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Analysis of Medical Image Processing and its Applications in Healthcare Industry

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Abstract

Medical image processing needs continuous enhancements in terms of techniques and applications to help improve quality of services in health care industry. The techniques used for interpolation, image registration, compression, medical diagnosis are to be improved to be abreast with growing demands in the industry and emerging technologies pertaining to mobile computing and cloud computing. In this paper we present the present state-of-the-art of medical image processing and its abilities to harness the hardware resources including ever growing GPGPU platforms for improving quality of clinical practices in terms of speed, accuracy, innovation, and globalization and so on. From the analysis of the literature it is understood that the health care domain has got much scope for further research in the areas of diagnosing life threatening diseases, usage of remote health monitoring applications for real time functioning to alert healthcare personnel. The integration of medical equipment and applications with wearable devices is also promising area for further research. This paper provides useful insights into the field of medical image processing and tries to define the future scope of work.

Index Terms *– Medical image processing (MIP), medical diagnosis, MIP methods and applications*

I. INTRODUCTION

Growing interest in health care domain has paved way for innovative approaches for medical diagnosis and clinical practices. Since health is considered to be wealth, the healthcare industry has been striving to use innovative medical procedures and treatment practices coupled with technologies in computations, harnessing advances in hardware resources. Precision in disease diagnosis and accuracy in clinical practices and improvement in state-of-the-art equipment is the ever-ending necessity in the health care industry. This has led to various best practices which are clinically proven. However, more needs to be done with ever-growing medical data, called big data now days, in order to discover hidden knowledge from the data.

Health care industry generates huge amount of data. Intelligent processing of such data can reveal hidden relationships among the data items which will help in clinical practices. The growth in usage of medical image processing can improve quality of services to reduce death toll and improve health standards of citizens of a country. For instance a survey in 2010 has released statistics pertaining to deaths due to malign cancer in Germany as shown in Figure 1. This situation can be improved with focused usage of technologies for medical image processing to leverage diagnosis, treatment and other clinical practices.

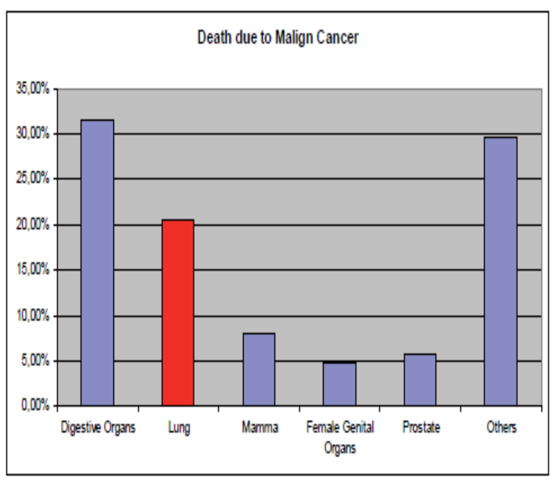

Figure 1 – Death due to malign cancer in Germany in 2010 [1]

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As can be seen in Figure 1 it is alarming that many deaths in Germany are due to cancer. Research into this area by exploiting computing innovations can improve the situation. Wongthanavasu and Tangvoraphonkchai [2] presented cellular automata-based algorithms and their desired applications in diagnosis of breast cancer which facilitates accurate and expert decision making which helps in combating the dangerous endemic disease. A typical medical imaging system appears as shown in Figure 1 which has provision for image capture and sharing of in health care industry thorough public network such as Internet. It can have various clinically useful methods conforming to DICOM to help healthcare professional make expert decisions.

