Remote communication, examination and training in stroke, Parkinson's and COPD care: work in progress testing 3D camera and movement recognition technologies together with new patient centered ICT services

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ABSTRACT

This paper describes strategy and work in progress. The combination of patient centered care where many care and nursing units are collaborating with focus on, and in concordance with the patient, the ability to project information focused on the patient total situation and needs independent from where the information was created, the ability to use sensor technology to collect a wide range of aspects of the individuals health situation, the ability to use sensor technology to assess movements both for assessment and intervention purposes, to keep the care and nursing process together through module based information services and a structured care plan containing goals, sub goals, defined activity types and a wide range of health status data involving great opportunities for patients having chronic diseases. This group of patients causes extensive resource consumption for society. Well-structured data and semantic definition of data is a key for communication between different types of multi-professionals actors with different background. New technology, such as a wide range of sensor types, allows the possibly to capture large amounts of data both for assessment and intervention purposes in a continuous way over time. One example is how each planned patient activity has been performed and resulting health status aspects. This research group has worked on these issues for several years and some important milestones have been reached. From a chronic point of view three groups of patients are the focus: stroke patients, chronic obstructive pulmonary disease (COPD) patients and patients with Parkinson's disease. Collaboration approaches, communication technology and adapted information services allow new ways to perform home based care. Integrated monitoring services of planned activities like motion activities using 3D sensors allows professionals and patient to, in an exact way, follow planned and executed motion activities which are of great importance to many patient needs.

1. INTRODUCTION

A stroke or any other neurological disease/damage, like Parkinson´s disease, has profound impacts on a person's life. The conditions are often life long and require continuous treatment and rehabilitation, as well as support for the activities of daily life. Communication and the performance of assessment activities as well as intervention activities are tiresome and it is a challenge to create a care situation with continuity for the patient in order to achieve results. Due to the low physical mobility and poor overall condition of these patients, traveling back and forth to doctors, nurses and rehabilitation centres can be exhausting tasks. Communication and interaction with relatives and friends is important but often become cumbersome and may also include long, strenuous trips. More developed forms of home based care, in combination with support from various kinds of professional units, has great potential for innovation, with information technology as an enabler.

Rehabilitation is essential in order to promote and maintain maximal level of recovery by pushing the bounds of physical, emotional and cognitive impairments. It is the foundation to enable full reintegration into the society and pursued occupation. Assessment is a key component in the care of the neurological patient and important for

both diagnostic and therapeutic purposes in clinical practice. Patients often perceive their experiences of rehabilitation care as non-connected or non-coherent over time. Continuity and early start for the patient regarding rehabilitation is important to reach constructive results.

For COPD patients the need and importance of performing exercise is similar. Performing exercise can aim at keeping existing capabilities of the individual and to contribute to the avoidance of exacerbation.

For many patients home based care can be an effective way to manage rehabilitation without being required to visit the hospital or other care unit when training has to be performed on a more daily basis. Video mediated remote strategies can be used to support and encourage the individual in being systematic regarding exercises for assessment and intervention purposes. Monitoring can be performed both by observing the individual, using video, but new possibilities are developed by using monitoring services which in detail can monitor how different movements have been performed using worked out representation approaches of sub-movements of each exercise type. Monitoring and storage of detailed results of each exercise instance can be used for feedback, visualization and analysis both for the patient and for the professional.

Stroke, Parkinson´s and COPD are examples of diagnoses where movements are of great importance both for assessment and intervention purposes and some exercises can be used for several diagnoses, but many types of exercises should be quite different depending on function resources and disabilities of the individual. For example, for stroke patients the rehabilitation service should allow exercises where differences between left and right parts of the body functions are focused.

In earlier work we have documented experiences of developing telemedical tools, tools for support of rehabilitation activities, including, sensor monitoring, 3D visualization and haptics (e.g. Pareto et al. (2011), Broeren et al. (2008), Goude et al. (2007)).

