An Over View: Classification of Medical Image Registration

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Abstract: Medical image registration is the procedure of geometrically aligning two image volumes so that voxels representing the same anatomical structure may be superimposed one on another. Basing on the Nine Criteria formulated by van den Elsen et al (1993), the Medical Image Registration can be divided into nine classes, each of which is again subdivided into one or two levels.

Keywords: Image Classification, Image Registration, Image Processing, Medical Image Process.

I. INTRODUCTION

The nine criteria and primary subdivision are

1. Dimensionality

2. Nature of registration basis

a. Extrinsic

b. Intrinsic

c. Non-image based

3. Nature of transformation

a. Rigid

b. Affine

c. Projective

d. Curved

4. Domain of transformation

5. Interaction

6. Optimization procedure

7. Modalities involved

a. Monomodal

b. Multimodal

c. Modality to model

d. Patient to modality

8. Subject

a. Intrasubject

b. Intersubject

c. Atlas

9. Object

Dimensionality:

According to whether all dimensions are spatial, or that time is an added dimension, this criterion is subdivided into spatial dimensions only and times series (more than two images) with spatial dimensions. In either case, the problem can be further categorized depending on the number of spatial dimensions involved: 2D-2D, 2D-3D, and 3D-3D.

Nature of registration basis:

This category can be further divided into image-based and non-imaged based. Image-based registration can also be subdivided into extrinsic, i.e. based on foreign objects introduced into the imaged space, and intrinsic methods, i.e. based on the image information as generated by the patient. If the imaging coordinate systems of the two scanners involved are somehow calibrated to each other, registration of multimodal images can be non-imaged based, but it is usually necessary that the scanners are brought into the same physical location, and the patient remains motionless between both acquisitions.

-Extrinsic registration methods

Artificial objects, which are designed to be well visible and accurately detectable in all of the pertinent modalities, are attached to the patient. A commonly used fiducial object is a stereotactic frame screwed rigidly to the patient's outer skull table, a device that provided the 'gold standard' for registration accuracy. Sometimes other invasive objects are used, such as screwed-mounted markers, but usually non-invasive marking devices are reverted to. Most popular amongst these are devices glued to skin.

Extrinsic registration methods is comparatively easy, fast, can be automated, and, since the registration parameters can often be computed explicitly, has no need for complex optimization algorithms. The accuracy of this method is commonly very high.

-Intrinsic registration methods

Intrinsic methods rely on patient generated image content only. Registration can be based on a limited set of identified salient points *(landmarks)*, on the alignment of segmented binary structures *(segmentation based)*, most commonly object surfaces, or directly onto measures computed from the image grey values *(voxel property based)*.

Nature of transformation

The nature of transformation can be divided into rigid, affine, projective, and curved. An image coordinate transformation is called rigid, when only translations and rotations are allowed. If the transformation maps parallel lines onto parallel lines it is called affine. If it maps lines onto lines, it is called projective. Finally, if it maps lines onto curves, it is called curved of elastic.

Domain of transformation

A transformation is called global if it applies to the entire image, and local if subsections of the image each have their own transformations defined.

Interaction

There are three levels of interaction which are automatic, interactive and semi-automatic, that can be recognized according to the interaction between user and software.

Optimization procedure

The parameters that make up the registration transformation can either be computed directly, i.e. determined in an explicit fashion from the available data, or be searched for, i.e. determined by finding an optimum of some function defined on the parameter space. So the optimization can be further divided into parameters computed and parameters searched for.

Modalities involved

Four classes of registration tasks can be recognized based on the modalities that are involved in follow table:

a. Monomodal: 1. Auto-radiographic, 2. CT or CTA, 3. MR, 4. PET, 5. Portal, 6. PECT, 7. US, 8. Video, 9. X-ray or DSA etc

b. Multimodal:1. CT—MR, 2. CT—PET, 3. CT—SPECT, 4. DSA—MR, 5. PET—MR 6. PET—US, 7. SPECT—MR, 8. SPECT—US etc.

c. Modality to model: 1. CT, 2. MR, 3. SPECT, 4. X-ray

d. Patient to modality: 1. CT, 2. MR, 3. PET, 4. Portal, 5. X-ray

Subject

Based on the images involved in a registration task, there are three classes of subject, which are intra-subject (using two images of a single patient), inter-subject (using two images of different patients) and atlas (one image acquired from a single patient and the other image constructed from an image information database which is obtained using imaging of many subjects).

