing the structure models, algorithms and technology for building the integrated medical information systems.

To achieve the dissertation’s purpose, the following tasks are stated and realized:

1. To analyse the existing situation of Electronic Health Record in hospitals and underline what should be improved. To identify the current isolated subsystems that should be integrated into Medical Information Systems.

2. To develop an algorithm for improving the quality of image retrieval which satisfy the condition that almost all the retrieved image results are relevant to the query images.

3. To develop an algorithm to detect the Pitch Marker (PM) by accumulating signal according to its geometric characteristics in the process of speech synthesis.

4. To develop a technology for combining the Image Retrieval System with the Picture Archiving and Communication System.

5. To develop a Telemedicine Platform using web services technology and grid services provided by gLite middleware.

The object of the research: Integrated medical information systems.

The subject of the research: Structure models and integration of subsystems for building the integrated medical information systems, algorithms of image retrieval and algorithms of speech synthesis in order to support doctors in diagnosis.

Scientific novelty

In this dissertation, the following new results have been obtained:

1. New Efficient Manifold Ranking Algorithm using low-level features normalized by 3σ-opt. It allows improving the accuracy in the query result of Image Retrieval System.

It is different from existed one by normalizing of low-level features and constructing a Fuzzy C-Means anchor graph on the data set to enhance the computational speed of manifold ranking.

2. New cumulative signal method and algorithms for speech synthesis that allows locating the pitch marker (PM) of the voice wave.

It is different from existed one by using only simple preprocessing steps on the set of the peaks of the cumulative signals, estimate PM points without estimation step for F0 values, and synthesize the F0 curve of Vietnamese syllables based on Xu's qTA tone performance.

3. New technology for combining the Image Retrieval system with Picture Archiving and Communication System that allows radiologist improving interpretation of rare abnormalities and determining a diagnosis in shorter time.

It is different from existing ones by fully accessing and using a large image database of PACS to find similar images in existed cases with patient and diagnosis data. It is an important image classification issue for automated processing of medical images to detect of lesions and also for differential diagnosis in the integrated medical information systems of hospitals.

4. New Telemedicine Platform that allows doctors using telemedicine environment to manage and share patient's information; such as electronic medical record and medical images between remote hospitals.

This platform is different from existed ones by using web services technology and grid services provided by gLite middleware and its AMGA metadata service.

Claims of the dissertation

1. The new Effectiveness Manifold Ranking algorithm ensures the accuracy of relevant images of diagnostic image query results. The algorithm assists in suggesting of many similar cases and assists radiologist to improve interpretation of rare abnormalities and help in determining diagnosis.

2. The Algorithms for speech synthesis process to enhance radiology report of radiologist in the hospital. It determines the Pitch Marker of the original speech signal based on its accumulative signals, and estimation quantitative Target Approximation Vectors (*qTAVs*) of one and two-syllable tones.

3. The technology for combining Image Retrieval System with Picture Archiving and Communication System. This allows radiologist to find similar images from a large imaging archive in the database of PACS. It potentially assists in the diagnosis of many similar cases, and evidence supplied by the similar cases supports the radiologist to improve interpretation of rare abnormalities and helps in determining a diagnosis.

4. The Platform was built upon the gLite middleware and particularly the metadata catalogue AMGA as well as GridSphere web portal. This platform for the secure management and analysis of medical data and images in a grid environment enabled providing the doctors new Telemedicine services in order to improve their collaboration capabilities. It provides doctors the capacity to upload and query medical image and clinical data stored over distributed servers.

Personal Contribution of the author

The dissertation is based on the results of the author's scientific investigation carried out at the Department of Information Management Systems, BSU. The scientific supervisor, Doctor of Technical Sciences, Professor, Academician of Academy of Science of Belarus Ablameyko Sergey Vladimirovich participated in the problem statement and discussions of approaches to the problem solution. In joint publications, the results were obtained personally by the author of the dissertation.

Approbation of the results and information about implementation

The main scientific and practical results of the dissertation were reported and discussed at the following international conferences:

The 3rd EGEE User Forum (Clermont Ferrand, France, 2008). The 1st Asian Winter School on Information and Knowledge Engineering (Ba Ria - Vung Tau, Vietnam, 2014); The 15th International Conferences on Pattern Recognition and Information Processing (Minsk, 2016); The International Symposium Neural Networks (Minsk, 2018); The 3rd Vietnam Conference on Medical Physics (Ho Chi Minh, Vietnam, 2018).

The Picture Archiving and Communication, Telemedicine and Hospital Information System implemented for research and education in Biomedical Informatics Center at Binh Duong University.

The system includes a medical digital image database with semantically structured data, a mechanism to search medical image in a database, and service functions with a unified interface. The system was successfully developed and used nowadays in Global Human Resource Solution Co., Ltd., as well as medical diagnosis courses of higher education school in Vietnam.

Publication of the results

The main results of the dissertation were published in 23 scientific works, including 11 papers in reviewed scientific journals (total volume of 5,72 copyright sheet) in accordance with item 18 of the "Statute on the Awarding of Academic Degrees and Conferring Academic Ranks in the Republic of Belarus", 12 papers in proceedings of scientific conferences.

The structure and volume of the dissertation

The dissertation consists of the list of abbreviations, the introduction, the overview of the dissertation study, 4 chapters, the conclusion, and the bibliography. The total volume of the dissertation is 130 pages, including 57 illustrations on 14 pages, 6 tables on 3 pages, the list of 125 references comprising printed works of the author on 13 pages.

MAIN CONTENT OF THE DISSERTATION

Chapter 1 describes the overview of E-Health and considers the main problems in using IT for automated processing of medical images and signals in the hospital. It analyzes the achievements of the new technologies to analyze and detect the weaknesses that still exist in medicine and need to be overcome to increase the efficiency in using information technologies for the health environment.

