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Multi-Modal volume registration by maximization of mutual information [rWVA+96]

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1 Introduction

The paper from Wells (see [rWVA+96]) presents a new idea (in 1996) that is the registration of volumetric medical images of different modalities by maximizing a statistical measure : the mutual information.

The two main ideas are on the one hand the registration of images coming from different imaging process and on the other hand the use of a mutual information in terms of entropy.

The registration works on two images : one of the image is considered as reference image and the other as image to be registered. The authors make the assumption that it exists a prediction function to pass from the reference image to the other one. The maximization of mutual information is iteratively computed on the predicted image and the actual image. After each iteration, the prediction function is corrected to make the registration converge. This method is first introduced in [Vio95].

The method is based on similarity measures between voxels and the idea of using intensity value of voxels has been well presented by Hill (see [HSH94]). The works done by Wells and Viola have been considering a lot the ones done by Hill and Hawkes.

Hill et al. have works on different similarity measures and among others the one developped by Woods (see [WMC93]).

In the section below, each main idea is trace back in the litterature.

2 Maximization of mutual information and information theory

In information theory, there are plenty of measure which can be used to measure similarity between signals, images (2D signals), volumes (3D signals),... Wells in [rWVA+96] has chosen to compare volumes (the one to register and the original one on which is applied a prediction function) with a similarity measure : mutual information.

The formulation used for the calculation of mutual information was defined in terms of entropy in the book of Papoulis (see [Pap91]) (the 3^{rd} edition of a book published 4 times). The entropies has been estimated, the way how to estimate the entropy pass through the approximation of probability density has described by Duda (see [DH73]).

In the paper [Bri90], the authors justify that maximize the estimation of mutual information is equivalent to optimize the relative entropy criterion. The idea of maximizing the estimation of mutual information has been presented in the paper from Bahl [BBdSM86].

With the increase of systems which can create images or signal, record them, capture them from the original world, it is possible to analyse situation, to get information from it. That's what is called theory information. In 1954 (see [Att54]), Attneave has describe some informational aspects of visual perception which are contained in images.

About the fact that similarity measure being calculated in terms of entropy, the first people who describe entropy measure was Shannon. By example in [Sha51], he describe the entropy in a very different subject which is the printed english.

3 Multi-modal volume registration

3.1 Registration and alignment

The idea of register multi-modal volume has been presented by Woods [WMC93], in an automatic fashion. But the methods was an adaptation of a within-modality volume registration[WCM92], so the adaptation requires a pre-processing which consist in manual segmentation of regions to be removed for the iterative process. However Woods was using the similarity measure : variance of intensity ratio of one modality to the second.

First papers about medical volume registration were focused on within-modality image alignment.

In 1990, Alpert et al. (see [ABKC90]) worked on registration of volumes using the first transformations which occur : translation fo center of mass coordinate system followed by a rotation.

In 1988-89, in the same manner than Alpert, Pelizzari et al. (see [PCS+89]) have been working on registration of images using least-squares matching on (brain) surface coordinates.

In 1986, the idea presented by Alpert was already introduced by Gamboa-Aldeco (see [GAFC86]), but it was not volume but surface registration.

The first idea of multi-modal registration arise with the development of medical imaging devices of different modalities. Previously, head-holdings device were used to maintain (non deformable) organs such as brain in the same position and permit the physical alignment as described in [BBE+81].