Object

The objects include head, thorax, abdomen, pelvis and perineum, limbs, spine and vertebrae, and so on.

Medical Imaging Modalities

Generally, medical imaging modalities are divided into two main categories: (1) the anatomical imaging with high resolution (CT and MRI) to describe the primary morphology. (2) the functional imaging with low resolution (PET, SPECT and fMRI) to study the functionality of underlying anatomical structures. The integration of the images from the different modalities provides the complementary information for surgical planning and guidance of radiotherapy.

Computerized Topography (CT)

CT was the first medical imaging modality [2]. The x-ray tube is rotated around the patient. X-rays are emitted by the tube as it transverses around the body. Linear detectors are installed on the other side of the x-ray tube to receive the transmitted x-ray beams after attenuation.

Since the x-ray attenuation properties of various tissues differ, the final transmitted x-rays can be correlated to the tissue properties within its path. Detectors will collect the profiles of x-rays with different strength passed through the patient and generate the projection data. Through the backward projection method, the cross-section image slice will be reconstructed from the collected data. Figure 1-1 shows the schema that x-ray tube rotates around the patient and detectors collect the passing beam of x-rays.

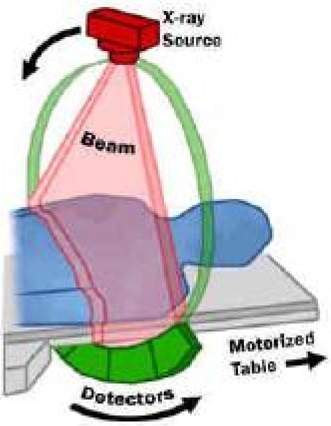

Figure 1 -1: The schema of computerized topography (CT) imaging

Source: http://www.fda.gov/cdrh/ct/what.html

Magnetic Resonance Imaging (MRI)

MRI is an imaging technology that does not employ ionizing radiation. According to the quantum mechanic of atomic structure, the nucleus of hydrogen spins around the axis and produces the magnetic moment. In the biological tissue there are abundant hydrogen nuclei with the form of water (H2O) and other carbon hydrogen compounds. Hydrogen nuclei (protons) have the strongest magnetic moment, which makes MR imaging possible by analyzing the reaction of protons within the biological tissue under the external magnetic field.

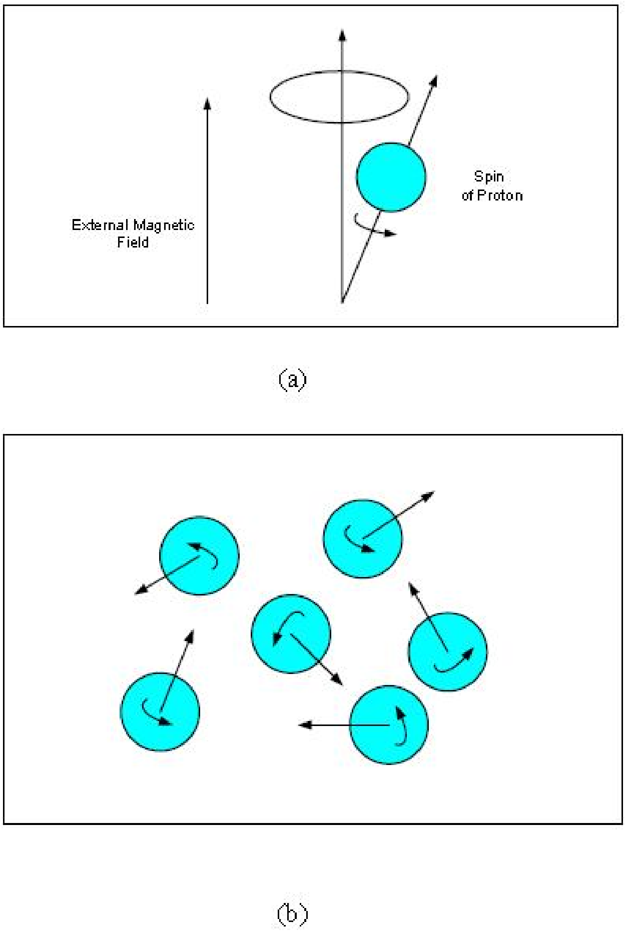

Figure 1 -2 The movement of proton. (a) spinning movement under the external magnetic field (b) random movement without the external magnetic field.