In addition to the patient information management functions in the hospital, new technologies such as lab test equipment and new modalities have been introduced into the hospital, but they have not shared their resources into hospital information systems. Property of the new environment and peculiarities of integrated medical information systems are determined on the basis of the analysis of the existing studies (figure 1). It has been shown that the traditional method which doctors using LIS, RIS, PACS and technologies could not overcome the emerged contradictions. Traditionally, the subsystems are separately controlled by each department, therefore the integration of the subsystems should be considered.
The regulation of data transmission between PACS and RIS/HIS were described which include workstation emulation, database-to-database transfer and interface engine. Based on these official regulations and the integrated hospital information systems is proposed A new approach to the building of the automated processing of medical images is proposed. The approach is based on relevant images system as a form of representing medical diagnosis knowledge, the relevance of which is confirmed by the contents of sources and feedback estimates

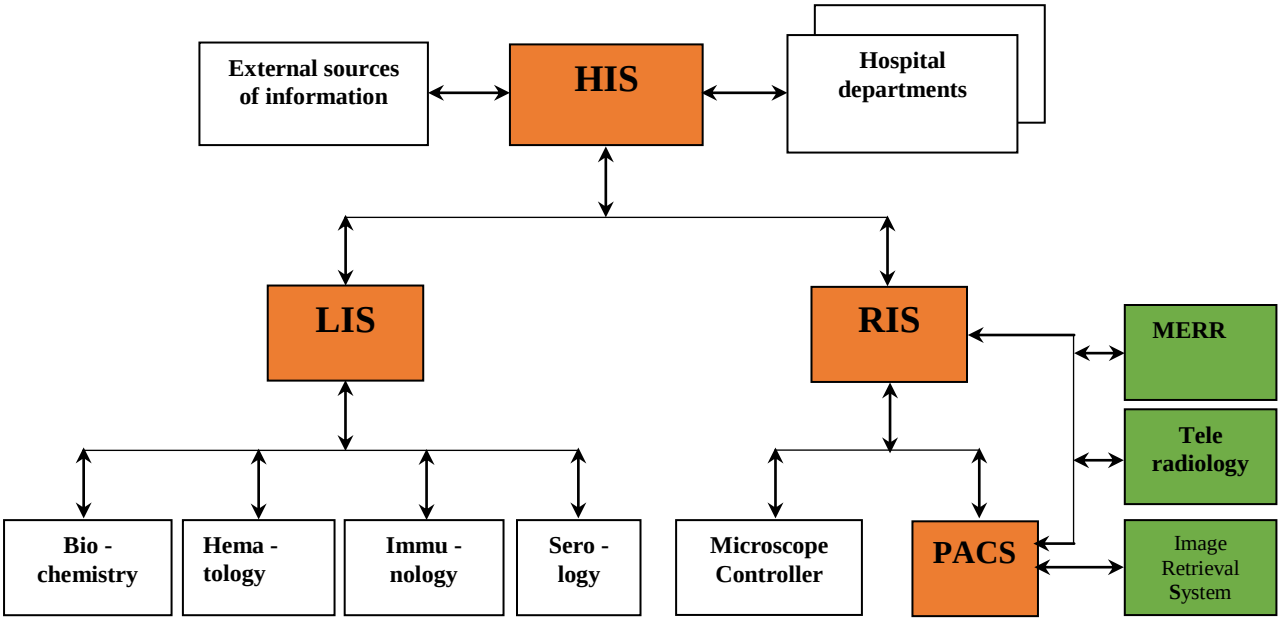

Figure 1. – General scheme of PACS/ RIS and IRS, Tele-radiology integration

A task for the development of computer technology for automated processing of medical images and signals is stated. The technology should include the construction of 1) Structure models of subsystems in the Hospital Information System; 2) An integrated environment structure for implementing the automated processing of medical images and signals; and 3) The algorithms and software to support the decision of doctor in diagnosis at the radiology department and at the PACS workstations in the hospital.

Chapter 2 is devoted the algorithms to improve accuracy of Content-Based Image Retrieval (CBIR). CBIR is one important task to support computer-aided medical image analytics. CBIR is integrated into networked radiology environment based on PACS/RIS/HIS/Tele-radiology systems.

CBIR (figure 2) can greatly help to retrieve useful information within enormous amount of medical images. For a new medical image to be analyzed, a CBIR system can first retrieve visually similar images in an existing database. Then, its high-level descriptions and interpretations can be explored based on the retrieved images. Image retrieval systems require the inclusion of descriptive information about color, texture, and shape feature at the same time. Each visual feature vector extracted from an image has the numerical components which belong to different intervals. The Efficient Manifold Ranking (EMR) framework is used in image retrieval to rank images of an image database by an image query. EMR algorithm firstly builds a weighted graph for all the data points in the feature space. The data points are inside or outside the feature database with an assumption that it has relative weights with nearby anchor point. In order to rank the images by image queries, firstly the queries are assigned a positive ranking while the remaining data points are assigned with zero. Then, all the data points spread their ranking scores to their neighbors via the weighted graph. This spreading process will repeat until a global stable state is reached, and all data points of the image database will have their own scores according to ranking by the queries.

