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Graphical user interface for analyzing radiological data

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ABSTRACT

Brain research is increasingly focusing on critically sampled multimodal data. Due to the complexity of the brain multiple measures are analyzed simultaneously to bring forth a more comprehensive picture of brain functions. Furthermore the data has markedly increased in size, which places new demands for analysis tools. This master’s thesis presents a MRI-compatible multimodal measurement arrangement, a Hepta-scan concept and a toolbox (Nifty) for analyzing the measurements. The concept measures brain (MREG), non-invasive blood pressure (NIBP), electroencephalography (EEG), near infrared spectroscopy (NIRS) and anesthesia data in synchrony. Nifty combines several existing and newly developed software to create a simple access point for all available tools. It includes a database which holds information of a large amount of data obtained in the multimodal measurements. This thesis presents the software and hardware parts of the Hepta-scan concept and explains the workflow in it. Finally the Nifty toolbox design is presented and the functionality of it explained.

Keywords: brain, neuroimaging, multimodal, MRI, toolbox

TIIVISTELMÄ


Avainsanat: aivot, aivokuvantaminen, multimodaalinen, MRI, työkalupaketti
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FOREWORD

The objective of this thesis was to develop a toolbox for processing and analyzing radiological data. The multimodal imaging system and neuroimaging in general proved to be very interesting to work on and provided an appropriate challenge. The project had its ups and downs but ultimately was very rewarding. I would like to thank my supervisors Vesa Kiviniemi and Tapio Seppänen for the thesis topic and continuous support. I also want to thank my coworkers who assisted and encouraged me during the project.

Oulu, 4.5.2016

Niko Huotari
## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAS</td>
<td>average artefact subtraction</td>
</tr>
<tr>
<td>AFNI</td>
<td>Analysis of Functional NeuroImages</td>
</tr>
<tr>
<td>BOLD</td>
<td>blood oxygen level dependent</td>
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<tr>
<td>DC</td>
<td>direct current</td>
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<td>DMN</td>
<td>default mode network</td>
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<tr>
<td>ECG</td>
<td>electrocardiography</td>
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<td>EEG</td>
<td>electroencephalography</td>
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<td>fMRI</td>
<td>functional magnetic resonance imaging</td>
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<tr>
<td>FSL</td>
<td>FMRIB Software Library</td>
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<tr>
<td>GUI</td>
<td>graphical user interface</td>
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<tr>
<td>Hb</td>
<td>deoxyhemoglobin</td>
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<tr>
<td>HbO</td>
<td>oxyhemoglobin</td>
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<tr>
<td>HOMER</td>
<td>Hemodynamic Evoked Response</td>
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<tr>
<td>ICA</td>
<td>independent component analysis</td>
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<td>LED</td>
<td>light emitting diode</td>
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<td>MBLL</td>
<td>Modified Beer-Lambert Law</td>
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<td>MNI</td>
<td>Montreal Neurological Institute</td>
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<td>MREG</td>
<td>magnetic resonance encephalography</td>
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<td>MRI</td>
<td>magnetic resonance imaging</td>
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<tr>
<td>NAP</td>
<td>NIRS analysis package</td>
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<tr>
<td>NIBP</td>
<td>non-invasive blood pressure</td>
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<td>NIRS</td>
<td>near-infrared spectroscopy</td>
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<td>OFNI</td>
<td>Oulu Functional Neuroimaging</td>
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<tr>
<td>QPP</td>
<td>quasi-periodic pattern</td>
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<tr>
<td>RSN</td>
<td>resting state network</td>
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<tr>
<td>SPM</td>
<td>Statistical Parametric Mapping</td>
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<td>VLFF</td>
<td>very low frequency fluctuation</td>
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1. INTRODUCTION

Human brain is a widely studied topic throughout the world. As technology advances and new tools are developed, we have increasing amount of methods and accuracy to measure brain activity. Brain research is a challenging task and has varied approaches for discovering the events that occur below the surface. One of the fundamental problems in neuroscience is to ascertain how physiological events such as breathing or heart pulsations sum up to the retrieved measurement signal from the brain and how to disentangle them from neurophysiological sources.[1]

This thesis consists of a short review of functional neuroimaging background, overview of multimodal imaging concept, Hepta-scan and a radiological data analysis toolbox, Nifty. Hepta-scan setup measures data in MRI environment with multiple modalities of MRI-compatible equipment simultaneously in temporal synchrony. The hardware and software components of the setup are explained and the workflow of the data processing and analyzing is presented. A large amount of data is gathered in this setup. This leads to a need of a tool which can combine several tools for data processing, analysis and keeping track of the data. These tools are integrated as a Matlab toolbox, Nifty and a dedicated database for data information tracking.[1]

The first part of this thesis focuses mainly on the multimodal imaging concept, Hepta-scan which measures the following signals: Magnetic resonance encephalography (MREG), electroencephalography (EEG), near-infrared spectroscopy (NIRS), non-invasive blood pressure (NIBP) and the data from anesthesia monitoring (respiration and electrocardiography (ECG)). This multimodal arrangement is MRI-compatible and allows simultaneous measurement. All these signals are gathered using different devices and their functionality is explained. Data from these modalities go through certain preprocessing pipeline to allow further analysis and some form of presentation of the obtained results.[1]

The second part of the thesis presents a toolbox, Nifty that allows the preprocessing, analyzing and presentation of the measured data of different modalities in the same environment. Nifty integrates several existing and newly developed tools under same access point for easier and faster use. The design and implementation phases of Nifty are presented. The design phase explains the requirements of the toolbox and the overall nature of the project. The implementation phase explains all the toolbox functionalities and presents the layout of the graphical user interface (GUI) elements. The toolbox also utilizes a database to keep track of the measured multimodal information.[1]
2. MULTIMODAL IMAGING

It was originally suggested by Professor Jim Hyde and Bharat Biswal that there should be something meaningful in the blood oxygen level-dependent (BOLD) signal in addition to activation responses. This was later demonstrated by Hyde, Biswal and their co-workers (Biswal et al, 1995) as spontaneously occurring functional connectivity in the form of very low frequency fluctuations (VLFFs) in the BOLD signal. These fluctuations were thought to disseminate the information between brain regions across the hemispheres. In their findings the VLFFs had a high degree of temporal correlation in regions of the sensorimotor cortex that were activated by hand movement concluding that the correlation of VLFFs “is a manifestation of functional connectivity in brain”.[1, 2]

Functional connectivity MRI (fcMRI) has increased in popularity as a new information source on brain pathology. While fcMRI is widely used the neurophysiological origin of the spontaneous brain activity is still relatively unknown. The VLFFs are observed in all of the primary sensory regions (Cordes et al, 1999). As these fluctuations are observed in different regions of the brain the meaningful separation of them becomes an important task. Independent component analysis (ICA) can be utilized separate the functional units of the brain to so called resting state networks (RSNs) and intrinsic regions (Kiviniemi et al, 2003, Beckmann et al, 2005). The RSNs are thought to be most active while the measured subject is not performing any explicit task. These are also called default mode networks (DMNs). Dual regression allows the detection of RSNs for a single subject (Filippini et al, 2009).[1, 3-6]

As the fcMRI increases in popularity and the knowledge behind it begins to spread around the researchers more sophisticated measurement setups come to exist. Multiple additional measurements can be done instead of only measuring the brain. These measurement systems can be called multimodal. The aim of multimodal setups is to link the physiological events of the measurements to those obtained from the brain such as respiration or heart pulsations. When correlating the events between the brain and other sources it is possible to track which areas of the brain has the most correspondence to certain measurement. With this information it can be possible to also map the brain so that which area of the brain has the corresponding signal first and which has it the last. This could give a more comprehensive picture of brain functionality as to in how a certain signal propagates in the brain.[1]

