IBK – A NEW TOOL FOR MEDICAL IMAGE PROCESSING

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ABSTRACT: *Along with the rapid development of diagnostic imaging equipment, software for medical image processing has played an important role in helping doctors and clinicians to reach accurate diagnoses. In this paper, methods to build a multipurpose tool based on Matlab programming language and its applications are presented. This new tool features enhancement, segmentation, registration and 3D reconstruction for medical images obtained from commonly used diagnostic imaging equipment.*

Keywords: *IBK, diagnostic imagining, medical image processing.*

1. INTRODUCTION

Diagnostic imaging is an invaluable tool in medicine. In recent years, hospitals in Vietnam are equipped with more and more modern diagnostic imaging equipment. The generation of conventional X-ray machine is gradually replaced by digital X-ray system and computed tomography (CT) scanner. Besides, other imaging equipment such as Magnetic Resonance Imaging (MRI), Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET), Digital Subtraction Angiography (DSA) etc. become more familiar modalities. In current clinical practice, these imaging modalities allow medical personnel to look into a living body with both anatomical and functional information, in order to diagnose many types of diseases. Compared with analog imaging equipment, such digital equipment have many advantages: no photochemical development of film is required, image can be displayed on monitor immediately after the exposure, stored information is more easily accessible by magnetic or compact disks, the capacity for information transmission between local departments through computer networks (PACS) or long-distance transmission via Internet to remotely diagnose (telemedicine), and especially the feasibility of image processing: magnify it or change the contrast level by using image processing tools etc.

Such image processing tools necessitate the use of computers for processing and analysis. The computer tasks can be split into four areas: (1) feature enhancement involved in noise, artifact removing or contrast increasing; (2) quantitative analysis by employing segmentation algorithms; e.g. tumor volume measurement, localization of pathology, study of anatomical structure; (3) detection of medical conditions by applying accurate registration to structural and functional images to extract information that was not apparent in an individual dataset and (4) visual reconstruction: a series of image slices can be aggregated into 3D representation of patient's anatomy. Although hardware-based solutions for registration are provided by PET/CT and SPECT/CT scanners, software-based registration may still be required to correct misregistration caused by patient motion between the PET scan and CT scan. There were a vast number of studies that have reviewed algorithms of the above techniques [1, 2, 3]. In this paper, the authors focus on methods which have been used to built an application named IBK and its possible applications in clinical environment.

Numerous foreign software packages are available for medical image processing and analysis such as eFilm, 3D-Doctor, DICOMWorks, BrainSuite etc. The drawbacks of such packages are their high price and their user interfaces are in English. Beside of these packages, equipment manufacturers have their own built-in software (e.g. Syngo, AVIA, Volumetrix Suite etc.) which has many powerful functions. However these software packages must only be installed on system manufacturer's computers. In case we need register two images obtained from different firms equipment, these packages can not help. In Vietnam, Biomedical Electronics Center at Hanoi University of Technology is a pioneer in writing medical image processing software. However their application software, BK-DICOM has a limited number of functionalities.

As a result, the authors desire to built a multi-purpose medical image processing application featuring enhancement, segmentation, 3D reconstruction, and registration of multimodal images obtained from different equipment. This application has a user interface in Vietnamese and would be either used as a flexible illustration tool for education purpose or distributed free to medical centers and hospitals in Vietnam in the future.

2. METHODS

2.1. Approach

Programmed in Matlab 7.7, the application has been supported by the following MathWorks toolboxes:

- Graphical User Interface Toolbox (GUIDE)
- Image Acquisition Toolbox 3.2
- Image Processing Toolbox 6.2

The application is divided into 4 main modules: image enhancement, image segmentation, image registration and 3D-reconstruction. In each module, there are common modules: image reading, image information displaying, saving and printing.

After programming process is completed, the application is tested and then packaged in an installation file by using Matlab Compiler tool.

2.2. Enhancement

Medical images are often deteriorated by noise due to interference and other phenomena that affect the imaging processes. Image enhancement is the improvement of image quality to increase the perception of information in images for medical specialists.