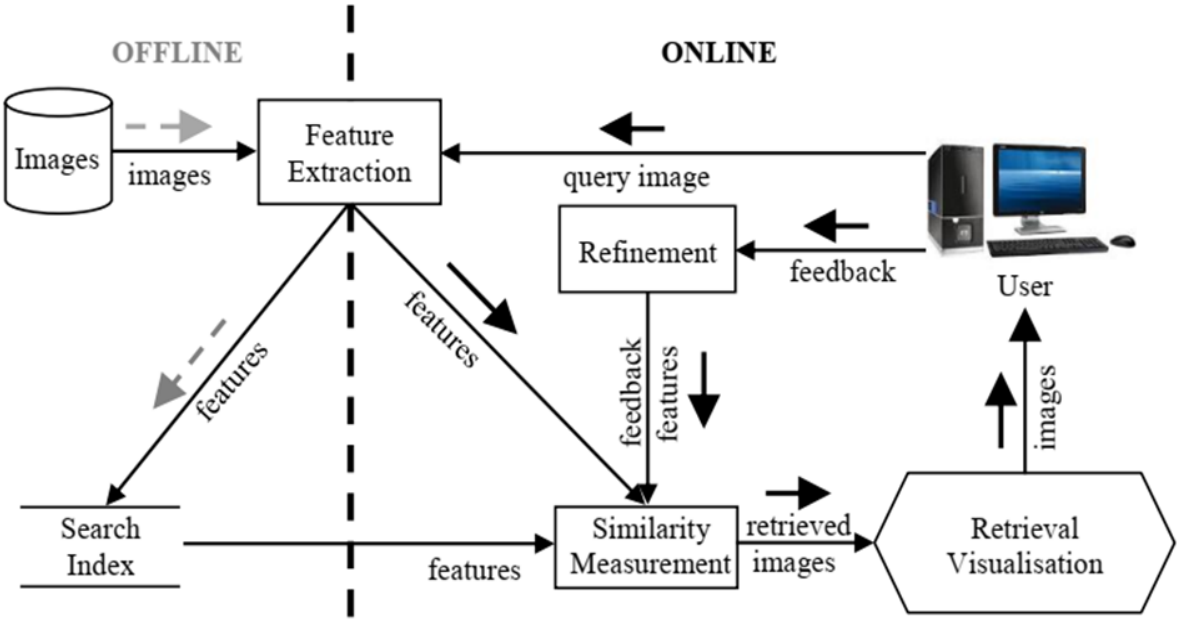

Figure 2. – A generic CBIR Framework

When combining multiple representational features for images to rank the image database by EMR, the distance between feature data points have to be

calculated. Low-level features that utilized in the EMR need a normalization technique while computing the weight of each edge in the graph to raise the accuracy of the ranking results. After normalizing of all components, normalized feature vectors belong to the same interval, namely the [0, 1]. So, we proposed a novel non-Gaussian feature normalization method to enhance the performance of manifold ranking algorithm EMR and its application in Content Based Image Retrieval system.

Next, we give the definition of proposed 3σ-opt normalization operator with optimal parameters in the details.

Definition:

Let $x = \{x_{t,j}\}_{j=1}^{m_t}$, $\forall 1 \le t \le T$ be an input feature vector of tuple t^{th} with m_t dimension (for convenience, we already denoted x_t by x).

The 3σ-opt normalization vector of vector **x** is a new vector $x^{norm} = \{x_{i,j}^{norm}\}_{j=1}^{m_t}$ defined by:

$$x_j^{norm} \overset{def}{=} a_{opt}\left(\min_{1\le c\le C}\left\{\frac{x_j - V_{t,c,j}}{3\sigma_{t,c,j}}\right\} + \max_{1\le c\le C}\left\{\frac{x_j - V_{t,c,j}}{3\sigma_{t,c,j}}\right\}\right) + b_{opt},\ \forall j = \overline{1, m_t} \qquad (1)$$

where a_{opt} and b_{opt} are two coefficients that satisfy:

$$0 < a_{opt} < 1,\ -0.5 \le b_{opt} \le 0.5$$

(a_{opt}, b_{opt}) is the optimized solution under the constraint of the objective function $F_t(a,b)$ where

$$F_t(a,b) = \left(1 + \left(\left(\sum_{i=1}^{n}\sum_{1\le j\le \dim E_{t,i} \wedge ad_{t,i,j}+b\in[-1,1]} (ad_{t,i,j}+b)^2\right)\left(n * \dim E_t\right)^{-1}\right)^{1/2}\right)^{-1} + \qquad (2)$$

$$+ \#\left\{j \in \overline{1,\dim(E_t)} / \#\left\{i \in \overline{1,n} / ad_{t,i,j} + b \notin [-1,1]\right\} > n * \alpha_{out}\right\} \to \min$$

and C is the desired cluster number of feature vectors $\{E_{t,i}\}_{1\le i\le n}$ of tuple t^{th} by using the *FCM* clustering algorithm, $V_{t,c,j}$ *(1 ≤ t ≤ T, 1 ≤ c ≤ C, 1≤ j ≤ mt)* is the component j^{th} of the clusters center c^{th} which obtained by *FCM* for $\{E_{t,i}\}_{1\le i\le n}$ and $\sigma_{t,c,j}$ *(1≤ t ≤ T,1≤ c ≤ C, 1 ≤ j ≤ mt)* is the standard deviation of component j^{th} of feature vector of tuple t^{th} for cluster c^{th}, $\sigma_{t,c,j}$ *(1≤ t ≤ T,1≤ c ≤ C, 1≤ j≤ mt)* is calculated by:

$$\forall 1 \le j \le m_t,\ \sigma_{t,c,j} \overset{def}{=} \sqrt{\sum_{i=1}^{n}\eta_{c,i}^{p}\left(E_{t,i,j} - V_{t,c,j}\right)^2 / \sum_{i=1}^{n}\eta_{c,i}^{p}} = \sqrt{\left(\sum_{i=1}^{n}\eta_{t,c,i}^{p}\left(E_{t,i,j}\right)^2 / \sum_{i=1}^{n}\eta_{t,c,i}^{p}\right) - V_{t,c,j}^2} \qquad (3)$$

$$d_{t,i,j} \overset{def}{=} \min_{1\le c\le C}\left\{\frac{E_{i,j} - V_{t,c,j}}{3\sigma_{t,c,j}}\right\} + \max_{1\le c\le C}\left\{\frac{E_{i,j} - V_{t,c,j}}{3\sigma_{t,c,j}}\right\},\ t = \overline{1,T}, i = \overline{1,n}, j = \overline{1,\dim(E_t)} \qquad (4)$$

$\alpha_{out} \in (0, 1)$ is the threshold for the number of elements of the feature vector component j[th] of the database $E = \{E_i\}_{i=1}^{n}$ which fall out of [-1, 1].

According to the 3σ-opt normalization operator above, we propose two algorithms as the following. The first algorithm is for normalization the feature vectors and clustering of the database image before applying the similarity measure in manifold ranking of CBIR:

Algorithm 1 Normalization of feature vectors and Clustering for image database

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Input: The database $\left\{E_{t,i}\right\}_{1\le i\le n}$ of tuple t[th] of feature vectors (1≤ t ≤ T), the desired cluster number $C = C(t) \in N^+, C \ge 2, m_t = \dim(E_{t,i}), \forall i = \overline{1,n}$. Percentage thresholds falling out [-1, 1] after normalizing: α_{out}.

Output: The database $\left\{E_{t,i}^{Norm}\right\}_{1\le i\le n}$ of normalized feature vectors where most of component j[th] of the tuple t[th] $\left\{E_{t,i}^{Norm}\right\}_{1\le i\le n}$ are in the interval [0, 1], the center vectors $\left\{V_{t,c}\right\}_{1\le c\le C_t}$ of cluters, $\left\{\sigma_{t,c,j}\right\}_{1\le c\le C_t, 1\le j\le m_t}$, the optimal parameters a_{opt} and b_{opt} of 3σ-opt.