In the absence of an external magnetic field, the direction of magnetic moment for protons is random. If an external magnetic field is applied, the nuclear magnetic moment will align with the external magnetic field.

In MR imaging, a radiofrequency (RF) pulses generated by RF coil, as the external field, are applied on the patient. Under the RF perturbation, the hydrogen nuclei (protons) in the patient absorb the energy and leave the location of equilibrium. Through the transverse relaxation and longitudinal relaxation, the protons will return to equilibrium after some time that depends on the magnetic property of the biological tissue. During this period of time, the energy of protons will be dissipated as the radio wave. These electromagnetic waves emitted by the protons will be detected by another coil (receiver) that surrounds the patient.

The slice selection is accomplished by varying the gradient of the magnetic field as a function of position. This causes the linear variation of the proton resonance frequency along with the position. The MR imaging system uses the frequency encoding and phase encoding to determine the position of each signal within the patient.

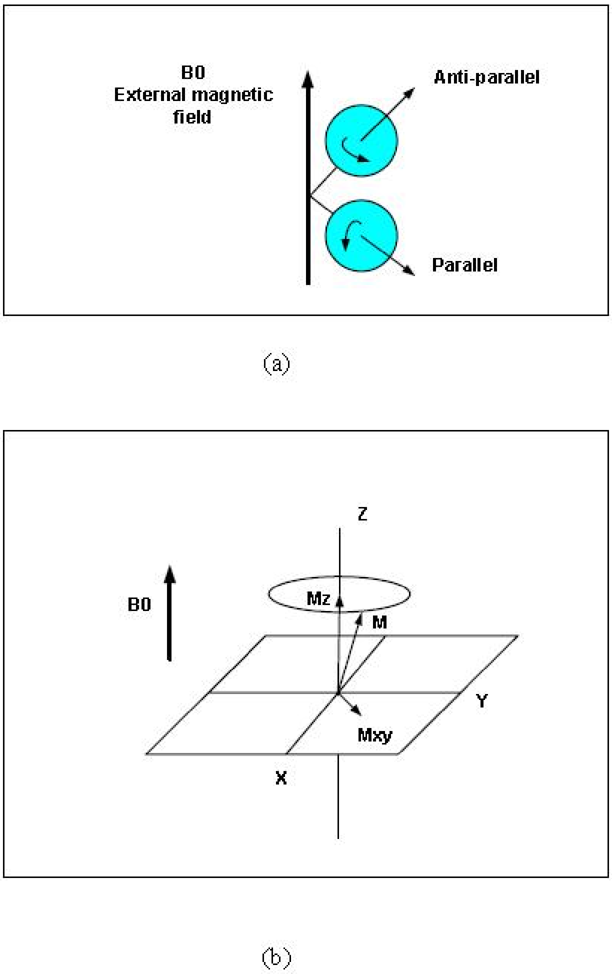

Figure 1 -3 a) with the external field the moment will aligned with B0, b) magnetic moment is turned into the transverse plane.

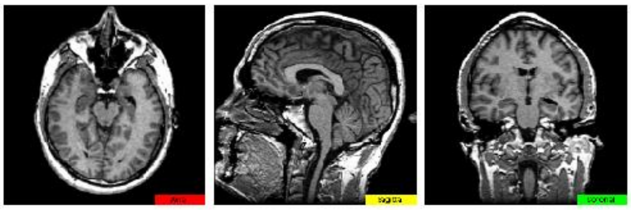

Figure 1 -4 Magnetic resonance (MR) images of human brain. Source: Visible Human Project (VHP), NLM

Functional Magnetic Resonance Imaging (fMRI)

Functional MRI is an approach to explore which part of brain is activated by various types of physical simulations (sound, sight and fear) or chemical stimulation.

A time series of 3D images are acquired during the functional MR imaging experiments. In general, the experiment is designed with two time periods: control period and stimulation period. During the control period the subject is performing normal functions or a normal task. During the stimulation period, the subject is applied with single or multiple well-controlled stimulus or specific tasks.

