A Full Body Sensing System for Monitoring Stroke Patients in a Home Environment

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Abstract. Currently, the changes in functional capacity and performance of stroke patients after returning home from a rehabilitation hospital is unknown to a physician, having no objective information about the intensity and quality of a patient's daily-life activities. Therefore, there is a need to develop and validate an unobtrusive and modular system for objectively monitoring the stroke patient's upper and lower extremity motor function in daily-life activities and in home training. This is the main goal of the European FP7 project named "INTERACTION". A complete full body sensing system is developed, whicj integrates Inertial Measurement Units (IMU), Knitted Piezoresistive Fabric (KPF) strain sensors, KPF goniometers, EMG electrodes and force sensors into a modular sensor suit designed for stroke patients. In this paper, we describe the complete INTERACTION sensor system. Data from the sensors are captured wirelessly by a software application and stored in a remote secure database for later access and processing via portal technology. Data processing includes a 3D full body reconstruction by means of the Xsens MoCap Engine, providing position and orientation of each body segment (poses). In collaboration with clinicians and engineers, clinical assessment measures were defined and the question of how to present the data on the web portal was addressed. The complete sensing system is fully implemented and is currently being validated. Patients measurements start in June 2014.

Keywords: Telemedicine · Architecture · Sensing system · Stroke · Home environment · Daily-life activities · Monitoring · Performance · Capacity

1 Introduction

Currently, the changes in functional capacity and performance of stroke patients after returning home from a rehabilitation hospital is unknown to a physician, having no objective information about the intensity and quality of a patient's daily-life activities.

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As a consequence, the physician is unable to monitor the prescribed training program for sustaining or increasing the patient's motor capacity (what a patient is able to do) and performance (what a patient is doing in actual practice) and cannot give advice to the patient outside the hospital setting. Therefore, there is a need to develop and validate an unobtrusive and modular system for objective monitoring of daily-life activities and training of upper and lower extremity motor function in stroke patients. That is the main goal of the European FP7 project named INTERACTION [4]. A physician will be able to continuously evaluate the patient's performance in a home setting by using the INTERACTION system, allowing the physician to compare the patient's performance at home with the patient's capacity in the rehabilitation hospital. Thereby, the system will support the physician in making decisions on, for example, altering the prescribed training programs.

The INTERACTION sensor system is composed of Inertial Measurement Units (IMUs), Knitted Piezoresistive Fabric (KPF) strain sensors, KPF goniometers, EMG electrodes and force sensors. These sensors are integrated into a custom-made modular suit for stroke patients (e-textile), which consists of a shirt, a pair of trousers, shoes and gloves. The iterative design process for the sensor suit includes several usability tests as well as an extensive user requirements analysis with medical and technical experts. Data are captured wirelessly on a home-gateway, which transmits the data to a secure database. Portal technology can access and process the data. The results can be consulted by a clinician whenever necessary.

In this paper, we describe the complete sensing system, including the architecture and the requirements for presenting the assessment measures to clinicians. Specifically, in Sect. 2, the system requirements are given along with an overview of the whole system and a detailed description of each component. The design of the sensing suit is described in Sect. 3. In Sect. 4, the data processing aspects of the system will be explored in further detail. In Sect. 5, the design process of the data presentation is elaborated upon. In Sect. 6, the current implementation of the system is presented and finally, in Sect. 7, the conclusions and future work are described.

2 System Architecture

2.1 System Requirements

Five major requirements were set before the initial system development:

1. The system should compute and display motor capacity and performance measures to evaluate stroke patients during daily-life activities (for example: grasping an object) in a home setting.
2. The sensing system should be unobtrusive for patients to wear and easy to use.
3. The system should be divided into several modules: upper extremity (shirt), lower extremity (trousers), gloves and shoes. This will allow clinicians to assign different modules to different patients according to the clinicians specific interests.
4. Analysis of the sensor data will not be done in real time. The system should be able to store the computed data such that it can be accessed by a clinician when needed.

5. The system should present the performance information of the patient to the clinician, such that it optimally supports monitoring the progress of the patient and decisions about continued therapy. The clinician should be able to inspect the information in progressive detail from global performance parameters to details concerning the quality of specific movement tasks, according to his or her needs.

2.2 System Architecture Overview

The INTERACTION system's architecture is based upon a generic architectural approach described by Pawar et al. [9]. Figure 1 shows a general overview of the current system's architecture. The Body Area Network (BAN) is composed of several sensors listed in Table 1 and a home gateway. The Xsens wireless Awinda protocol is used to connect and synchronize the sensors to the home gateway, which captures the data and stores it in a European Data Format (EDF) [2]. The EDF file protocol was extended for the INTERACTION project by adding additional signal labels to the header of the file. The home gateway application uploads the EDF file to a secure and remote SQL database if an internet connection is detected. A server, installed at the University of Twente, runs Liferay portal software with Matlab [4, 5]. The portal obtains the data from the database and sends the results to Matlab for processing. The results are saved and visualized on the web-portal on request. Each component is explained in detail in the following subsections.