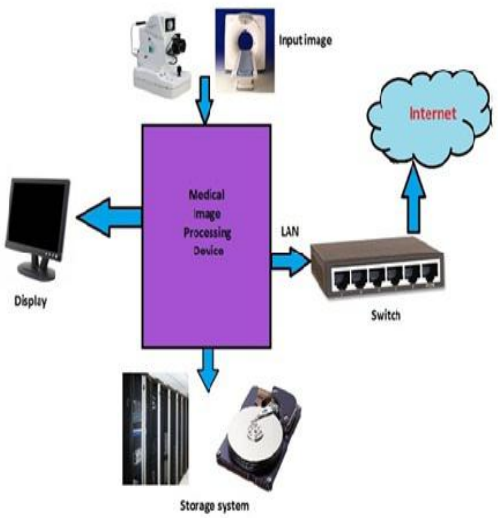

Figure 2 – Illustrates a typical medical imaging system [3]

As can be seen in Figure 2, it is evident that the medical imaging system has provision for capturing images, storing them, processing them and sharing them across the industry through reliable communication networks. Section II provides more details about the present status of the medical image processing area which is relevant to healthcare industry. Our contributions in this paper are as follows.

- We bring about insights from the review of literature on medical image processing. This knowledge helps in understanding the technical innovations in the industry and further research needs.
- We analyze the usage of innovative technologies in the area of mobile computing and cloud computing besides harnessing GPGPU platforms for high quality healthcare services.

The remainder of the paper is structured as follows. Section II reviews literature pertaining to medical image processing, its methods and applications. Section III discusses the finding made in the literature review. Section IV concludes the paper.

II. RELATED WORK

Literature on medical image processing has been reviewed and presented in this section in terms of general medical image processing approaches, harnessing the power of GPGPU platforms for medical image processing, exploiting the cloud computing advantages and so on.

A. Medical Image Processing in Healthcare Industry

Lehmann et al. [4] explored B-Spline interpolation techniques for medical imaging in order to improve the quality of images. This has an important utility as healthcare users need to have good visual perception of images. Banos Jr, Sehn and Krechel [5] proposed a service model known as “Integrated Image Access and Distributed Processing Service” which is a distributed environment which facilitates radiological medical personnel to gain access to image processing features. Matthew J et al. [6] proposed an application for medical image processing as well as visualization which enabled professional to study, diagnose clinical disorders. Later 3D imaging came into existence to leverage medical image processing. Li, Papachristou and Shekhar [7] provided a reconfigurable architecture for 3D medical image processing. The system has four operational stages namely parameter generation, input brick fetching, medical data stream processing and output brick storing. Tian and Ha [8] reviewed applications for medical image processing that make use of wavelet and inverse transforms. These applications are used for clinical diagnosis. Chen, Yi and Ni [9] proposed a platform known as Medical Image Processing Platform (MIPP), which is used for web based processing of medical images. The platform was used for design and manufacturing of stents used for heart patients.

In 2005 Regrain et al. [10] built an open source library of functions using Python language meant for medical image processing. This library has improved the pace in application development. Ogiela et al. [11] proposed a cognitive approach for analyzing diagnostic features of images. Thus obtained knowledge was used to analyze pathological cases in health care domain. Srinivasan N and Vaidehi V [12] studied cluster computing in medical image processing for improving diagnostic methods. Hui et al. [13] studied medical image processing and then constructed a knowledge center which is helpful to community in healthcare domain to improve their knowledge through the e-Learning platform (knowledge center). It is being used by Tsinghua University.

Vaida and Todica [14] explored the integration of medical image processing applications in distributed environment using service oriented architecture (SOA). The medical applications are used as reusable components such as Healthlmag and Image Diagnose that are dynamically adapted for medical image processing. The distributed medical application is thus capable of supporting operations pertaining to DNA, echography measurements stereo logy. Wongthanavasu and Tangvoraphonkchai [15] presented cellular automata-based algorithms and their desired applications in diagnosis of breast cancer. The application is useful for medical professionals. Peng et al. [16] presented a new way of using stochastic resonance for quality image processing in medical domain. Sarkar et al. [17] proposed an interpolation kernel for medical image processing. The technique uses many Gaussian filters at various levels to improve images based on perception of human eye. Siemens Medical Ultrasound Scanner is used to capture video frames for empirical study. Selvarasu et al. [18] proposed an algorithm for automatic interpretation of thermo grams and quantify them in order to find abnormality. The hotspots in thermograms can reveal abnormalities in medical thermograms. The algorithm is efficient in terms of time, image specificity and parameter dependency. Tian et al. [19] designed and implemented a software platform for medical image processing with activities like registration, segmentation, reconstruction and visualization. Todica and Vaida [20] proposed an SOA based distributed architecture as platform for medical image processing. This is a flexible platform which allows components as service renderers which can be plugged dynamically. Thus the application can improve its services over a period of time. Han and Jia [21] explored the processing of Computed Tomography (CT) and Medical Rapid Prototyping (MRP) models. These models were further used in 3D visualization. Qi and Yu [22] also focused on edge detection of CT images using multifractal theory for best detection medical CT images.

