Neuroimaging

Improved modelling for three-dimensional scanning

A new computational method can build accurate three-dimensional images of brain activity from near-infrared spectroscopy data

For some medical applications, near-infrared spectroscopy (NIRS) imaging can provide cheaper, more portable alternatives to magnetic resonance imaging (MRI). In particular, NIRS is useful for tracking changes in the blood supply to different parts of the brain. But improving the mathematical models used to interpret NIRS data and construct three-dimensional (3D) images of brain activity has been a key challenge, and one which NAIST researchers have advanced.

When a specific part of the brain is activated, the flow and volume of oxygenated blood in that location peaks dramatically in response. Haemoglobin, the protein in red blood cells that transports oxygen, takes different forms when it is oxygenated and deoxygenated, and these forms absorb near-infrared light to different extents. Hence, NIRS systems that emit and then detect near-infrared light can indicate which parts of the brain are active.

The complex process of combining NIRS data to build 3D images is called diffuse optical tomography (DOT). Recently, Kazushi Ikeda and his colleagues at the NAIST Graduate School of Information Science, together with scientists across Japan, succeeded in improving NIRS-DOT images by enhancing the computational efficiency of the DOT approach[1].

Generally, DOT methods use information from previous states of the brain to calculate new states; in the language of Bayesian statistics, these are called the prior and posterior states, respectively. Conventional DOT models utilize the 'minimum norm estimation' to calculate the posterior state — but this cannot fully account for localized brain activities.

The major advance made by Ikeda and co-workers was to introduce a new type of input state for DOT modelling, called the 'automatic relevance determination' (ARD) prior. They also employed a variational Bayes method to calculate the posterior state more efficiently.

A similar approach had previously been employed for processing data from another brain imaging technology, magnetoencephalography (MEG). However, MEG depends on the brain's magnetic permeability, which is almost constant everywhere, whereas NIRS depends on the optical transparency, which varies with position. This meant the problem faced by the NAIST team was considerably more difficult to solve.

By performing a wide series of numerical experiments using synthetic brain data, Ikeda and his co-workers showed that their new DOT method could create improved 3D images that were robust against variations in optical transparency across the brain. Since their study was published, they have been working to confirm the method using real brain data recorded by more expensive techniques such as MRI.

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Near-infrared spectroscopy data can be used to generate three-dimensional images that indicate which parts of the brain are active at different times.

Reference

1. Miyamoto, A., Watanabe, K., Ikeda, K. & Sato, M. Variational inference with ARD prior for NIRS diffuse optical tomography. *IEEE Transactions on Neural Networks and Learning Systems* (Available online at http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6839041).

More information about the group's research can be found at the Mathematical Informatics Laboratory webpage: http://isw3.naist.jp/Contents/Research/ai-04-en.html