#176 - Lecture or Poster

A Software For Surgical And Radiotherapy Planning Through Multimodal Brain Image Registration And Fusion

Clinical Applications / Surgery and Subspecialties / Oncologic surgery

Sandra Morales[1], **Valery Naranjo**[1], Alvar-Ginés Legaz-Aparicio[2], Jorge Larrey-Ruiz[2], Angela Bernabeu[3]

1. Universitat Politècnica de València, Valencia, Valencia, Spain
2. Universidad Politécnica de Cartagena, Cartagena, Murcia, Spain
3. Inscanner S.L, Unidad de Resonancia Magnética, Alicante, Alicante, Spain

keywords:Brain Image Registration, Brain Image Fusion, MRI, PET, FMRI, DTI, MRS

Purpose:
Intracranial neoplasms are a health problem that affects people of any age with different etiology, prognosis and treatment. The combination of anatomical, functional and molecular images provides clinicians additional information and can help them to determine the best strategy in every case.

This work presents an interactive medical tool for supporting clinical decisions about the treatment of brain pathologies through intra-patient multimodal image registration and fusion. The tool is useful for surgical planning, by selecting the type of image to be fused in order to optimize biopsy acquisition or tumor excision, as well as for radiotherapy planning, by better establishing the tumor limits so that the distribution, location and infiltrative pattern of lesion is known.

This software is able to register and fuse a Magnetic Resonance Image (MRI) with a Positron Emission Tomography (PET), functional Magnetic Resonance Image (fMRI), Diffusion Tensor Image (DTI) and Magnetic Resonance Spectroscopy (MRS). MRI provides high-resolution anatomical information of the brain. PET is used to visualize tissues with increased metabolism and can detect tissue changes before these can be seen in their structure. fMRI measures brain activity by detecting associated changes in blood flow. DTI allows to detect changes in myelination that prevent normal water diffusion in the brain. MRS lets determine the concentration of brain metabolites.

The final result is a visualization 2D /3D of the spatial distribution of the anatomical, functional and molecular images which facilitates diagnosis, interpretation and posterior surgical or radiotherapy planning. The goal of the tool presented in this paper is to provide radiologists and surgeons as much information as possible to perform therapies, biopsies and/or surgeries.

Methods:
Image registration is the process by which a reference dataset and a template dataset, that are captured at different times, from different points of view and/or by different sensors, are aligned though a global and/or local transformation in such a way the transformed template matches the reference [1]. Medical image registration is mainly used for combining intra-patient image modalities, comparing patient data with anatomical atlases and analyzing lesion evolution. The presented CAD software performs intra-patient multimodal registration. This type of registration is called multimodal due to the different contrast and intensity values of the image modalities. The most important part of multimodal registration process is to find the one-to-one correspondence between images, when the correspondences are usually not visible in the different imaging modalities. In general, spatial resolution, signal-to-noise ratio and contrast in functional images is lower than in anatomical images, being brain structures very fuzzy and imprecise in fMRI and DTI and, even more, in PET images. In the case of MRS studies, metabolic brain maps are generated through a spectroscopic tool, named IMFUTEC [2]. This tool performs a previous registration between the spectroscopic data and the MRI that is simultaneously acquired by the same scanner. Both datasets belong to the same spatial location. If the metabolic map wants to be registered with other MRI, the proposed software must only perform a registration between the two MRIs and apply the same transformation to the metabolic map before fusion. Due to the fact that DTI does not have enough information shared with MRI, the same procedure performed with MRS is followed for DTI, i.e, instead of performing a DTI-MRI registration, the MRI simultaneously acquired with the DTI is registered with the other MRI and the resulting transformation is applied to DTI.

The registration method used in the presented software is an implementation in the frequency domain of diffusion registration [3]. This non-parametric registration can be approached in terms of the variational calculus by defining the joint energy functional to be minimized as $J[u]=D[R,T,u]+\alpha S[u]$, where u is a non-rigid displacement field that makes the transformed

template data set (T) similar to the reference data set (R), D is an energy term that measures the similarity between T and R, S is a penalty term which determines the smoothness of the displacement and acts as a regularizing term, and α controls and weights the influence of regularization. It can be solved in the frequency domain by using the d-dimensional Fourier transform. This implementation of variational registration is twice as efficient as the faster and most efficient approach in the spatial domain [3].

Once the images have been registered (MRI with PET, fMRI, DTI and/or MRS), they can be fused to provide complementary information to clinicians either to surgeons or radiologists. The tool allows to modify the transparency of each image for better visualization of all layers.

Results:
To validate the performance of the registration method, three different similarity measures were evaluated before and after the registration procedure: peak signal-to-noise ratio (PSNR), mutual information (MI) and correlation ratio (CR). Table 1 shows the results of several experiments. The results of the registration method used in the tool [3] are compared with those provide by Elastix [4].

Some results of image fusion are depicted in Figure 1.

Conclusions:
The software presented in this paper combines the most used image modalities for brain pathology detection and treatment (MRI, PET, fMRI, DTI and MRS). The result is a 2D/3D anatomical, functional and molecular visualization of the brain able to assist clinicians in surgical and radiology planning. The experiments show that the registration method implemented in this tool gets good results and improves the results provided by Elastix both in registration quality (PSNR, IM and CR) and in less computational time.

References:
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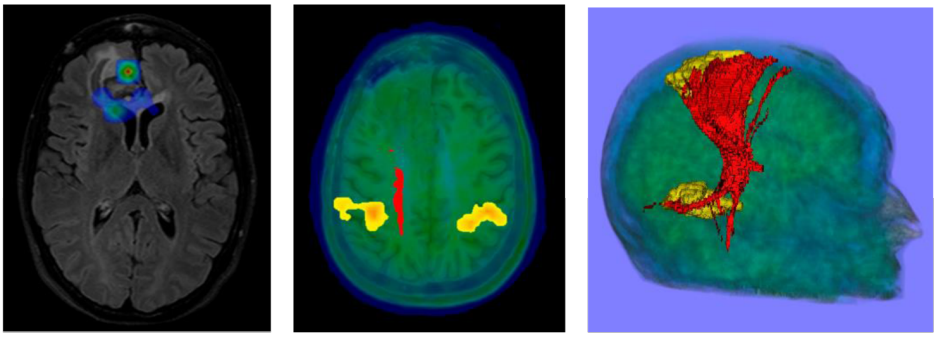
Table 1. Registration results.

		MRI-fMRI	MRI-PET	MRI-MRI
PSNR (dB)	Before registration	21.64	17.29	26.76
	After registration	29.33	27.56	32.56
	Elastix [4]	28.70	26.40	29.78
MI (bits)	Before registration	1.01	0.82	0.92
	After registration	1.24	1.17	1.29
	Elastix [4]	1.17	1.12	1.06
CR (%)	Before registration	64.54	62.85	71.84
	After registration	90.55	88.27	93.58
	Elastix [4]	88.53	85.53	85.18
Time (s)	After registration	71	108	71
	Elastix [4]	126	192	126



(a) (b) (c)

Figure 1. Image fusion results: (a) MRI-MRS (the metabolic map is drawn in red-blue scale on MRI); (b) MRI-PET-fMRI-DTI (MRI in grey scale, PET in red-blue scale with transparency, fMRI in red hot scale and DTI in red colour); (c) 3D view of (b).