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Article Title: A Low Cost 'Activities of Daily Living' Assessment System for the continual assessment of post-stroke patients, from inpatient/outpatient rehabilitation through to telerehabilitation

Year of publication: N/A

Link to published article:
http://www.icebergevents.com/sft11/Program/

Publisher statement: None

A Low Cost 'Activities of Daily Living' Assessment System for the continual assessment of post-stroke patients, from inpatient/outpatient rehabilitation through to telerehabilitation

by

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Presented at:
Successes and Failures in Telehealth, Brisbane, Australia 1-2 December 2011
http://www.icebergevents.com/sft11/

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Disclosure Statement:

The authors of this paper confirm that there are no conflicts of interest.

Summary

Research regarding telerehabilitation for stroke patients' places little emphasis on monitoring and assessment. To effectively monitor a patient, assessment must be continuous; from the inpatient/outpatient setting, to the remote. However, assessment methods used by Occupational Therapists' can be qualitative and difficult to automate for a remote location. The aim of this research is to develop a system which presents the Occupational Therapist with a tool that, whilst not altering current routine, provides Range of Motion (ROM) analysis from current and previous rehabilitation sessions. Amalgamated data can then be achieved through the use of the same prototype in a remote location. Results from the prototype are outputted in graphical format, detailing movement throughout the session. The system details minimum and maximum extremities of patient ROM throughout all sessions and can be compared with the ROM required to perform certain activities of daily living. This prototype system allows the therapist to continue traditional rehabilitation, whilst providing graphical feedback over time, including detailed ADL assessment. If then used by the patient in a remote location, movements can be analysed and reported to the therapist. The prototype provides visual feedback, helping to increase motivation, whilst providing data that can generate adaptable rehabilitation programs.

1.1 - Introduction

On average, fifteen million people worldwide suffer a stroke every year. Five million of these strokes will result in fatality, and another five million will result in permanent disability (1). Stroke results in a 'neurological lesion' in the brain, causing symptoms such as Hemiplegia (paralysis of one side of the body) and Hemiparesis (loss of strength in the arm and leg) (2). Rehabilitation from stroke allows new neural pathways to be formed away from the lesion (3), allowing the patient to acquire neuromuscular control that has been lost due to the stroke.

Research suggests that in recent years there has been an increase in stroke risk factors including rapid ageing, diabetes and obesity (4). This has resulted in a higher incidence of stroke worldwide, and hence, a high demand for the long term rehabilitation of stroke patients. This can place pressure on healthcare services to provide adequate staff to deal with the situation. Over the last decade a concept has emerged that could help support this field and ease pressure on healthcare staff; this is known as 'Tele-rehabilitation' and can be defined as:

"*Conventional rehabilitation services at a distance, using telecommunication technology as the service delivery medium (5).*"

Telerehabilitation has been shown to not only reduce current therapy costs (6), but also reduce timing constraints through travelling (7). This in turn will allow therapists to see more patients through inpatient and outpatient care.

A vital part of the current rehabilitation process, and one of the first steps that must be taken towards telerehabilitation, is the assessment and progress monitoring of patients, and in particular, assessment for motor impairment that is caused by a stroke (8-9).

Assessment methods that are currently used by physiotherapists and occupational therapists are typically based around assessment scales. In particular ‘activities of daily living (ADL)’ scales, such as the barthel index (10), the ‘functional independence measure (FIM)’ (11) and the ‘modified motor assessment scale (MMAS)’ (12). These scales ask the relevant therapist to assess the patient based on their own viewpoints, and hence, can be highly subjective.

There have been attempts at assembling standard methods for the assessment of stroke patients for rehabilitation and quantifying them for the purposes of telerehabilitation. Russell et al. (13) used software to test range of motion, strength, girth and gait analysis. Durfee et al. (14) performed a range of tests including range of movement and strength testing that involved the use of a goniometer and remote control of a patients camera. Hoffmann et al. (15) and Russell et al. also used goniometer’s in tests to measure range of movement in patients through videoconferencing, demonstrating high intra and inter rater reliability scores.

Palsbo et al (16) took 26 patients (excluding those with consciousness and comprehension problems) and tested a videoconferencing system using the functional reach test and European stroke scale. The idea of comparing face-to-face assessment and internet based assessment has become a popular method in this field.

The issue with these tools is the lack of automation; a therapist is still required at all times during assessment and with the scarcity of healthcare resources, this additional therapy could prove to be an even greater burden. A further problem area is the high cost of any system. Any attempts at automation should involve low cost equipment, therefore avoiding the depletion of resources that could otherwise be used for the training and employment of additional therapists. This paper will introduce a system which tackles both of these matters, providing a low cost, accurate assessment tool for telerehabilitation.

2.1 – Proposed System

2.1.1 – Overall System

This paper presents a novel prototype system to support occupational therapists in the assessment of persons who have suffered a stroke and has been developed using the opinions of occupational therapists and physiotherapists in the UK ‘National Health Service’ (information was gathered through formal interviews). The system focuses on the assessment of upper limb function to detect problems such as hemiplegia and hemiparesis.

The proposed system performs this assessment by asking the patient to complete certain ‘activities of daily living (ADL)’. Patients often perform ADL tasks during stroke rehabilitation with an occupational therapist for assessment and therapy purposes; this involves tasks using everyday objects, for example, using a jug to pour water into a cup.