This thesis examines a multimodal imaging setup, Hepta-scan which utilizes magnetic resonance encephalography (MREG) which measures the BOLD signal, electroencephalography (EEG), near-infrared spectroscopy (NIRS), non-invasive blood pressure (NIBP) and the anesthesia monitor data. It has been shown that EEG correlates with BOLD signal (Huster et al, 2012) and it has been shown to correlate also in wide range of frequencies from direct current (DC) to 50Hz (Hiltunen et al, 2014). In addition NIRS (Mesquita et al, 2010) and NIBP (Korhonen et al, 2014) signals have been shown to correlate with functional brain networks. These findings form a foundation for the Hepta-scan concept that there is something meaningful waiting to be found in these modalities when analyzing them with the obtained brain data.[1, 7-9]

The neuronal activity in RSNs of the brain is thought to operate in very low frequency fluctuations (VLFFs < 0.1Hz). A multimodal imaging arrangement located in Oulu University Hospital and maintained by Oulu Functional Neuroimaging
(OFNI) group allows the analysis of the measured data (MREG, EEG, NIBP, NIRS and anesthesia monitor) in these frequencies simultaneously in addition to higher frequencies. This multimodal arrangement is MRI-compatible. This means that the devices and objects used in MR environment are not significantly affected by the MR equipment and the equipment do not affect the quality of the diagnostic information significantly allowing safe and reliable measurements. In addition, all the measuring methods are non-invasive.[1]

2.1. Hepta-scan

The Hepta-scan arrangement (figure 1) consists of MR-system (Siemens 3T SKYRA), NIRS measurement device, EEG BrainAmp system (32 channels), NIBP measurement device and anesthesia monitor. With multiple devices, precise timing is required for accurate analysis. The MR-scanner timing pulse operates in accuracy of milliseconds and is used to synchronize data gathering for NIRS, NIBP and EEG. Anesthesia monitor is timed by the scanner artefacts that are reflected in the ECG-leads.[1]

![Figure 1. Hepta-scan setup.](image)

2.1.1. MREG

The MR-system measures blood oxygen level dependent (BOLD) signal to observe different areas of the brain. It has been ascertained that vasomotor waves such as blood pressure contributes to the BOLD signal. In addition the BOLD signal is altered when there is variability in heart rate and respiration. According to the Nyquist theorem sampling rate should be 2 times faster than the physiological signal or aliasing will occur. Now that the BOLD signal is sampled at a frequency of 0.5Hz
there is an apparent problem which causes the separation of different sources to be difficult due to aliasing. Moreover, head motion during slow scanning produces nearly unrecoverable errors in the data.[1, 10]

Recent technological advances in ultra-high temporal resolution fMRI allow the use of magnetic resonance encephalography (MREG) sequence in the MR-system. The Hepta setup utilizes MREG sequence (Assländer et al, 2013) obtained from Freiburg University (Lee et al, 2013; Zahneisen et al, 2012), which samples the brain at 10Hz frequency allowing 20 times faster scanning compared to conventional fMRI. This enables critical sampling of the brain without aliasing and easier source separation. Hepta system utilizes Siemens 3T SKYRA MR-system (figure 2) with 32 channel head coil.[1, 11-13]

![Figure 2. Siemens 3T SKYRA GUI with MREG as a selected sequence.](image)

### 2.1.2. EEG

The electroencephalography (EEG) records electrical activity of the brain measured from the scalp. EEG data is recorded by using a 32-channel EEG cap, BrainAmp amplifier and BrainVision Recorder (Brain Products). The cap utilizes Ag/AgCl electrodes that are placed according to the international 10-20 system (figure 3). In addition, one of the channels records the ECG which is also obtained from the anesthesia monitor.[1]

The signal quality is tested outside the MR environment. The testing consists of recording 30 second periods of signal both eyes closed and eyes open. For DC-potential measurement the skin potential needs to be removed which is done by stick abrasion (Vanhatalo et al, 2003). The quality of the contact is visualized by BrainVision Recorder (Brain Products).[1, 14]
2.1.3. NIRS

The near-infrared spectroscopy (NIRS) device (figure 4) measures the cerebral blood flow of the brain cortex. The measurement device is attached on the subject’s head and emits light to the brain. The measurement method utilizes high power light emitting diodes (LEDs) to obtain information of hemoglobin concentration changes in the brain. The device distinguishes the concentrations of deoxyhemoglobin (Hb) and oxyhemoglobin (HbO) in synchrony with fMRI. Hb is a form of hemoglobin without oxygen and HbO with the oxygen.[1]

The device can be operated in multiple different combinations of wavelengths such as 660, 830 and 905 nm. At least two wavelengths are used simultaneously. Mainly the wavelengths of 660 and 830 nm are used to measure Hb and HbO concentrations which are chosen from both sides of the absorption spectrum. In between the wavelengths at 800 nm (isosbestic point) the Hb and HbO absorbs the light emitted by LEDs at the same intensity (Sorvoja et al, 2010). Additionally the wavelength of 905 nm can be used to measure the activity of cytochrome aa3.[1, 15]
2.1.4. NIBP

The non-invasive blood pressure (NIBP) device (figure 5) measures the blood pressure non-invasively. Cardiovascular pulses induce tiny movements on the skin. The NIBP device detects these movements from skin surface using two sensors placed on the aortic valve and carotid artery (neck and chest). This allows the calculations of pulse transit time between the sensors, the transition time between each starting pressure pulse and the change in diameter in the carotid. Furthermore, the pulse wave velocity (speed of the pressure pulse) can be calculated (Myllylä et al, 2011) when the pulse transit time and the distance between sensors is known.[1, 16]

The distance of the placed sensors vary between each subject which causes the largest variation in the calculations. The cuff based NIBP from anesthesia monitor is used to calibrate the NIBP device before starting a MRI scan so that the differences in distance and the slight differences of blood flow in arteries between subjects are taken into account.[1]
2.1.5. Anesthesia monitor

Anesthesia monitor (GE Datex-Ohmeda, Aestiva/5 MRI) (figure 6) records ECG, oxygen saturation (SpO$_2$), cuff based NIBP (NIBP$_{cuff}$), respiration (CO$_2$) and its complement (O$_2$). The data is transferred optically and collected by S/5 Collect software with a sampling rate of 300 Hz. The cuff based NIBP is used to calibrate the NIBP device.[1]
2.2. Software

Several software and tools has been developed for the purpose of neuroimaging. Hepta-scan utilizes many of these in the preprocessing, analysis and the presentation of the data. This section contains software tools that are generally used around the world in neuroimaging and in Hepta-scan protocol. Some widely used tools are FMRIB Software Library (FSL), Analysis of Functional NeuroImages (AFNI), FreeSurfer, Hemodynamic Evoked Response (HOMER), Brain Vision Recorder and Analyzer.