Step 1: Do $FCM\left(C_t, p_t\right)\left(\left\{E_{t,i,c}\right\}_{1\le i\le n; 1\le t\le T}\right)$, obtain the center vectors $\left\{V_{t,c}\right\}_{c=1}^{C_t}$ and the membership matrix.

Step 2: Calculate $\left\{\sigma_{t,c,j}\right\}_{1\le c\le C_t, 1\le j\le m_t}$ according to formula (3).

Step 3: Calculate $\left\{d_{t,c,j}\right\}_{1\le c\le C_t, 1\le j\le m_t}$ according to formula (4).

Step 4: Solve $F_t(a,b) \to \min$ with a∈ (0, 1) and $b \in$ [-0.5, 0.5] where $F_t(a,b)$ determined by formula (2) as the following sub steps:

4.1: Start $a = (C+1)^{-1}$, $b = 0$.

4.2: Repeat, change a and b such that $F_t(a,b)$ reaches the approximate value of the idea smallest value .

4.3: Stop, obtain a_{opt} = a and b_{opt} = b.

Step 5: Normalization in [-1, 1]:

Repeat to each tuple t^{th} of each feature vector $E_{t,i}$:

5.1: Repeat with each component j^{th} of $E_{t,i}$, $j = \overline{1, m_t}$ and calculate $E_{t,i,j}^{norm}$ according to formula (1).

5.2: Normalize in [0, 1] (to apply for CBIR):

Calculate $E_{t,i,j}^{norm} = \min\left\{\frac{\max\left\{E_{t,i,j}^{norm}, -1\right\}+1}{2}, 1\right\}$.

Return: $\left\{E_{t,i}^{norm}\right\}_{1\le i\le n}$, $\left\{V_{t,c}\right\}_{1\le c\le C_t}$, $\left\{\sigma_{t,c,j}\right\}_{1\le c\le C_t, 1\le j\le m_t}$, a_{opt} and b_{opt}.

Based on Algorithm 1, we proposed Algorithm 2 to modify the original EMR algorithm for ranking the relevant images in Image Retrieval as follows:

Algorithm 2 Efficient Manifold Ranking with normalization of low-level features by 3σ-opt

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Input: normalized vectors $\left\{E_{t,i}^{Norm}\right\}_{1\le t\le T,1\le i\le n}$, cluster centers $\left\{V_{t,c}\right\}_{1\le t\le T,1\le c\le C_t}$, $\left\{\sigma_{t,c,j}\right\}_{1\le t\le T,1\le c\le C_t,1\le j\le m_t}$ and params $\{a_t\}_{1\le t\le T},\{b_t\}_{1\le t\le T}$ optimized by objective functions $F_t(a,b)$. $Q=\left\{Q_t\right\}_{1\le t\le T}$: feature vectors of the query image. nA: the number of anchors for EMR, parameter a ∈ (0, 1) (a ≈ 1).

Output: r $=\left\{r_i\right\}_{1\le i\le n}, r_i\in[0,1]\forall i=\overline{1,n}$ the similar values of E_i ranked by Q.

Step 1: (offline step), do EMR for $\left\{E_{t,i}^{Norm}\right\}_{1\le t\le T,1\le i\le n}$ with nA anchors we obtain the weighted matrix Z with size of nA x n, the adjacent matrix W is calculated by

$$W=\left(w_{ij}\right)_{1\le i,j\le n+1}, W\overset{def}{=}Z^TZ,\ w_{ij}=\sum_{k\in Nb(i,s)\cap Nb(j,s)} z_{ki}*z_{kj}, 1\le i,j\le n+1$$

and the cluster center matrix aLandMark with nA feature vectors of m dimension, where $m=\sum_{t=1}^{T}\dim(E_{t,1})$.

Step 2: Put $Q^{Norm}=\left\{Q_t^{Norm}\right\}_{1\le t\le T}$, where $Q_{t,j}^{Norm}$ are calculated by

$$Q_{t,j}^{Norm}\overset{def}{=}a_t\left\{\min_{1\le c\le C}\left\{\frac{Q_{t,j}-V_{t,c,j}}{3\sigma_{t,c,j}}\right\}+\max_{1\le c\le C}\left\{\frac{Q_{t,j}-V_{t,c,j}}{3\sigma_{t,c,j}}\right\}\right\}+b_t,\forall j=\overline{1,m_t}$$

and then $Q_{t,j}^{norm}=\min\left\{\frac{\max\left\{Q_{t,j}^{norm},-1\right\}+1}{2},1\right\}$

Step 3: Extending the matrix Z to obtain a new matrix Z_Q with size of nA x (n+1).

$$Z=\left(z_{ki}\right)_{1\le k\le C,1\le i\le n+1}, z_{ki}=\frac{K\left(\frac{\left\|E_i-A_k\right\|}{d_s}\right)}{\sum_{l\in NB(i,s)}K\left(\frac{\left\|E_i-A_l\right\|}{d_s}\right)}\forall k\in Nb(i,s), z_{ki}=0\forall k\notin Nb(i,s)$$

Step 4: Put $r_Q=\left\{r_i\right\}_{1\le i\le n+1}, r_i=0\forall i=\overline{1,n}, r_{n+1}=1.0$.

Using the matrix Z_Q, do EMR to obtain r_Q^* and normalize r_Q^* to [0, 1].

Return: $r=\{r_{Q,i}^*\}_{1\le i\le n}$.

Experiments in image retrieval with large image databases that are widely used in Image Retrieval such as the datasets based on the visual evaluation and objective estimation index, have proved the effectiveness of the similarity ranking of the EMR-3σ-opt. Experiments show the effectiveness of the proposed algorithm for the EMR and the CBIR quality is really improved.

The Multimedia Enhanced Radiology Report of radiologist is realized and used in the hospital. For speech synthesis, we propose three algorithms, the first algorithm to determine the pitch markers of the original speech signal based on its cumulative signal. The approach in the first algorithm is simple, with no need to divide a voiced segment into short segments (frames) as other approaches, yet still achieving high accuracy. With the Vietnamese speech data of the lexical tones and phonetics tested (the full coverage of the Vietnamese phonetics was included), the results of calculating the pitch markers according to our new approach was proved to be correct.