Table 1. Sensor overview.

Type of sensor	Number of sensors			
	Shirt	Trousers	Pair of shoes	Pair of gloves
IMU[a]	6	4	2	2
KPF Strain[b]	2			
KPF goniometer[b]	1	2		6
EMG electrode set[b]	2			
Force[c]			4	12

[a]Xsens MTw and MTw CE sensors [15].

[b]Developed by the University of Pisa.

[c]Tekscan FlexiForce® [12] and Interlink force sensors [5] for shoes and gloves.

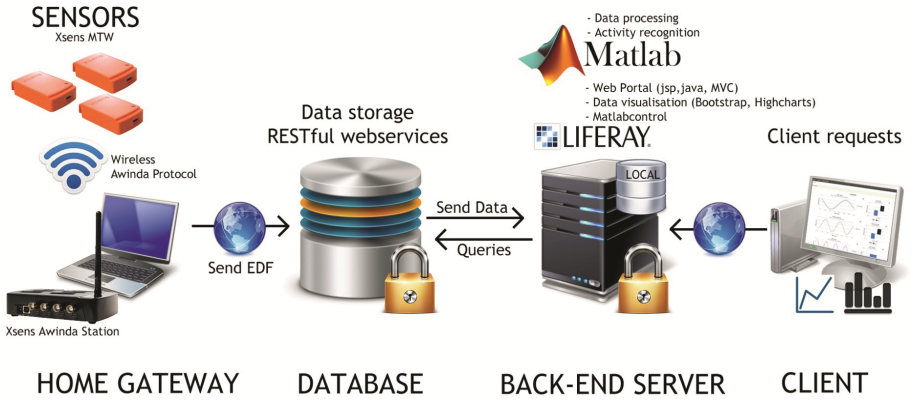

Fig. 1. System architecture. The home gateway captures sensor data and sends it in a EDF to a secure database. Portal technology can access and process the data and visualize the results to clinicians on a web-portal.

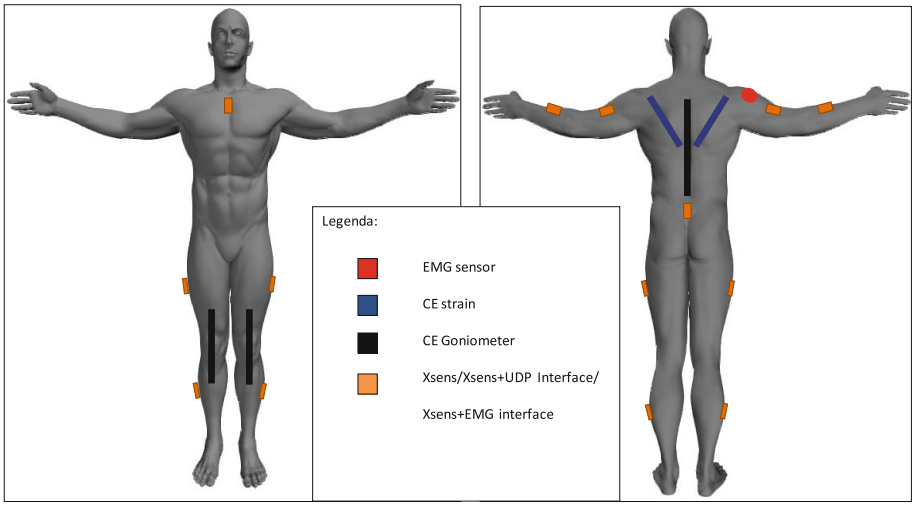

Fig. 2. Sensing system overview. The CE goniometers over the knee and spine are removable and only one EMG sensor set, located on the affected side of the patient, is connected.

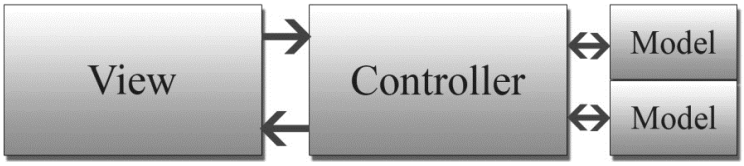

Fig. 3. A spring Model-View-Controller structure of a portlet.