2.2.1. FSL

FSL is a software library of tools for analyzing MRI brain imaging data. FSL is a GUI (figure 7) that contains these tools as separate modules. FSL can be used as a command line tool as well. FSL is widely used around the world in neuroimaging and heavily used in Hepta-scan to preprocess and analyze MREG data. In addition to its GUI elements it has over 230 individual command line tools. Few of the common tools that Hepta-scan utilizes are FSL motion correction MCFLIRT, BET brain extraction, MELODIC ICA for component independent separation and visualization tool FSLView.[17]
FreeSurfer is an open source suite of tools for automated analysis of human brain. It is mainly used to quantify the functional, connectional and structural properties of the brain and perform segmentations. Some of the core features of FreeSurfer are volumetric segmentation, segmentation of hippocampal subfields, inter-subject alignment based on cortical folding patterns, segmentation of white matter using diffusion MRI, thickness mapping of cortical gray matter and surface model construction of the human cerebral cortex. FreeSurfer is a command line tool.[18]

2.2.3. AFNI

AFNI is a software package for processing and analyzing human brain in fMRI. It visualizes neural activation maps (figure 8) in brain images in three anatomical planes (axial, sagittal and coronal). These can be viewed simultaneously and multitude of different processing can be done such as correlation calculations and different statistical analysis. For Hepta-scan it is mostly utilized as a viewing tool to show activations in brain. Additionally InstaCorr tool is used to create instantaneous correlation map of the brain data.[19]
2.2.4. **HOMER**

HOMER (figure 9) is a Matlab tool for NIRS data processing and analysis. It is used to calculate hemoglobin (deoxyhemoglobin, oxyhemoglobin and their summation) concentration changes in brain. It features optical wavelength selection, stimulus addition and other instrumental parameters. HOMER requires a NIRS file with appropriate structures such as the measured data and used wavelengths to function. After successful import of the data the hemoglobin concentration changes can be exported to an output file.[20]
2.2.5. **Brain Vision**

For EEG data, Brain Vision products Recorder and Analyzer (figure 10) are used. Brain Vision Recorder records the 32-channel EEG data in raw format during the MRI scan. Brain Vision Analyzer is used to process the raw EEG data and to remove artefacts caused by MRI scanner and cardiac pulsations. The processing includes segmentation, checking of timings and possibly importing the data to Matlab for further processing. In addition there are ICA tools for creating independent components of the EEG data.[1]
2.3. Workflow

Some sort of workflow is present for each modality in Hepta-scan. First the data needs to be preprocessed with some sort of pipeline and software so that it can be analyzed. After preprocessing the data can be analyzed with certain tools. And finally the results can be presented in some way. This process can be divided to three parts: preprocessing, analysis and presentation.

2.3.1. Preprocessing

Some form of preprocessing is needed for all modalities of the Hepta-scan. After the MREG data is obtained from MRI sequence it is preprocessed with FSL pipeline. Motion correction is done with FSL MCFLIRT and after that the brain is extracted with FSL BET. Spatial smoothing is done with fslmaths. MREG data is then registered to MNI-space (Montreal Neurological Institute), which is one of the most widely used coordinate systems in the neuroscience community. The obtained MREG data is sampled at 10Hz which is used as a target sampling rate for all the other modalities to match them temporally.[1]

For EEG data segmentation is done to include only the data that is obtained during the scan and remove data before and after the scanning sequence. After this two major procedures are done: The removal of ballistocardiographic (BCG) and gradient artifacts. These are caused due the magnetic field during MRI scan. Average artefact subtraction (AAS) method (Allen et al, 1998, 2000) is used to remove the artefacts. After the subtraction the EEG data is checked visually to determine whether there are no identifiable artefacts present and the overall quality of the data is passable. All these steps are done using Brain Vision Analyzer. The EEG data is down-sampled to 10Hz to match MREG sampling frequency.[1, 21, 22]

NIRS processing and analysis is mostly done using Hemodynamic Evoked Response (HOMER) software. For this the original measured data needs to be
formatted to NIRS file format which is used by HOMER. The NIRS file is created using a Matlab script that creates the needed structures required by HOMER. In the script additional data information such as used wavelengths, detector distances and possible stimulus is added to the data. Also the NIRS data is down-sampled to match the MREG sampling frequency.[1, 20]

NIBP data is generally calculated from the differences in time between the data obtained from chest and neck sensors. The pulse transit time is calculated between the sensors. This partially reflects the blood pressure. By calculating the pulse wave velocity from pulse transit time we obtain more sophisticated estimation for blood pressure. The NIBP data is down-sampled to 10Hz.[1, 16]

Anesthesia data needs to be timed to the same starting point as MREG (and other modalities). This can be done by appointing the actual start point of the measurement as the same point as where the ECG scanner artifact begins. Using this we can match the timing reliably with other modalities. Anesthesia data is then down-sampled to 10 Hz.[1]

2.3.2. Analysis

For analysis there is a large variety of different software. Matlab is mainly used for simultaneous multimodal analysis. Multimodal analysis consists of calculating correlations, time shifts and plotting the data in any point of time and viewing them. In addition band pass filtering and other processing is usually required for analysis. In usual case the modalities are band passed to VLFs or to same area of frequency as physiological events such as respiration or cardiac pulsations. As separate modalities MREG, EEG, NIRS and NIBP are analyzed in Matlab or with software that are designed just for the purpose of that modality.[1]

The MREG data is usually the main interesting component in the analysis as it is used to analyze the events in brain. It can be analyzed spatially by viewing the brain and temporally by examining the time series. This data can be viewed as activations in the regions of brain. For MREG analysis there are previously mentioned FSL and AFNI which can show these activations. Temporal components can also be calculated for direct comparison with other modalities. Furthermore several tools provide additional approaches for MREG analysis. Such tools are quasi-periodic pattern (QPP) analysis which records cardiac and respiratory pulsations in brain (Kiviniemi et al, 2015), avalanche video creation which creates video files from high-activity peaks observed in MREG data (Rajna et al, 2015) and Higuchi’s fractal dimension analysis (Rubin et al, 2013) which utilizes the fractal dimensions to provide the complexity or pattern information of the brain in different regions. The ways to analyze the MREG data are practically limitless.[23-25]

The EEG data can be compared channel-wise to other modalities after the data has been preprocessed. It is known from which position of the head each channel of the EEG data is recorded from. Though, usually ICA is done for the data using either Brain Vision Analysis or EEGLAB. The reason for this is that the source separation of the EEG signal is very difficult. Even though we know the positions of the electrodes places on the cap, the extracted signals get mixed with each other from all over the measurement area of scalp. As a result the ICA may separate the 32 channel EEG to more “meaningful” components. The analysis consists of mostly correlating and comparing the data directly to other modalities. This can be done for VLF band and above.[1]
The NIRS data analysis is partially done utilizing HOMER software. The raw data is converted to time courses representing temporal changes of the hemoglobin concentrations. The method is based on Modified Beer-Lambert Law (MBLL) (Boas et al, 2001) which assumes global concentration changes. The NIRS data is usually compared or correlated to other modalities, especially to MREG data.[1, 26]

Measurements consisting of simultaneous NIBP and BOLD signals are very rare so the analysis of NIBP data in fMRI terms is in its birth steps. Currently the NIBP data is correlated to other modalities when it is available.[1]

2.3.3. Presentation

For presentation there are plenty of available tools. There is no one correct way to present results. It is always dependent on the measured data, the characteristics of the analysis and intention on how to display the results to support analytical assumptions of targeted areas. An example image (figure 11) showing activation in typically used resting state networks such as DMN_pcc (posterior cingulate cortex) and DMN_vmpf (ventromedial prefrontal cortex) and the corresponding Hepta modalities. In the image the MREG signal (black) is the average time series of these brain networks, EEG signal (blue) is the component that has the highest correlation to the MREG, NIRS signal (red) represents concentration change in Hb and the NIBP signal (green) is the measured blood pressure.

