Open smart glasses development platform for AAL applications

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***Abstract*— This paper describes an open platform for multisensory electronic glasses that supports new and enhanced methods for intelligent interaction with patients, with smart objects, or to be used as new data input modalities like proximity sensor or smart textile interfaces. All the activities have been developed, investigated and evaluated within EU CHIST-ERA eGlasses project (http://www.eglasses.eu/). The technological platform of the eGlasses provides a software API to control all input / output devices and to support standardized wireless communication with other Internet of Things (IoT) devices. The software libraries support data processing functions, including evaluation of heart rate from a video sequence, eye tracking in reference to the front camera images, and other AAL-related applications. It was shown that such measurements like ECG, EEG, EMG, and respiration waveform can also be measured using electrodes located on or near the frame of the smart glasses.**

***Index Terms*— Internet of Things, AAL, smart glasses, human machine interaction, perceptual computing**

I. Introduction

Increased life expectancy and decreased birth rates are challenging developed countries worldwide, with a rapidly growing elderly population, and a declining workforce. The Internet of Things (IoT) may provide significant enhancement to the quality of life for the elderly and, in general, people in need, bringing new algorithms, architectures and platforms into Active (Ambient) and Assisted Living (AAL). A peculiar aspect of IoT relies in enabling the collection of massive amounts of data, generated from physical and virtual sensors, things, smart objects and users. As such, IoT is totally functional to AAL, with the pervasive collection of environmental and personal data related to the monitored subjects / objects and their processing. IoT in relation to AAL is also aimed at generating information to be used in different types of applications, from behavioural analysis, to new interaction techniques, action and context recognition.

II. Related Work and Motivation

Miniaturization, constantly decreasing prices and growing connectivity capabilities of mobile sensing technologies have recently led to the convergence of wearable computing and ubiquitous computing [1]. Mobile phones sensing techniques [2] as well as developments on wearable computing based methods for human activity recognition [3] have made significant progress over the last decade.

The technological maturities as well as the high penetration rates of mobile and wearable computing have paved the way for other domains like social psychology and consumer behavior research [4].

Furthermore, increased computational power and availability of multimodal sensors on mobile personal devices (smartphones) has opened numerous possibilities for completely new applications like comprehensive context recognition [5] that can be successfully used for AAL and variety of health management applications [6].

On the software side the progress has been also seen in the area of user-friendly integration of heterogeneous body sensor networks [7] aiming at plug-n-play functionality for end-users despite of often different hardware device vendors.

The state-of-the-art today has finally reached the stage when multimodal sensor fusion allows dynamicity through adaptive activity and context recognition of end-users [8].

However, the user experience (UX) as well as look-and-feel perception of dedicated wearable sensors still often cause different acceptance problems by the end-users. One general way to overcome the denial to use any new technology can be described as embedding the new functionality into commonly accepted UX. The corrective glasses or sunglasses are good examples of commonly accepted UX that is regularly used by significant part of world population. In the recent years, the idea to embed into glasses frame also the front looking camera with the near-to-eye display (for presenting the information acquired by the camera or other sensors) has become popular.

As a result, several smart glasses platforms including Google Glass, Snap Spectacles, Vuzix M100, M300, Vuzix Blade 3000, Epson Moverio BT-100, BT-200, BT-300, ODG R7 AR/R8 and R9, Recon Jet, Solos, Level, Brother AirScouter WD100G, Lumus DK-40, Sony SmartEyeGlass (Attach), Jins Meme [9] have been introduced.

Several new applications are proposed and developed including the ones for AAL and healthcare. For example, Evena Medical developed a modification of smart glasses to identify and overlay the veins in a patient's body [10]. Other smart glasses applications also come from the “quantify yourself” trend and vary from top-level activity classification like differentiation between walking, driving or cycling [11] to high resolution activity recognition like swallowing, chewing or other Activities of Daily Living (ADLs) [12].

III. eGlasses Development Platform

In order to improve acceptability by end-users the eGlasses research project has designed an open platform for multisensory electronic glasses that support new intelligent and enhanced interaction methods for interaction with patients, with smart objects, or to be used as new data input modalities like proximity sensor or smart textile interfaces.