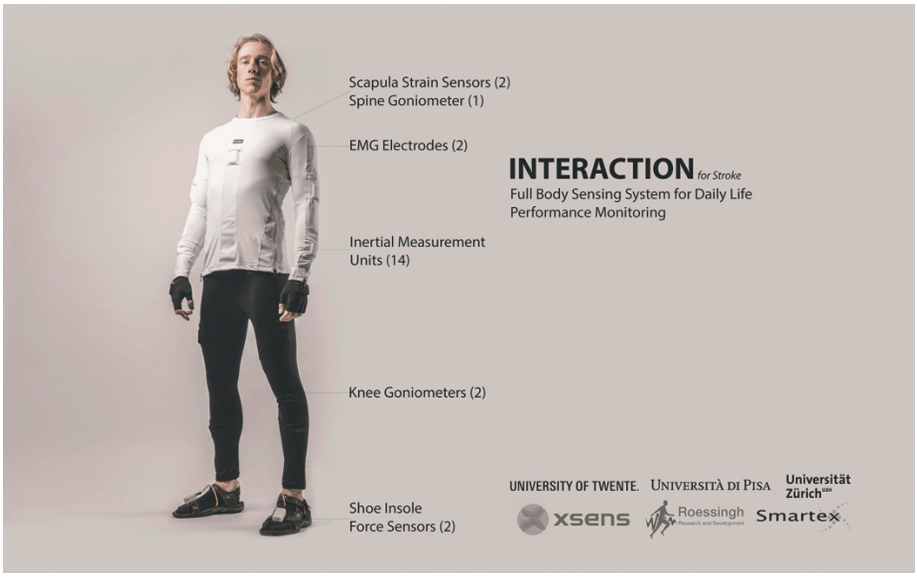

Fig. 4. The final design of the INTERACTION suit.

2.3 Body Area Network

The Body Area Network (BAN) consists of all body sensor components and a gateway to capture, store and upload sensor data.

Sensors. The INTERACTION sensor system is divided into four modules, each of which comprises of a number of sensors as listed in Table 1. Each Xsens MTw sensor box includes 10 primary signals: a 3D accelerometer, a 3D goniometer, a 3D magnetometer and one Pressure channel [15]. Knitted Piezoresistive Fabric (KPF), the properties of which include a short transient time, reduced aging, washability and signal reproducibility has been employed both as strain sensors and, arranged in a double layer structure, as goniometers to monitor joint movement of the shoulder and respectively the thoracic spine, knees and fingers. The KPF sensors are developed by the University of Pisa; the strains are fully integrated in the e-textile suit, but the goniometers for the knees and spine are removable. Two sets of EMG electrodes are integrated into the shirt (on the left and right shoulder) and the signal is pre-processed by an on-body front-end system into a smooth rectified signal. Only the EMG electrode set, located on the affected side of the patient, is connected. The choice of realizing an unobtrusive, minimal EMG sensor set led to the use of the electrodes on the deltoid only, due to its anti-gravitational function, to detect its activity and discriminate the presence of compensatory movements in the shoulder.

The kinaesthetic and kinetic glove module was designed to identify reaching and grasping activities. KPF goniometers were integrated in the metacarpal-phalangeal area

of thumb, index and medium fingers. Moreover, force sensitive resistors were integrated in the palm and lateral side of the glove to measure contact pressures and give an indication of hand loading in stroke patients. An additional force sensor was integrated on the lateral side of the middle phalanx of the forefinger to complete the information derived from the goniometers and to improve the discrimination between hand positions that have similar joint angular values (Fig. 5). Force insoles were made for different shoe sizes to be fitted into the patients shoes. Each insole comprises of two pressure sensors: one under the heel and the other under the forefoot, such that they measure the pressures at the main pressure points under the feet (Fig. 6).

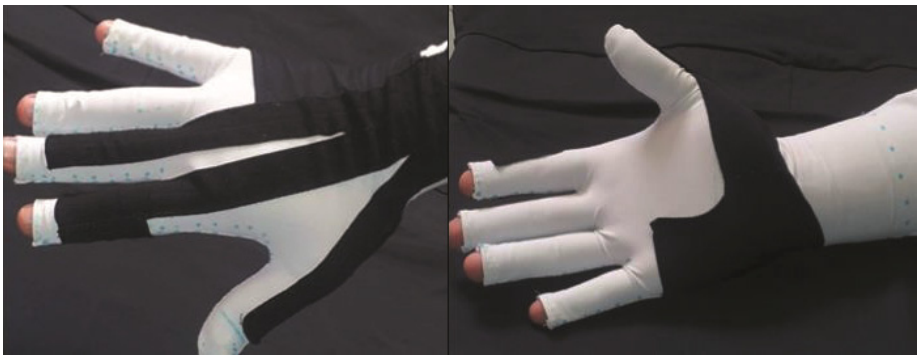

Fig. 5. Glove design. KPF goniometers were integrated in the metacarpal-phalangeal area of thumb, index and medium fingers. Force sensitive resistors were integrated in the palm, lateral side of the glove and the lateral side of the middle phalanx of the forefinger.