It is believed that when an area of the brain is activated with the specific task, it will require more energy and oxygen. Consequently, the blood flow increases to that region of activity. The MRI is sensitive to the slight changes in blood flow and therefore the intensity in that region changes. Frequently this response is labeled Blood Oxygenation Level Dependant (BOLD). Pixels with significant change or corresponding changes in image intensities indicate their association of the input specific task. With the statistical analysis, the areas of activated pixels are determined. The map of brain activation can either be overlapped on the co-registered anatomical image or "lit up" over multiple time steps and visualized in three-dimensional brain surface. This approach provides the researchers to study the areas of brain function and illness.

The statistical time analyses include Student T-test, Anova (univariate analysis of variance), Manova (multivariate analysis of variance) and GLM (General Linear Regression Model).

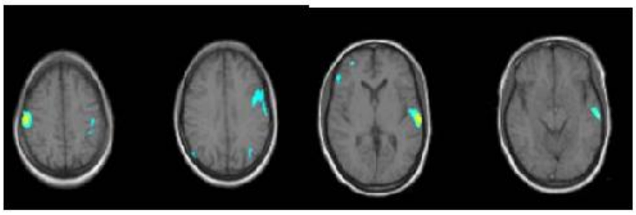

Figure 1 -5 "Lit-up" example of function MRI brain analysis.

Source: http://astor.som.jhmi.edu/~esg/TALKS/fMRI.ppt

Positron Emission Topography (PET) and Single Position Emission

Computerized Topography (SPECT)

PET and SPECT images are generated by depicting the distribution of radioactive isotopes in patients. When the radio-labeled compounds are injected in trace amounts, their emissions can be detected similar to x-rays in CT imaging. The resulting image represents the distribution of the labeled compound, which may reflect the blood flow, oxygen or other metabolism.

Image Fusion

Importance of fusion:

After an accurate multi-sensor registration, the complementary information provided by different sensors with multiple spatial and spectral resolutions can be integrated through image fusion. The general object of image fusion is to combine the complementary information from multimodality images

In the recent years, the study of multimodality medical image fusion attracts much attention with the increasing of clinic application demanding. Radiotherapy plan, for instance, often benefits from the complementary information in images of different modalities. For medical diagnosis,

CT provides the best information on denser tissue with less distortion, MRI provides better information on soft tissue with more distortion, and PET provides better information on blood flow and flood activity with low space resolution in general. With more available multimodality medical images in clinical applications, the idea of combining images from different modalities becomes very important and medical image fusion has merged as a new and promising research field.

[CT image offers high resolution in the visualization of bone structures but its soft tissue contrast is poor. Conversely, MR imaging offers high contrast for the visualization of the soft tissue morphology, but it produces weak signal intensity in bone. Due to their complementary information it is desired that both X-ray computed tomography and magnetic resonance imaging are integrated. For this image fusion techniques are employed. Fused images are valuable in clinical diagnosis in planning surgery and in image guided surgical intervensions.]

Image fusion is process by which two or more images are combined in to a single image retaining the important features from each original image. It aims at the integration of complementary data to enhance the information apparent in the images as well as to increase the reliability of the interpolation. The successful fusion of the images acquired from different modalities is an instrument is of great importance in many applications such as medical imaging, microscopic imaging, remote sensing, computer vision and robotics.

Some image fusion methods have been introduced in the literatures, including statistical method (Bayesian's decision), Fuzzy set method , Neural network method, Laplacian pyramid method and wavelet transform method .It should be noted that the fusion methods are application- dependent. In this project we present a scheme of image fusion by calculating the wavelet transform method.

Command line for fusion:

WFUSMAT Fusion of two matrices or arrays.

C = WFUSMAT(A,B,METHOD) returns the fused matrix C obtained from the matrices A and B using the fusion method defined by METHOD. The matrices A and B must be of same size. The output matrix C is of the same size as A and B.

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Available fusion methods are Simple, where METHOD is

'max' : D = abs(A) abs(B) ; C = A(D) + B(~D)

'min' : D = abs(A) abs(B) ; C = A(D) + B(~D)

'mean' : C = (A+B) / 2 ; D = ones(size(A))

'rand' : C = A(D) + B(~D); D is a boolean random matrix

'img1' : C = A 'img2' : C = B

Parameter-dependent where METHOD is of the following form:

METHOD = struct('name',nameMETH,'param',paramMETH)

where nameMETH can be

'linear' : C = A*paramMETH + B*(1-paramMETH),

where 0 paramMETH 1

'UD_fusion': Up-down fusion,

with paramMETH 0

x = linspace(0,1,size(A,1));

P = x.^paramMETH;

REFERENCES

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