Experiences of this earlier work lead to the insight that:

1. Information services is needed to keep track of the whole set of relevant conditions and goals of the individual to be able to tailor personal plans which can encourage the individual to perform evidence based care activities
2. Be able to perform more of self managed care activities
3. Make it possible to add new types of sensors and to use the values for them in a structured way so that analysis and conclusions can be drawn related to accepted health condition types and classifications
4. Being able to point out affordable packages of equipment and services which can be affordable to most patients

Games are assumed to stimulate and reward a person, and to make it fun and engaging to perform serious activities. The aim is often and to reach results in terms of keeping up to a structured and individual exercise plan. If exercise activities can be performed through games a lot of encouraging effects can be made. A lot of development work is being performed to create a workable representation structure so that a good representation of exercise types (and its sub-movements) can be associated with one or several game type alternatives. The user can choose between different games for the purpose to perform certain types of evidence base exercises important for the individual.

For Parkinson's disease we are developing tools for remote assessment of motor function. The underlying scientific procedure is called Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Process, Format, and Clinometric Testing Plan (Goetz et al. (2008)).

Recent work is focusing on monitoring, visualization and assessment of how the planned execution of the exercises really was executed. A specific monitoring part of the services has been developed that monitors and stores how every movement has been performed. This monitoring sub-service used the body representation and body posture to describe how every moment has been performed. Further, we have showed that depth cameras and other types of sensors are useful to follow movements (e.g. prescribed exercises) overtime and can provide a measure of rehabilitation progress in a wide range of remote health monitoring. The objective of this investigation is to develop tools and knowledge to identify if new technology matched with patient oriented services and new care procedures will lead to better rehabilitation in terms of both cost-effectiveness and quality for the individual. The overall goal is a multi-purpose, configurable ICT service platform supporting home based care highlighting the individual patient's specific needs.

Related to monitoring, one type of monitoring can consist of automatic collection of data concerning for example how an exercise has been performed, one other important type of monitoring is self-assessment by the individual him-/herself. For example, to COPD it is of interest to collect data about how tiresome the performance of a particular exercise was experienced by the patient. For this purpose the Borg Scale can be used

(Borg (1982)). Borg scale assessments must be linked to the exercise performance and to the elements of the sub-movements.

2. MATERIAL & METHODS

3D sensors like the Kinect and other types of motion sensors like Leap Motion (LM) sensors are marker less motion capture systems which offer an attractive solution for home based rehabilitation. Although marker based tracking systems are more accurate, with spatial and temporal correspondence that marker less system lacks, the Kinect and LM devices' precision are sufficient enough for rehabilitation purposes (Fernández-Baena et al. (2012), Moeslund et al. (2006)). The devices' accessibility and low cost render them an advantageous solution for home based rehabilitation. The video game environment provided by the sensors has the potential to become powerful motivation tools for performing regularly rehabilitation exercises. Data from tracking the execution of the exercises in real time can be used for assessment of patients' physical status, which can trigger the need for interventions. Furthermore, captured data can be utilized to provide guidelines to the user, thereby optimizing the effect of the exercise.

A promising approach, explored in some depth for stroke and COPD patients, is to integrate support for video-mediated communication into the rehabilitation support platform, which includes both LM and Kinect devices. The Kinect device is in this situation used both as a body tracking device and a camera, while the LM device is used for tracking of hand and finger movements. A therapist/doctor can thereby remotely assist or instruct the home cared patient, in cases where direct physical interaction is not needed. Related to patients with Parkinson's disease their motor performance will remotely be registered with the Kinect and LM sensors connected to a laptop or tablet computer. During the fall of 2013 we implemented one of the MDS-UPDRS procedure, namely "alternating movements" and tested it interactively with doctors and patients. Here the patient is instructed to repeatedly approach and remove the thumb and the index finger from each others as much and as fast as possible. For COPD patients there are similar challenges. One of the challenges is the importance of keeping up training and movements and repeatedly meet health care professionals for plan change and updates and also to meet relatives and friends to avoid depressions etc.

For several diagnoses, the risk of falls is significant and structured fall prevention activities are hence important. Many of the tools and technologies explored for Stroke, Parkinson's and COPD patients can also be used for fall prevention. Assessment, risk calculation and intervention activities can be designed to reduce the risk of falls, which can be beneficial for many kinds of home care.

