# D5.1 – Rapid Prototyping Environment

| Del 5.1 | Executive Summary |
|---------|-------------------|
| This document describes the rapid prototyping environment for the BCI control system. In this document we first describe the hardware consisting of the EEG cap, the active electrodes, the preamplifier g.GAMMAbox and the bio-signal amplifier g.Mobilab+ which is connected via Bluetooth interface to the laptop on which the rapid prototyping software environment is installed. The second part of this document describes the software issues. The main part of the software for the rapid prototyping environment is the SIMULINK driver which allows an easy data acquisition and data analysis using MATLAB/SIMULINK. | |

| **Dissemination Level of this deliverable (***Source: Alias Technical Annex p20 & 22***)** | |
|---|---|
| **PU** | Public |
| **Nature of this deliverable (***Source: Alias Technical Annex p20 & 22***)** | |
| **R&P** | Report and Prototype |

| Due date of deliverable | 31/12/2010 |
|-------------------------|------------|
| Actual submission date | 23/02/2010 |
| Evidence of delivery | Device available |

| Authorisation | | | |
|---------------|--------|--------------|------|
| **No.** | **Action** | **Company/Name** | **Date** |
| 1 | Prepared | GTEC | 23/02/2010 |

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## Contents

## Introduction

The principal goal of ALIAS is to develop a mobile robot system that interacts with elderly users. The system is intended to monitor the users and provide them with cognitive assistance and create connections to their family and friends. The robot will offer several different control interfaces, a touch screen, speech input and an EEG based BCI interface, which has to be adopted and enabled for the dedicated applications and components of the ALIAS robot system. To this end for a fast progress a rapid prototyping environment is necessary. Figure 1 shows the difference between a traditional development process and a rapid prototyping development process. While in the traditional approach the algorithm has to be implemented on a software environment running on a hardware to be designed, with the rapid prototyping approach the developed algorithm can be directly implemented on the target system without further software and hardware development steps.
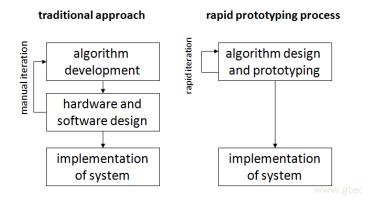


*Figure 1: Comparison of a traditional development approach and a rapid prototyping process*

A rapid prototyping environment for ALIAS has to allow:

- measurements and online analysis of EEG data
- measurements and online analysis of additional physiological data
- sending and receiving commands of the components and systems of the robotic platform developed in ALIAS

In its first version, as it is distributed by M6, the rapid prototyping is designed as EEG/BCI processing system only. The system will be able to acquire EEG data and analyze data in real-time, identify the command which was selected by the user and send the corresponding command string to the other components of ALIAS like the dialog manager, developed in task T3.3, for execution. The system is based on MATLAB/Simulink for fast design iterations and will be installed at specific partner sites developing the ALIAS specific components of the ALIAS robot.

In a later stage of the project the rapid prototyping environment will be extended to record other bio-signals like ECG, respiration, galvanic skin response etc. and extract related features and parameters such as heart rate (HR), heart rate variability, respiration rate, etc. Therefore in Simulink (see *e.g.* Figure 2) the driver for the portable bio-signal amplifier and

the interfaces to the robotic platform used in ALIAS will be available as block sets which allow the partners a fast implementation of real time BCI control strategies.

For measuring the EEG g.GAMMAcaps with locations according to the 10/20 system will be used. Due to the superior data quality which can be achieved, active electrodes will be applied within the project having in mind that the users will move during measurements. Additionally the application of the electrodes is very fast.
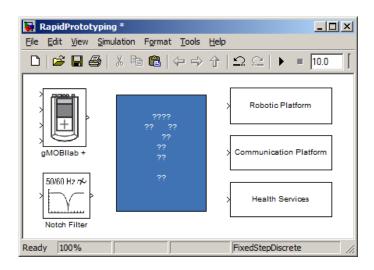


*Figure 2: Rapid prototyping environment under Matlab/Simulink*

Guger Technologies OG supplies the partners with the hardware consisting of

- EEG cap with active electrodes
- Preamplifier for the active electrodes
- g.Mobilab Biosignal amplifier

and the software (except the licenses for Matlab® and Simulink®) as described below.

