Multimodal platform for communication, training and health monitoring at home

J. Rumiński, T.Kocejko, A. Bujnowski, J.Wtorek
Department of Biomedical Engineering
Gdansk University of Technology
Gdansk, Poland
jwr@biomed.eti.pg.gda.pl

Abstract—**Health monitoring at home could be an important element of care and support environment for older people. Diversity of diseases and different needs of users require universal design of a home platform. In this work the design of multimodal platform for communication, training and patient monitoring at home is presented and discussed. Two specific problems were investigated: visually guided human-computer interface for immobilized users and GSM-based module for user's home environment monitoring. Results of the camera based eye tracking system shown accepted hit accuracy with longer action time in comparison to traditional mouse. However, user training can highly improve the results. Possible extensions of the tracking and monitoring system are presented.**

Keywords-health monitoring, helth kiosks, human-computer interfaces, wireless sensors

I. Introduction

Health personalization and support for older and immobilized people is actually very important target of many national and international initiatives (e.g. Framework Program 7, Hong Kong "Care for the Elderly 2007 - Active Mind" [http://www.clp-care.com.hk/index-en.html]). Different research areas are connected with those initiatives including "Wearable Sensors (WS)" [1], "Body Area Sensors (BAS)"[2], "Wireless Sensor Networks (WSN)" [3] and telemedicine methods [4]. As a result of this research different sensors and integrated solutions were proposed, usually dedicated for a particular goal. Designing a home platform for support of older or immobilized people different categories of existing and possible components should be considered from particular sensors to central computer stations.

In case of systems with integrated sensors many solutions were proposed like Crossbow IRIS [5], Sun SPOT [6], eWatch [7], Smart-Its [8] or other [9]. Many motes are currently under constructions, however they are usually equipped with embedded sensors (e.g. temperature, light, and location), expending slots (e.g. sandwich model) and communication modules (Bluetooth or based on IEEE 802.15). Dedicated, medical extensions are often proposed like results of CodeBlue project [10], MobiHealth project [11] or UbiMon (Ubiquitous Monitoring Environment for Wearable and Implantable Sensors) project [12]. Typical solutions used for such extensions (or standalone systems) are universal medical diagnostic devices, including ECG, pulsoxymeter, blood pressure/pulse monitors, etc.

Communication interfaces allow data acquisition (especially at home) from motes to a one central station (or a middleware). The central station may be used to process data to assess user state based on many parameters and inform a user relatives or healthcare professional (a nurse, GP) about the patient condition. The central station is often required to limit data processing at sensor node and to build an integrated view on the patient (including ontology based context models [13]).

Human-computer interface (HCI) for older citizens or immobilized people/patients is also very important aspect of the home-based system. Specially designed user-interfaces and interaction devices are often required. This includes different methods of eye-gaze and eye-movement tracking based on Electro-Oculography [14] [15] [16], Limbus, Pupil and Eye/Eyelid Tracking [17][18][19][20][21] Contact Lens Method, Corneal and Pupil Reflection Relationship [22]. A special role for immobilized patients plays Brain-Computer Interface technology [23].

The main goal of this paper is to present a design of the multimodal, integrated platform for communication, training and health monitoring at home. Communication includes technical and functional methods of a user communication with his/her environment as well as processing of alerts from a home/user sensor network. The training is mainly related to promote mental activity of a group of patients in danger (e.g. patients with dementia). Home monitoring is devoted to collect patient-related data and home environment data (e.g. fire detection). The very important aspect of the presented platform, is designing of a central computer station to collect data, process events/alerts, supply a proper human-computer interface, etc. In section II the design of the proposed system is presented. Next results of first module implementations are shown, including human-computer interface for immobilized patient and a module for home environment monitoring.

II. Methods

A. The platform design

Home monitoring of people/patients is a wide term and different applications are possible. Some users are highly

Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2009.6048
http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2009.6048

immobilized (only basic head/eyes communications) others are free to move but suffer dementia. The platform design requires creating a multi-modular system. The most important features of the platform are human-computer interface (or human-platform interface), middleware (e.g. used for data processing) and sensor/communication nodes. Generic platform design is presented in figure 1 as a component-like model.