Figure 11. Spatial map of DMN_pcc (top left) and DMN_vmpf (top right) and the measured modalities during the whole scan (middle) and a portion of it (bottom).
2.4. Objective

Hepta–scan multimodal arrangement proposes many challenges concerning the data processing, analysis and presentation. Some preprocessing tools might not be readily available or are slow to use. The analysis tools might not be easily available or are missing features for multimodal analysis. Finally the presentation of the results might be difficult due to scattered tools especially in multimodal simultaneous analysis when the requirements for presentation change frequently. The multimodal measurement system also produces considerable amount of data, which needs organizing. These challenges formed an objective to design some sort of toolbox which would integrate some of the existing tools and add additional flexibility to data handling. This would then lead to the design and implementation of Nifty toolbox.
3. DESIGN OF NIFTY

The initial design for Nifty was a GUI implementation. This would allow multiple tools in same access point and quick usage. In the early stage of development it was decided that the GUI would consist of modules which contained specific tools for that module. The characteristics of Nifty are similar to that of the modular look of FSL.

Several methods for GUI programming were considered. In the end, Matlab was chosen as the development environment. There were several advantages using Matlab. One was there were already existing tools that were Matlab scripts and the inclusion of these tools in Nifty would be relatively smooth. Another one was the signal processing toolboxes available in Matlab which allowed more straightforward approach in many tasks regarding preprocessing and the overall analysis of the data.

3.1. Requirements

The nature of the Nifty design was mostly free from any strict guidelines. Most of the requirements were formed after the implementation phase had already begun as the whole scope of the project was not yet fully realized. Later, it seemed that it was feasible to have some sort of tools for all the workflow steps presented previously in the Hepta-scan segment: preprocessing, analysis and presentation. These formed the initial requirements. For example the toolbox should be able to perform some sort of filtering as a preprocessing step, correlation calculation as analysis step and show results of the analysis in some way. Then it became apparent that the system should have some sort of data information tracking which was later realized as a PostgreSQL database for mostly MREG data. Some existing dedicated MREG tools then formed a loose requirement to integrate these in the toolbox.

3.2. Structure

The structural architecture of the Nifty GUI was planned on an early phase of the development. It was quickly decided that the tools should be included as a separate modules (referred to as blocks) within the main menu of the GUI, similar to FSL. However the actual content of these modules came along at a later phase of the development. The initial architecture after some development consisted of several clearly separate blocks: Database, Preprocess, View and some dedicated MREG tools to which were to be added during the development. These MREG tools were later realized as following blocks: Avalanche, Sicatica, QPP and Fractals. Furthermore a separate NIRS analysis block, Homer was added to the toolbox. The structure became more detailed (figure 12) as the implementation phase went on.
3.3. Database

The main design concept of the database was to include at least the obtained MREG data and that it should contain some relevant information such as date, subject type and other information. The inclusion of MREG data was especially important because the size of the data for one measurement can be several gigabytes. This easily causes the limited amount of hard disks dedicated for research purposes in the hospital network to become full and ultimately the data is then scattered between multiple hard disks or partitions. This creates a need to track where certain types of MREG data are located. Initially the design consisted of only showing the stored information so that the user can do actions based on this information. At a later stage of the development the design changed to also include some easy to use database addition tools.

3.4. Functionality

The measured data is obtained from several machines during the MRI scan. All the data are in different formats and needs some form of syncing to conduct analysis. Even though the syncing is done automatically by trigger signal sent by the scanner all the modalities are measured in different sampling rate which causes some deviations when down sampling all to MREG data frequency (10Hz). Furthermore the signal modalities need to be partitioned to include only the measuring period of the scan. In addition the anesthesia data is manually segmented to correspond with MREG utilizing ECG artefacts. 

Even if there were no strict requirements for the Nifty design, some sort of functionality design was present while maturing during the development process. Initially it was just to be able to view all the modalities in sync in a same figure.
Later on, the functionality design evolved to include signal shifting and correlating to obtain the time shift with the highest correlation (figure 14). These viewing and correlating tools would then form a basis for the View block. In addition, many basic processing steps were integrated to the design such as downsampling and filtering. These formed the beginning point of the Preprocess block which later included several additional tools such as extracting SKYRA/anesthesia data from their specific data formats. At first the database part of the Nifty was considered to exist only as a listing of available MREG data. Later it was decided that it should have its own block for adding the data into the database in addition to only listing the information. To decide which MREG tools to integrate and develop as new blocks was more difficult to envision than the previous ones. Ultimately the need for a certain tool came from a request from a coworker that would spark the development. Additionally there was no clear order in which they were integrated as they all started as a small part of some other tool or were in development simultaneously with other blocks.

The main idea in the functionality design was to keep the design alive still in the implementation phase as there would be more blocks to be added and the existing blocks to be expanded. The blocks named after major workflow steps such as Preprocess and View would continue to expand as the imaginable tools for these were practically limitless.

Similarly, the testing process of the Nifty toolbox was ongoing during the development. In addition to my own testing the GUI tools were tested by coworkers whenever the tools were needed to perform some preprocessing or analysis step. New tools were and implemented in a rapid rate which ensured rigorous testing for the most utilized tools. Similarly the amount of external testing was naturally smaller when a certain tool was not needed as frequently. Testing was a large commitment in this project as the amount of tools and different data types were quite immense. Furthermore, different anomalies in the measured data increased the challenge for testing.

![Figure 13. Hepta-scan data modalities in synchronized form in one figure.](image)
3.5. Security

The measured Hepta data is confidential and not for the public eye. The measured data does not log the names, social security numbers or any other sensitive information of the subject. This information is strictly kept in the same way as other hospital patient information. There is no threat considering sensitive patient information regarding the use of Nifty.

The Nifty GUI is located in a hard disk dedicated to research. The source code is available there but is only readable for users without administrative access. This way the code cannot be altered until the user is an administrator. No sensitive patient data can be revealed but the most damaging aspect would be a harmful alteration of the database content including removal of database entries. However this is only a very small risk as several backups of the database are kept. The database is also accessible only from internal hospital network and requires network user account. The measured data in the server is accessible only for authorized users so the risk for data alteration or deletion is minimal. In addition the database itself is password protected. The loss of the actual measured multimodal data is also well prevented by utilizing regular backups. The weakest link in data preservation is immediately after the measurements (excluding MREG) as the data needs to be manually copied to the server from the measuring laptops. If the hard disk of the measurement machine fails the data is lost unless it is copied to the server. It is important to regularly copy the data to the research servers.

Figure 14. Two signals compared and highest correlating signal shift calculated.
4. IMPLEMENTATION OF NIFTY

Nifty is a toolbox and a GUI which aims to integrate additional processing and viewing tools for easier and faster analysis of multimodal data in Matlab environment. Its main tools are Database, Preprocess, View, Avalanche, Sicatica, Homer, QPP and Fractals. These are shown in the main menu of Nifty (figure 15). We will refer to these as blocks. There are already powerful tools for MREG data analysis. However with multiple modalities it is feasible to use a common ground such as Matlab for simultaneous analysis.

In addition there are other (Other button) toolboxes added to Nifty as a shortcut so that they are easy to access. These are Statistical Parametric Mapping (SPM), NIRS analysis package (NAP) and EEGLAB which are Matlab-based programs and therefore relatively easy and practical to include within the same interface. For users who are not familiar with Matlab these serve as shortcuts to these programs. Nifty offers a guide (Help button) for using these blocks except the additional toolboxes which have their own guides. Nifty guide is presented in Appendix 1.

Figure 15. Nifty main window.
4.1. Database

The Database block (figure 16) of Nifty can be used to browse, search and add to the database. The database contains paths to different data files and holds certain information regarding the scan dates. The database entries contain valuable information regarding different data files such as date, name, type of the data and some other information that is specified for each database table. The block also contains tools to either add new MREG scan date or add new MREG files or MREG group run paths to the database. For adding the MREG data the user only needs to input the path to the file and it automatically extracts relevant information related to it, such as a date and adds it to database. To add new scan date to the database the user needs to input date, amount of subjects scanned that date and type of the subject. For more detailed functionality refer to appendix 1.