Wang et al. [23] proposed an algorithm for contour extraction and denoising which can be used for medical image analysis, feature extraction, image smoothing, image enhancement, and image reconstruction. The algorithm makes use of combinations of wavelet transform and median filtering and contour tracing and canny edge detection. The experimental results reveal that their algorithm is capable of processing images which were captured with poor quality containing high spatial redundancy, and noise. Khayati et al. [24] presented a distributed system which enables computer aided diagnosis to physicians remotely. The system also keeps requests transparent and ensures privacy of sensitive details. Zhu et al. [25] proposed a system that can pre-process medical X-Ray images. Especially they used a filter named "temporal recursive self adaptive filter". Field Programmable Gate Array (FPGA) and other devices were used to achieve this. The system has enhanced the signal-noise ratio (SNR) of X-Ray images through the pre-processing. Wu and Chi [26] proposed a novel pre-processing method that can enhance the quality of medical images before being processed. Unlike the technique in [25] it uses shape-preserving fitting for pre-processing of medical images. The medical images obtained by CT scanner are improved before processing them. Wang and Kang [27] applied a novel algorithm on correlation theory and contourlet transform for medical image processing. Especially their algorithm has better compression performance then wavelet transform. Digital Imaging and Communications in Medicine (DICOM) has been considered a standard in processing medical images in terms of transmitting, printing, storing, and handling. Hu et al. [28] proposed an interactive approach for medical image processing that is in conformance with DICOM. The methods provided by them assisted doctors to make well informed diagnostic and treatment decisions.

Lee et al. [29] combined wavelet edge detection and segmentation for quantitative coronary analysis. It helps doctors to diagnose heart diseases like heart artery stenosis. This method is supported by 3D image processing to improve quality coronary angiography images.

B. Medical Image Registration

Medical image registration is a process of establishing correspondence among a series of images. This is a challenging task. Du et al. [30] proposed a mixed-type approach for medical image registration under the standards of DICOM. For image matching Mutual Information (MI) is used as similarity measure. This method proved to have less computational complexity, high accuracy and more speed. Sugimoto et al. [31] built many image processing application in collaboration with researchers in healthcare domain. Their applications support dynamic image processing, especially for images pertaining to cardiovascular disease. Figure 1 shows functionality of one of the applications explored in [31] that is meant for image registration.

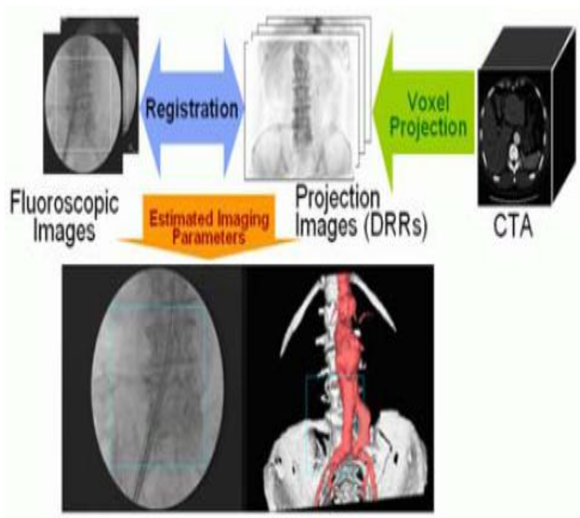

Figure 3 – 2D/3D image registration method [31]

As can be seen in Figure 3, it is evident that the image registration method is required to have a series of images to be processed in order to make them ready for various processes and decision making exercises.

