A biofeedback based portable device to support elderly mobility in the home environment

Lorenzo Chiari, Elisabetta Farella, Laura Rocchi, and Luca Benini

***Abstract*— We present a device to support elderly balance and mobility in the home environment based on the sensory augmentation principle. We designed and tested an audio-biofeedback system that is wireless and lightweight, and can be easily worn and operated by elderly subjects. Having in mind wearability and unobtrusiveness it is based on a palmtop computer, a stereo headset, and body sensors networks. Preliminary validation was performed on a sample of 5 older people with Parkinson's Disease. Promising results were obtained, both in terms of ease-of-use and users' acceptability of the device, and in terms of postural improvement induced by the use of the biofeedback system.**

Keywords: ambient assisted living, assistive technologies, telemedicine, biofeedback

I. INTRODUCTION

Balance disorders can be a critical health problem, because they seriously affect the activity of daily life, and they can originate even more serious problems, related to falls and disabilities. Annual costs associated with falls, particularly in an elderly population, are exceeded only by those associated with motor vehicles injuries [1]. In fact, one-third to one-half of the population over age 65 reports some difficulty with balance or ambulation [2],[3]. In Europe, approximately one-third of community-dwelling adults over 65 years and 50% of those over 80 years fall at least once a year [4]. Twenty to thirty percent of those who fall suffer injuries that reduce mobility and independence and increase the risk of premature death [5],[6].

The improvement of balance ability and consciousness is an important point for reducing falls and increasing the quality of life. Increased body awareness and position sense is necessary to compensate functional limitation in balance disorders. Balance improvements may be achieved by adding artificial sensory information (sensory augmentation or substitution) that enlightens the brain about actual body posture and movements. This information may be coded into an appropriate sensory signal and provided in real-time; in this case, brain and muscle activities, that are not normally controlled voluntarily, may be changed accordingly to the new information available. This is a typical example of biofeedback (BF), a training technique in which people are taught to improve their health and performance by using signals from their own bodies.

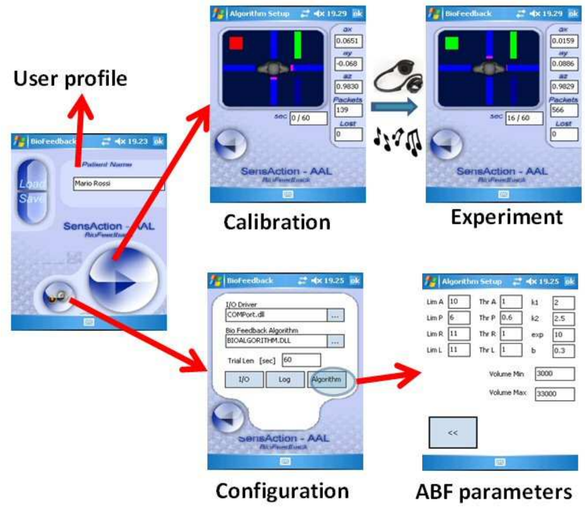

Fig. 1. Graphical user interface – basic and advanced windows

It has been demonstrated that physical activity based interventions, including biofeedback therapies, can improve functioning in older people. In specific elderly populations, such as older fallers and patients with Parkinson's disease (PD), there is evidence that interventions may improve both cognitive and motor functions. Available results suggests more effect when interventions take place over longer time periods, when they are individually tailored, and include exercises in the home environment [7].

Due to recent technological advances, it is now possible to use body-fixed sensors in combination with advanced ICT solutions to effectively monitor older people in their home environment and to introduce BF-like interventions that are tailored to individual needs. This new approach allows, e.g., tele-rehabilitation solutions where, from a distance, medical professionals monitor and assist older people. This is one of the scenarios of usage being deployed within the EU-funded project SENSACTION-AAL (FP6-IST-2005-2.6.2-045622).

II. SYSTEM ARCHITECTURE

The portable and wireless BF system was designed to include modular hardware architecture for diverse sensors integration and wireless communications, and a modular software design to allow easy and optimized integration of different sensors, communication protocols and BF algorithms. The hardware architecture was designed to

Manuscript received May 7, 2008. This work was supported by the EU-funded project SENSACTION-AAL (FP6-IST-2005-2.6.2-045622).

L. C. is with the Department of Electronics, Computer Science and Systems (DEIS), University of Bologna, Viale Risorgimento 2, 40136 Bologna (phone: +390512093014; fax: +390512093073; e-mail: lorenzo.chiari@ unibo.it).

E. F., L.R. and L.B. are with the Department of Electronics, Computer Science and Systems (DEIS), University of Bologna, Viale Risorgimento 2, 40136 Bologna (e-mail: elisabetta.farella|laura.rocchi|luca.benini@ unibo.it).

potentially include a network of sensing nodes, and is capable to drive different actuators as BF generators (e.g. audio, tactile, visual). In its simplest release, the body area network consists of an inertial sensor (3D accelerometer and/or 3D gyroscope), a headset, a processing node, and a PDA. This minimal configuration was chosen to comply with users' acceptability of the system.

The software architecture has been designed to best accomplish real-time data processing, I/O synchronization, trouble-free integration of further BF algorithms, independence from sensor node(s) characteristics and set-up. Furthermore, the software allows the detection of possible radio communication problems (packet losses), notifying the user in case of misuse of the system. The processing node manages the data from the body sensor, in order to estimate the user's posture and to provide adequate audio BF [8]. Such features have been combined with a friendly graphical interface for non-expert users (leftmost window presented in Fig.1). An advanced set of dialogue windows offers the caregiver or training supervisor the possibility to select the appropriate BF algorithm and user-specific options, and to perform a spot-check on the correct functioning of the sensing node (right side of Fig.1).

