MACHINE LEARNING FOR IDENTIFICATION OF BRAIN ACTIVITY PATTERNS

WITH APPLICATIONS IN GENTLE TOUCH PROCESSING

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by

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The thesis is based on the following papers:

I Malin Björnsdotter, Karin Rylander and Johan Wessberg, A Monte Carlo method for locally-multivariate brain mapping (submitted manuscript).

II Malin Björnsdotter Åberg and Johan Wessberg, An evolutionary approach to the identification of informative voxel clusters for brain state discrimination, in *IEEE Journal of Selected Topics in Signal Processing*, 2008, 2(6), pp. 919-28.

III Malin Björnsdotter, Karin Rylander, Johan Wessberg and Håkan Olausson, Separate neural systems underpin discriminative and affective touch in humans (manuscript).

IV Malin Björnsdotter, Line Löken, Håkan Olausson, Åke Vallbo and Johan Wessberg, Somatotopic organization of gentle touch processing in the posterior insular cortex, in *Journal of Neuroscience*, 2009, 29(29), pp. 9314-20.

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Abstract

Since the first mention of artificial intelligence in the 1950s, the field of machine learning has provided increasingly appealing tools for recognition of otherwise unintelligible pattern representations in complex data structures. Human brain activity, acquired using functional magnetic resonance imaging (fMRI), is a prime example of such complex data where the utility of pattern recognition has been demonstrated in a wide range of studies recently (Haynes et al., Nature Reviews Neuroscience, 2006, 7(7), pp. 523-34).

In contrast to conventional methods, pattern recognition approaches exploit the distributed nature of fMRI activity to achieve superior sensitivities in detecting subtle differences in brain responses. The first objective of this thesis was to implement and empirically evaluate such novel machine learning algorithms for detection and, specifically, spatial localization of regional brain response patterns. Two complementary methods are proposed, namely a Monte Carlo approximation designed for coarse whole-brain mapping, and an evolutionary optimization scheme for refined identification of specific brain regions. As demonstrated on real and simulated data, both methods were more sensitive than conventional approaches in localizing differential brain activity patterns.

The second objective was to utilize these methods to study brain processing of gentle touch mediated by a system of thin, unmyelinated mechanoreceptive C tactile (CT) afferents (Vallbo et al., Brain Research, 1993, 628(310), pp. 301-4). These afferents are thought to modulate affective aspects of tactile sensations, and to act in parallel with thick, myelinated $A\beta$ fibers which signal discriminative information (Löken et al., Nature Neuroscience, 2009, 12(5), pp. 547-8). First, the Monte Carlo algorithm identified differential response patterns due to C tactile and $A\beta$ activation in the posterior insular cortex. Second, the evolutionary scheme revealed a C tactile induced somatotopic insular activation pattern similar to that previously described in relation to other thin-fiber mediated sensations such as pain (Björnsdotter et al., Journal of Neuroscience, 2009, 29(29), pp. 9314-20).

In addition to demonstrating the utility of brain response pattern analysis, the results have a number of implications. The findings support the hypothesis that parallel networks of C tactile and Aβ fibers project affective and discriminative aspects of touch, respectively, and that C tactile afferents follow the projection path of other thin fibers. This further solidifies the hypothesized sensory-affective role of the C tactile system in the maintenance of physical well-being as part of a thin-afferent homeostatic network.

Keywords: somatosensory, machine learning, pattern recognition, fMRI, support vector machines, neuroscience, brain, BOLD, signal processing, artificial intelligence, touch, human, unmyelinated, sensory, affective

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