## Software requirements for the rapid prototyping environment

For running the rapid prototyping environment the following **software requirements** are **necessary**:

- **Matlab Licence**: supported Matlab version: R2009b: Following toolbox is mandatory:
  - **Signal Processing Toolbox**
- **Simulink Licence**: supported Simulink version: R2009b: Following blockset is mandatory:
  - **Signal processing Block Set**

## Rapid Prototyping System

In the following the rapid prototyping system will be described. Therefore the description is separated into hard- and software and in how to use the rapid prototyping environment at the end of the section.
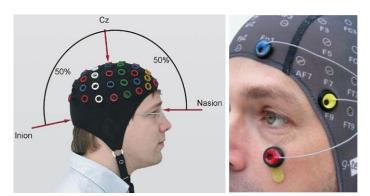
## Hardware description

### EEG cap and EEG cap montage:

EEG electrodes are normally distributed on the scalp according to the international 10-20 electrode system. Therefore, the distance from the Inion (see Figure 3) to the Nasion is first measured. Then, electrode Cz on the vertex of the cap is shifted exactly to 50% of this distance, as indicated on the left picture of Figure 3. However in ALIAS the recently developed g.GAMMAcap as shown in the right picture of Figure 3 will be used. This cap is able to work with active ring electrodes.

The applied system is a single electrode system with the following main properties:

- Advantage: if one electrode breaks down it can be removed immediately.
- Advantage: every electrode montage can be realized easily.

- Disadvantage: all electrodes must be connected separately each time.



*Figure 3: left: EEG cap montage; right: g.GAMMAcap with active electrodes*

### Active electrodes and preamplifier

For the measurements within the ALIAS project active Ag/AgCl ring electrodes (g.LADYbird) as shown in Figure 4 are applied since they show good performance for the application intended to be used. Active electrodes have a pre-amplifier (g.GAMMAbox; see Figure 5) with gain 1 inside the electrode which makes the electrode less sensitive against environmental noise such as power line interference and cable movements. Because of this fact, active electrodes also work if the electrode-skin impedance is higher than for passive electrodes (should be below 10 kOhm). Active electrodes have system connectors to supply the electronic components with power. It is possible to use them for measuring EEG, EOG and EMG. In this cases a double sided adhesive washers can be applied to fix the electrodes to the skin.

For further EMG measurements passive electrodes consisting of the disposable electrode shown in Figure 6 and the ECG electrode cables with clip lead shown in Figure 7 can be applied. The ECG electrode cable is fitted with a 1.5mm medical safety connector which can directly be plugged into the amplifier.

*Figure 4: Active ring Ag/AgCl electrodes*



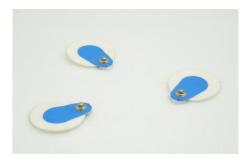*Figure 5: g.GAMMAbox for active electrodes*



*Figure 6: Disposable electrodes*



*Figure 7: Electrode cable with clip lead*

## Biosignal amplifier: g. Mobilab+ EEG



*Figure 8: Portable channel EEG amplifier g.Mobilab+ with Blue-Tooth based connection*

One of the key components of a physiological recording and analysis system is the bio-signal amplifier. Figure 8 illustrates the g.MOBIlab+ amplifier which sends the digitized EEG signal via Bluetooth to the processing unit.

This device has 8 input channels, which are bandpass filtered and digitized with 16 Bits. Then the signals are sent to a controller which transmits the data via Bluetooth wireless connection to the PC.

Table 1: Technical key properties of the g.Mobilab+ EEG and muli purpose biosignal amplifier for BCI operation. summarizes key technical properties of the g.Mobilab+.

## Biosignal amplifier: g. Mobilab+ EEG

*Table 1: Technical key properties of the g.Mobilab+ EEG and muli purpose biosignal amplifier for BCI operation.*

|  | g.obilab+ EEG | g.Mobilab+ Multipurpose |
|---|---|---|
| Signal type | EEG: 8Ch | EEG: 2Ch, EOG/EEG: 2Ch, ECG/EMG: 2Ch, Analog: |
| Number of Channels N | 8 | |
| Sampling rate [Hz] | 256 | |
| Simultaneous sample and hold | Yes | |
| ADC inside amplifier | Yes | |
| #ADCs | 1 | |
| ADC resolution [Bit] | 16 | |
| Interface | Bluetooth 2.0/class I + | |
| Power supply | 4 Standard AA (Rechargeable) Batteries | |
| Operation time on battery [h] | 25-100 | |
| Input Sensitivity | ±500 µV | EEG: ±500 µV, EEG/EOG: ±2mV, |
| Low pass [Hz] | 100 | |
| High pass [Hz] | 0.5 | EEG: 0.5, EEG/EOG: 0.01, ECG/EMG: 0.5, Analog: 0 |
| Derivation | monopolar | bipolar |
| # ground potentials | 1 | 1 per Input Port |
| Applied part | BF | |
| Isolation of applied part | Opto-coupler | |
| Digital I/Os | 8/4 | |
| Scanned with inputs | Yes | |

