Daily-life tele-monitoring
of motor performance in stroke survivors

Progress of the EU project INTERACTION

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Abstract- the objective of the EU project INTERACTION is to develop an unobtrusive and modular sensing system for objective monitoring of daily-life motor performance of stroke survivors. This will enable clinical professionals to advise their patients about their continued daily-life activity profile and home training, and evaluate and optimize rehabilitation programs. A modular textile-integrated sensing system was developed and performance and capacity measures were proposed and clinically tested in stroke subjects. Telemonitoring facilities were developed and tested. In the last stage of the project, the system will be tested during daily-life.

Keywords-stroke, daily-life monitoring, balance, reaching and grasping, functional performance, functional capacity

1. INTRODUCTION

Stroke often results in impaired motor control, affecting functional performance of both upper and lower extremity. During post-stroke rehabilitation, motor functions, including reaching, grasping and mobility, are trained in order to prepare the stroke survivors for their return to daily-life. The objective of training is to optimize daily-life functional motor performance, but only functional motor capacity is evaluated during rehabilitation using clinical tests. In fact, it is unclear how the stroke survivors perform during daily-life and how this is related to the rehabilitation training they received.

It is the objective of the EU project INTERACTION to monitor motor performance of stroke survivors during daily-life and to make this information accessible to the clinical professional on a distance for guiding individual stroke subjects to optimize their daily-life performance, advise them concerning continued training and to evaluate and optimize the impact of rehabilitation programs.

2. MATERIAL AND METHODS

User requirement analysis

User requirements were assessed at the start of the project by consultation of medical professionals involved in stroke rehabilitation in the Netherlands and Switzerland using a questionnaire and a round table interview with three stroke survivors in the Netherlands. Subsequently, a consensus meeting with the partners involved in the INTERACTION project was held. PACT (People, Activity, Context and Technology) and FICS (Functionalities, Interaction, Context and Service) frameworks [1],[2] were used to translate user requirements and technical state of the art into functional requirements and technical specifications.

Development of a textile-integrated sensing system

A modular and wireless textile-integrated sensing system was developed, including inertial movement sensors, textile-based goniometers, EMG and pressure sensing. The design of the system is shown in figure 1. Depending on the need, different combinations of the modules, including shirt, trousers, shoes and partial gloves, can be used. Methods were developed for gesture recognition using the gloves.
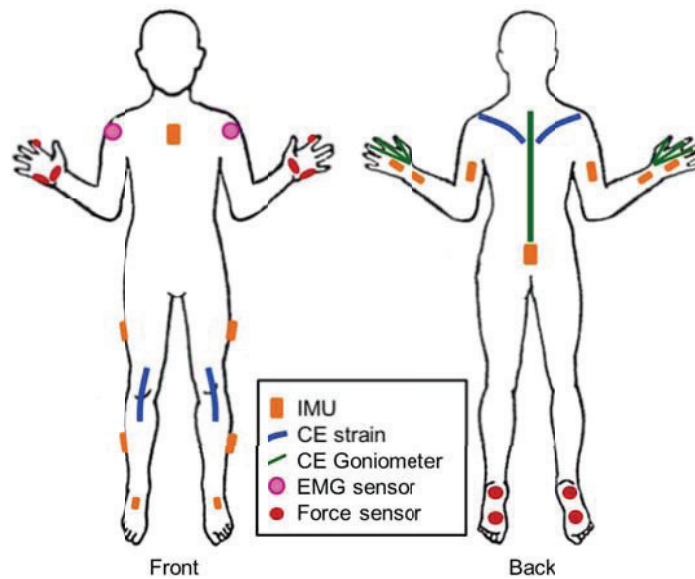
Figure 1. INTERACTION textile-integrated wireless sensing system for daily-life assessment of motor performance in stroke, including inertial sensor modules on main body segments, shoulder abduc or EMG, shoulder strain sensing, spine an hand goniometers, force sensing under shoes and in glove. The system is modularly divided into shirt, trousers, shoes and partial gloves. Patient specific combinations of modules can be chosen.

Development and testing of measures to monitor quality of motor performance

Measures were developed to characterize the quality of performance of re ching and grasping as well as mobility and balance during daily-life using the INTERACTION sensing ystem. These measures were based on motor control concepts of pathological synergies between shoulder abduction and elbow flexion in stroke [3] and assessment of balance, relating center of pressure to estimated body center of mass movements [4],[5].