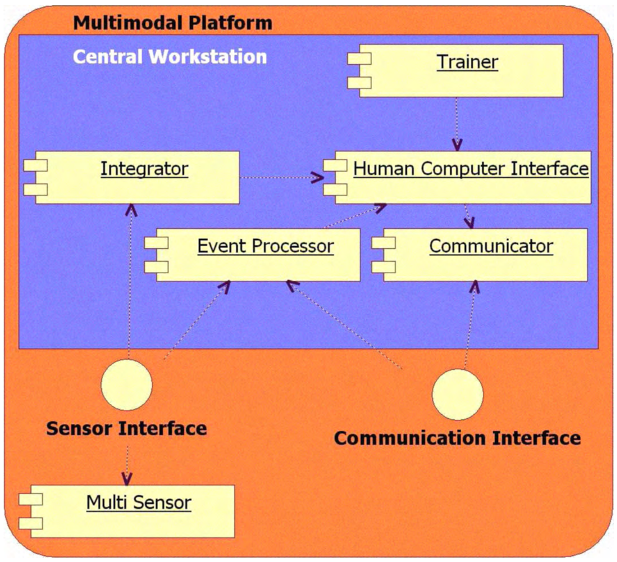

Figure 1. Generic model of the multimodal platform.

The model consists of two parts: central workstation and peripherals presented here using sensor and communication interfaces.

1) Peripherals

Multimodal platform will use different sensors (or multi sensors) to collect information about person/patient state and his/her environment. Different categories of sensors are currently prepared to measure: heart pulse, temperature, body composition parameters (weight, fat content, etc.), glucose concentration, blood pressure, electric heart activity (ECG), and posture activity (accelerometer). Additionally special multi-sensors are considered to design for a particular group of patients (disease-oriented). Appropriate database structure is designed to collect information from each sensor. The one-to-many relationship is used between mother table (directory of sensors) and sensor tables. Each sensor has its own data table (tables). Particular data event is marked using timestamp so it is easy to analyze a set of measurements from many sensors during given period of time. The platform can be easily scaled with a new sensor (multisensory) using plug-in methodology (common interface, XML configuration file, a new data table).

Another group of sensors consists of those related to monitor user environment parameters. This is especially important for older people deciding to live alone without permanent, personal help. Taking into account the privacy of those persons, different sensors can be required to observe fire and gas dangers, humidity/temperature conditions at home, activity of the person, emergency calls (e.g. symptoms of heart attack, ischemia, etc.).

The last group of sensors comprises of those related to Human-Computer Interfaces.

Communication interface in the platform model describes possibility of external communication. At last two modes are required: mobile telephony with a modem and cable Internet connection using ISP link or using cable telephony. Two redundant paths are used for communication with relatives, guardians, health professionals (nurses, GPs), which are configured in the system with appropriate privileges (e.g. to receive information, to request for information, etc.). There are two operating modes: asynchronous and synchronous. In the asynchronous mode information is sent in case of alerts and alarms. This mode is also used to send a rescue message to public services (emergency calls). The synchronous mode is used to send information packages with a configurable frequency or using request-response model. This is a very important aspect which can be used to control application of medicinal products or parameters of current health status.

Communication interface is also used to supply the Internet services for a user. The separate virtual machine is used to separate health and environment related monitoring from Internet activity. A set of Internet services (e-mail, WWW, radio, etc.) could be useful for older/immobilized people to integrate them with society. However, this requires creating new user interfaces.

2) Central workstation

The role of central workstation combines the middleware functionality and HCI (described later). The following functionalities are requested from the central workstation:

- database management,
- sensor data collection and processing,
- events dispatching and processing (e.g. "take a pill" and "no activity alarm"),
- data integration, classification, rules induction and other activity related to create overall person/patient model including his/her environment,
- communication management (e.g. which interface should be used to send a particular message),
- access control and support for other security mechanisms,
- support for mental training (actually discussed with psychologists/neurologists), and
- Human Computer Interface.

B. Human-computer interface

The human-computer interface is one of the most important elements of the platform. The user acceptance of the entire system depends highly on the method how the system can be used by older/immobilized users. Three elementary modes of the HCI were designed:

- Interface based on touch screen,

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http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2009.6048

- Visually guided interface, and
- Audio guided interface.