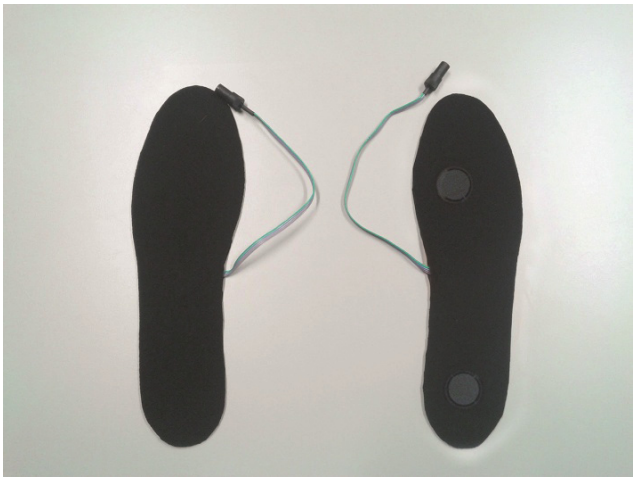

Fig. 6. Force shoe insoles. Each insole comprises of two pressure sensors: one under the heel and the other under the forefoot. The right insole shows the sensor locations.

The Xsens Awinda Auxiliary Data Functionality enables users to combine data coming from a wide range of devices with the inertial data from the MTw sensors and use the wireless link of the MTw as a means of transporting this data. The KPF strain sensors, KPF goniometers, EMG electrode set on the patient's affected side and force sensors on the gloves and shoes are each physically linked to a modified MTw sensor box by passing the data to the MTw's pressure channel. The strain sensors and force sensors on the shoes and the force and goniometers on the gloves are multiplexed to be sent over one channel. As a result, the wireless capabilities of the MTw's for data transmission from the BAN to the gateway are preserved. The integrated sensors are connected via waterproof connectors to insure the washability of the shirt. Figure 2 provides a global overview of the sensing system for the upper and lower extremity. Each MTw sensor unit outputs 10 primary signals, each of which is assigned a unique sensor label within the EDF file. The data collection rate is dependent on the number of sensors. In the INTERACTION project, the collection rate is set to 20 Hertz. This data collection rate has been assessed to be appropriate, since 3D kinematics is analyzed at a higher frequency (1800 Hertz) inside the MTw sensor units before transmission to the Awinda base station. This local analysis provides a more accurate estimation of acceleration and angular velocity values. 20 Hz is an appropriate rate for transmission of 3D orientation as well as the other quantities measured by the sensors, as specified in Table 1.

Gateway. The home gateway has three main functions: (1) collecting the data from the sensors, (2) storing the sensor data inside an EDF file every five minutes and (3) uploading the EDF file to the database. The sensor data is first logged using an Xsens mtb file structure to handle sensor packet loss and data retransmissions and then converted to EDF. The software automatically tries to reconnect with the sensors in case one or multiple sensors are out of range.

The data storage interval of five minutes was determined by considering the available network bandwidth as well as the decreasing overhead of the EDF file with measurement time. With five minutes of data, the EDF data record has a size of 1.6 MB in total according to Eq. 1 (also called the "payload") and a header size of 35.25 kB according to Eq. 2. Therefore, the header occupies only 2.15 % of the total EDF file space. The ratio between the payload and the header of a file is called the "overhead".

$$\text{Payload size} = M_t * F_s * N_{imu} * N_{signals} * 2 \text{ bytes} \tag{1}$$

$$\text{Header size} = \left(N_{imu} * N_{labels} + 1\right) * 256 \text{ bytes} \tag{2}$$

The inputs for Eqs. 1 and 2 are as follows: Nimu: 14 (Number of IMU's), Nsignals: 10 (Number of sensor signals per IMU), Nlabels: 10 (number of sensor labels), Mt: 300 s (Measurement time) and Fs: 20 Hertz (data collection rate). The 256 bytes in Eq. 2 is the size of the general EDF header. The data is uploaded to the database with SSL secure data encryption over the network using RESTful web services, and the users of the database are authenticated using a username and password combination. Furthermore, within the EDF file, only a device ID is used to identify each sensor suit, so no patient names are exchanged.

The home gateway software is used by clinicians to setup the INTERACTION system for collecting patient data at home or in the clinic. The user interface was designed in an iterative process throughout the INTERACTION project. Several usability tests were done during software development. Clinicians were monitored (with video cameras) while performing several measurement scenarios with the hardware and software while thinking out loud. After the scenarios were done, interviews were conducted to get the clinician's opinion. This cycle was repeated several times while developing the gateway software. Options in the interface include: choose a patient, choose the type of measurement (a calibration measurement, a performance measurement or a capacity measurement), switch a sensor (in case of a malfunction) and view sensor data. The interface provides visual feedback on the duration of the measurement, when sensors get out of range or when data is uploaded to the server.