3. RESULTS

From our previous experiences of stroke rehabilitation, we know that 3D sensor based approaches like Kinect works well in an interactive situation in assessing kinematic information of motor function of the trunk, arm and leg. Now we have developed support for detection of hands and individual fingers. In most cases the interaction/instructions from the examiner can be pre-recorded ´machine´ standards. Our preliminary study of the MDS-UPDRS indicates a drawback, namely that some tests must comprise a physical interaction or/and an, at the actual moment, individualized instructions from the therapist/doctor. In these cases, we have to develop alternative procedures or omit these parts. An added value, as compared to the clinically performed MDS-UPDRS, is that with the ICT tools we can assess kinematic, numerical, values specifying the tested functions. Examples are frequency of tremor, time/velocity/acceleration/precision in movements**.**

Further findings are that one has to structure the entire set of subservices to really take advantage of the technology potentials which can be used in the home. Development and tests have shown that the following parts are suitable:

- A component that can, in depth, represent a particular exercise type often consisting of a set of sub-movements. This includes variation variables for individual adaptation (see below),
- A component that allows the therapist to define which movement a patient should perform, including definition of regime, intensity, repetition, sets and adapted movements. This is part of the individualization and needs and goals for the individual,
- A component that can monitor and store how the patient actually is performing each particular movement at each particular occasion,
- A component that can represent all relevant health condition types and classification related to a set of diagnoses, over all goals, sub goals, goal values of health condition types and relevant relationships to activity types.

- A video-mediated communication tool designed for communication between a professional and a patient where the professionals really can see how different movements are performed in each planned session,
- A component that can describe game types and how they are related to evidence based exercise types.
- A follow-up module where results of each training session are visualized related to goals. This includes more exact monitoring of how each movement is performed by each body part monitored in real time.

To capture, store and analyze large amounts of data about how all exercises have been performed, approached based on Big Data analytics will be used. When monitoring every training instance, e.g. for COPD patients, it can be very fruitful to monitor and store all training instances including sub-movements and also simultaneously monitor medical sensor data such as blood oxygen saturation levels when performing a particular exercise. Based on the collected data, assessments can be performed and conclusions can be drawn about how that patient should perform certain types of exercises, resulting in an updated care plan.

The following plot (Figure 1) shows the distance between the index finger and the thumb on the x-axis with respect to the relative speed between the two fingers on the y-axis. It shows an arc like concentration of dots which is what it typically looks like for a person without any disorder. The more a person is affected the more irregular and flat like are the plotted set of dots. This measure is an indicator of dysdiadochokinesia, the inability to perform rapid alternating movements, a sign of cerebellar and/or frontal cerebral lobe dysfunction. This kind of assessment can be accomplished by having the Leap Motion sensor attached to any home computer and having the patient simply surf to a web URL where the test can be carried out.