In the future BCI will be also taken into account.

All interfaces require a new design of the graphical user interface. This includes to prepare a platform front end (with selection of services divided into three groups: emergency, medical, and personal activity), GUI of each service and virtual devices (e.g. keyboard). Visually guided interface is especially designed for this category of patients, which are unable to move. Even in this group there are different subcategories that should be taken into account (patient can use only eyes; patient can move his/her head; patient can move head and a hand, etc.).

We assumed that the platform should also use existing internet services, however, redesigned for the older/immobilized people.

1) HCI implementation

Human-computer interface was first implemented using visually guided "virtual mouse".

A developed system consists of two cameras, frame glasses, an electronic circuit and electro-luminescent diodes (IR LEDs). The head-mounted camera is attached to the frame of glasses while the second camera is mounted on the top of the screen. IR LEDs are used to mark the center of the glasses and to illuminate the tracked eye surface. The screen-mounted camera is used for tracking the IR marker which represents position of a user head. Both cameras used in the project have the same resolution (320x240). The screen-mounted cam is equipped with a day-light blocking filter. The received image can be easily segmented to include only IR marker position. The same procedure can be used for detection of pupil and head positions using the algorithm presented in [20].
In case of patients with mobile head/hand another modification of the system was used. The horizontal head position and movement was used to control the "mouse activity". The control of an eye blinks (with two thresholds of period of time as a measure of user's controlled blink) and/or wrist movements were used to simulate mouse button pressed events and the change of the movement direction (up-down or left-right).
Before using the system it has to be calibrated. The calibration relies on detection of eye positions when it gazes at a chosen set of screen points. It enables to achieve a prescribed relation between particular points on computer screen and corresponding eye positions. The calibration process is necessary to map screen coordinates of borders/corners to the matrix (eye - matrix) storing captured eye image and pupils center coordinates. While the head-mounted camera observes the eye, the screen-mounted one observes and captures the position of IR marker mounted in the center of glasses frames.
The system has been designed to work in two different modes:
- localization of the mouse cursor on the screen according to the user's fixation point,
- movement of the mouse cursor is initiated by the detection of the eye deflection.

The calibration procedure in the latter case may be reduced to detection of the eye position in reference to the screen position and dimensions mapped on the eye.
In case of fixation point detection four corners of the screen have to be projected on the image of an eye (fig. 2).

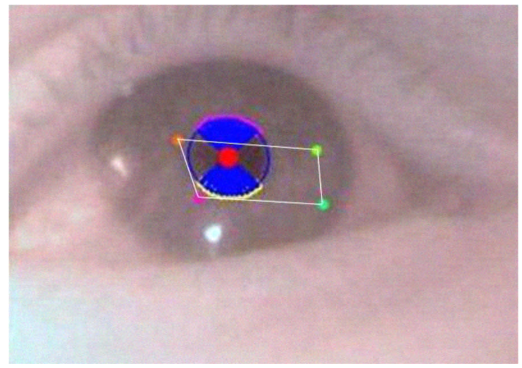

Figure 2. Screen corners projected on an eye.

The screen is represented as the collection of points projected on the image of the user's eye. When a pupil center is detected between screen borders (determined by projected points) its position is also marked on the image. The following operations are required to calculate relation between the pupil position, the screen coordinates and position of the mouse cursor on the screen:

1. computation of scale coefficients,
2. normalization of the screen representation, and
3. normalization of the fixation point.

Scale coefficients (SC) are computed separately for both axes and are represented as SC = (sx, sy). The "sx" is the ratio of x-screen resolution to width of the detected (in pixels). The same procedure is performed for "sy" using screen height. Normalization of screen representation (approximated as a rectangle) is performed using affine transform (mainly rotation and translation).
The normalization process of fixation point is similar as for the detected screen coordinates. After normalization process, the mouse cursor position may be computed. Knowing the "virtual" position of the screen corners and the position of the fixation point the "actual" position of the mouse cursor can be computed using simple scaling operation.
After calibration (current position of the eye) the system is ready to work. If the position of the eye changes, moving outside of the mapped screen borders, the mouse cursor is shifted proportionally (using Operating System events). Short look outside the left screen border initiates the mouse cursor move in left direction. Similarly, a user can initiate the mouse move in other directions. The stopping condition can be set by fast eye deflection in opposite direction to current cursor movement.
If the head-camera is not used for eye-tracking the head position is determined using previously (IR LED-based) described method. Another calibration procedure is required to collect data in regard to head displacement and saves the range