![Figure 16. Database block of Nifty.](image)

4.2. Preprocess

The Preprocess block (figure 17) is created as a means to do additional processing to the data which is not done in existing toolboxes. The block is meant to be a vast array of simple tools which are relatively simple to do but also quite slow when you have to do them manually. Preprocess tools can be used for all data types used in Hepta-scan. For example there are tools for creating a Homer compatible NIRS file, preprocessing Skyra/Anesthesia data so that they are instantly readable in Matlab, down sampling a data file, low pass and band pass filtering. For more detailed explanations for all functionality refer to appendix 1.
4.3. View

The View block (figure 18) is intended for viewing and comparing different data. One can view all Hepta data (MREG, EEG, NIBP, Hb and HbO) simultaneously or compare two of them. One can also select data from a file or from a Matlab workspace variable to view and compare them. One of the main tools in View is correlation calculation which computes the best time shift and correlation between two signals. Also for Hepta data we can choose one them as a comparison point and compare other four data types related to it in overlapping time windows.

Some options are available for the selected data: Full band (only for selected Hepta data), smooth and detrend which do additional processing to the data. In addition some basic processing that is often done for multimodal data is included for fast processing purposes. These include band pass filtering, option to view FFT spectrum of any data and resampling of the data.

Anesthesia and Skyra data can be viewed based on date in the Anesthesia/Skyra section. The MREG section allows us to obtain the MREG data of any date and view it in spatial (Voxels) or temporal (Melodic) plane. When using temporal melodic data we can also view the Fast Fourier Transform (FFT) of the data. Also the data is
directly viewable in AFNI and FSL. For further information for the functionality refer to appendix 1.

Figure 18. View block of Nifty.

4.4. Avalanche

The MREG data occasionally shows high activity peaks or co-activation patterns (Liu and Duyn, 2013). These are referred here as avalanches. While avalanches happen regularly and are clearly seen in the data as peaks, its relation to physiological events in brain is not known. In the Avalanche block we choose these as interest points and capture them. We utilize a video creation script (Rajna et al, 2015) to detect these peaks and create video clips from around the activity spreads and create an average video of them for further analysis.[24, 27]
4.4.1. Workflow

The Avalanche block (figure 19) creates the avalanche videos. It requires only a date, Plot & Crop settings and a spatial component of interest. The MREG data is chosen automatically based on the selected date. Plot & Crop settings are used to either test (plot) the data or create the video (crop). The Plot setting shows a plot that shows whether the video script is using correct data and component. The Crop setting creates the actual video clips. The date corresponding to the MREG data can be selected from a list of dates or use the “Select” – button to select it manually. Finally we can run the mainCreateVideo script that runs the script and asks for the IC-components which we want to analyze.

Figure 19. Avalanche block of Nifty.

4.5. Sicatica

Sicatica block is used to compute variable amount of temporal IC components from a chosen spatial IC component. FastICA (figure 20) calculates a large amount of temporal IC components utilizing fixed point algorithms (Hyvärinen, 1999) from MREG data which can be reduced to desired amount. These components can then be viewed and saved. To further analyze these components the sTICA analysis tool can be utilized.[28]
4.5.1. *sTICA* analysis

The *sTICA* analysis tool (figure 21) is included in the Sicatica block. This is an additional tool which can be used to analyze and compare temporal IC components obtained from Sicatica. Usually we utilize anesthesia data to determine which IC components have the most power in certain frequencies to remove these components from the analysis. In here we are interested in signals that have the least amount of physiological noise and leave other signals out. We can view correlation matrices between two temporal IC components with different spatial IC components. These correlation matrices can be used to dictate highly correlating components with the information that which components have the least physiological data in them. Then we can view correlation and time shift between these interesting components with or without band passing the data. For more details refer to appendix 1.
4.6. HOMER

HOMER software (introduced in chapter 2.2.4) is a Matlab tool for NIRS data processing and analysis. It calculates hemoglobin concentration changes in the brain including the Hb and HbO components and their summation. In addition, the calculated components can be exported to a file. HOMER is included in Nifty toolbox as a one of the blocks.

4.7. QPP

The QPP block (figure 22) records cardiac and respiratory pulsations in the brain and creates a video of it. These pulsations are based on a theory (Kiviniemi et al, 2015) that there is a glymphatic convection mechanism in the brain that occurs continuously. The video is created from MREG data which is selected either from the date list or from a file selection dialog. It is recommended that the MREG data is first band passed using AFNI 3dBandpass to exclude frequencies that are not wanted. User can choose to use a reference file if one is available which will find the length of a single pulsation (window length). This can be set manually. In addition the starting point is required. In ideal case the starting point is specified as the point where the first pulsation peak in the MREG data occurs. The algorithm then searches for all of these peak-to-peak pulses and creates an average template from them ultimately creating the video from this average template. Alternatively, the user can also utilize the registering and averaging tool to create an average video from multiple subjects. For more details refer to Appendix 1.[23]
4.8. Fractals

Fractal analysis is one way to analyze MREG data. The Fractals block calculates Higuchi’s fractal dimension for the data to determine the complexity patterns in different regions of brain. There is a study which takes examines the Higuchi’s fractal dimension as a measure of brain complexity (Rubin et al, 2013). The tool (figure 23) provides two main tools for this: voxel based computation which creates a video file showing the complexity changes within brain voxels and melodic IC based computation which shows a matrix with the complexity changes. The user needs to select the window settings (width and step) and a kmax value. The window settings determine the amount of time windows utilized for single voxel or Melodic IC time series. The kmax value determines the value of the maximum allowed complexity value. For additional information refer to Appendix 1.[25]
4.9. Other

Other toolboxes serve as simple shortcuts to SPM, NAP and EEGLAB (figure 24). These are specified as other toolboxes as they are used less often but still contain useful tools. SPM utilizes statistical tools such as generic linear model for analysis. NAP is an analysis package for NIRS. EEGLAB is used for EEG data processing.
4.10. Case study

This section presents a case study which observes all the workflow steps and the overall procedure of one of the Nifty blocks, Sicatica to produce results from MREG data. The MREG data has gone through the FSL preprocessing pipeline. The Sicatica block is used to fetch wanted amount of temporal IC from selected spatial IC. In addition the sTICA analysis can be used to then compare and correlate selected interesting components with each other.

First the MREG data is loaded (prompts the date and components selections) using FastICA GUI (Load data) which separates the data to a varying amount of components. We will select date 20150116 and choose spatial IC component 15 (figure 25) for time-domain ICA based on spatial ICA component. Spatial ICA was done earlier to functionally segment the brain and minimize noise. Temporal ICA is done to do fine-grained analysis of functional signal sources.

![FastICA GUI](image)

Figure 25. Sicatica block. Calculate MREG components using FastICA.