The functioning principles of the system and its architecture are illustrated in Fig.2. In summary, the main building blocks of the software architecture consist on (i) an acquisition manager in charge of enabling the communication between the wireless sensor and the handheld device (e.g. open the communication port, selection of the protocol, configuration of main parameters such as baud-rate, etc.) and of extracting meaningful data (the payload) from the packet received; (ii) a data processing module implementing the BF algorithm and generating the corresponding feedback (e.g. the sound); (iii) a data manager, which is the module handling the communication with the actuator and the storage of data on the palmtop computer; (iv) a graphical user interface to easily handle basic functionalities (e.g. to start and stop the application) and advanced configuration for expert user (e.g. algorithm selection, advanced user profiling, algorithm parameters set-up, etc.).

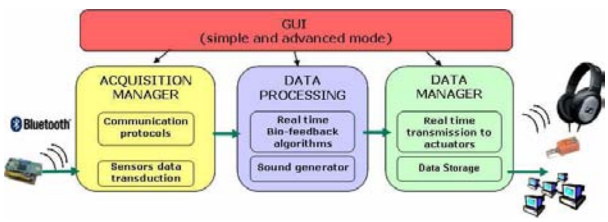

Fig. 2. System architecture

III. CASE STUDY AND DISCUSSION

The system was preliminarily tested on a sample elderly volunteer population of 5 patients with PD (Hoehn & Yahr, II-III), with severe problems of camptocormia (forward stooped posture). The patients were not in their chronic stage of the trunk abnormalities, but still in an early phase, where correction of the trunk position was still reachable, with a firm intentional effort. The experimental set-up used for this test is shown in Fig. 3.

Fig. 3. Experimental set-up shown on a young, healthy volunteer

Our preliminary results confirmed the twofold potentials of the portable BF system in patients with PD: i) for improving cognitive function and, ii) for a direct correction of stooped posture. In fact, PD subjects found the system easy-to-use and adequate, and they were able to correctly follow the audio information, when available, and to properly extend the trunk toward a more physiological position, during trials of 60 seconds in a quiet-standing position (both eyes open or closed). Results from a representative subject are shown in Fig. 4, where forward/backward accelerations of the trunk (whose DC values reflects trunk inclination) are shown in two trials, with and without the BF information available. The postural response at the start of the audio BF (ABF) is evident in this patient.

Such results, whereas preliminary, are promising and an extended campaign for the clinical validation of the device is in preparation (start date: June 2009) among the clinical partners of the SENSACTION-AAL project after adequate approval from the local Ethical Committees.

The development of tele-care exercises to train and facilitate additional motor tasks like gait and postural transfers, that highly impact on the quality of life, are desirable on such population of PD patients and, in general, on elderly people at large, with the aim of improving their mobility and independence, especially in the home environment.

IV. CONCLUSION

In this paper we presented a wireless, portable device to support elderly mobility in the home environment which is suitable for a ubiquitous use. The device affects balance and mobility by taking advantage of the essential principles of biofeedback-based interventions. Moreover, it has been designed with both an hardware and software

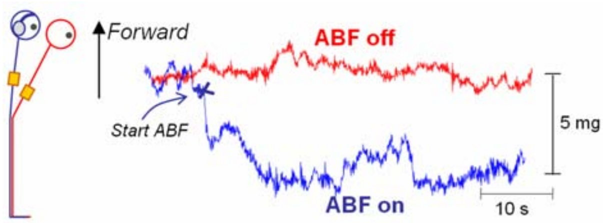

Fig. 4. Trunk acceleration estimates trunk inclination during an exercise for a PD patient

modular architecture to allow an easy interoperability and a wide versatility. Different usage scenarios, different training conditions, different feedback signals may be easily included on the device without major changes in its architecture. The preliminary validation process is showing an adequate behavior of the system and a good acceptability by the elderly users, who are constantly kept at the center of the design and refinement process in a user-centric perspective.

REFERENCES

[1] P. Loughlin and M. Redfern, "Analysis and modeling of human postural control.," *IEEE Eng. Med. Biol. Mag.*, vol. 22(2), p.18, 2003.

[2] C. Coogler, "Falls and imbalance," *Rehab. Management*, p.53, 1992.

[3] J. M. Hausdorff, D. A. Rios, and H. K. Edelberg, "Gait variability and fall risk in community-living older adults: a 1-year prospective study," *Arch. Phys. Med. Rehabil.*., vol. 82(8), pp. 1050-1056, 2001.

[4] M. Halter, "Falls in the older population: a pilot study to assess those individuals who are attended to by the London Ambulance Service as a result of a fall but are not conveyed to an accident and emergency department," London Ambulance Service NHS Trust, 2000.

[5] M. E. Tinetti and M. Speechley, "Prevention of falls among the elderly," *New Engl. J. Med.*, vol. 19(320), pp. 1055-1059, 1989.

[6] C. Freeman, "Quality improvement for people with hip fracture: experience from a multi-site audit," *Qual. Saf. Health Care*, vol. 11, pp. 239-245, 2002

[7] A. Ashburn, L. Fazakarley, C. Ballinger, R. Pickering, L. D. McLellan, and C. Fitton, "A randomised controlled trial of a home based exercise programme to reduce the risk of falling among people with Parkinson's disease," *J. Neurol. Neurosurg. Psychiatry*, vol.78, pp.678-684, 2007.

[8] L. Chiari, M. Dozza, A. Cappello, F. B. Horak, V. Macellari, and D. Giansanti, "Audio-biofeedback for balance improvement: an accelerometry-based system," *IEEE Trans. Biomed. Eng.*, vol. 52, pp. 2108-2111, 2005.