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of horizontal head movement. After calibration the actual mouse control can be started. When user reaches the limit of his/her head movement in right or left direction, software initiates the mouse movement in particular direction (up, down, left, and right). Head mounted camera continuously observes users pupil, when pupil is not detected for more than T seconds (in our experiments we used T=0.5) software recognize it as the eye blink and simulates the mouse click. The click is being signaled visually (the GUI component) and with sound.

If the user can operate his/her wrist another method can be used to modify mouse direction and to fire mouse button press events. We have currently designed a wrist rotation sensor based on FT 232BL FTDI integrated circuit and ATiny Atmel microcontroller. FTDI circuit enables communication with PC trough USB port and Atmel microcontroller contains algorithms necessary to complete the design interface.

III. Results

The platform model was used to start implementation work in parallel. The first results are related to HCI and user environmental data monitoring. Other modules are under construction.

A. *HCI system*

Verification of the visually guided HCI was performed using two different tests. In the first one, tester was asked to place the mouse cursor in various places in reference to a generated regular grid of rectangles. The number of elements increases starting from relatively large areas (3x3 and 4x4) up to small rectangles (25x25). During the test every area was lighted a specified number of times (10 for big rectangles, 1 for small) using a given order. The user's task was to direct his/her eye pupil to the lighted area. Every correct attempt was registered. Since a tester used first big rectangles and then small it was possible to learn the method of the system control so achieved hit accuracy was about 100%.

Another tests were based on the comparison of time performance of the visually guided mouse in reference to a performance of traditional pointing devices. The touchpad and digital joystick/keyboard cursors were used as reference. Results are presented in table 1.

TABLE I. Results of time performance of the virtual mouse

Activity type	**Action time in [s]**		
	Touchpad	***Joystick***	***Virtual mouse***
Diagonal move through the screen	4	14	24
Cursor move from virtual key "Q" to "J"	3	9	13

Time required for moving a mouse cursor is longer for the visually guided mouse than for other devices. However a tester (one of the authors) has a long experience using touchpad not the "virtual mouse".

In parallel, the touch screen monitors were used (EIZO FlexScan L363T) to test new graphical user interface requirements. The platform will be implemented using micro computers integrated with the monitor (e.g. Asus Eee Box).

B. *User environment monitoring*

The General Purpose Input Output (GPIO) interface was used to connect different sensors for user's home environment monitoring. Currently, a thermistor-based temperature measurement sensor and an optoelectronic-based movement detector were implemented. Humidity, fire and gas detectors are under construction.

The Siemens TC65T module was used as a main controller for home environment monitoring multi-sensor. The module combines GPIO and GSM communication interface. Using Java 2 Micro Edition a set of Midlets was prepared to process GPIO events and communicate with the environment. The module is used as one of the external communication interfaces (described earlier in Section II).

The central workstation was build using Java 2 Enterprise Edition, Apache Web server and MySQL database management system. Events from the TC65T modules are stored in MySQL tables and can be processed and visualized using dynamically constructed web page. The external access to information services is limited by access lists and is secured by SSL. Additionally, a set of J2ME Midlets was prepared for mobile phones to remotely manage the TC65T module. Midlets allow to set alarm limits (e.g. smallest and highest acceptable temperatures – fig. 3) which are used to decide about alert generation to a privileged user (e.g. relative, guardian). The module accepts also SMS requests (from the configurable phone numbers) for sending current status data (request-response model).