The second and third algorithms for generating F_0 trajectories of one–syllable tone and two-syllable tones. Lastly we describe here the third algorithm for Estimating *qTAVs* as follows:

Algorithm Estimating quantitative Target Approximation Vectors (*qTAVs*) of two-syllable tones

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Input: Given F_0 trajectories $\left\{ f_0^1(t) \right\}_{1 \le t \le T_1}$ and $\left\{ f_0^2(t) \right\}_{T_2 \le t \le T_3}$ of two-syllable tones tn_1 and tn_2 respectively.

Parameters: $\Theta = \{m, Q_1, Q_2, first, last, \beta, \gamma, k_{min}, k_{max} \mid m > 0, Q_1, Q_2 \in \mathbf{N}, 0 < k_{min} < k_{max} < 1, \beta > 0, \gamma > 0\}$,

Output: *qTAVs* v_{tn_1}, v_{tn_2}, and a new F_0 generated $\left\{ f_0^{2,new}(t) \right\}_{1 \le t \le T_3}$.

Step 1: Calculate T_c by formula (1), $\overline{f_0^2}(t)$, $t = \overline{T_1, T_2}$ by formula

$$\overline{f_0^2}(t) \overset{def}{=} \left(1 - \tanh(m*(t-T_1))\right) f_0^1(T_1) + \tanh(m*(t-T_1)) * f_0^2(T_2) \forall t \in (T_1, T_2),$$

Step 2: Calculate $v_{tn_1} : v_{tn_1} = SPTF_{\Theta_1}\left(\left\{ f_0^1(t) \right\}_{\overline{t=1,T_1}} \right)$,

where $\Theta_1 = \{ Q_1, first, last, \beta, \gamma , k_{min}, k_{max}\}$.

Step 3: Calculate $v_{tn_2} : v_{tn_2} = SPTF_{\Theta_2}\left(\left\{ \overline{f_0^2}(t + T_c - 1) \right\}_{\overline{t=1,T_3 - T_c - 1}} \right)$,

where $\Theta_2 = \{ Q_2, first, last, \beta, \gamma , k_{min}, k_{max}\}$.

Step 4 (optional step): Calculate $\left\{ f_0^{2,new}(t) \right\}_{1 \le t \le T_3}$,

$f_0^1(t) \neq NAN : f_0^{1,new}(t) = a_{tn_1} * t + b_{tn_1} + (k_{tn_1})^t P_{K,tn_1}(t), t = \overline{1,T_1}.$

$f_0^2(t) \neq NAN : t' = t - T_c + 1,\ f_0^{2,new}(t) = a_{tn_2} * t' + b_{tn_2} + (k_{tn_2})^{t'} P_{K,tn_2}(t'), t = \overline{T_2,T_3}.$

Return: v_{tn_1}, v_{tn_2}, $\left\{ f_0^{2,new}(t) \right\}_{1 \le t \le T_3}$.

The experiments also show the effectiveness of the proposed algorithm when generating the F_0 trajectories of two-syllable tones with complex shapes in Vietnamese language. The F_0 trajectory generating algorithm by *qTA* vectors is highly generalized, so in our next studies we will expand the results to generate for multi syllable tones (more than two).

Chapter 3 addresses problems existed in the environment of the hospital with separated of the subsystems PACS/ RIS/ LIS/ Tele-radiology.

This chapter explained the basis structures of the subsystems of HIS and proposed the solutions and structure models for solving the problems of how to improve the quality of automated processing of medical images and signals in the radiology and clinical department, and then how to expand it to the global community of the hospitals by using Telemedicine Platform. They were described as the following. The architecture of Hospital Information System and the ER – diagram of LIS are proposed. Testing results from LIS support the radiologist and physician in making diagnosis by adding more information of patient, especially in almost the emergency case. The structure model of PACS core is proposed. Base on the proposed criteria and selected solution for developing the medical image database, it provides the image which was collected from modalities to the doctors for making diagnosis. The structure model for integrating Teleradiology with PACS is proposed, which ensures synchronization of medical image and report interaction between image database servers, workstation displays at the hospital. The general scheme includes all departments of the hospital network. PACS/RIS/LIS handle local radiology storage and workflow management while teleradiology addresses remote access to image. The above integration supports complete site radiology workflow for attending physician, whether on-site or remote ones.

The technology for combining the Image Retrieval System (IRS) with PACS is proposed. This proposed solution creates more effectiveness to the Image Retrieval System, due to the accurate image-based diagnosis depends on the quality of both the image acquisition and the image interpretation. These images have been participated not only in diagnostic methods but also in treatments using image-guided methods. With the integrated environment of PACS/ RIS/ HIS, once the IRS finds related image, radiological report and medical records of these images are retrieved and provided to the radiologist. This feature allows radiologist to use of

previous cases diagnosis in order to increase doctor diagnostic accuracy. The feature is also valuable for training radiologists.

The Telemedicine platform based on the gLite middleware is proposed. AMGA administers medical data and images (figure 3). That platform gives physicians an easy method to use telemedicine environment to manage and share patient's information (such as electronic health record, images in DICOM format) between remote locations (figure 4). In the discussion, we proposed to consider perspective of network architecture based on state-of-the art wireless technology and the analysis of recent satellite based telemedicine network. This can open new practice options for radiologist on a local, regional and cross-country level and provide a vehicle for implementing governmental initiatives to better utilize radiology services over large area