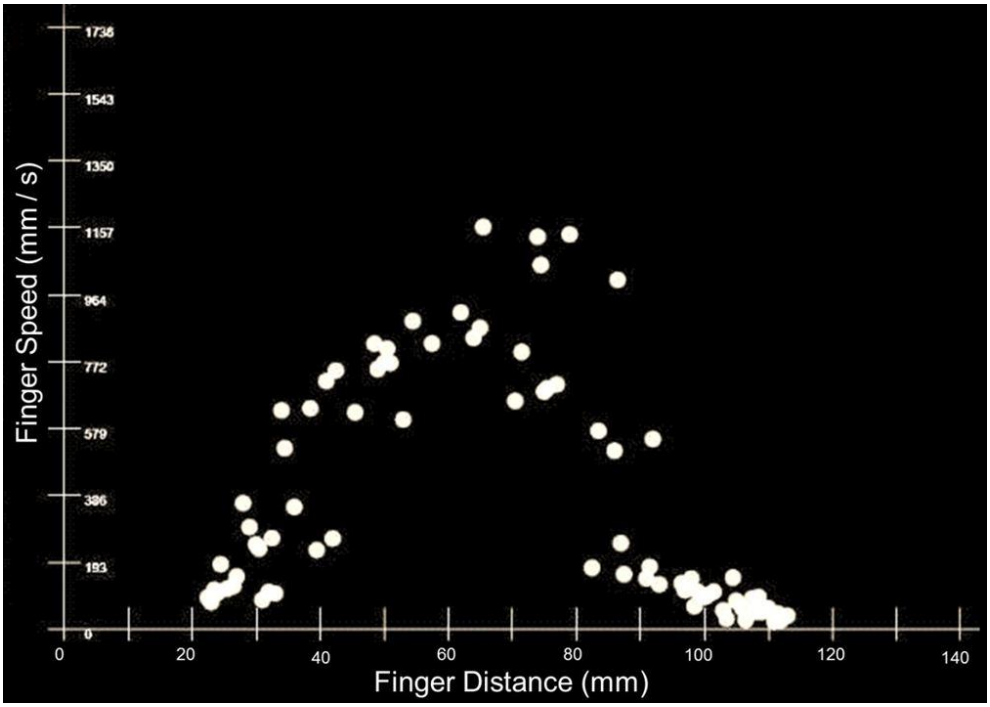

Figure 1. *The distance between the index finger and the thumb on the x-axis with respect to the relative speed between the two fingers on the y-axis.*

4. DISCUSSION

The work is in a development and exploration phase but soon more systematic comparative studies will be performed in order to measure effects. Fundamentally, the health cooperation concept is cross organizational process where different care and nursing units and actors can participate. The focus is the patient's overall situation and needs. All actors involved in different types of activities can access selected information in a distributed unit, based on the roles that they have related to the individual. The individual and relatives are heavily involved in the performance of the activities.

The platform architecture has two main parts: the service level and the sensor level. A large number of new sensors have been developed and new sensors will appear. Sensors are typically interpreted in relation to an assessment scale, reflecting a specific health care aspect. The service level is concerned with the logical process oriented interpretation, computation, visualization and storage of data. This architecture will continuously allow new technology to be adapted and integrated. All activities are structured into activity types and activity

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instances. Some activities are aimed at assessment of conditions and some activities are aimed at interventions related to goals (that change with time). The health plan is an important concept keeping all assessment activities, goals and intervention activities together. The plan can contain prevention as well as assessment and intervention activities.

In this patient/person centric approach, specific e-services, involving sensor technology, can be used for development of other movement oriented health assessment and intervention activities, like prevention of fall injuries and training of motor functions aimed at restoring muscle performance or breathing capacity. The e-services will contain subparts like definition of particular movement oriented activity types, support of how a particular activity instance should be executed, recognition of results of a particular activity instance, reporting of results of an activity instance, video-mediated communication with professional and other actors for support of a particular activity instance. For many activity types, including stroke assessment and rehabilitation, COPD rehabilitation and fall prevention activities, whole body tracking is the most important. For the UPDRS assessment activities, high precision finger tracking is also required.

The tool set outlined here can also contain tool parts supporting powerful assessment scales like the ICF scale. (The International Classification of Functioning, Disability and Health) (WHO) for the purpose of make an extensive analysis and assessment of the situation of the individual. This support can also contain support for setting of goal values related to ICF and the selection of activities for the individual.

5. CONCLUSIONS

Sensors, computers, displays and communication technology is getting better and cheaper enabling advanced e-services for home based care, including real time support from remote medical professionals. The developed solutions can be both cost effective and provide high quality for the patients, due to improved continuity of care, less need for travel, and improved motivation to perform physical activities more often. This means that e-health services for home based care, including communication with healthcare professionals, have a great potential to overcome the challenge with increasing demands of care due to an aging population. The services must support both asynchronous communication of patient data, as well as real time interactions for monitoring, assessment, and support. Not only health care personnel, but also relatives and other informal cares need to be included in the communication. By designing an ICT platform supporting both synchronous and asynchronous communication of data from tracking devices and other sensors, including depth cameras and video cameras, a flexible and configurable multi-purpose care solution for home cared patients can be developed. Until such a sophisticated platform is realized, however, experiments with enabling technologies in specific patient groups must be performed, which is the objective of our present study.

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