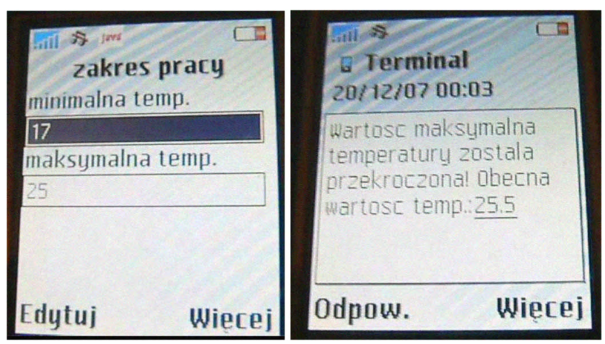

Figure 3. Mobile phone screen copies. Left: acceptable temperature range specification (Celsius degrees). Right: Message from the terminal that the maximum temperature was exceeded.

Additionally the Java servlet was prepared to supply a USB camera service. The Java Media Framework was used to communicate with camera and capture images with a given frequency. Image resolution and capturing frequency can be configured using another Java servlet (operating in the Apache Tomcat container). An interested party (e.g. relative) can observed images (movies) by a servlet invocation using any WWW browser (under defined security rules). Further

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modifications will allow sending captured images using multimedia service - MMS.

IV. Discussion and Conclusion

The design of multimodal platform for communication, training and patient monitoring at home was presented. Two already implemented modules were described including visually guided human-computer interface and GSM-based module for user's home environment monitoring. The very important aspect (especially for older people on retirement) of the system is the cost. We assumed to build implementations of all platform elements using no expensive solutions. The already implemented modules are using free software and relatively inexpensive hardware elements.

The visually guided HCI has been already implemented for a lateral amyotrophic sclerosis (LAS) patient. A lot of further work must be undertaken to reduce time required to perform a mouse actions. One possibility is to optimize the GUI of applications and design special virtual keyboards (with limited set of key). Different options of HCI are required for different group of patients. The new audio commands processing subsystem is required (modified version of the general purpose system present in Microsoft Vista/7). Finally the combination of visually and audio guided interfaces could be more comfortable for many patients.

Dedicated multi sensors for special group of patients are still under designing. The final goal is the possibility to collect a platform from building blocks according to the given patient needs. That is why the proper system design is so important.

Another open problem is respecting people/patients privacy and creates a highly secure system in a house and in external communications. Some previous works were published [24][25] but this is still an open subject.

Acknowledgment

We would like to thank Mr. Karol Murawski for implementation of Midlet Java code for the TC65T terminal and a mobile phone.

References

[1] P. Binkley, Predicting the Potential of Wearable Technology, IEEE Eng. in Medicine and Biology Magazine, vol. 22, No. 3, pp. 23-24, 2003.

[2] E. Jovanov , A. Milenkovic, Ch.Otto C, P. Groen , A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation, Journal of NeuroEngineering and Rehabilitation 2005, 2:6, pp. 1-10, 2005.

[3] Proceedings of the 1st International Workshop on Wireless Sensor Networks for Health Care, WSNHC 2007.

[4] Y. Jasemian, Elderly comfort and compliance to modern telemedicine system at home, Proceedings of Second International Conference on Pervasive Computing Technologies for Healthcare, PervasiveHealth 2008. Jan. 30 2008-Feb. 1 2008, pp.60 – 63, 2008.

[5] Crossbow, Crossbow IRIS, http://www.xbow.com/Products/Product_pdf_files/Wireless_pdf/IRIS_Datasheet.pdf, 2008.

[6] Sun, SPOT - Small Programable Object Technology, http://www.sunspotworld.com/docs/, 2008.

[7] U. Maurer, A. Rowe, A. Smailagic, D.P. Siewiorek, eWatch: a wearable sensor and notification platform, Proc. of the Int. Workshop on Wearable and Implantable Body Sensor Networks, 4 pages, 2006.

[8] L.E. Holmquist, F. Mattern, B. Schiele, P. Alahuhta, M. Beigl and H.W. Gellersen. Smart-Its Friends: A Technique for Users to Easily Establish Connections between Smart Artefacts, Proc. of UBICOMP 2001, Atlanta, GA, USA, Sept. 2001.

[9] Wikipedia, Sensor node, http://en.wikipedia.org/wiki/Sensor_node, 2009.

[10] Shnayder V., Chen B., Lorincz K., Fulford-Jones T., Welsh M., Sensor Networks for Medical Care, Harvard University Technical Report TR-08-05, April 2005.