The amount of these components can be reduced (Reduce dim.) to a more feasible amount. In sake of simplicity we will use 10 components. Then the actual ICA can be done (Do ICA) to extract the components for further analysis. Then the component information needs to be brought to local workspace (Save results). User can then view the components using Plot IC_reduced (figure 26) and save (Save IC_reduced) the components to a file. Additionally the saving process will copy the motion data associated with the MREG file which is needed later as we remove noise components from analysis. We will repeat the previous procedure from the beginning once more to get 10 components from spatial IC 32 and save them to a file. Two files are required for sTICA analysis.
In sTICA analysis (figure 27) we select the two data files (TICA1 and TICA2) corresponding to the two previously selected spatial IC. If the user wants to examine only a part of this data it can be cut with Current range selection. After this we search (Search) for the anesthesia data files corresponding to the date. This tool is also in the Preprocess block. It searches the respiration and cardiac components from the found anesthesia data and shows the starting point of the scan (figure 28). The user can check with this that the anesthesia data is utilized from a correct point in the data. Then the power of the noise components (scanner warming, scanner helium pump, respiration, cardiac and motion induced noise) will be calculated (Powers!) and compared to a certain threshold. Then correlation matrices can be viewed (Corr. matrices) which shows all the TICA1 and TICA2 components correlation values with each other. In addition a figure is shown which contain only the components that don’t have too much noise in them (figure 29). As seen the noise exclusion excludes plenty of components but this is usual when observing only 10 components.
Figure 27. sTICA GUI with selected data and searched anesthesia data.

Figure 28. Anesthesia data showing two scans with beginning point marked.
Figure 29. Correlation matrices with (left) and without (right) noise exclusion.

Only one combination was left after the exclusions. For TICA1 it is IC 10 and for TICA2 it is IC6. Then we select these single components in the Causality section of the GUI (seen previously in figure 27). We utilize another Preprocess block feature, Bandpass to perform band pass filtering. We can then perform connectivity analysis by calculating the correlation and phase shift (View block feature) of the selected components (figure 30). In addition, plain signal viewing and its FFT spectrum is available for examination (figure 31). After analysis is finished some sort of results can be presented. In this case study we use an example result image which shows all the noise components and some signal components with their FFT spectra (figure 32).

Figure 30. Two components compared and highest correlating signal shift calculated.
Figure 31. Single component and its FFT spectrum.

Figure 32. Noise and signal components with their FFT spectra.
5. DISCUSSION

The objective of the thesis was to create a GUI and a toolbox for radiological data processing and analysis that was suitable for a unique multimodal data environment. The purpose was to create basic processing tools and some more advanced means for analysis that could be utilized from a single access point. No strict requirements were set at the beginning of the work. In addition, the amount of tools possible to implement for data analysis is practically limitless. These proposed a challenge that some sort of boundaries had to be set as the scope of the project kept expanding as time went on. Ultimately the toolbox had eight base modules consisting either of dedicated single dedicated analysis tools (e.g. Avalanche) or multiple general processing tools (e.g. Preprocess).

The resulting toolbox, Nifty mainly succeeds in what it was set to do but also many points for improvements are easily found. I have seen many Matlab GUI toolboxes for research purposes which all contain different set of tools depending on the type of measurements and data that is used. Similarly, Nifty is a toolbox for pretty much only this multimodal setup and data. Many of the tools cannot be used in different systems unless heavily modified. In addition the database segment of the work is completely attached to the hospital server and the code cannot be used elsewhere in its same form. Additionally some processing tools might not recognize certain data formats or might not have certain checks that the data is in correct format and therefore will not work altogether. It is still a bit difficult for a new user to use Nifty even though there is a guide available. Some sort of additional GUI help messages could be made to ease the use and provide information why certain error might have happened. Errors can also be found as a new batch of data has been created and something is different than the time before.

There are a lot of possible improvements to be made but real benefits have also been already achieved. Images produced in Nifty are often used in the ongoing research. One tool that has been used fairly often is the correlation or shift analysis. It offers a fast way to compare two signals to view the correlations between them with different time shifts. Also many of the preprocessing tools are used regularly for instance to view FFT spectrum of the data quickly or just to do a swift band pass filtering. The database offers information concerning the scanning days so that every user can confirm the subject types, dates and so forth. Some of the preprocessing and viewing tools such as correlation analysis and band pass filtering are included also in some other blocks, such as Sicatica (as presented in chapter 5.10).

The testing process was ongoing during the development. Testing was performed by me and my coworkers who used the toolbox regularly during the development. The majority of the testing shifted to the most utilized tools. This meant that the more frequently used tools could become more refined than some of the less used ones. However, all the functionality has gone through some sort of testing even in case of rare use. The more heavily used tools have more sophisticated error handling as a result compared to the ones that are used less. In addition more specific data selections and handling can be performed. The code modules consisted of already existing code and ones created from scratch. It was easier to further refine the blocks that I developed or heavily modified because I was naturally more familiar with my own code as opposed to an already existing module developed by someone else. Errors and differences in the measured data also created challenges considering testing and the development in general.
There are limitless amount of possible improvements to be made. One could add more help texts to GUI itself. More data types could be allowed to work with no error messages. More tools altogether could be added and the existing tools could generally be improved in many ways. The database could contain additional information. It ultimately boils down to the question of how to use the time and which tool to prioritize over another one as there are already quite many tools and some are used more than other ones. One could say that a tool will be improved whenever there is a new use for it or a new problem with its use is found. These are found all the time and it is getting more difficult to keep track of which tool might have been lacking in some area especially if the focus has been on a different tool or tools for a while.

Generally the project has been very giving. I have had a plenty of freedom to decide which things to include in the toolbox and I got a plenty of great suggestions concerning it. Help was almost always available by email or within the same working space. I was offered a lot of assistance during the development in the form of ideas which helped the project to progress probably a lot better than it could have been without it. It felt great to be a part of a research team that offered meaningful feedback and there was a sense of success when the toolbox could assist in analysis and provide results. During the development I learned a great deal about the multimodal imaging in general, coding, working in hospital environment and medical principles behind many interest points in research.
6. SUMMARY

This thesis presents a multimodal measuring arrangement, Hepta-scan and the implemented toolbox and GUI, Nifty which is designed and implemented to process and analyze the obtained multimodal data. Hepta-scan devices measure magnetic resonance encephalography (MREG), electroencephalography (EEG), near-infrared spectroscopy (NIRS), non-invasive blood pressure (NIBP) and the data from anesthesia monitor (respiration and electrocardiography (ECG)). These devices are MRI-compatible.

The multimodal imaging chapter of this thesis explains the functionality behind the measurement devices and which kind of data is obtained from them. In addition to the hardware components of the setup some main software tools in Hepta-scan and neuroimaging in general are introduced. Finally, the workflow of the system is presented consisting of preprocessing, analyzing and presentation aspects and the challenges they present are observed.

The design and implementation chapters of Nifty present the requirements, structure and the tools that were implemented. The resulting Nifty GUI consists of eight main modules (blocks): Database, Preprocess, View, Avalanche, Sicatica, Homer, QPP and Fractals. The implementation chapter presents all of them in a concise way and explains their functionality. A case study is also introduced which presents an example how all of the workflow steps are utilized in certain case scenario.
7. REFERENCES


8. APPENDICES

Appendix 1. Nifty GUI functionality
Appendix 1. Nifty GUI functionality

**Nifty startup in Matlab:**

Path for Nifty is `/data14/fmri/MREG/HEPTA/gui/`. Few methods to run the main program `nifty.m`:

1. Open Matlab in path given above and write ‘nifty’ in the command window
2. Copy the contents of the ‘gui’ folder to your home directory and run nifty.m from there.
3. Write following in Matlab: `addpath('/data14/fmri/MREG/HEPTA/gui/')`
   After entering the command you can open Nifty from anywhere in path by entering ‘nifty’
4. Create (or modify existing) startup.m file and add a line: `addpath('/data14/fmri/MREG/HEPTA/gui/)` in it. Startup.m file is run when opening Matlab if it is in Matlab path (for example in home directory). Enter ‘nifty’ to command window.

**Main:**

In the main window of Nifty we have the following functionalities/blocks:

- Database
- Preprocess
- View
- Avalanche
- Sicatica
- Homer
- QPP
- Fractals
- Help
- Other

**Database:**

In database block one can view the contents of the database or add new data to it.

