Computational Sensemaking on Examples of Knowledge Discovery from Neuroscience Data: Towards Enhancing Stroke Rehabilitation

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Abstract. Strokes are often associated with persistent impairment of a lower limb. Functional brain mapping is a set of techniques from neuroscience for mapping biological quantities (computational maps) into spatial representations of the human brain as functional cortical tomography, generating massive data. Our goal is to understand cortical reorganization after a stroke and to develop models for optimizing rehabilitation with non-invasive electroencephalography. The challenge is to obtain insight into brain functioning, in order to develop predictive computational models to increase patient outcome. There are many EEG features that still need to be explored with respect to cortical reorganization. In the present work we use independent component analysis, and data visualization mapping as tools for sensemaking. Our results show activity patterns over the sensorimotor cortex, involved in the execution and association of movements; our results further supports the usefulness of inverse mapping methods and generative models for functional brain mapping in the context of non-invasive monitoring of brain activity.

Keywords: Knowledge discovery, data mining, human-computer interaction, gait analysis, biomedical informatics, infomax independent component analysis.

1 Introduction, Methods and Experiment

Strokes are one of the most devastating of all neurological diseases, often leading to death or at least to physical impairment. There is a growing awareness of the potential for computer-mediated neuro-rehabilitation, which has led to various novel concepts for delivering these therapies (Harwin, Murgia & Stokes, 2011); advances in robotics along with an increased understanding of the latent neurologic potential for stroke recovery led to increasing use of robotic rehabilitation devices, having great potential to deliver efficient and reproducible therapies (Lo et al., 2010). Moreover, robotic therapy can be used to save time and energy for the therapist, making rehabilitation sessions more efficient, and rehabilitation protocols can be tailored to individual

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patients (Scherer et al., 2009). Rehab in practice works, therefore we hypothesize that there is a causal relationship between therapy and brain, supported by incorporation of functional clinical scores (Simonic et al., 2011). However, the biomedical experts are confronted with increased masses of highly complex, multi-variate and often weakly structured data (Holzinger, 2011). The integration of statistical methods and intelligent information visualization, to support sensemaking, thereby decision making is essential (Wong, Xu & Holzinger, 2011).

In this work we applied independent component analysis (ICA), for separating a multivariate signal into additive subcomponents supposing the mutual statistical independence of the non-Gaussian source signals (Comon, 1994), (Boehm, Faloutsos & Plant, 2008). The goal is to express a set of random variables as linear combinations of statistically independent component variables. In our experiment the electro-cortical activity was recorded from 120 channels, equally distributed over the participant's head during walking in a robotic gait orthosis (Riener et al., 2010). Current neuroimaging methods make it very difficult to record bio-signals during whole body movements; as fMRI, MEG and EEG are prone to artefact contamination. Our EEG data was decomposed into 120 independent components and EEG data analysis was performed in Matlab using EEGLAB 8.0.3.5b (Delorme & Makeig, 2004). An equivalent current dipole was calculated for each independent component scalp projection using a standardized three-shell boundary element head model (BEM) (Oostenveld & Oostendorp, 2002). We expected to find a source in central midline areas related to foot movements during walking. This was achieved by the application of expert knowledge about the neurophysiology and the representation of brain processes in the EEG. The independent components were visually inspected by the domain expert and classified into brain related sources and components representing artefacts.

2 Results, Conclusion and Future Research

Our results showed patterns over the sensorimotor area that is involved in the execution and association of movements. To acquire these results we used big data sets of various sources including EEG-data (electrical potentials), MRI Images and 3D-space coordinates of the electrodes positions. Consequently, we acquired a visual representation of the brain activity and mapped this on the subjects' individual anatomy. Infomax independent component analysis proved again to be powerful. Image segmentation, forward- and inverse modeling were necessary to get a set knowledge. Since each of these tools need a set of user defined parameters or boundary conditions the expertise of the user is crucial to provide neurophysiological meaningful results. Constituent and essential was the interactive involvement of an domain expert, who visually inspected and classified brain related sources and components representing artefacts. We consider our work as a small, but important step towards enhancing stroke rehabilitation – to get from data to patient centered therapy. Our results confirm the usefulness of inverse mapping methods for functional brain mapping and generative models in the context of non-invasive monitoring of brain activity. In other terms we showed that we can create knowledge out of big data, by combination of several computational tools and human expertise that is meaningful for known patterns. The next goal of our future research is to interpret this generated knowledge for unknown patterns to provide more information in the context of modeling of the plasticity of the brain after injury, e.g. stroke.

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