2.4 Database

An SQL database was configured at the Roessingh Research and Development centre (RRD) by reason of their technical experience in secure databases. Dedicated API's were constructed for communication between the home gateway and portal using SSL. For obtaining the data, a correct combination of username and password is required to authenticate the user, and a separate authorization model is in use which determines the access rights of the user, including his or her reading and writing rights. A query engine is developed based on RESTful web services to obtain EDF sensor data from the RRD database on receiving a request from the web portal with a start and end time.

2.5 Portal

The web-portal is responsible for controlling and visualizing the data. We chose the Liferay portal framework as it provides a flexible working environment to develop portlets in a Spring Model-View-Controller (MVC) structure using Java, JavaScript, CSS and JSP. This structure is shown in Fig. 3. Liferay includes a dedicated Content Management System, which allows the portal to be personalized for different users by means of a detailed access-control scheme for assigning different rights to different users. The View component is responsible for displaying the processed data to the user and includes two visual libraries: the Highchart library [3] for graphs and the Bootstrap library [13] for a responsive layout and website elements. The front end Controller component is connected with the View and initiates the Model(s). The Model components obtain the data from the database by use of multiple queries and subsequently send the data to Matlab via a Matlab-Java bridge [8]. Users are able to send requests for different types of measurement data in a specific portlet (by pressing, for instance, a button on the web-portal). These requests are directly forwarded to the Controller component associated with that portlet. This Controller initiates several Models accordingly. With this MVC structure, we are able to process and visualize large amounts of data in an organized way. Multiple portlets can be constructed, each having a different function to show different types of data on the same web-page or on separate web-pages.

3 E-Textile Suit Design

The INTERACTION sensor suit combines a shirt, trousers, shoe insoles and gloves. These fabrics are characterised by a different amount of elastic component and different weight. A heavier fabric with higher elasticity was used for the sensing part of the shirt and the trousers to guarantee a good fitting with the body shape, whilst a fabric based on ceramic components was used to realise the rest of the suit. These mineral components, that are introduced at fibre level, affect the thermo-regulation of the body and improve blood micro-circulation when in contact with the skin for more than six hours. The properties of the fibres do not deteriorate after repeated washing cycles. Several prototypes were realized in a joint effort between designers, engineers, clinicians and stroke patients. To evaluate the functionality of the KPF strain and goniometer sensors, a series of testing prototypes have been designed. These prototypes offer the possibility to evaluate different configuration of the system by varying the location, the dimension and the number of textile sensors. The prototypes were accessorised with velcro® strips to facilitate this process. The positions of the strips were varied to test the functionality of the corresponding sensors that can be attached with the velcro® on the garments. Decisions on the materials, dimensions, shapes and locations of the textile EMG electrodes were made after a round of experiments, performed to determine the best solutions that optimized the functionality of the garments in terms of their sensing properties [11].

The sensing glove has to accurately fit the hand in order to provide an adherence similar to a second skin. Furthermore, thermal comfort is another fundamental requirement, solved by the selection of a suitable material in term of breathability and elasticity. A patented fabric has been used for the basic prototype of the glove, which combines two types of fibres: a polyamide microfiber and LYCRA® elastomer. In Fig. 5, the glove is shown in detail. The force shoe insoles were designed based on Regular shoe insoles. Two layers of fabrics were merged, where the force sensors were placed in between to make a tight fit. The force insoles are shown in Fig. 6.

The final designs resulted in a system that balances the wearability properties of the prototypes with the requirements in terms of the positions and mechanical constraints of the sensors. Patients tested the final designs, in which solutions were added to increase the easiness of wearing and removing the sweatshirt and the leggings (for example, zippers on the side of the shirt and sleeves). Different designs were made for male and female. In total, four complete sensing systems and one back-up system were made, each with several e-textile clothing sizes ranging from S to XL. In Fig. 4, the INTERACTION sensor system is shown.

4 Data Processing

Within INTERACTION, sensor data is captured from up to 14 IMU's. The data is stored in a secure database and will be processed over night. This ensures a short waiting time during the day for displaying patient reports to clinicians on a website. Matlab [7] software is used for data processing, which also includes several external libraries from Xsens. The data processing flow is shown in Fig. 7.

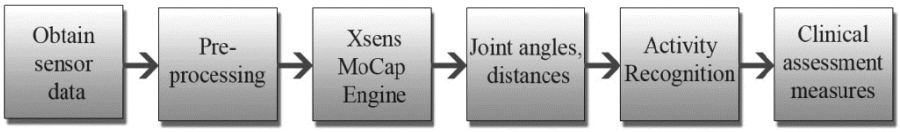

Fig. 7. Data processing flow.