The sensing system and the derived quality of performance easures have been evaluated in structured clinical experiments before daily-life evaluation in the final hase of the project. Nine stroke survivors have currently been included of the planned 20. First, standard clinical tests inc uding Berg Balance Scale and Fugl-Meyer test were performed. Subsequently, stroke subjects performed a 10 meter walk test and performed maximal reaching tasks with their affected and non-affected arms as a capacity measure. Finally, as a performance measure, they performed a predefined ADL task including the following activities: sitti g, rising up from a chair, walking to another room, opening a door, manipulating a d object while standing and returning to the starting position.

Telesupervision

A wireless telesupervision system was developed (Figure 2) [6]. Data are captured wirelessly on a home-gateway (either tablet or pc), which transmits the data to a secure database via a European Data Format (EDF). Portal technology can acc ss and process the data. Clinicians can remotely evaluate motor performance of stro e subjects on the web portal.
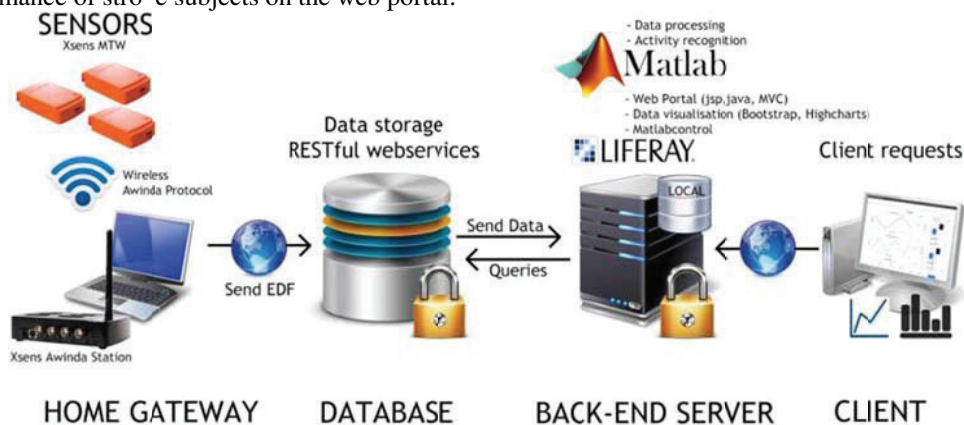

Figure 2. INTERACTION Tele upervision s stem.

3. RESULTS

User requirements analysis

The questionnaire was returned b   13 Dutch and three Swiss medical professionals. The questionnaire results, discussion with the end users and a consortium consensus meeting lead to the conclusion that it is important to assess the progress of motor capacity and relate the capacity to performance in the home setting. Therefore it is necessary to monitor which activities are performed, how   hey are performed and at which intensity (frequency and duration). Monitoring of the upper extremity function should be directed to reaching and grasping performance and the involvement of both the non-affected and affected arms. For the lower extremity it was decided to focus on balance and walking performance of stroke subjects in the home setting.

Textile-Integrated Sensing systems

Figure 3. Prototype of the modular and wireless INTERACTION textile-i tegrated sensing system.

Capacity tests for reaching movements indicated that several of the stroke subjects were able to reach over considerable distances with their affected arm (figure 4). The asymmetry of Center of Pressure (CoP) and estimated body Center of Mass (CoM) showed a shift to their affected side during the 10 meter walk test (figure 5).

Data analysis of the simulated ADL tasks in two of the nine subjects using the sensory data indicated that the reaching capacity of the affected arm was hardly used during these tasks and CoP and CoM positions shifted more to the non-affected side than during the 10 meter gait t st. Finally, the asymmetry in gait and arm usage during performance of ADL tasks did not appear to correspond to the scores of standard clinical tests like the Berg Balance Scale and Fugl Meyer assessment.
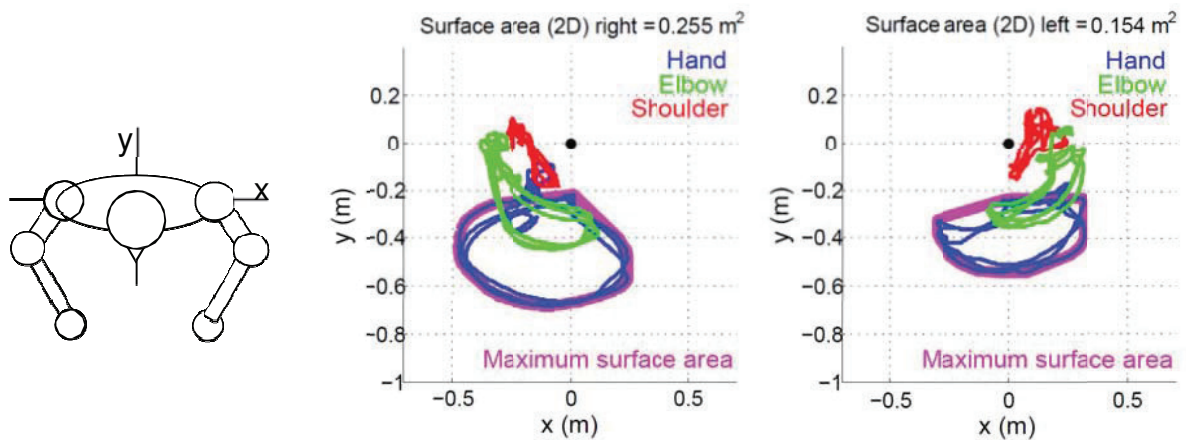