C. Exploiting GPGPU Platforms for Medical Image Processing

General Purpose Graphics Processing Units are many times powerful than CPUs. These platforms can be used to enhance the services in healthcare industry. Wei-Hung et al. [32] proposed acceleration of the NMI (Normalized Mutual Information) procedure for medical image registration. They employed an approach that makes use of the power of Graphical Processing Units (GPUs) for parallel processing to leverage the performance image registration. The experiments were done using GPU platform CUDA with graphical processor GeForce 9600 GT from NVIDIA.

Tiejian et al. [33] presented embedded 3D medical image processing which overcomes the limitations of the present approaches. The proposed method performs medical image processing and visualization concurrently. This method is capable of exploiting hardware resources to speed up medical image processing. Thus this image processing approach can cater to temographic imaging and medical diagnosis. Suresh and Babu [34] explored the research on medical image processing techniques that can harness the power of GPGPU platforms. Thus the pressure on rendering quality diagnosis and treatment is possible when GPU is used to speed up the processing.

D. XML Based Medical Image Processing

XML has been used widely for data representation since it is platform and device independent. Miri et al. [35] presented a web based framework for medical image processing. The framework makes use of Image Markup Language (IML). It provides a platform for distributed medical image processing and renders good ideas to have customized workflows useful for different users in the health care industry. Oa-Zhe et al. [36] studied Medical Image Understanding Process Definition Language (MPDL) which is meant for an array of medical image processing activities. The MPDL helps in medical image understanding. It is a tool which leverages software development for medical image processing besides having the abilities to control image presentation and data flow.

E. Imaging Devices vs. their 2D, 3D and 4D Representations

In healthcare domain various devices are used as imaging devices such as scintigraphy, roentgen, ultra sound, CT, MRT, PET, SPECT, and 4D-CT. These imaging devices have varied capabilities to work in 2D, 3D, and 4D representations as shown in Figure 4.

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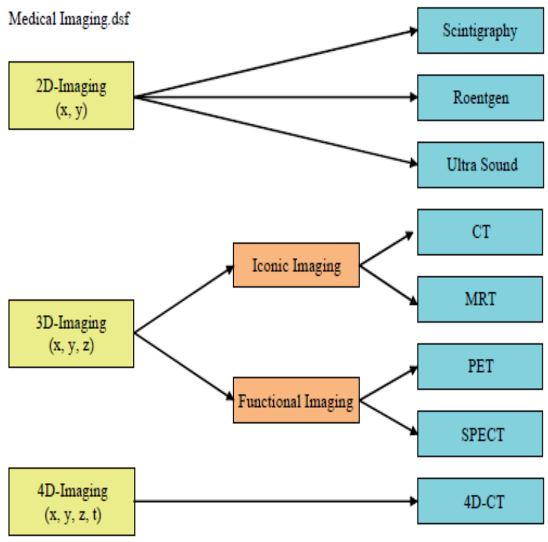

Figure 4 – Overview of imaging devices vs. 2D, 3D and 4D imaging representations [1]

Irradiation of moving tumors is performed as part of medical irradiation therapy which is of three types again namely resection, radiation therapy and chemotherapy [1]. Recently mobile devices are also used for medical image processing. For instance Lin et al. [37] proposed a mobile application that works in small hand held devices. The application takes medical images and extracts haptic parameters from visual features. Then the application notifies doctors concerned for possible findings of unwanted diseases with the aid of medical imaging. This will help doctors to make decisions in further diagnosis.

