Techniques For The Deformation Morphology Of MRI Data Using Modifications Of The Kohonen Network Model

Simon J. P. MEARA, John Suckling, Steven C. R. Williams, Tommoy Sharma

1Brain Image Analysis Unit, Department of Biostatistics & Computing, Institute of Psychiatry, de Crespigny Park, London, United Kingdom; 2Guy's, King's and St. Thomas' School of Medicine, Denmark Hill, London, United Kingdom; 3Neuroimaging Research Group, Institute of Psychiatry, de Crespigny Park, London, United Kingdom; 4Section of Cognitive Psychopharmacology, Division of Psychological Medicine, Institute of Psychiatry, de Crespigny Park, London, United Kingdom;

Introduction

In order to make cross-sectional or longitudinal voxelwise comparisons between a number of magnetic resonance (MR) neuroimages, it is necessary to use a registration method to map the images into the same standard co-ordinate system. Such techniques act either in a global sense (i.e. the model used will be the same at every point in the image) or else they permit local registration. A registration method has been proposed[1] which uses a modified Kohonen network (MKN) to perform local transformations based on the neighbourhood context of image pixels. This MKN model has been adapted for the registration of structural magnetic resonance imaging (MRI) data of the brain. Moreover, an alternative neighbourhood transformation is proposed and compared to both the original and modified Kohonen networks.

Methods

Huwer et al. presented a data-driven method for the registration of two-dimensional MR mammographic images based on a modification of the Kohonen network model[2]. The MKN is an artificial neural network in which neurons (vectors containing several image features) are used to represent the pixels in an input image. The mapping of this image onto a template image in a standard co-ordinate system is optimised by successively presenting vectors representing the pixels of the template image to the network. For each template-image pixel, the "distance" between the presented vector and various neurons in the network is calculated as a weighted sum of the differences between the components of the vectors. The neuron giving the lowest value for this distance measure is identified; this neuron (the "winner") is that which is most similar in context to the presented vector. The winner neuron, and its neighbours, are then updated to move more closely resemble the presented vector. After iteratively repeating this process, the spatial components of the neurons in the neural network represent the local transformations necessary for registration.

The modification proposed by Huwer et al. to the original Kohonen network (OKN) is a change to the learning process used to update the network. In the OKN, neighbouring neurons of the winner are updated so that they all move towards the presented vector. In contrast, in the MKN the neighbours are collinearly updated, so that the movement is parallel to the direction in which the winner neuron moves. In both the OKN and the MKN, the magnitude of the movement of a neighbouring neuron is given by the magnitude of the movement of the winner multiplied by a factor which is an exponential function dependent on the spatial distance from the neighbour to the question to the winner.

An alternative modification of the Kohonen network model was investigated, in which the neural network is updated according to elastic properties. This "elastic Kohonen network" (EKN) thus implements techniques which have previously been used in the registration of MR images of the brain[3]. Furthermore, it can be shown that equating the updating process with the deformations of an elastic solid introduces smoothness constraints, eliminating the superposition or "folding" of neurons which can occur by using the learning process of either the OKN or the MKN.

Results

Extensive development of the MKN method was carried out to produce an optimised registration technique. This included investigations into appropriate image features to be included in the information carried by the neurons in the network, such as linear scale-space features[4]. In addition, a number of other algorithm parameters have been defined.

The effect on the performance of the registration of changing the updating procedure has also been studied. The OKN, MKN and EKN methods have been used to register simple geometric images, and also proton density-weighted images of the brain obtained using a fast spin-echo sequence. The results suggest that whereas the performances of the OKN and the MKN are similar, the EKN produces better results than either of these methods in all cases, seen (for example) in a reduction of the root-mean-square error between the output image and the template image.

Conclusions

Results suggest that a modification of the Kohonen network model may be useful for image registration as applied to the deformation analysis of structural MRI data. It has been found that changing the learning process by which the neural network is updated strongly affects its performance. It is contended that updating the network according to elastic properties improves the registration, and also avoids problems that may be created by using either the OKN or the MKN.

Future developments will include the extension of the method to three dimensions, and an investigation into the use of the local deformations produced by the EKN as an alternative metric for assessing cross-sectional and longitudinal differences in subjects with psychiatric disorders.

References