[11] van Halteren, A.T. and Bults, R.G.A. and Widya, I.A. and Jones, V.M. and Konstantas, D., Mobihealth-Wireless body area networks for healthcare, Wearable eHealth Systems for Personalised Health Management, Studies in Health Technology and Informatics Vol. 108, pp. 121 - 126,2004.

[12] Ng J.W.P., Lo B.P.L., Wells O., Sloman M., Toumazou Ch., Peters N., Darzi A., Yang G.Z., Ubiquitous Monitoring Environment for Wearable and Implantable Sensors (UbiMon),Proc. of the International Conference on Ubiquitous Computing (Ubicomp), 2 pages, Sep 2004.

[13] Dong-Oh Kang, Hyung-Jik Lee, Eun-Jung Ko, Kyuchang Kang and Jeunwoo Lee, A Wearable Context Aware System for Ubiquitous Healthcare, Proceedings of the 28th IEEE EMBS Annual International Conference, New York City, USA, Aug 30-Sept 3, 2006.pp. 5192-5195.

[14] A. E. Kaufman, A. Bandopadhay, B. D. Shaviv, "An Eye tracking Computer User Interface", *Research Frontier in Virtual Reality Workshop Proceedings*, IEEE Computer Society Press, October, 1993, pp. 78-84.

[15] K. Hyoki, M. Shigeta, N. Ustno, Y. Kawamuro, T. Kinoshita, "Quantitative electro-oculography and electroencephalography as indices of alertness" in *Electroencephalography and Clinical Neurophysiology*, 1998

[16] Zhao Lv; Xiaopei Wu; Mi Li; Chao Zhang; Implementation of the EOG-Based Human Computer Interface System, Proceedings of The 2nd International Conference on Bioinformatics and Biomedical Engineering, 2008. ICBBE 2008, 16-18 May 2008, pp. 2188 – 2191.

[17] Z. Zhu, Q. Ji, "Novel Eye Gaze Tracking Techniques Under Natural Head Movement", *IEEE Transaction on Biomedical Engineering*, Vol. 54, No. 12, December, 2007, pp. 2246-2260.

[18] C. Collet, A. Finkel, R. Gherbi, "A Gaze Tracking System in Men-Machine Interaction", *Proceedings of IEEE International Conference on Intelligent Engineering Systems*, September, 1997.

[19] S. Miyazaki, H. Takano, K. Makamura, "Suitable Checkpoints of Features Surrounding the Eye for Eye Tracking Using Template Matching", SICE Annual Conference 2007, Kagawa University, Japan, September, 2007, pp. 356-360.

[20] T. Kocejko, A. Bujnowski, J. Wtorek „Eye Mouse for Disabled" IEEE Conference on Human System Interaction, pp. 199-202, 25-27 May 2008.

[21] Abu-Faraj ZO, Bou Sleiman HC, Al Katergi WM, Heneine JLD, Mashaalany MJ. A Rehabilitative Eye-Tracking Based Brain-Computer Interface for the Completely Locked-In Patient. In: Wickramasinghe N and Geisler E; Editors. Encyclopedia of Healthcare Information Systems, First Edition, Hershey, PA, USA: IGI Global, Vol. III, pp. 1153-1160, 2008.

[22] T. E. Hutchinson, K. P. White Jr., W. R. Martin, K. C. Reichert, L. A. Frey, "Human-Computer Interaction using Eye-Gaze Input", IEEE trans. On Systems, Man and Cybernetics, Vol. 19, No. 6, 1998, pp. 1527-1534.

[23] IEEE Computer Society, Computer, Vol. 41, No. 10, October 2008.

[24] H S Ng, M L Sim and C M Tan, Security issues of wireless sensor networks in healthcare applications, BT Technology Journal,Vol. 24, No. 2 April 2006, pp. 138-144, 2006.

[25] Y. Jasemian, Security and privacy in a wireless remote medical system for home healthcare purpose, Proceedings of Pervasive Health Conference and Workshops, 2006, Nov. 29 2006-Dec. 1 2006, pp. 1 – 7, 2006.

Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2009.6048
http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2009.6048