1 Introduction

At the outset of this thesis, a brief introduction to functional Near-Infrared Spectroscopy and its advantages will be given for motivation and an objective will be formulated.

1.1 Motivation

Functional Near-Infrared Spectroscopy (fNIRS) is a relatively new technology pioneered by Jöbsis in 1977 [1] that allows non-invasive and continuous measurement of cerebral oxygenation levels using near-infrared light.
The possibility of retrieving spatial functional information of the brain while using non-invasive, comparatively low-cost, compact and hazard-free technology motivated an increasing number of researchers to further investigate the technical as well as the physiological aspects of fNIRS. After Jöbsis' proof of concept, research in the late 1980s and in the 1990s focused on enhancing the understanding of the physiology of the signal, NIRS instrumentation and mathematical concepts. In 1988, Delpy et al. provided a mathematical way to relate the measured NIRS signal to relative oxygenation levels by taking light scattering into account [2]. After this, several NIRS instruments were built with the aim to enhance instrumentation and find ways to obtain absolute oxygenation values [3–6]. In 1993, four research groups independently demonstrated the feasibility of non-invasive brain activity investigation using fNIRS [7–10], followed by an increase of publications using NIRS technology for brain activity studies. From the 2000s until today, the next major step was the design of imaging instruments for brain activity mapping from topographic information: functional Near-Infrared Imaging (fNIRI).
Today, fNIRS and fNIRI have entered neuroscience as a research tool and it has been shown that they are reliable and trustworthy for research based on investigating groups of subjects [11]. This research into NIR based brain activity monitoring is motivated by several potentials as an alternative or addition to functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET):

- fNIRS provides (complementary) information about physiological parameters that are not available in other modalities, e.g. oxygenation information [12] or cytochrome oxidase as marker of metabolic demands [13]
- fNIRS has a higher temporal resolution than both fMRI and PET.
- The equipment is low-cost, small, bed-side applicable, can be made portable and is in general less restraining and therefore

- makes it possible to conduct brain activation studies in clinical offices and under more realistic conditions and is usable for subjects who cannot use fMRI, e.g. are not able to stay sufficiently still [14].
- The equipment can easily be combined with other modalities such as EEG [15].
- fNIRS is electrically isolated and non-ionizing and therefore does not limit the number of scans one can undergo [13].
- fNIRS is robust to motion artifacts.

Other than offering potentially complementary information and new areas of application compared to fMRI and PET, fNIRS seems to be a promising alternative or multimodal expansion to EEG-based Brain Computer Interfaces (BCI) [12, 16–19] with the advantage of being much less sensitive or non-sensitive at all to electrical artifacts in the body.

The increasing interest in fNIRS technology led to the design of several instruments from research groups and first commercial devices on the market. While most of the instruments are static and tabletops, old devices mostly using lasers, high-voltage photo-amplifiers and optical fibers for signal transmission, new technology has become available that allows the instruments to become more compact, safe and even mobile.
Only very few of the devices in up-to-date publications are truly mobile in the sense of being completely worn on the body, enabling free movement. Furthermore, an often reported issue that seems not to be resolved satisfactorily so far is the optode attachment to the head guaranteeing both stable optical contact, sufficient light levels and comfortable wearing [13, 20] as the stable fixation of optodes to the head is one major limitation on accuracy [21].

1.2 Objective

The aim of this work is the design and evaluation of a compact, modular, fully mobile (wireless) multichannel functional Near-Infrared Spectroscopy system for brain activation studies in the field of brain computer interfaces.
At the same time, a mechanical design for optode attachment and system housing is to be designed that allows a comfortable fixation on a subject's head while ensuring robustness of the signal and user mobility.
For instrument analysis and verification, the hardware design is to be characterized and the physiological value of the measured data is to be evaluated by performing standard tests and BCI classification trials.