Figure 4. An example of a maximal reaching capacity test in a male stroke subject assessed with the body-mounted sensing system, left being the affected side. Horizontal projecti ns of the hand, elbow and shoulder trajectories are shown relative to the pelvis position (black dot at position (0,0)).
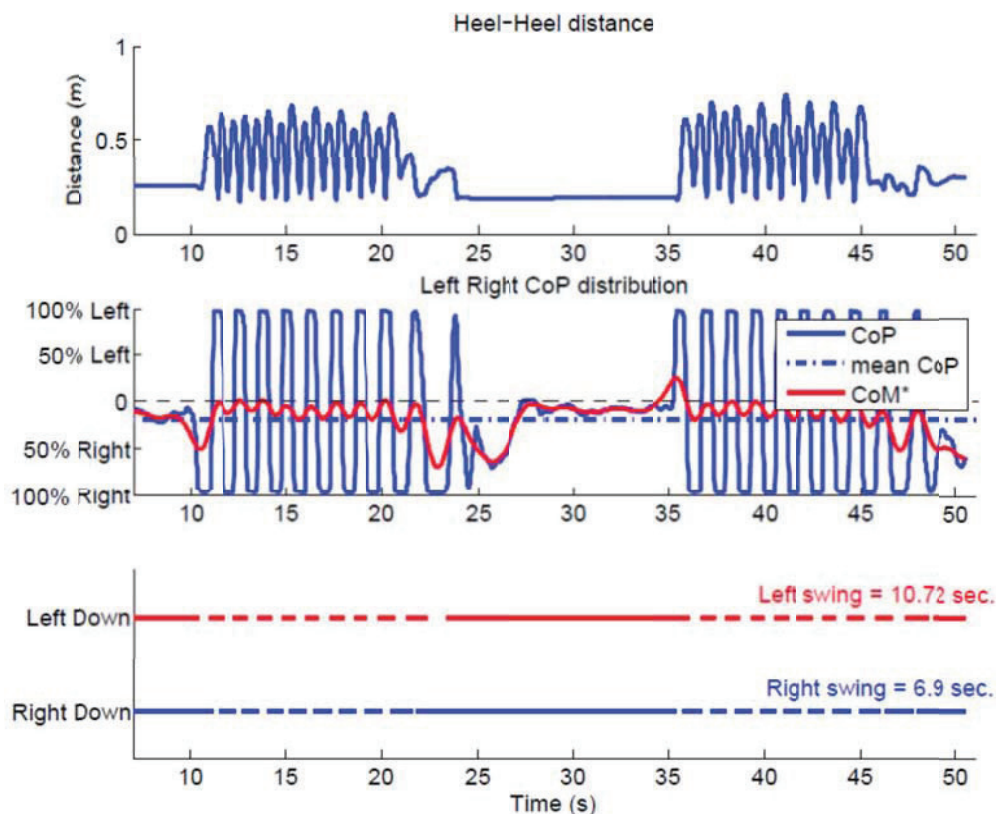
Figure 5. an example of a gait test in a male stroke subject assessed with the body-mounted sensing system. The subject walked 10 meter at comfortable speed, turned around and walked back. Estimated heel-heel distance, Center-of-Pressure (CoP) and estimated Center of Mass (CoM) trajectories [5], together with stance-swing timing of both feet are shown.

4. DISCUSSION

Performance of daily-life ADL ta ks may not correspond to clinically assessed functional motor capacity and asymmetry of reaching and grasping and mobility appears larger during relatively difficult daily-life ADL tasks than expected from clinical motor capacity testing. This supports the need for assessment of the quality and quantity of motor performance during daily-life in stroke survivors. Daily-life tests will be performed in the final year of the INTERACTION project.

5. ACKNOWLEDGMENT

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