Functionality:

- **Browse**: Browse the contents of the database with Matlab browser.
  **Username**: xmreg. **No password**. May require two login attempts.

- **Search database** is used to search information regarding scan dates and location of certain data. Use:
  - **Get dates** –field lists all subject types that have been scanned. For example **Controls** –button shows all controls that have been scanned (dates and amount of subjects). **ASD** –button shows all ASD scans, **Epilepsy** all epilepsy scans etc. **All** (recommended) shows all scans (dates, amount of subjects and their types).
• **Get paths** section is used to search the location of different data modalities in the server. First choose a date from the list. Then choose what file type to search for. For example, **Get MREG path** shows the location of the MREG data corresponding to the chosen date. **All** (recommended) shows locations of all data types at once. **Raw** section implies that the data is not preprocessed (EEG & NIBP). Their location is still viewable.

• **Get groups** lists all group data paths.

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**-Add new scan date to database:** Add new MRI scan to database. How to use:

- Give a scan date (**Enter date**) in format yyyymmdd (example: 20151231).
- Choose the amount of scanned subjects (**Amount of subjects**).
- Choose subject type (**Enter type**).
- Add to database (**Add to DB**).

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**-Add new MREG/group data to database:** Adds MREG file to database. Usage:

- Enter the path to MREG/group data folder (**Full path to MREG dir**).
- Add to database (**Add to DB**).

  If no date detected from the path the program asks for it. Format yyyymmdd (example: 20151231).

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**Preprocess:**

Preprocess block is meant as a fast way to do additional processing for HEPTA data:

**-MakeNIRS:** Create .nirs file from chosen NIRS file (.txt). Used in HOMER. Usage:

- Choose NIRS file (.txt).
- Give NIRS file type (**MREG5**, **MREG10** or **Other**).
- Ask whether to remove samples from beginning. (**No** or **10 sec off**).
- Choose OXY and DEOXY columns. Default: 3, 4.
- Choose wavelengths. Default: 830, 660.
- Saves the result .nirs file.

**-Mannitol:** Normalizes the BBBD NIRS data based on the time point when mannitol is given. It highlights the change in signal caused by mannitol. Usage:

- Give NIRS BBBD file (.txt).
- Give the time point when mannitol is given (in samples).
- Saves the baseline transformation (normalized data) to _bl.mat and _bl.txt files.

**-Skyra/Anesthesia:** Transforms Skyra/Anesthesia data to readable form. Usage:

- Give Skyra (.resp or .puls) or Anesthesia (.asc) file

  1. Skyra: Plots the heart signal (.puls) or respiration signal (.resp), and puts it to Matlab workspace for additional analysis.
  2. Anesthesia: Puts anesthesia data components (respiration (CO2), pulse (Pleth) and ECG) to Matlab workspace for additional analysis.
• Asks if the user wants to save the transformed data.

Skyra: Saves in format *_skyra_spo2.txt (puls) or *_skyra_belt.txt (resp)

Anesthesia: Asks the user which data to save (CO2, Pleth or ECG1).

One can determine the starting point of the scan from ECG (beginning of artefact).

-Best comp: Mainly for EEG. Compares two files (1. file: EEG, 2. file: something else) and finds highest correlating component (column). How to use:
  • Give file 1 (in most cases EEG (32 columns)).
  • Give file 2 (something else (1 column)).
  • Gives the best correlating column and its correlation value.

-Resample: Downsamples data to 10Hz. How to use:
  • Give the original sampling rate of the data.
  • Press resample.
  • Saves the downsampled (10Hz) data to file *_rs.txt.

-ThresholdIC: Fetches IC – component time series from MREG data (filtered_func_data.nii.gz). Usage:
  • Choose date (and single data if multiple choices for that date).
  • Choose IC – component (x).
  • Choose threshold value. Default: 3.
  • Saves the MREG IC – component in format date_MREG_meanbold_ICx.txt

-Melodic: Fetches IC – component time series and FFT – spectrum from MREG data (melodic_mix). Usage:
  • Choose date (and single data if multiple choices for that date).
  • Choose IC – component.
  • Puts the time series (time1) and FFT – spectrum values (fft1) to workspace for further analysis.
  • Can be plotted (PLOT).

-NIBP: Combines NIBP – files (.lvm) to one file and down samples the data to 10Hz. How to use:
  • Combine asks for .lvm – file and combines all .lvm files to one *_trig.txt file.
  • Resample down samples the created *_trig.txt file and saves it with the same name.
  • BP & HR asks for BPHR (Blood pressure/Heart rate) file and plots them.

-Average: Creates an average from multiple files. How to use:
  • Choose more than one file (ctrl + click for multiple file select).
  • Asks for file name that is to be saved containing the averaged data.

-PLOT: Plot the result of previously made action. Example:
• Pressed the Resample –button and got the downsampled result. Now we can press the PLOT –button and view the result as a plot.

-FFT: Plots FFT –spectrum for chosen data. How to use:
  • Asks whether the FFT is calculated for a workspace variable or a file.
  • Write the variable name or choose a file.
  • Write sampling rate of the data (Fs).
  • Plots the FFT –spectrum and shows the highest frequency value in hertz.

-Bandpass filter: Executes bandpass filtering for chosen data in chosen band. Use:
  • Load asks whether the filtering is done for workspace variable or a file.
  • Write the variable name or choose a file.
  • Give a band (Band [Hz]). Default [0.009 0.08] (VLF).
  • Column field can be used if the data has multiple columns. Empty field indicates that the filtering is done to the whole data. By choosing some column the filtering is done only to that.
  • Filter! executes the filtering for chosen band.
  • Save file saves the filtered data in *_.bp.txt format.

-Lowpass filter: Executes lowpass filtering for chosen data with chosen lowpass value. How to use:
  • Load asks whether the filtering is done for workspace variable or a file.
  • Write the variable name or choose a file.
  • Give a lowpass value (Fstop). Default 0.15.
  • Column field can be used if the data has multiple columns. Empty field indicates that the filtering is done to the whole data. By choosing some column the filtering is done only to that.
  • Filter! executes the filtering for chosen band.
  • Save file saves the filtered data in *_.lp.txt format.

View:
The view block is a set of tools to view processed data and compare them. Functionality:
-Hepta: Meant for HEPTA –article data (MREG, EEG, NIBP, OXY, DEOXY, 11 subjects). How to use:
  • Choose MREG IC –component (MREG IC comp).
  • Choose date (Date).
  • The data corresponding to the date can be viewed in View –section. Whole visualizes all Hepta 10min signals and Windowed displays all Hepta data in 2min time windows with 1min overlap.
  • Hepta data can be correlated to each other in 1min time windows (Best corr).
  • When comparing two signals they need to be chosen (Signal 1 and Signal 2).
  • These can be correlated with button Two signal corr.
-Select variables: Select variable(s) from workspace. How to use:
  • Give the variable name and press OK. If more than one variable separate them with colon “,”.

-Select file: Choose a file from computer.

-Selection: This section is meant for the selected data (Select variables or Select file).

-Range: Part of the data can be specified for use. Format start:end in samples (example: 101:2200).

-View: View selected data as a whole (Whole) or in windows (Windowed).
  • Whole shows the all the selected data.
  • Windowed shows the data in user specified windows. Asks for window length in samples and whether to use overlap between windows. If two data chosen they will be correlated in these windows.