Figure 5 – Medical Image Processing Assistant running in Tablet PC (a) and iPad (b) [37]

As can be seen in Figure 5 it is evident that the application takes care of medical image processing based on the images provided and notify doctor for possible ailments to improve the quality of service in health care domain.

F. Diagnosis of Cancer & Heart Ailments

Data mining techniques are being used for processing medical databases. Kharya [38] proposed a methodology for diagnosis and prognosis of breast cancer. Decision tree model was used to represent actionable knowledge pertaining to breast cancer. Artificial Neural Networks (ANNs) were also used to diagnose breast cancer. Krishnaiah et al. [39] used classification techniques for lung cancer prediction. Their system is used for early detection of lung cancer and accurate diagnosis of it which will save time of doctors besides helping them in clinical practices. Srinivas et al. [40] used data mining techniques for prediction of heart attacks.

G. Cloud and Medical Image Processing

Cloud computing has evolved as a new computing model which can provide huge computing resources in pay per use fashion. It has promising characteristics to help healthcare industry. Chiang et al. [41] proposed and implemented a Service Oriented Architecture (SOA) for building a cloud service that can be used by general public and medical personnel for reliable medical image processing. They combined the resource integration of cloud and "ImageJ", the image processing software into a cloud service. This has paved way for applications worldwide to gain access to the cloud service seamlessly. Figure 2 presents the SOA with cloud and a sample image processing activity that can be supported by the cloud service.

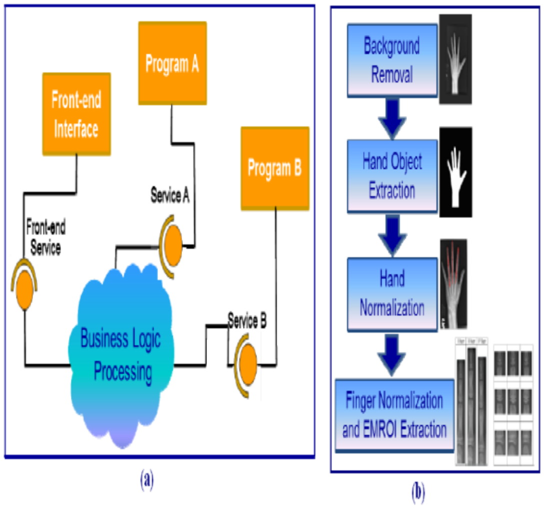

Figure 6 – Illustrates (a) cloud architecture and (b) the steps followed for EMROI extraction [3]

As can be seen in Figure 6, it is evident that the business logic required by various image processing activities such as EMROI extraction are kept over cloud and the services are made available to public in order to access the business logic in platform independent fashion [3]. Eilam et al. [42] explored medical ultrasound imaging and possible usage of cloud computing. They developed a medical imaging system for medical ultra sound imaging with the help of cloud. Their results were encouraging and thus concluded it to be feasible to use cloud help for ultrasound imaging.

III. DISCUSSION

In this section we analyze the developments in the area of medical image processing technologies, applications in healthcare domain. From the preceding sections various insights were considered for this discussion. At a broader level it is understood that medical image processing has promising consequences in leveraging quality practices in clinical practices. State of the art equipment and technologies are available these days and there is quest for excelling in medical diagnosis and treatment with utmost quality. Towards this various technologies came into existence. Though the corporate hospitals do not disclose their proprietary methods, in this paper, we focused on the available methods in the literature. The evolution of techniques and applications in medical image processing has made the professions in the domain to have more effective practices. Some techniques pertaining to interpolation, image registration, diagnosing lung cancer, breast cancer, heart ailments were known in the literature. Data mining techniques and image mining techniques were also found in the literature which improved the quality of services in the health care domain.

Recently medical image processing is making strides in using powerful technologies like virtualization and cloud computing to speed up processing. It is also making use of GPGPU platforms for high speed computation of medical procedures. Mobile technologies are also used to exploit the convenience the mobile devices provide for doctors and patients by making suitable applications. Wearable devices are also used to processes patients' vital signs and help professionals to make well informed decisions. Thus patients are saved from unnecessary round trips to hospital premises by using remote medical image processing applications. The summary of the findings with respect to techniques used in medical image processing are presented in Table 1.