The first step in processing the data is obtaining sensor data in EDF from the database. This step is realized by the use of RESTful web services to access the database and implemented via a custom-made Java portlet in the Liferay web-portal software. The second step is to initiate Matlab and pre-process the EDF sensor data for the later steps. The pre-processing includes matching the correct calibration data with the measurement data, estimating the orientation of the sensors and structuring the data. Furthermore, Additional sensors from the INTERACTION suit, such as the KPF strain sensors on the shoulders, goniometers and force sensors inside the glove and force sensors in the shoe insoles, are demultiplexed.

Step three consists of inserting the pre-processed sensor data into the Xsens MoCap Engine (XME). The XME computes poses of all body segments, where a pose is defined as an orientation and position of a body segment [10]. A full body 3D reconstruction can be made by using the XME. From these poses, joint angles according to the ISB standards and several kinematic distances (like the hand-sternum distance) are calculated as part of step four.

Table 2. Examples of clinical assessment measures in the INTERACTION system.

1	Arm usage of the affected and non-affected arm
2	Maximum reach of the affected and non-affected arm
3	Range of Motion of the elbow and shoulder of the affected and non-affected arm
4	Range of Motion of the trunk
5	Maximum grasping force of the affected and non-affected arm
6	Number of grasps of the affected and non-affected arm
7	Number of steps, step length and step time
8	Weight support by affected and non-affected leg

In step five, basic activities of the patient are detected based on the results of step three and four. A number of daily-life activities were classified and these activities are shown in Fig. 8. The activity algorithms were developed with the goal of getting a high specificity in identifying the activities. In the final step, the INTERACTION clinical assessment measures are computed. These measures are presented to the clinicians in the form of a report and should provide valuable insight into the patient's capacity and performance during daily-life activities. These measures are being determined in a joint

effort among clinicians and engineers. Several examples of these measures are listed in Table 2.

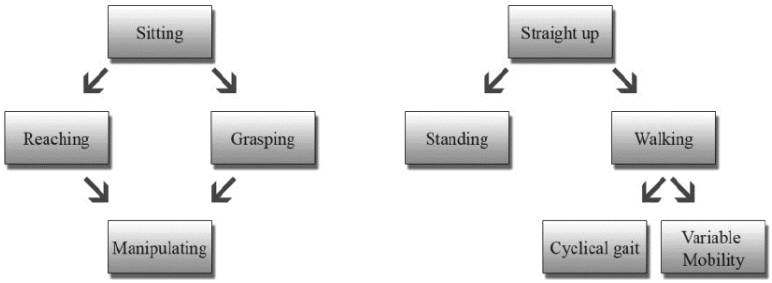

Fig. 8. Activity classification.

5 User Interface

Designing a graphical user interface for clinicians to access the web-portal and determining which clinical assessment parameters to present on the web-portal is one of the major challenges in the INTERACTION project. The INTERACTION system will be collecting data that clinicians are not familiar with in current practice and the data has to be presented in a format that clinicians can understand and evaluate within a few minutes. Therefore, in close collaboration with clinicians, we investigated which clinical outcome measures are relevant and how to present the data in such a way that the capacity and performance of a patient can be easily evaluated and compared over time. We first collaborate with clinicians directly involved in the project only and, when final decisions have been made, will evaluate the results with clinicians not related to the project. At the start, interviews were conducted with clinicians and engineers from the Netherlands (Roessingh Research and Development centre, Enschede) and Switzerland (University hospital in Zürich and Cereneo Rehabilitation centre, Vitznau). We concluded the following: Clinicians can have as many as 40 stroke patients in treatment at a given moment, all of whom have to be evaluated within one hour by the end of the week. This amounts to only a few minutes per week to analyze the performance of each patient. Hence, there is a need for a basic overview of all patients on the web-portal with an option to successively drilldown to a particular data set for a particular patient. As soon as the patient data is processed, it will be available in a report format on the website. This report includes the assessment measures of INTERACTION for the upper extremity and lower extremity. A basic overview of all the subjects is available. The clinician is then able to choose a subject and a measurement day and ask for the report for that day. In this report, the patients capacity measurements in the clinical setting (consisting of multiple clinical measures such as the Berg Balance Scale [1]) are compared with his or her performance measurements in a home environment and can also be compared with healthy subject measurements. An example of the upper extremity webpage is shown in Fig. 9.

