Automatic Segmentation of Brain Tissues Using CNN in Functional MRI

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Abstract:Accurate segmentation of different brain tissue types is the first step of understanding the neuronal activity in functional magnetic resonance imaging (fMRI).Due to the low spatial resolution of fMRI data and the absence of an automated segmentation approach, human experts require high resolution structural MRI images, which the fMRI data are superimposed on for analysis. The recent advent of high-resolution fMRI, along with temporal characteristic of fMRI data,suggests the possibility of segmenting fMRI image without relying on the higher solution structural MRI image. This work proposes a patch-wise deep learning segmentation method using long-term recurrent convolution network architecture. The proposed method comprises of three stages: spatial feature extraction with convolution neural network, temporal feature extraction with long short-term memory, and brain tissue class prediction with soft max classifier. The proposed method aims to segment five classes in fMRI images, which are gray matter, white matter, blood vessel, non-brain and cerebrospinal fluid. It achieves high accuracy than conventional segmenting algorithms

I.INTRODUCTION

The idea of localisation of function within the brain has only been accepted for the last century and a half. In the early 19th century Gall and Spurzheim, were ostracised by the scientific community for their so-called science of phrenology[1]. They suggested that there were twenty-seven separate organs in the brain, governing various moral, sexual and intellectual traits. The importance of each to the individual was determined by feeling the bumps on their skull. The science behind this may have been flawed, but it first introduced the idea of functional localisation within the brain which was developed from the mid 1800's onwards by clinicians such as Jackson [2] and Broca[3]. Most of the information available on the human brain came from subjects who had sustained major head wounds, or who suffered from various mental disorders[4]. By determining the extent of brain damage, and the nature of the loss of function, it was possible to infer which regions of the brain were responsible for which function.

Patients with severe neurological disorders were sometimes treated by removing regions of their brain. For example, an effective treatment for a severe form of epilepsy involved severing the corpus callosum, the bundle of nerve fibres which connect left and right cerebral hemispheres. Following the surgery patients were tested, using stimuli presented only to the left hemisphere or to the right hemisphere[5]. If the object was in the right visual field, therefore stimulating the left hemisphere, then the subject was able to say what they saw. However if the object was in the left visual field, stimulating the right hemisphere, then the subject could not say what they saw but they could select an appropriate object to associate with that image. This suggested that only the left hemisphere was capable of speech.

II.FUNCTIONAL MRI AND MRS

Since functional magnetic resonance imaging (fMRI) is the subject of this thesis, little will be said in this section as to the mechanisms and applications of the technique, as this is covered later in the chapter. The purpose of this section is to compare fMRI to the other modalities already mentioned, and also to consider the related, but distinct technique of magnetic resonance spectroscopy (MRS).During an fMRI experiment, the brain of the subject is scanned repeatedly, usually using the fast imaging technique of echo planar imaging (EPI). The subject is required to carry out some task consisting of periods of activity and periods of rest. During the activity, the MR signal from the region of the brain involved in the task normally increases due to the flow of oxygenated blood into that region. Signal processing is then used to reveal these regions. The main advantage of MRI over its closest counterpart, PET, is that it requires no contrast agent to be administered, and so is considerably safer. In addition, high quality anatomical images can be obtained in the same session as the functional studies, giving greater confidence as to the source of the activation. However, the function that is mapped is based on blood flow, and it is not yet possible to directly map neuroreceptors as PET can. The technique is relatively expensive, although comparable with PET, however since many hospitals now have an MRI scanner the availability of the technique is more widespread.

FMRI is limited to activation studies, which it performs with good spatial resolution. If the resolution is reduced somewhat then it is also possible to carry out spectroscopy, which is chemically specific, and can follow many metabolic processes. Since fMRS can give the rate of glucose utilisation, it provides useful additional information to the blood flow and oxygenation measurements from fMRI, in the study of brain metabolism.

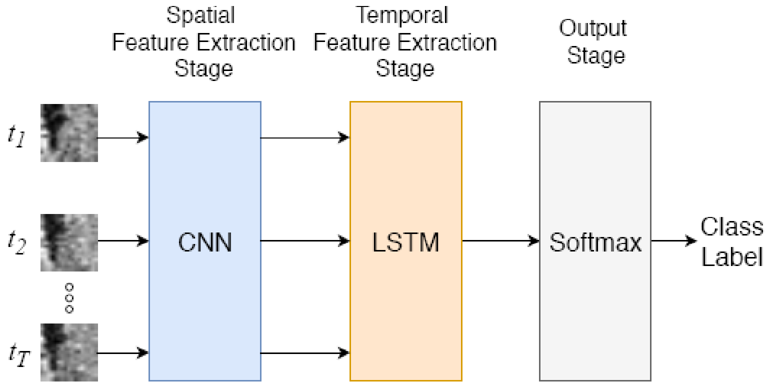

Figure 4.1: Block diagram of the proposed network.

III.RESULT AND DISCUSSION

The brain imaging techniques that have been presented in this chapter all measure slightly different properties of the brain as it carries out cognitive tasks. Because of this the techniques should be seen as complementary rather than competitive. All of them have the potential to reveal much about the function of the brain and they will no doubt develop in clinical usefulness as more about the underlying mechanisms of each are understood, and the hardware becomes more available. A summary of the strengths and weaknesses of the techniques is presented.