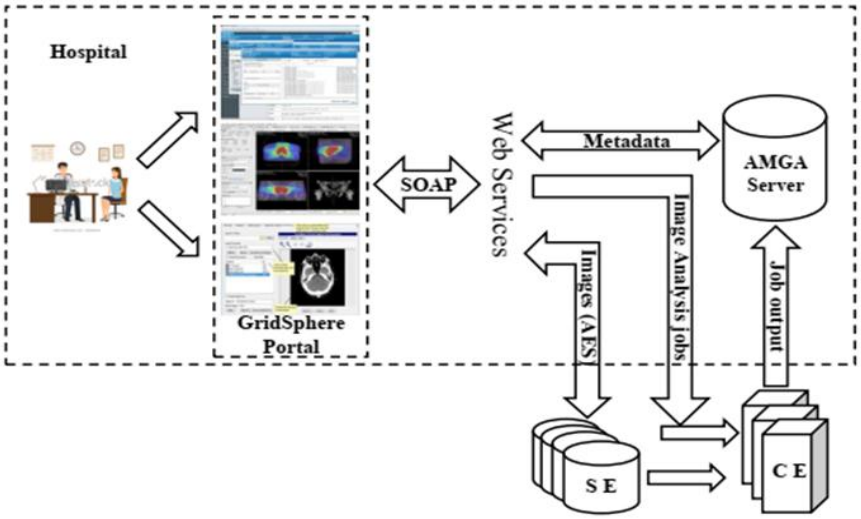

Figure 3. – Medical data and image management inside a hospital

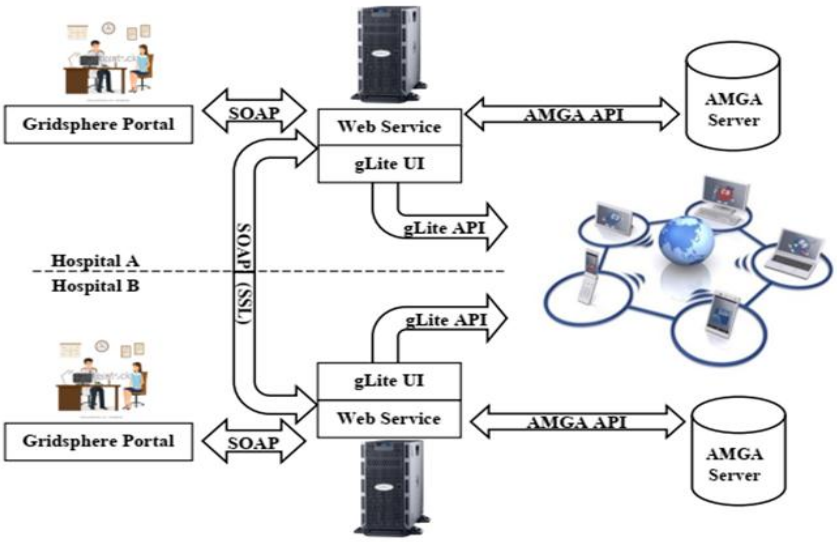

Figure 4. – Medical data and Image sharing between hospitals in different location

Chapter 4 describes the composition of software and methods of its use and provides some results obtained in when implementing the integrated HIS/ RIS/ PACS/ Teleradiology and automated processing of medical images and signals in the Vietnam hospitals. (figure 5). There are three additional problems for effective deployment and using medical image database and EMR in the hospital: 1) Identify the new working process and normalized flow chart to apply computer-aided diagnosis from registration department and emergency room, radiology department and at other departments in a hospital. 2) Training for radiologist and physician for all departments how to use all application software of computer-aided diagnosis system. 3) Train IT engineer for control and manage the system and support a physician using and maintenance the system. It is proposed that the first principle in designing the PACS system architecture is to maximize the use of existing industry standards to fit the entire PACS design scheme, which also means minimizing design software for users. Moreover, the use of both hardware and software standards will increase the ability to upgrade changes to the system.

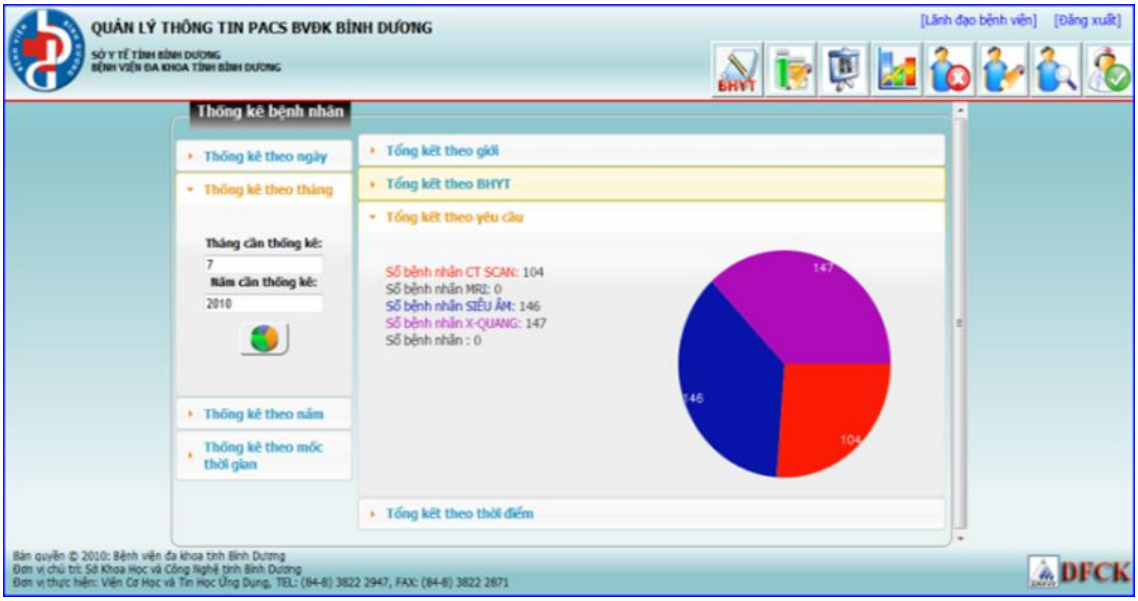

Figure 5. – The software for management and tracking paptient's data

In order to PACS system to be an open system, the following requirements have to satisfied: If two modules of PACS system in the same hospital cannot be communicated, they become the isolated ones and each module having patient information is separate. Transfer data from this PACS module should be established to other PACS modules. Format of data and image must be used correctly; Computer protocol must also be a standard protocol.

Based on these requirements, this chapter also described the main components of the storage and transmission images system, the detail as follows:

The first component is the Gateway. It is implemented for receiving image and data from modalities and sending image to the image database. We used dcm4chee, Java JDK 1.6, Net framework 2.