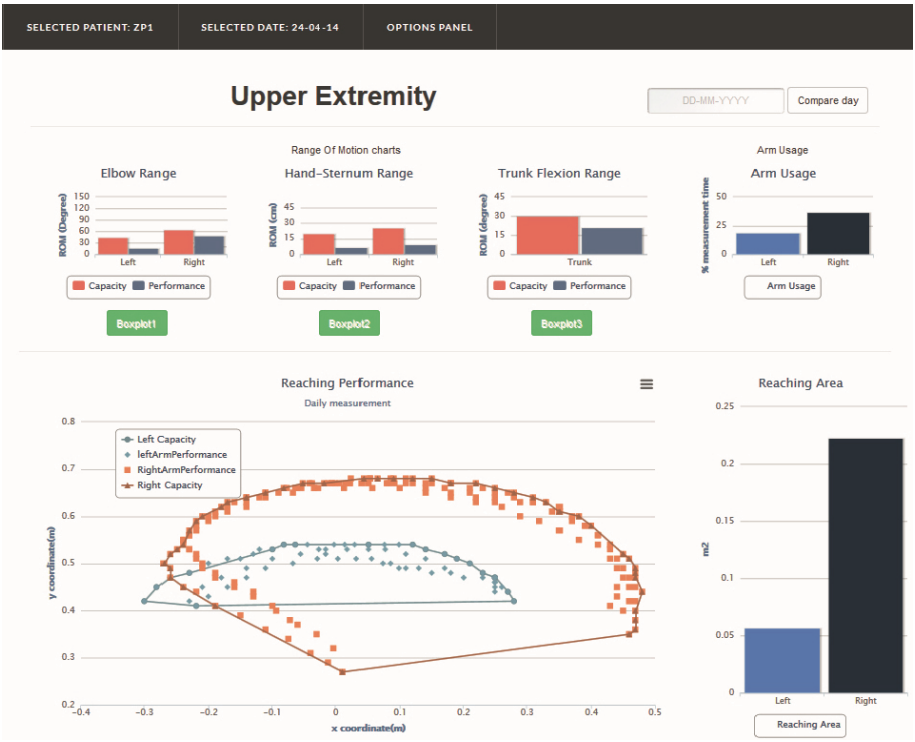

Fig. 9. Example of the upper extremity webpage. The patients capacity is compared with his or her performance during reaching activities for the left and right arm. Several range of motion graphs are shown on top. A plot of the hand-sternum distance in the transversal plane (x,y) is shown on the bottom. The outline is visualized and the area in this outline is computed.

Different Range of Motion charts for the elbow angle, hand-sternum distance and trunk flexion angle are shown for comparing capacity with performance during reaching activities. Box plots are available as well to show the distribution. Furthermore, the reaching positions of the left and right hand relative to the sternum are shown as a top view (x,y) along with, for example, the reaching areas for comparing the left and right arm. Extracting relevant assessment measures and how to visualize them is, and remains an ongoing process within INTERACTION.

6 Implementation

We finished and tested the complete system architecture, from sensors to web portal, with a full body configuration. This includes all system components with over 14 Xsens MTw sensors. Prior to this, the systems architecture was constructed by first using one sensor, then extending it to three sensors with a combination of a basic upper body

biomechanical model and finally to a total of 14 sensors with a full body biomechanical model. The gateway software, web-portal software and biomechanical model were developed in parallel and merged together in May 2014.

To measure with the INTERACTION system, the Xsens Awinda base station is connected to a laptop which runs the gateway software. A pre-determined sensor configuration (for example, full body with gloves and shoes), subject ID and the type of measurement have to be set using the gateway software options menu. The mode to initialize the system then becomes available. Initializing the system includes waking up the sensors (they are in sleep mode when not used and can be woken up by a slow turning motion), and waiting until all sensors are synchronized with the Awinda base station. We use an anatomical print with sensor locations upon which sensors can be placed during the initialization phase. The clinician then knows which sensor is assigned to which body segment and can later place the sensor boxes in the correct textile suit pockets. After all sensors are synchronized, the software automatically goes into calibration mode and waits for the user input to measure. In this phase all MTw sensor boxes are placed in the e-textile suit pockets and additional sensors like strain, goniometers and force sensors are connected. The subject is now instructed to stand in an N-pose (standing up straight with arms alongside the body) for 20 s for a calibration measurement. When a calibration is successfully performed, the software continues to the specified measurement mode and when the user and subject are ready, the measurement can be started by the clinician by pressing "start measurement".

A number of test were done on healthy subjects with the complete sensing system,prior to the start of patient measurements, in the lab and in a home environment in April and May 2014. An example of a healthy subject performing a 10 - m walking test is shown in Fig. 10. A 3D visual reconstruction is shown on top and the left knee joint angle is plotted for the different axes according to the ISB standards. The walking test started by sitting in a chair, then standing up, walking 10 m in a normal pace, turning around, waiting, walking back and finally sitting down again. During sitting, the knee joint angle is at about 90 degrees flexion, and when walking it oscillates from 5 to 75 degrees for this particular subject. The activity recognition schemes are successfully implemented and healthy subject measurement data was successfully selected for the specified activities for further analysis. Upper extremity clinical assessment measures were shown on the web-portal based on the test data.