-Correlation: Correlate chosen Hepta data to other Hepta data (Best corr). Correlate two signals (Hepta or selected data) and shows correlation in different time points (Two signal corr). How to use:
  • Best corr: Choose Hepta data which is to be compared to other Hepta data. Press Ok. Plots 9 figures, which show the highest correlating Hepta data (top plot) in that time window. The last figure shows all the results from the window figures.
  • Two signal corr: Choose whether to use Whole signal or Specify range. If Specify range is selected give the range in format start:end (example: 1001:2500). Visualizes the best correlating time point between two signals. Shows how many seconds the upper signal is to be moved and which direction so that we get the highest correlation.

-Options: Here we can preprocess data. Press before selecting anything else!
  • FB is meant for Hepta data. When pressed the Full Band data is used.
  • Detrend executes Matlab –function ‘detrend’ which removes a trend from signal.
  • Smooth smooths the data.
  • Tools. Work in progress.

-Processing: Data can be bandpassed (BP), downsampled (Resample) and the FFT spectrum can be analyzed (FFT). The results can be analyzed for example in View -> Whole. How to use:
  • Bandpass requires the band (Band) in format [x y] (default: [0.009 0.08]). After this press BP. If the data is not 10Hz the sampling rate is asked.
  • Downsample to 10Hz by pressing Resample. Asks for the original sampling rate of the data.
• FFT spectrum can be analyzed by pressing FFT. Asks for the original sampling rate of the data.

-Anesthesia/Skyra: Here the Anesthesia/Skyra –data can be analyzed. How to use:
  • Choose date.
  • Choose either Anesthesia or Skyra.
  • Press View.

-MREG: In this section we can choose MREG data and analyze it. How to use:
  • Choose date (Date).
  • View motion: Shows the motion data for selected MREG data.
  • AFNI: Shows the selected MREG data in AFNI.
  • FSL: Shows the selected MREG data in FSL.
  • We can inspect certain voxel coordinates in FSL (Voxels). Requires voxel values X, Y and Z. Press View.
  • We can analyze certain Melodic IC –component (Melodic). Choose IC –component from menu Time & Power and press View. Shows the time series and the FFT spectrum. Data can be saved by pressing Save.

Avalanche:
Avalanche block creates avalanche videos for selected MREG data. Usage:
  • Choose date: Choose date from list.
  • Select: Alternatively select the MREG data manually.
  • Plot & Crop settings: Three options: Plot & Crop, Plot only, Crop only. Plot & Crop shows a testing plot and creates the result videos. Plot only is for testing. Can be used to check that the data and the IC –component are correct. Crop only creates the result videos and no test plot.
  • Run mainCreateVideo: Executes the mainCreateVideo –script (Zalan Rajna). Asks which IC –component is to be analyzed. The user can choose one component or multiple (separate them with colon (example: “5, 20”). Creates videos to the selected MREG data path.

Sicatica:
Sicatica opens the FastICA GUI. It searches from sICA (spatial ICA) component the tICA (temporal ICA) components. Usual usage:
  • Load data: Asks for “ICA group”. Check command window. Asks for a date and loads the MREG data.
  • Reduce dim: Choose the amount of tICA components (example: Range from 1 to 10).
  • Do ICA: Computes the chosen amount of tICA components.
  • Save results: Saves variables to Matlab workspace (for plotting and saving).
- **Plot IC\_reduced**: Plots the IC\_reduced variable (tICA components). Shows the date and the IC – component. Plot the motion vectors.
- **Save IC\_reduced**: Saves the IC\_reduced plot figure and .mat file.

**sTICA analysis**: Can be used to compare two TICA files (.mat). 10min data with 5822 samples. Usage:
- Choose whether to analyze the whole 10min signal or some specified range (Range, default 1:5822). Example: Choose 101:3700 to use samples from 101 to 3700.
- Choose TICA1 file (Select). Can be viewed (Plot).
- Choose TICA2 file (Select). Can be viewed (Plot).
- **Search** finds the anesthesia data corresponding to the TICA files (Pleth & CO2). Asks user for a correct *waves.asc file. Shows the scanning start point in plot if one is found.
- **Powers!** calculates which TICA components have the largest noise powers.
- **Corr.matrices** shows correlation matrices between TICA1 & TICA2.
- **Causality** – section is used to compare single TICA components (TICA1 & TICA2). These can be correlated and compared.
- We can do a bandpass (Bandpass). Give a band (default: [0.009 0.1]) and press Filter.
- **Shifts** shows correlation between TICA signals when they are shifted in time and shows the largers correlation points.
- The empty field determines how many samples the signal is shifted to both directions (default: 50 samples = + 5 seconds).
- **View** – section allows viewing single TICA components as they are and analyze their FFT spectra.

**Homer:**
Homer uses .nirs files made by MakeNIRS. Calculates DEOXY –, OXY – and total hemoglobin concentration changes. How to use:
- Use one .nirs file at a time. (File needs to be where the Homer is used from).
- Toggle **show Stim** off (Resting state).
- Choose channel (Click at channel/”line” to make it active).
- Change **Options** parameters (if needed).
- Run.
- In **Plot** section press Conc selection button to view the results. Can be saved by right clicking the graph and choosing “Export this trace” or “Export all visible traces”.

QPP:
Creates QPP videos from MREG data. The script searches peak-to-peak pulsations in
brain and creates videos based on single or multiple MREG data. QPP video creation
for one MREG data:
  - Choose date: Choose date.
  - Select: Alternatively choose MREG data manually.
  - Reference: Choose whether to use reference file to determine window
    length (WL). Default: None. If no reference used, choose starting point
    and window length manually. Defaults: 1 and 10 (Around 10 for heart
    pulsations and 30 for respiration).
  - Run QPP: Runs the QPP script (made by Xindi Wang) and creates video of
    same length that the window length.

External section contains GUIs for creating 3dBandpassed, registered (masked) and
averaged videos.
3dBandpass executes 3dBandpass for MREG data. How to use:
  - Choose band: Choose band. Default: [0.8 1.2].
  - Path from date: Choose date to determine the MREG data which for the
    3dBandpass is made.
  - Select: Alternatively select the MREG data manually.
  - Input file: Shows the path to the chosen MREG data. Can be inputted
    manually.
  - Output path: Path for the result file. Default: the path where the original
    MREG data is located. Can be inputted manually.

Register/Average is for registration (masking) and for creating average videos. How
to use:
  - Add manually: Choose a file with Select button or write the path
    manually.
  - Add: Add a path to path list (the list determines the files that are to be
    used).
  - Select multiple files: Used when selecting files from different folders.
  Write to How many QPP’s field how many files to use and press Select
files. One alternative is to press the Select files button without any other
selections. Then you can choose a directory which contains all the files. In
this case the files need to be named so that they can be found (example: give “*masked” or “masked*” when asked and the program finds the files
which have this string).
  - Registration: Register (mask) the listed files. Asks the result file name
    and numbers them (format: “givenname1_masked.nii.gz”,
    “givenname2_masked.nii.gz” etc).
  - Averaging: Creates an average video from the registered (masked) files.
    Asks how long the average video is to be made. Finally asks for a result
    file name.
**Fractals:**
Used to calculate fractal dimensions. Calculates the complexity of the signal in brain voxels and compares changes in them between different patient groups and healthy controls. Creates video data utilizing Higuchi’s fractal script (Jussi Kantola) from MREG data. How to use:
- Choose date *(Choose date).*
- Alternatively choose MREG data manually *(Select).*
- Choose window width *(Width).* Default: 500.
- Choose window step *(Step).* Default: 100.
- For voxel coordinates, select Run preparegrid.
- For melodic components, select Run fdslide.

**Other:**
Consists of shortcuts to additional Matlab based analysis software. Currently includes SPM, NAP and EEGLAB.

**Help:**
Shows this text.