A. Common smart glasses platform hardware components

The eGlasses platform hardware consists of 3 boards with possibility of connecting additional extensions. Block hardware diagram is shown in Fig. 1. Base board, which is located in the left side panel is the system main board. It contains main CPU, RAM, FLASH, radio interface (WiFi and Bluetooth), SD-card slot, MEMS sensors and power supply. This board contains additional interfaces to micro display cameras and similar tools such as GPS, USB OtG and general purpose serial terminal. In the opposite – right panel an extension board is located. It contains additional USB hub and USB-to-serial converter. It provides additional 3 USB ports for extensions and I2C, SPI, USART or GPIO ports. In this panel a LiPo battery is also located. Small T-board is located in front panel, which contains the front visual light camera and FLIR Lepton infrared camera. All boards are interconnected by means of the flexible ribbon connectors.

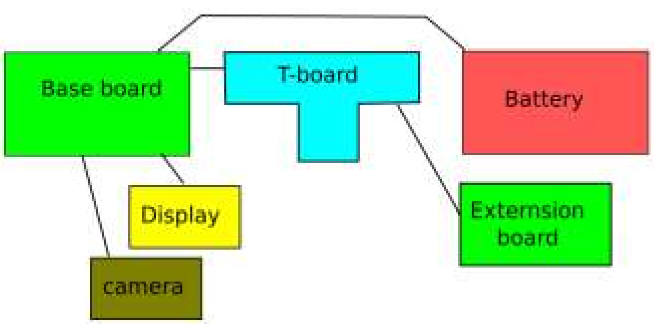


Figure 1: Block diagram of the eGlasses platform

Major advantage of the eGlasses development platform is a possibility to exchange even it's major component such as the main board. So, due to possibility of adding various extensions it is possible to highly customize the platform.

B. Smart glasses platform main boards, component locations and case parts

Two versions of the base board were prepared. The first version is based on dual core ARM SoC – OMAP4460. It was created using already available on market module DART-4460 [www.variscite.com]. The first version of the base board is shown on Fig. 2 and Fig. 3. Basically, this is a holder for theDART-4460 module with external power supplies, MEMS-sensors and all necessary connectors.

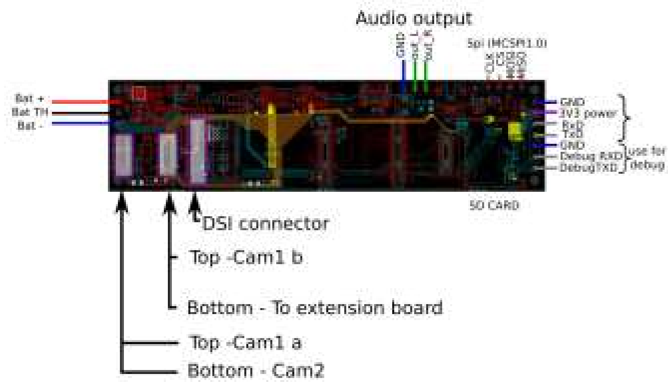


Figure 2: Base board in version 1

Figure 3: Assembled base board in version 1

The board itself is prepared to run under Linux and Android OS as well and can handle up to 3 CSI cameras. Unfortunately, only one camera can be used at the same time due to firmware limitations. Despite of its robustness and flexibility, this board has limitations such as the closed firmware parts, which makes further development difficult. Therefore, it has been decided to design a second more open version of the base board, using the iMX6 quad-core SoC (Freescale – currently NXP).

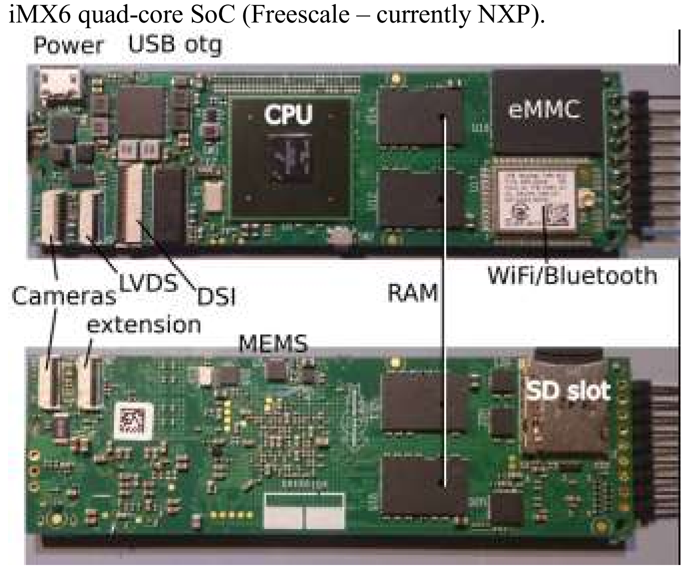


Figure 4: Base board in version 2

Second version, shown on Fig.4, is more powerful and the support from the hardware vendor is much better. Two boards have compatible connectors pin-out and they can be used interchangeably.