The second component is the Storage server. it is implemented for building an image database by using Linux CentOS. 5.5, Oracle Standard Express 10g Version 10.2.0.0 for DBMS of medical image database server and controller PACS is built for managing the processes of PACS by using PACS API, interface with RIS, HIS, LIS, Teleradiology and CBIR.- The third component is the Application server and Web server. They were built to communicate client-server by using Apache 2.2.14 with programming language PHP 5.3.1. The fourth component is the Workstation displays. They were used at Radiology department and Clinics by using the application software for medical Diagnosis including CBIR.

The fifth component is the Network system. It was developed to connect all the components.

The figure 6 shown the software implemented the necessary functions to assist the physician to diagnose such as the extracted patient information, search, view detailed photos/video of patient diagnosis. Moreover, the software also supports operations change of the image size, image change direction, increase or decrease the contrast, changing the light/dark, Hounsfield (HU) factor analysis, measuring the size of the damaged region, recording results and conclusions.

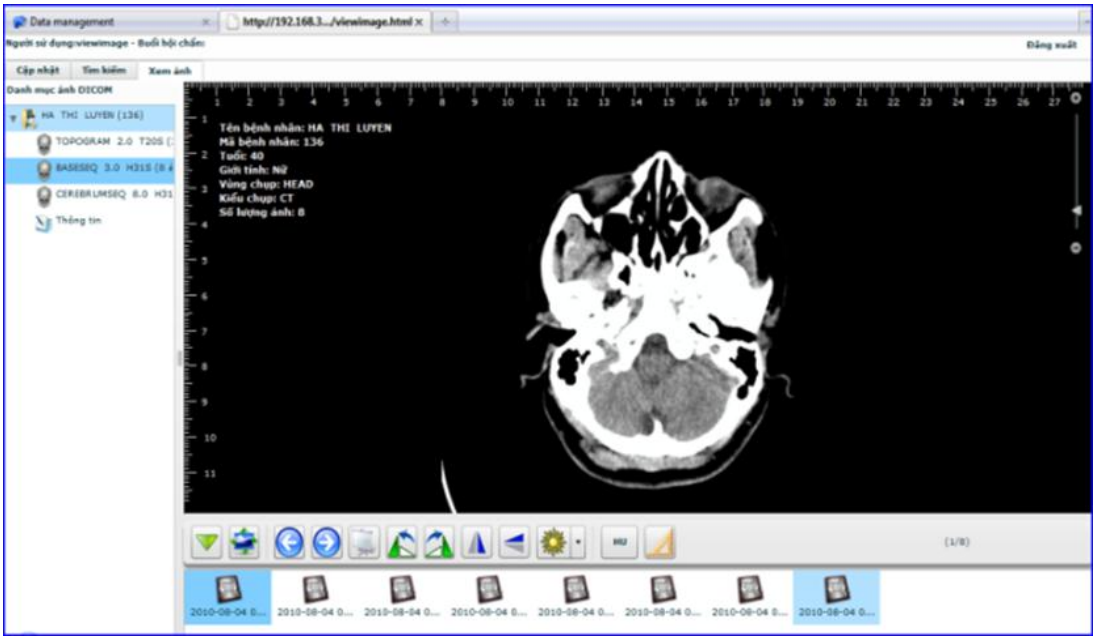

Figure 6. – Specialized software for medical image filtering and visualization

New perspectives in both data storage and distribution have also been brought forward due to the emergence of new paradigms, such as GRID, peer to peer, and cloud computing.

Hospital Open Software Platform for E-Health has exploited a large number of resources, providing a set of tools in which help the doctors to share easily medical data and resources. Through this shared resources, the experts and the researchers with their high experiences will have fully time to analyze, compare the information with each other. It will help them to diagnose and anticipate the results in treating quickly and exactly.

Final part of the chapter provides case study of PACS Server and PACS Gateway, which have been implemented at Pham Ngoc Thach Hospital to carry out the Tuberculosis Prevention Program of HCM City Public Health Association (figure 7). In order to use Imaged-based Medical Diagnosis support medical image analysis at radiology department for tuberculosis prevention and monitoring of lung cancer.

Figure 7. – A case of a lungs CT archived in the database of Tuberculosis Prevention Program

We have shown some illustrations to deploy the system based on the general scheme in the hospital. The integrated environment of medical image and clinical data management were created. It supports radiologist to use the output from a computerized understanding of medical image as assistance in detecting lesions and in making a diagnostic decision.

CONCLUSION

Main scientific results of the dissertation

In this investigation, we received the following main research results:

1. Developed Algorithm 3σ-opt normalization operator with optimal parameters and Algorithm EMR-3σ-opt to modify and enhance the performance of the Effective Manifold Ranking Algorithm and its application in Content Based Image Retrieval system to ensures the accuracy of relevant images of diagnostic image query results. This assists in suggesting of many similar cases and assists radiologist to improve interpretation of rare abnormalities and help in determining diagnosis [8; 10; 13; 19; 20; 21].

2. Developed Algorithms which determined the Pitch Marker of the original speech signal base on its accumulative signal, the indirect Pitch Marker method without of dividing a voice segment into the frames and the Algorithm for estimation quantitative Target Approximation Vectors (qTAVs) of one and two-syllable tones [3; 8; 9; 11; 22].

3. Developed technology for combining the Image Retrieval system (IRS) with Picture Archiving and Communication System (PACS). This allows radiologist to find similar images from a large imaging archive in the database of PACS. It potentially assists in the diagnosis of many similar cases, and evidence supplied by the similar cases support the radiologist to improve interpretation of rare abnormalities and helps in determining a diagnosis [1; 2; 4; 9; 12; 13; 17; 18].

4. Developed Telemedicine Platform which offers the physicians new telemedicine services in order to improve their collaboration capabilities. It provides to doctors the capacity to upload and query medical image and clinical data stored over distributed servers. It was developed base on the gLite middleware and particularly the metadata AMGA as well as GridSphere web portal system [5; 6; 7; 11; 14; 15; 16; 23].

Recommendations for the practical use of the results

Theoretical and technological results obtained in the thesis can be used to realize the integrated medical information system. This helps the doctor to make an accurate diagnosis and effective treatment. The results of this work were applied and implemented in the development of systems, as described in the certificate from the company, and are also used in the educational process, as indicated in the document from Binh Duong University.