• Noise Suppression: suitable noise suppressing algorithm is selected based on what type of noise presented in the image [4]. *Impulse noise* (having distribution of extreme values, only isolated pixels are affected) should be removed by Mean or Median filter. *Narrowband noise* (a few strong frequency components form the noise) is suppressed by removing false frequency coefficients from the discrete two-dimensional spectrum and reconstructing the image from the new spectral information.

• Sharpening: enhancing the sharpness by accentuating edges may contribute to raise more visible details in an image. *Laplacian, Sobel, Rebert Cross* are some algorithms used to extract edges and thus increase the sharpness of the image.

• Contrast Enhancement: the appearance of an image depends significantly on the image contrast. There are three contrast enhancement methods: *Linear contrast adjustments, nonlinear contrast adjustments* (the brightness mapping is described by linear or nonlinear functions) and *histogram equalization* (changing pixel intensities so that the histogram is optimized with respect to even distribution).

2.3. Segmentation

Image segmentation is the process of partitioning an image into sets of pixels corresponding to regions of physiologic interest. It could be used for evaluating anatomical areas in diagnosis and treatment. Segmentation methods can be classified into two categories [3]:

• Region segmentation: searching for the regions satisfying a given homogeneity criterion. *Threshold, region growing, morphological watershed* are some common region segmentation methods.

• Edge-based segmentation: Instead of locating the interior of the object itself, edge-based segmentation methods search for edges between regions with different characteristics.

Sometimes segmentation for color images is needed, e.g. microscopic images. A color image is constructed by 3 monochromatic color components (color spaces). The segmentation is performed for each color space.

2.4. Registration

Image registration is the process of combining images acquired from multiple sensors (multimodal registration), at different times (temporal registration), or at different viewpoints (viewpoint registration). Information that was not apparent in an individual dataset can be extracted by registration. The main task of the registration algorithm is to find a mapping between two image sets so that these images can be aligned into a common coordinate system. The study-image set is compared with the reference-image set using a similarity measure. Many criteria have been used as the basis for similarity measure. Generally, these criteria can be classified into 3 categories:

• Landmark-based registration uses corresponding features selected by users. These features are usually points which can be anatomical markers attached to the patient in both image modalities. The transformation that is required to spatially match the landmarks is then applied to the image datasets. The number of identified points determines the type of transformation (linear conformal, affine, projective).

• Intensity-based registration operates directly on the image intensity information. It is more flexible than landmark-based registration and can be fully automated. In practice, it is common to use multi-resolution approach to speed up the registration process. Numerous methods for intensity-based registration have been proposed. These include *correlation-based methods, minimization of variance of intensity* [5, 6], *Fourier-based methods* etc.

• Segmentation-based registration attempts to align anatomical structure (curves, surfaces etc.) obtained by segmentation. The transformation is determined by either corresponding segmented structures of two images or the segmented structure of one image to the whole unsegmented second image (in this case, it is required that the boundary of the segmented structure matches to edges found in the second image). Because processed information is limited on the segmented structures, this method is faster than the intensity-based method. However, the performance of the registration relies on the accuracy of the segmentation step.

2.5.3D-reconstruction

3D-reconstruction technique creates three-dimensional (3D) image from a set of two-dimensional (2D) slices which can be obtained using various equipment such as CT, MRI, Ultrasound etc. Generally, the process of 3D-Reconstruction is composed of the following steps: (1) 2D slices are read and arranged in the right spatial order, forming a data volume. (2) The data volume is then rendered by multiplanar rendering (MPR), surface rendering (SR) or volume rendering (VR) to visualize the images in 3D.

3. RESULTS

IBK version 1.0 has the following built-in functions:

3.1. Input: Multimodal images: X-ray, DSA, CT, MRI, Ultrasound, SPECT, CT, Microscopic image; Multi file formats: JPG, BMP, PNG, TIF, GIF, DICOM, DICOMDIR.

3.2. Process: 4 features:

▪ ***Image Enhancement:*** Resize, Resize Canvas, Crop, Rotate, Flip, Noise Removal filters, Brightness/Contrast, Histogram Equalization, Levels, Desaturation, Invert, Threshold, Colormap, Grayscale window.

▪ ***Image Segmentation:*** Single thresholding, Double thresholding, Region growing, Object counting, Distance measurement, Region area calculation, Region ratio calculation, Velocity and cardiac output calculation in Doppler image.