Major component location and assembled eGlasses platform is shown on Fig. 5. All parts of the case were either printed using 3D printer or already available on the market (nuts, bolts, etc.).

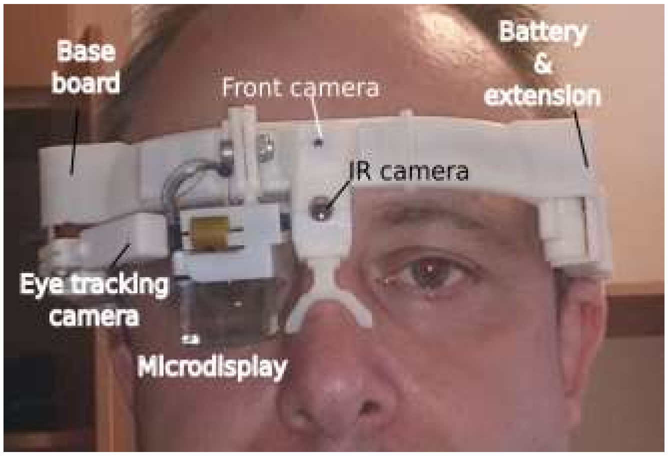


Figure 5: Platform component locations

Additional extensions can be connected using one of serial interfaces that are available. These are: USB otG, 3xUSB, SPI, I2C, 2x USART. One of serial ports is already occupied by the experimental, optical proximity radar. This can for example act as a gesture sensor for the user interface.

eGlasses development platform can also connect to the external IoT gateways and devices using WiFi or Bluetooth interfaces.

IV. AAL RELATED APPLICATION EXAMPLES

The eGlasses platform was designed and implemented to enable the experimental verification of different interaction methods possible for wearable smart glasses. In this section we present a short review of the performed studies.

A. Interaction with recognized people

The cameras of the eGlasses platform were used in experiments focused on recognition of people, description of people, data retrieval for recognized people and remote diagnostics.

Identification of people using the face recognition from images is very popular methodology. The user of smart glasses can use such method to obtain information about the observed person (e.g., "Who is that person") or could also obtained information about some important context (e.g., "Is he my son" – important in dementia or in prosopagnosia). In our studies we developed and verified algorithms for face recognition using the modified Local Ternary Patterns operator [13]. Additionally, we proposed two-steps approach. The result of the first step (face recognition using the modified Local Ternary Patterns method) is the ID of the recognized person. In the second step additional information about the person with the given ID are retrieved from the connected database. Such additional information includes a photo of a person and some personal data (if available). These data are presented on the near-to-eye display and can be used in verification procedure performed by the user (wearer) of smart glasses.

If the identification is verified additional operations are possible. We proposed and in several studies we experimentally verified methods for the estimation of vital signs of the observed person. In our experiments we estimated heart rate, respiratory rate, regularity of pulse and respirations, the presence and length of apnea events, the temperature distribution on face, etc. Such methods are very important for healthcare professional, because they allow collecting important medical information without connection of dedicated hardware to the patient. This is more natural method (no stress, etc.).

The estimation of pulse rate was based on the analysis of video recorded in visible light. The method is based on photo plethysmography. We originally proposed to process data from forehead region using the data from Y or V color component of the YUV color model. The mean difference value between estimated and reference pulse rates for three studies ([14][15][16], 101 video sequences) was (mean ± std. dev.): 1.57±1.30 beats per minute.