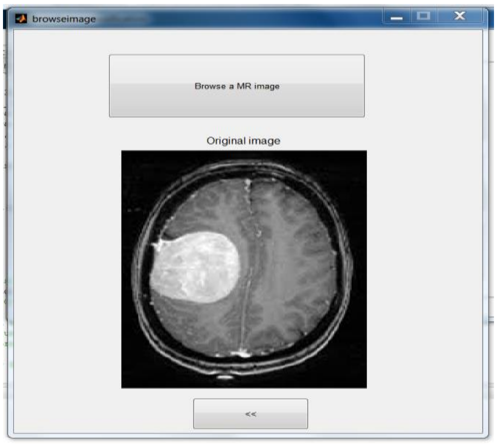

Figure 2 - Input image

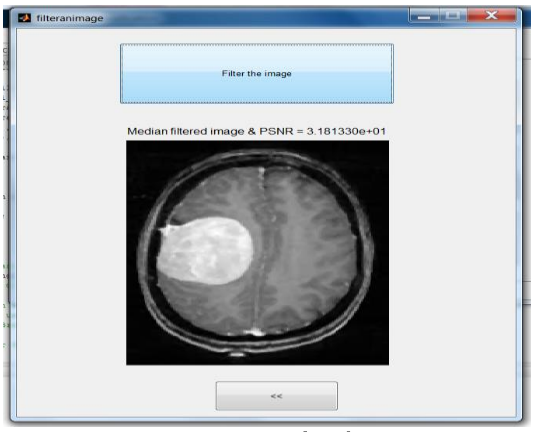

Figure 3- Filtered image

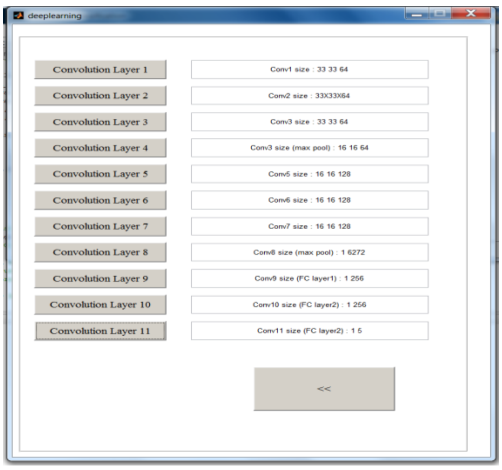

Figure 4 - Layer processing

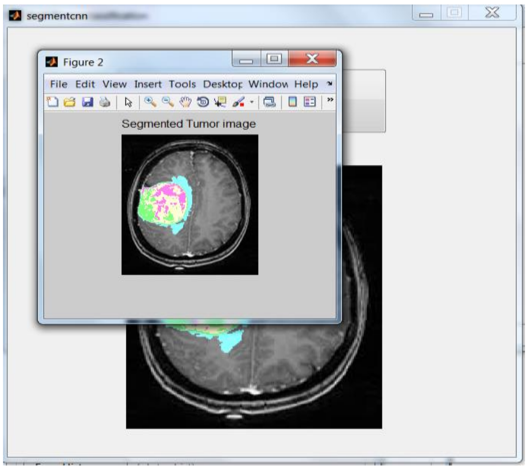

Figure 5 - Segmented result

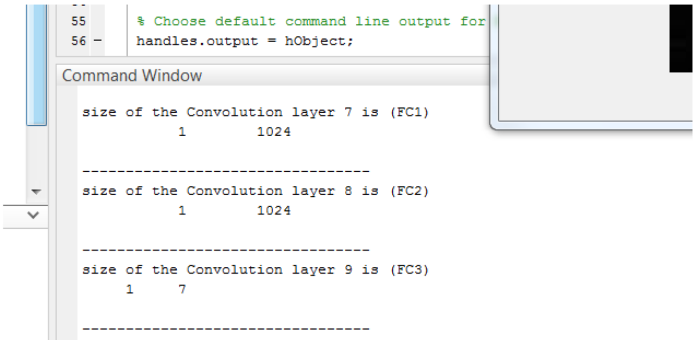

Figure 5 - classification result

The forget gate scales the internal state of the cell before adding it back to the cell as input through self recurrent connection, therefore adaptively forgetting or resetting the cells memory. The modern LSTM architecture also contains peephole connections from its internal cells to the gates in the same cell to learn precise timing of the outputs

IV.CONCLUSION

The main objective of this research is to develop an automated approach for fMRI brain tissue segmentation proposed a novel patch-wise segmentation method based on deep learning for automatic segmentation of brain tissues in fMRI. The proposed method comprises three stages: spatial feature extraction with convolutional neural network, temporal feature extraction with long short-term memory and brain tissue class prediction with softmax classifier. The network was trained using the Adam optimizer with the categorical cross-entropy loss function.Fourth, we conducted experiments to determine the optimum hyperparameters for the proposed method. The proposed method was also compared with several temporal domain and spatial domain classifiers. The experiments were conducted using five-fold cross-validation.

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