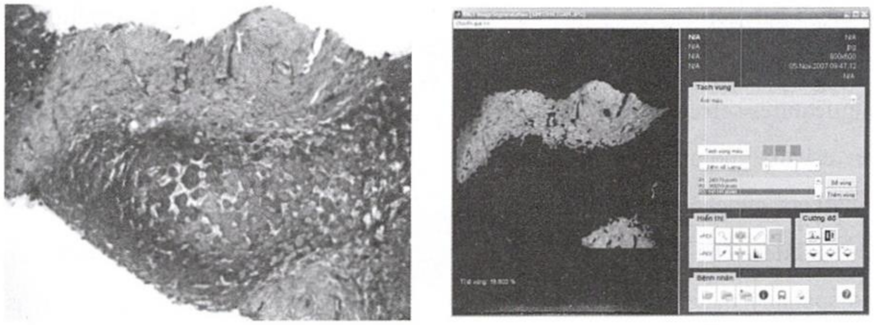

Figure 1. Fibrous tissue (appeared as green region) is segmented to calculate the ratio of its content to non-fibrous content.

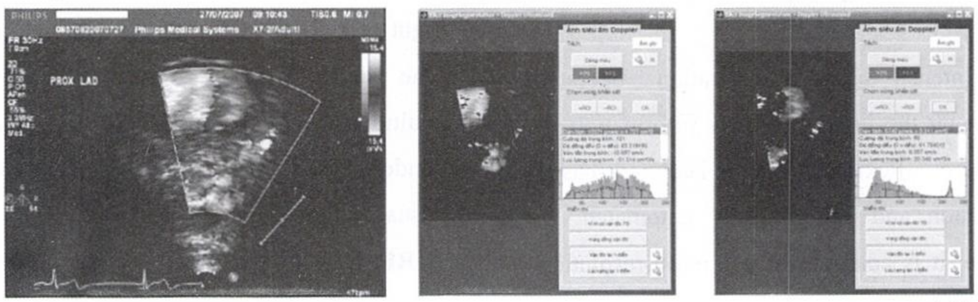

Figure 2: Red-blue region segmentation & its properties (velocity, flow, distribution) in Doppler ultrasound image

- **Image Registration**: Image Fusion: manual mode (translate, rotate, resize image by hand), semi-auto mode (pick points in a pair of images that identify the same features or landmarks in the images), automatic mode (perform automatically by correlation-based algorithms); Subtraction to analyze temporal evolution or detect differences: manual and semi-auto mode; Multi image Registration.

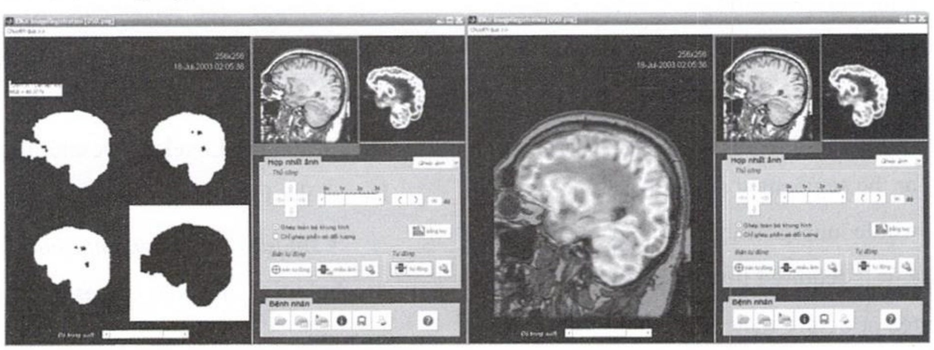

Figure 3. Auto registration mode

- **3D-Reconstruction**: multiplanar rendering (MPR), surface rendering (SR), volume shear rendering (VSR).