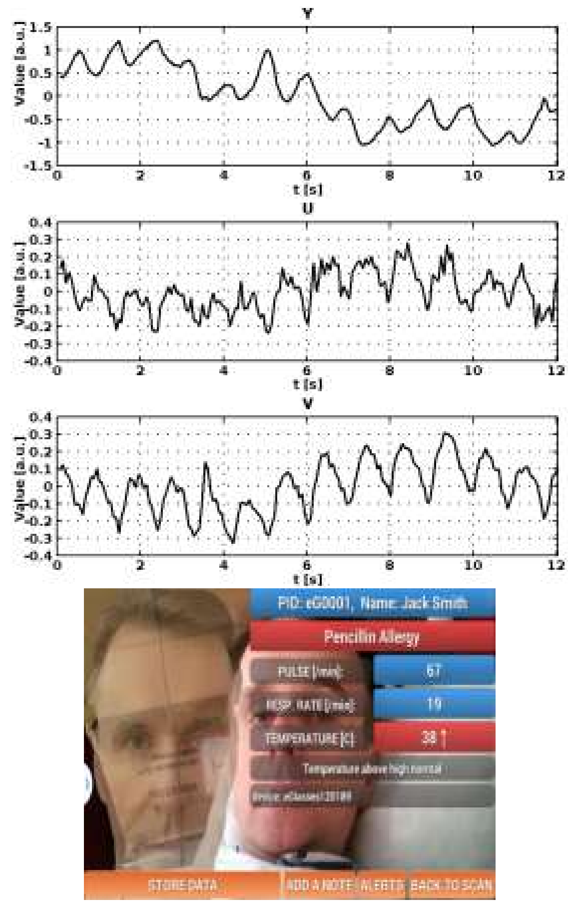


Figure 6: Raw YUV data obtained for forehead ROI and interface generated for the recognized person presentating estimated data

The estimation of respiratory parameters was based on the analysis of thermal sequences. Data collected for mouth and nostrils regions were processed to detect the temperature change due to respiration. In several experiments we proved that the use of small thermal camera (FLIR Lepton, resolution 80x60) is sufficient to obtain reliable results. The mean difference value between estimated and reference respiratory rates for three studies ([17][18][19]) was 0.458±0.449 breaths per minute for experiments were observed people were silent and 2.55±2.37 breath per minute for speaking people.

Additionally, we proposed a method to exchange medical parameters of the recognized person using HL7 FHIR standard (Fig. 7). We experimentally verified three scenarios: 1) data about the recognized person are retrieved from a connected healthcare information system; 2) vital signs estimated using eGlasses are uploaded to the healthcare information system; 3) medical data downloaded from the recognized medical device connected to a patient are annotated using the eGlasses and uploaded to the healthcare information system. It was proved that the whole process could be realized very fast (near to real time).

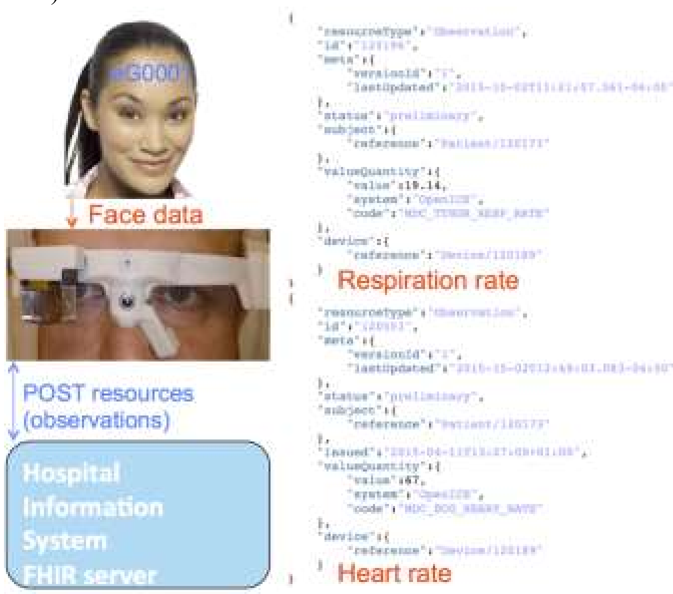


Figure 7: Estimated vital signs encodded using the HL7 FHIR standard for the exchnge with healthcare information system.

Currently, the eGlasses platform is used in experiments to efficiently deliver image data for cloud services providing video recognition algorithms including Microsoft Cognitive Services (e.g. Face API, Emotion API), IBM Bluemix Watson Services, etc.

B. Interaction with smart objects

Interaction of objects assumes that the object is recognized (or discovered) and identified so the connection can be established between smart glasses and the smart object (direct or through the gateway). Different methods for the identification of objects (or spaces like a patient's room) were investigated including: static graphical markers (QR-codes, bar-codes, color-codes, etc.) [20], graphical features of objects (object appearance) [21][22], active markers (LED matrixes, matrixes of heaters for thermal camera) [23], dynamic markers (changing graphical patterns using NIR LED matrixes) [23], etc. It was shown that the different codes can be used for different categories of applications and can be easily processed from short distance (<2m) between the eGlasses and the marker. A movie demonstrating the experiments is available on request to authors.