Several training days were organised in Enschede and Zurich to train clinicians in using the INTERACTION sensor system. The training included how to use the hardware and software of the complete sensing system in several measurement scenarios and practicalities such as how to wash the specialized e-textile suits. In Fig. 11, clinicians are measuring with the complete sensing system. The sensing suit is worn under regular clothing. Support protocols were created so that technical experts are available during patient measurements and one complete set of sensors was built as backup in case of sensor failure. Measurement protocols were made for patient measurements in the clinic and at home.

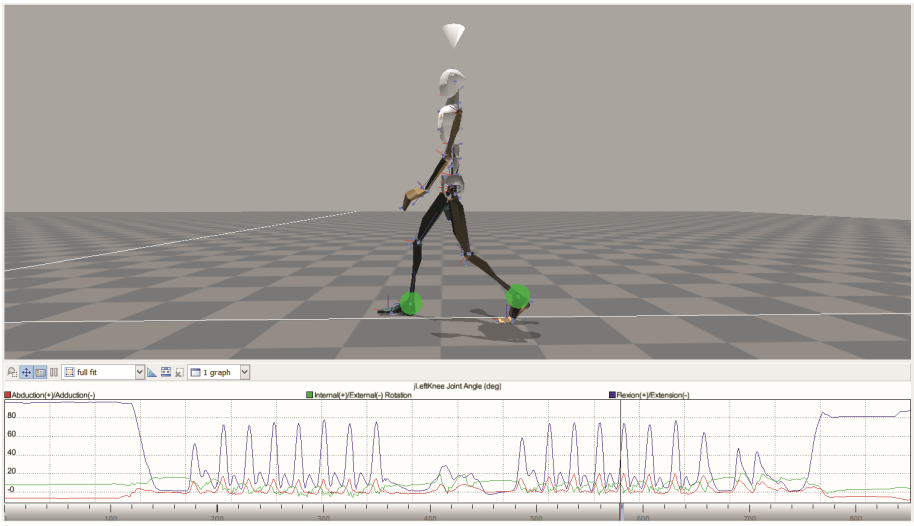

Fig. 10. INTERACTION 3D full body reconstruction during a walking test. The left knee joint is plotted over time for abb/adduction, internal/external rotation and flexion/extension.

Fig. 11. Clinicians measuring with the INTERACTION system. The sensing suit is worn under regular clothing.

A number of lab and in-home tests were done by wearing an on-body tablet pc with an Xsens Awinda USB dongle to overcome connection issues with the Xsens Awinda base station when walking out of range. These tests were successful and further options are explored like how patients can safely wear a small tablet on-body (in for example a

pouch attached to a belt) and optimizing the wireless connection by the placement of the USB dongle.

7 Conclusion and Future Work

The INTERACTION project aims to develop and validate an unobtrusive and modular system for objectively monitoring of upper and lower extremity motor function in stroke patients during daily-life activities. The system's complete architecture was developed according to the requirements identified at the beginning of the project. The architecture, including all its components, have been tested for up to 14 MTw sensors for a full body configuration. The biomechanical model, including the Xsens MoCap Engine (XME), is optimized for the INTERACTION sensor configuration and provides a full body 3D reconstruction. Position and orientation of body segments, joint angles and anatomical distances were computed successfully from several test measurements with healthy subjects in the lab and at home. The gateway software is fully tested and extended with an auto-reconnect feature when sensors become out of range and return within range. This will ensure that more measurement data are collected when measuring subjects at home, which is prone to out of range issues. Furthermore, the portal's MVC structure has been designed to be extensible and provides a flexible coding environment for engineers by the inclusion of a Matlab-Java bridge for back-end data processing algorithms. The XME, and the algorithms for activity recognition and for computing clinical assessment measures are included within the back-end data processors.

An option was investigated for the out of range issues, namely by measuring with an on-body tablet. This option was successfully tested in the lab and at home with a full body configuration and is currently being optimized for use. The next step is to validate the sensor suit by comparing it with Vicon [14] as an optical reference measurement system. The activity recognition algorithms for upper and lower extremity measures need to be validated as well and the specificities need to be determined. Patients measurement are starting in June 2014 at both the Roessingh Research and Development clinic in the Netherlands and the neurorehabilitation clinic Cereneo in Switzerland as well as at the patients home. At home measurements will provide additional challenges as external factors such as unpredictable magnetic distortions and movement of clothing will have larger influences on sensor data than in a controlled environment.

In this project, we have identified an extensive list of potential clinical assessment measures. The list of clinical assessment measures given in this paper is an example of what the INTERACTION system will deliver. We are now in the process, together with clinicians and engineers, to make a final selection of these measures to be implemented by the system.

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