Author (s)	YEAR	Techniques	Purpose	Advantages
Lehmann, Gönner and Spitzer [4]	2001	High degree B-Spline Interpolation	Improves the quality of images in medical imaging	• Reasonable computing times • Smallest interpolation error • Superior Fourier properties

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Tian and Ha [8]	2004	Wavelet transform and inverse transform	ECG signal processing	Clinical diagnosis and therapy
Wongthanavasu and Tangvoraphonkchai [2]	2007	Cellular automata algorithms	To determine hypothesis spots of breast cancer	Diagnosis of breast cancer
Wang et al. [23]	2008	Denoising and contour extraction algorithm	Denoising and contour extraction	• Medical image analysis • Feature extraction • Image smoothing • Image enhancement • Image reconstruction
Khayati et al. [24]	2008	**Distributed system**	**For medical request processing.**	Helps physicians to have diagnosis requests remotely.
Zhu et al. [25]	2008	**Temporal Recursive Self-Adaptive Filter**	**Pre-processing of medical X-Ray images**	Improves SNR of X-Ray images
Wu and Chi [26]	2008	**Shape – preserved fitting**	**Pre-processing of medical images**	Quality of CT scanned images are improved further
Wang and Kang [27]	2008	Contourlet transform	Time frequency localization and multi-scale analysis	• Performance is improved in denoising and image compression • Better than wavelet transform
Hu and Gui [28]	2009	Interactive image processing technique	For user-friendly and interactive image processing technique.	• Clinically useful • Assists diagnosis
Du et al. [30]	2009	Mixed-type registration approach	For medical image registration	• Speed of registration is more • Accuracy of registration is more
Lee et al. [29]	2009	Wavelet edge detection and segmentation	Quantitative coronary analysis	Helps doctors to diagnose heart ailments like heart artery stenosis

Wei-Hung et al. [32]	2009	*acceleration of the NMI procedure*	For acceleration of medical image registration	• 23.4x increase in speed in registration • Computationally cost effective
Tiejian et al. [33]	2010	Embedded 3D medical image processing	Temographi imaging and visualization	• Disease diagnosis • Exploits hardware resources • Space and computation efficient
Oa-Zhe et al. [36]	2010	MPDL framework	Building prototypes for medical image processing	• Cost effective and user friendly development of software for medical image processing
Chiang et al. [41]	2011	Cloud service for BL sharing	Providing access to applications across the world to share BL of medical image processing	• Consistency • Interoperability • Security

Table 1 – Summary of findings

As can be seen in Table 1, the medical image processing approaches, applications and techniques have given insights to ascertain the present state of the art as much as possible. However, the research on medical image processing has much scope to proceed further. This we will continue further in future.

IV. CONCLUSION

In this paper we studied medical image processing in health care domain for valuable insights into the subject. The analysis of medical image processing, its applications in healthcare industry are presented in this paper. Medical image processing has revealed significant growth in harnessing new technologies and processing capabilities. It is capable of leveraging the power of GPGPU platforms, cloud computing and other technologies. Medical image processing is also involved in data mining and image mining in order to improve quality of services in hospitals. Usage of hand held devices, cloud computing and wearable computing is witnessed which reflects the progress being made in usage of emerging technologies for diagnosis and clinical practices. An important insight from the literature is that though there are improvements in medical image processing, lot of research is left unattended which encourages researchers to focus on. For instance remote health care systems can be enhanced so as to let patients use them for preliminary health decisions. Another research direction is to integrate wearable devices of patients to health care servers so as to alert physicians concerned to take steps early to keep situation in control before proceeding further. Yet another research direction in future is to develop software systems that interface with medical hardware for accurate and real time diagnosis of life threatening diseases like heart ailments, cancers of various kinds and diabetes.

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