Two architectures were analysed: with and without smart objects gateway. The use of gateways enables the better scalability of the smart home providing a one interface for the smart glasses. In this work we used the JSON / RPC2 technology to communicate between smart glasses and the gateway. However, the gateway provides the JSON document that represents the interface of the smart object, so the interaction methods can be automatically parsed and used in the client (Android) code. Additionally, the API was developed to automatically map simple services of smart objects to GUI components (e.g. read one value -> Label or Button, etc.).

In experiments using direct connection to smart nodes we used the LinkIt Smart 7688 Duo (MediaTek) modules. Two additional PCB boards were designed and implemented. The first one was providing power supply for the LinkIt module and providing means for power consumption analysis, power control of the connected socket, control of the connected LED lamp (colour change, intensity change) etc. The second module was equipped with a set of sensors to monitor parameters of the local environment: temperature, humidity, noise level, light level, concentration of gases and motion. Fig. 8 presents some examples of the boards and the test environment (two "walls" with the embedded modules. Graphical codes were used to recognize the ID of the node. The developed software API for the eGlasses enables the automatic connection to the WiFi node and starting the interaction procedure (using the generated GUI for the node).

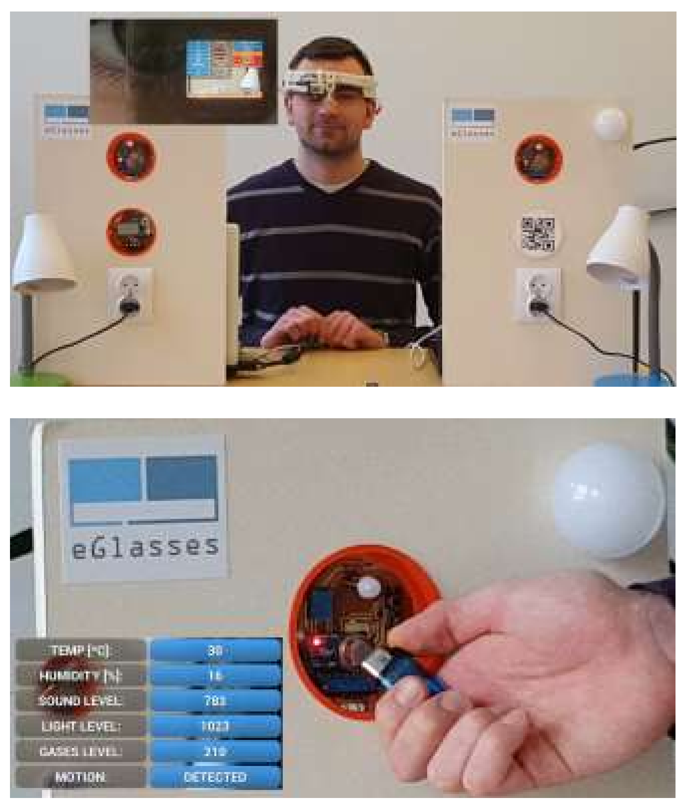


Figure 8: (top) The "walls" with embedded sensor nodes operated by the LinkIt module and automatically generated GUI view for the connected node are shown. (bottom) Demo showing gas detection.

C. User support

The eGlasses platform was used to support a user in some special tasks. The software for colour recognition, simulations and transformations (for dichromate) has been developed and tested using simulated environments (smartphones). The implemented algorithms enable colour naming for a particular object (in the centre of view). The important achievement is data processing in real time for images with simulated colours as observed by dichromate (it can be configured to choose protanopia, deuteranopia, tritanopia); for calculation of colour perception difference between an average observer and observer with a given type of dichromacy; for colour transformations (two methods to modify colours in such way that dichromate can distinguish colour contrast between "unseen" colours). Some examples of software are presented in Fig. 9 and Fig 10. More details are presented in [24].

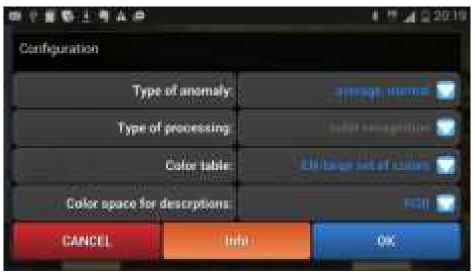
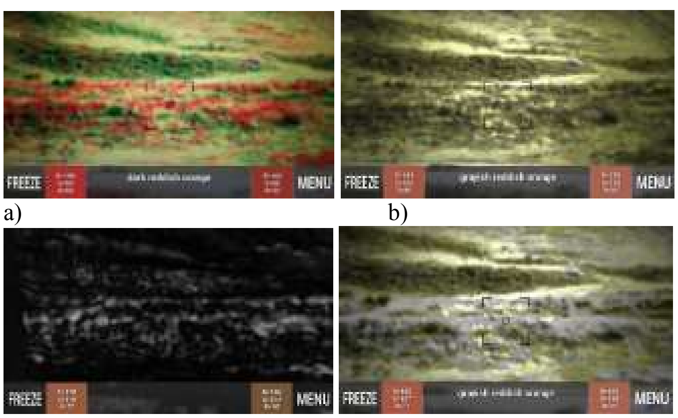