## Recording setup

The electrodes can be mounted to any position of the cap. The electrodes are then connected to the g.GAMMAbox:

**IMPORTANT: The ground electrode must not be exchanged with the reference electrode!**

The g.GAMMAbox is then connected via the g.GAMMAbox connector to the g.Mobilab+, which is further connected to the laptop on which the required software is installed.

## Software describtion

The signal flow oriented Simulink which runs under MATLAB allows people to create block diagrams for signal processing. Therefore, a hardware-interrupt driven device driver was implemented which sends the data in real-time to the Simulink model (High-speed On-line Processing for Simulink toolbox).

The amplifier is pacing the whole block model, which guarantees the real-time processing. The utilized algorithms represented via the Simulink blocks can be written in MATLAB code or in C code and are called s-functions (system functions).

Simulink provides also a large library of signal processing blocks including filtering, down-sampling, online FFT, which can be integrated by drag-and-drop into the models. A further big advantage is the exchangeability of the blocks. Each Simulink block also represents an encapsulated object which can be used and tested individually.

## System Architecture

Figure 9: BCI architecture with Matlab/Simulink shows the system architecture of the rapid prototyping system. The biosignal amplifier g.Mobilab+ is connected via Bluetooth 2.0 to the laptop. The g.Mobilab+ High-speed On-line Processing for Simulink toolbox is used for the signal processing and paradigm presentation in real-time.

As shown in Figure 9: BCI architecture with Matlab/Simulink on the laptop there are installed

- MATLAB/Simulink with corresponding toolboxes
- Highspeed Processing for Simulink (driver for g.Mobilab+)

The software packages for offline biosignal anaylsis *g.BSanalyze* and for online analysis *g.RTanalyze* are used to extract specific features out of the data and to perform biosignal analysis. The partners can implement their own biosignal analysis in MATLAB and/or in Simulink.
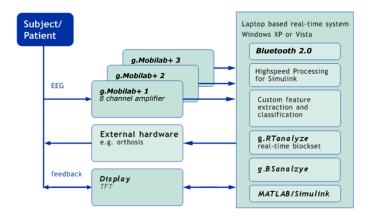


*Figure 9: BCI architecture with Matlab/Simulink*

The interface to the external hardware, the non-ambulatory robot and the ambulatory robot is under development and will be optimized for the robots.

## Using the Rapid Prototyping in MATLAB/Simulink

After installing the Highspeed Processing Toolbox for Simulink, a library called gMOBIlablib is available. The blocks can then be used in Simulink by drag and drop. The library includes 4 blocks (see Figure 10):

- g.Mobilab driver block
- g.Mobilab+ driver block

- 50/60 Hz Notch filter
- Scope Scaler

Before starting the simulation it is necessary to connect the g.Mobilab+ with the laptop, to switch it on and to do the amplifier settings. For explanation of the single settings the reader should be referred to the manual.
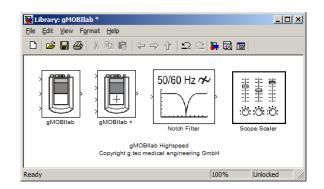


*Figure 10: Simulink library for g.MOBIlab+*

# Conclusion and Outlook

In this deliverable report a brief description of the Rapid Prototyping Environment in a first stage is presented. The rapid prototyping environment allows measuring, processing and analyzing physiological data. Necessary and possible extensions are discussed.

A trainings course for using the system will be suggested to the partners. This training course will include:

- How to set up the BCI interface
- Discussion of the applied hardware
- Learn how a BCI system works

The Rapid Prototyping system is ready for use with EEG and non-EEG measurements. For the work within ALIAS the following extensions are necessary:

- Interfacing of the robotic platform and software components :
  - Selection of the components and applications to be controlled via BCI
  - Definition of the control commands available for each component
  - Definition of the feedback from the robotic to the software environment
- Interfacing of further measurements for integration of physiological parameters and signals like ECG

Therefore g.tec will closely cooperate with the partners in order to define and to implement the interfaces within this rapid