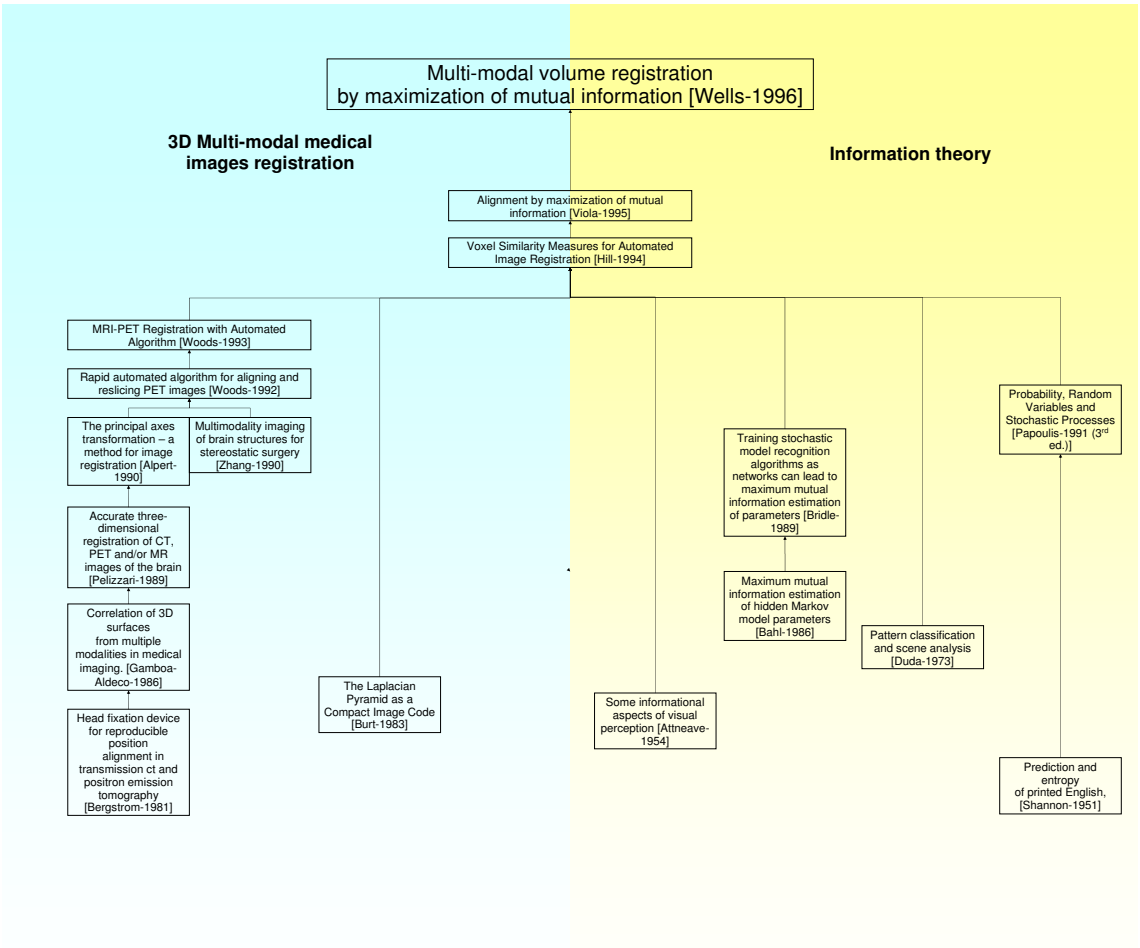
3.2 Image analysis

The underlying problem is the analysis of complementary images coming from different imaging modality in clinical routine. In the paper [ZLW+90], the authors describe a complete image analysis system which use registration with landmarks and allow analysis of 3D - regions of interest (ROI).

3.3 Registration algorithm

The registration as implemented by Wells in [rWVA+96] has been performed in a coarse-to-fine fashion. The idea of representing this problem in a pyramidal manner has been described by Burt et al. in [BEA83]. This methods is appropriate to speed up computation, especially in image processing where volumes have big size. Instead of considering each voxel separatly, the process is done on groups of voxels. Then the similarity measures concern cluster measure.

4 Tree


Multi-modal volume registration
by maximization of mutual information [Wells-1996]
3D Multi-modal medical images registration
Information theory
Alignment by maximization of mutual information [Viola-1995]
Voxel Similarity Measures for Automated Image Registration [Hill-1994]
MRI-PET Registration with Automated Algorithm [Woods-1993]
Rapid automated algorithm for aligning and reslicing PET images [Woods-1992]
The principal axes transformation – a method for image registration [Alpert-1990]
Multimodality imaging of brain structures for stereostatic surgery [Zhang-1990]
Accurate three-dimensional registration of CT, PET and/or MR images of the brain [Pelizzari-1989]
Correlation of 3D surfaces from multiple modalities in medical imaging. [Gamboa-Aldeco-1986]
Head fixation device for reproducible position alignment in transmission ct and positron emission tomography [Bergstrom-1981]
The Laplacian Pyramid as a Compact Image Code [Burt-1983]
Some informational aspects of visual perception [Attneave-1954]
Training stochastic model recognition algorithms as networks can lead to maximum mutual information estimation of parameters [Bridle-1989]
Maximum mutual information estimation of hidden Markov model parameters [Bahl-1986]
Pattern classification and scene analysis [Duda-1973]
Probability, Random Variables and Stochastic Processes [Papoulis-1991 (3rd ed.)]
Prediction and entropy of printed English, [Shannon-1951]

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