Figure 9: Prototype of colour processing software: a dialog window with configurable options



a) b)

c) d)

Figure 10: a) Colour recognition mode with colour naming – original image b) Simulation of an image observed by a person with protanopia, c) perception difference (average observer vs. person with protanopia) d) transformed colours to observe contrast

The eGlasses can be also a source of valuable medical data related to smart glasses wearer. Therefore, we investigated possible device usage to measure respiratory rate from MEMS sensors data, bio signals from dedicated electrodes placed around the eGlasses frame. Fig. 11 presents some examples of the RAW MEMS sensor data recorded for one volunteer (sitting position). 11 volunteers participated in the study [17]. The respiratory rate RMSE (Root Mean Square Error) obtained for subjects was between 1.73 and 2.99 breaths per minute.

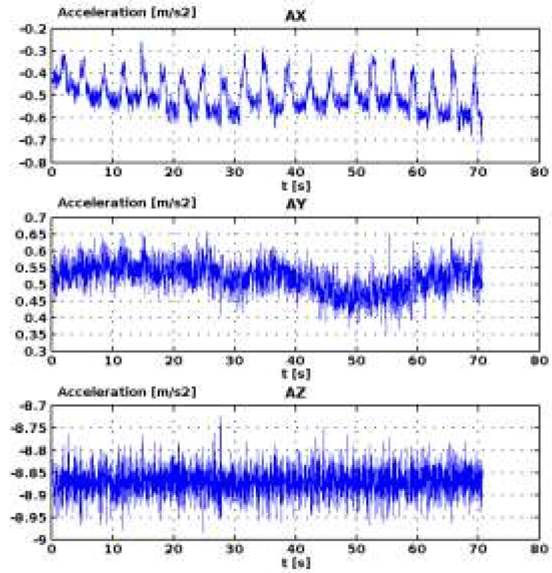


Figure 11: RAW MEMS data recorded for the sitting person (an example for the accelerometer).

It was shown that bio signals like ECG, EEG, EMG, respiratory rate (using a thermistor) can be recorded from the sensors connected to eGlasses.. Some examples of this study are presented in Fig. 12. Please see [25] for details.

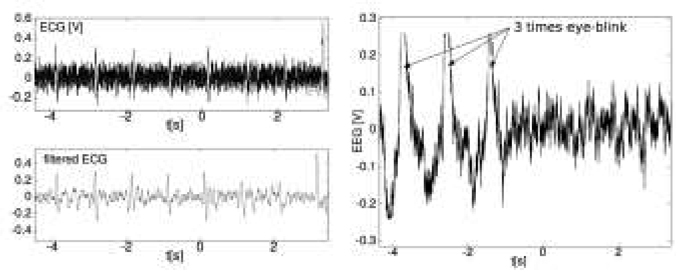


Figure 12: (left) The raw 1-lead ECG signal and its filtered version (right) EEG signal with the visible eye-blink events.

Other methods have been also investigated, for example to analysed the size of the pupil size (e.g. due to some environmental or mental changes). This analysis was possible using the eye-tracking camera of the eGlasses platform.

V. Conclusion

Main contribution of presented work is an open modular flexible SW / HW platform for multisensory electronic glasses for experimental research supporting new and enhanced interaction methods. The prototype of the eGlasses platform is equipped with different input sensors and output devices including corresponding APIs. While developing the platform prototype, the authors could perform several experiments on interaction methods for future AAL and healthcare related applications, assuming that IoT and sensing technologies will allow making the glasses small and comfortable soon. The interaction methods, authors experimented with, include the interaction with recognised persons / objects; face recognition for interaction with patient's data; object detection and initial navigation; eye gaze tracking in reference to the near-to-eye display; colour recognition, labelling and transformations for users with dichromacy; smart textiles user interaction; active proximity sensor usage for gesture recognition and for text entry, context analysis related to eating / drinking activities. Some experiments were also performed to measure biomedical signals and data related to the smart glasses user (wearer). Further eGlasses platform developments and experimental research on interaction methods are planned by authors' team.

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