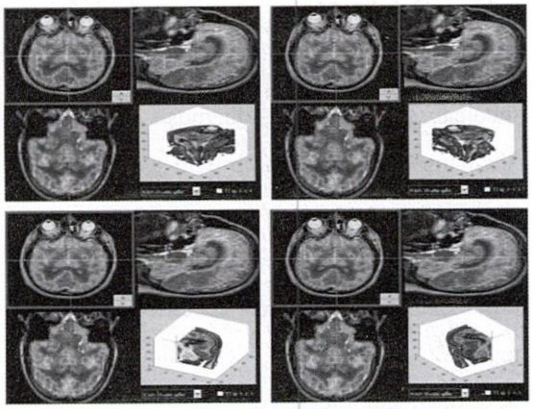

Figure 4. MPR images

3.3. Output: Patient information; Quantitative information *(area, number of objects, blood velocity, cardiac output)*; Result images *(Enhanced / Segmented / Registered / 3D image)* & 2 storage ways: saving as file (JPG, BMP, PNG, TIF, GIF, DICOM) or printing.

4. APPLICATIONS

Based on specific characteristics of different kinds of medical images, processing procedures for images of X-ray, DSA, CT, MRI, SPECT, PET, Ultrasound and Microscopic Image have been proposed [7]. Based on these procedures, some clinical applications of IBK include:

- Applications in the brain: Registration to localize tumors, eloquent cortex, regions of dysfunction; detect disease such as Multiple Sclerosis, Alzheimer at an early stage; monitor patient responses to treatments.

- Breast Image Registration: Breast cancer is often detected by X-ray mammography, pre-post contrast MRI, ultrasound techniques. Registration of pre- and post-contrast MRI sequences can effectively distinguish different types of malignant and normal tissue.

- Whole-body Registration in Oncology Studies: PET scanning reveals metabolic information and is critical in cancer detection, disease progress and treatment response. On the other hand, CT or MRI scanning provides information on anatomical changes. Proper registration to fully utilize complementary information of these modalities is thus highly desirable.

- DSA (digital subtraction angiography): A sequence of X-ray images is taken to show passage of injected contrast medium through vessels of interest. The background structures are removed by subtracting the mask image from the contrast image to reveal interested vessels.

- Measuring volume of tumors, bones, muscles, blood vessels, white / gray matter, cerebrospinal fluid spaces of the brain. Several neuropathologies such as epilepsy, schizophrenia, Alzheimer etc. are related to functional changes in the brain.

- Segmentation in microscopic analysis: the aim is to analyze, extract and measure different regions in microscopic images. For example, in a microscopic image of diseased tissue, the tissue exhibits two types of characteristics: fibrous tissue and non-fibrous (normal) tissue. Microscopic evaluation (i.e.

calculating ratio of fibrous to non-fibrous content) by medical technologists is a time-consuming and inaccurate job. It is thus advantageous to apply computer-aided segmentation.

In addition, segmentation helps to quantify the number of multiple sclerosis lesions, blood cells etc. automatically, instead of counting by human.

5. CONCLUSIONS

Medical Image Processing is an important tool in diagnosis and it has been useful in many clinical applications. Several methods of image enhancement, segmentation, registration and 3D-reconstruction have been reviewed. Based on these methods, we have built the image processing tool, IBK to assist educators in training of medical image processing and medical specialists in diagnosis practice in Vietnam. Future research will be orientated toward improving the accuracy and computational speed. IBK also allows new processing modules for specific anatomical regions, pathological conditions to be developed and integrated.

IBK – MỘT CÔNG CỤ MỚI TRONG LĨNH VỰC XỬ LÝ ẢNH Y TẾ

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TÓM TẮT: *Cùng với sự phát triển không ngừng của các thiết bị chẩn đoán hình ảnh y khoa, phần mềm xử lý ảnh cũng đóng vai trò quan trọng trong việc hỗ trợ các bác sĩ đưa ra chẩn đoán chính xác. Trong bài báo này, chúng tôi trình bày phương pháp tiếp cận để xây dựng một công cụ xử lý ảnh y tế đa dụng dựa trên ngôn ngữ lập trình Matlab và một số ứng dụng của nó. Công cụ mới này có khả năng xử lý, phân vùng, hợp nhất và tái tạo 3D các ảnh chụp thu được từ các thiết bị chẩn đoán hình ảnh thông dụng.*

Từ khóa: *IBK, chẩn đoán hình ảnh y khoa, phần mềm xử lý ảnh.*

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