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РЭЗЮМЭ

Дао Ван Туиет

Алгарытмы і тэхналогія пабудовы інтэграваных медыцынскіх інфармацыйных сістэм

Ключавыя словы: Аўтаматызаваная апрацоўка, пошук малюнкаў, медыцынскія выявы і сігналы, EHR, LIS, RIS, PACS, Telemedicine.

Мэта працы: Распрацоўка структурных мадэляў, алгарытмаў і тэхналогіі пабудовы інтэграванай медыцынскай інфармацыйнай сістэмы. Падтрымлівае аўтаматызаваную апрацоўку малюнкаў і сігналаў у інтэграванай асяроддзі медыцынскай інфармацыі і малюнкаў.

Метады даследавання і выкарыстаная апаратура: Тэхналогія электроннага аховы здароўя, Інфармацыйныя тэхналогіі ў ахове здароўя, Тэорыя аўтаматычнай апрацоўкі медыцынскіх малюнкаў і сігналаў, Тэорыя праграмных тэхналогій і алгарытмаў.

Атрыманыя вынікі і іх навізна: Пабудаваны наступныя алгарытмы: алгарытмы павышэння дакладнасці пошуку малюнкаў, алгарытмы сінтэзу гаворкі танальнай мовы. Распрацаваны новыя мадэлі, структуры, алгарытмы і тэхналогія пабудовы ядра PACS і сістэмы пошуку малюнкаў для аўтаматызаванай апрацоўкі медыцынскіх малюнкаў. Прапанаваная тэхналогія аб'яднання сістэмы пошуку малюнкаў у сістэму PACS для выкарыстання базы дадзеных DICOM. Яна патэнцыйна дапамагае ставіць дыягназы ў многіх падобных выпадках. Прапанавана платформа тэлемедыцыны для кіравання і абмену медыцынскімі дадзенымі і малюнкамі. Платформа выкарыстоўвае тэхналогію вэб-сэрвісаў і грыд-сэрвісаў, якая прадстаўляецца праграмным забеспячэннем gLite і сэрвісам метададзеных AMGA gLite.

Атрыманыя тэарэтычныя і тэхналагічныя вынікі дазваляюць распрацоўніку ствараць недарагія, простыя ў выкарыстанні сістэмы, якія забяспечваюць хуткую дакладнасць і масавае выкарыстанне малюнкау і гаворкі ў дыягностыцы.

Рэкамендацыі па выкарыстанні: Распрацаванае праграмнае забеспячэнне можа быць выкарыстана для стварэння сістэм, у якіх выкарыстоўваюцца сігналы і малюнкі для падтрымкі прыняцця дыягнастычных рашэнняў урач-рэнтгенолагам ў розных галінах медыцыны.

Вобласць ужывання: Прадстаўленыя вынікі ўкаранёны ў некаторых бальніцах В'етнама, а таксама на трэнінгах ў універсітэце Бін Дуонг.

РЕЗЮМЕ

Дао Ван Туиет

Алгоритмы и технология построения интегрированных медицинских информационных систем

Ключевые слова: Автоматизированная обработка, поиск изображений, медицинские изображения и сигналы, ЛИС, РИС, САПИ, Telemedicine.

Цель работы: Разработка структурных моделей, алгоритмов и технологии построения интегрированной медицинской информационной системы. Поддерживает автоматизированную обработку изображений и сигналов в интегрированной среде медицинской информации и изображений.

Методы исследования и использованная аппаратура: Информационные технологии в здравоохранении, Теория автоматической обработки медицинских изображений и сигналов, Программные технологии и алгоритмы.

Полученные результаты и их новизна: Построены следующие алгоритмы: алгоритмы повышения точности поиска изображений, алгоритмы синтеза речи тонального языка. Разработаны новые модели структуры, алгоритмы и технология построения ядра САПИ и системы поиска изображений для автоматизированной обработки медицинских изображений. Предложена технология объединения системы поиска изображений в систему САПИ для использования базы данных изображений DICOM. Она потенциально помогает ставить диагнозы во многих схожих случаях. Предложена платформа телемедицины для управления и обмена медицинскими данными и изображениями. Платформа использует технологию веб-сервисов и грид-сервисов, предоставляемую программным обеспечением gLite и сервисом метаданных AMGA gLite.

Полученные теоретические и технологические результаты позволяют разработчику создавать недорогие, простые в использовании системы, обеспечивающие быструю точность и массовое использование изобраажений и речи в диагностике.

Рекомендации по использованию: Разработанное программное обеспечение может быть использовано для создания систем, в которых используются сигналы и изображения для поддержки принятия диагностических решений врачами-рентгенологами в разных областях медицины.

Область применения: Представленные результаты внедрены в некоторых больницах Вьетнама, а также на тренингах в университете Бин Дуонг.

SUMMARY

Dao Van Tuyet

Algorithms and technology for building integrated medical information systems

Keywords: Automated processing, Image retrieval, medical images and signals, EHR, LIS, RIS, PACS, Telemedicine.

The purpose of the research: Development of structure models, algorithms and the technology for building integrated medical information system. It supports automated processing of images and signals on integrated environment of medical information and image.

Research methods: E-Health technology, Health Information Technology, Automated processing of medical images and signals theory, Software technology and algorithms.

The obtained results and scientific novelty: The following algorithms are constructed: the algorithms for improving the accuracy result of image retrieval system, the algorithms for speech synthesis of tonal language. New structure models, algorithms and the technology for building a PACS core and Image Retrieval System as automated processing of medical images are developed. The technology for combining the image retrieval system into the PACS system for using its DICOM image database, it potentially assists in suggesting diagnoses of many similar cases, and evidence supplied by the similar cases assist the radiologist to improve interpretation of rare abnormalities and helps in determining a diagnosis. The Telemedicine platform to manage and exchange medical data and medical image, the platform use web services technology and grid service provided by gLite middleware and AMGA metadata service of gLite.

The obtained theoretical and technological results allow the developer to construct low-cost, easy to use systems that ensure rapid accuracy and mass use of diagnosis knowledge.

Usage recommendations: The developed software can be used for building automated processing of medical images and signals systems that use diagnosis knowledge to support making diagnosis decision of doctors, radiologist in the rapid growing areas of the medicine, such as the modern technology applied in design and producing the modalities, computer technology, E-Health technology, medicine, education, etc.

Application area: The presented results are implemented in a hospital in Vietnam, as well as in the training at Binh Duong University.