Whilst patients are performing ADL tasks, the system will measure 'Range of Motion (ROM)' in the upper limbs, acting as a real time goniometer. Upper limb ROM is measured using two separate processes. Firstly, a Microsoft Kinect™ (a device utilised with Microsoft's Xbox 360™ games console) is used to measure ROM at the elbow joint (flexion and extension) and shoulder joint (currently abduction and adduction, however, additional data can be provided) using markerless motion tracking. Secondly, an accelerometer is attached to each of the objects used during the execution of ADL tasks; this accelerometer is used to measure rotation of the object, and can consequently be used to calculate pronation and supination of the forearm (and possibly medial and lateral rotation at the shoulder joint).

The prototype that has been developed is designed to be used in two unique conditions (a use case diagram of the system can be seen in figure 1). Firstly, the system is targeted at use during standard inpatient/outpatient rehabilitation, whereby the patient is in a therapy session with an occupational therapist present.

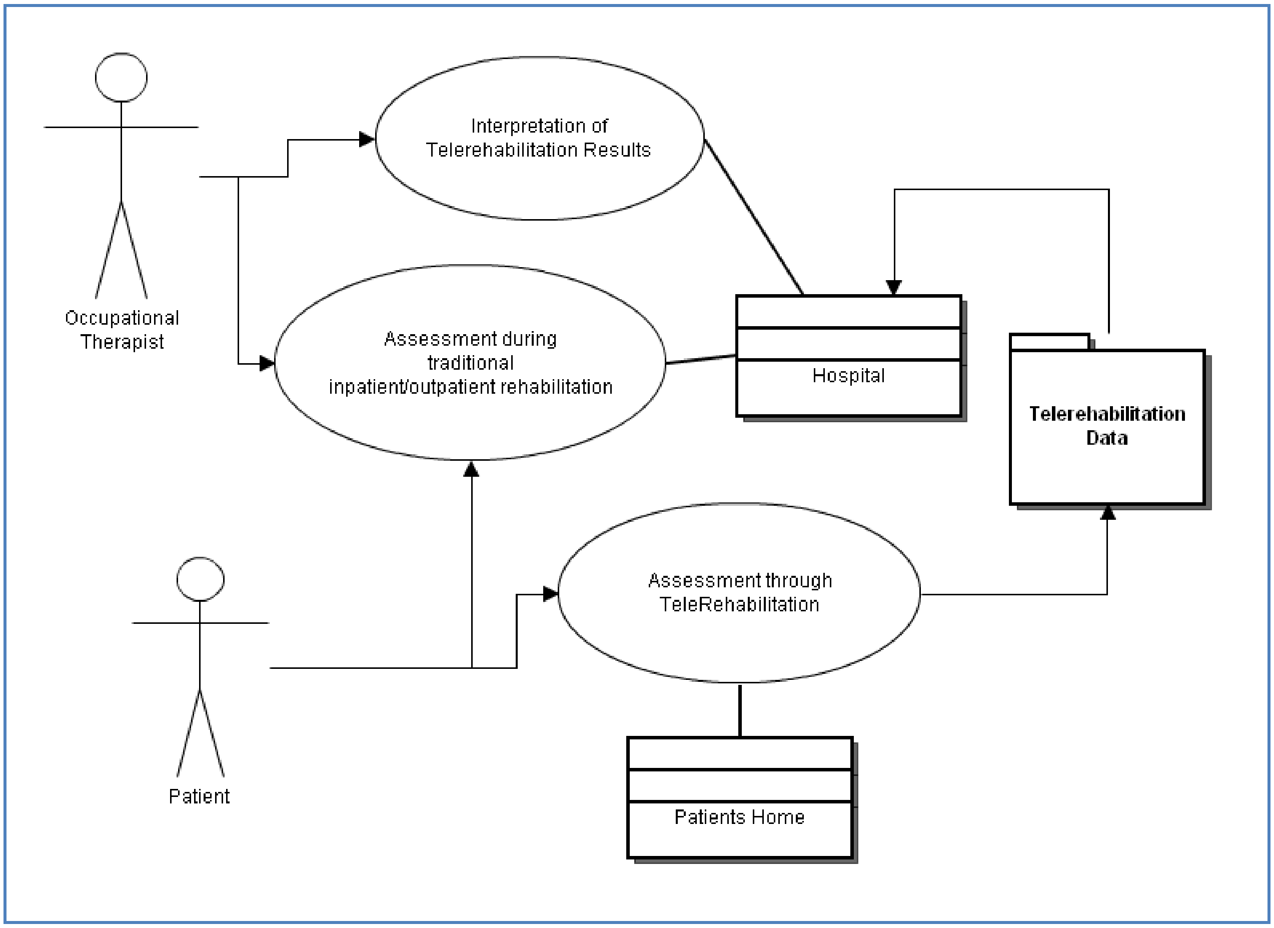

Figure 1 – Use Case Diagram

Secondly, the device is for use in a post-outpatient setting. In this instance, the patient will be given a system to use outside of the hospital environment (e.g. in their own residence), where a form of telerehabilitation can be provided. An overall system model is displayed in figure 2. The system has been developed in this manner to create a continuous throughput of quantitative data from the inpatient/outpatient setting, through to a telerehabilitation condition. These systems will consist of the same hardware, but variations of software (inpatient/outpatient software and telerehabilitation software). Furthermore, as the system is used in two separate stages, patient acceptance can hopefully be increased, due to a patient having interacted with the device prior to using it for telerehabilitation.

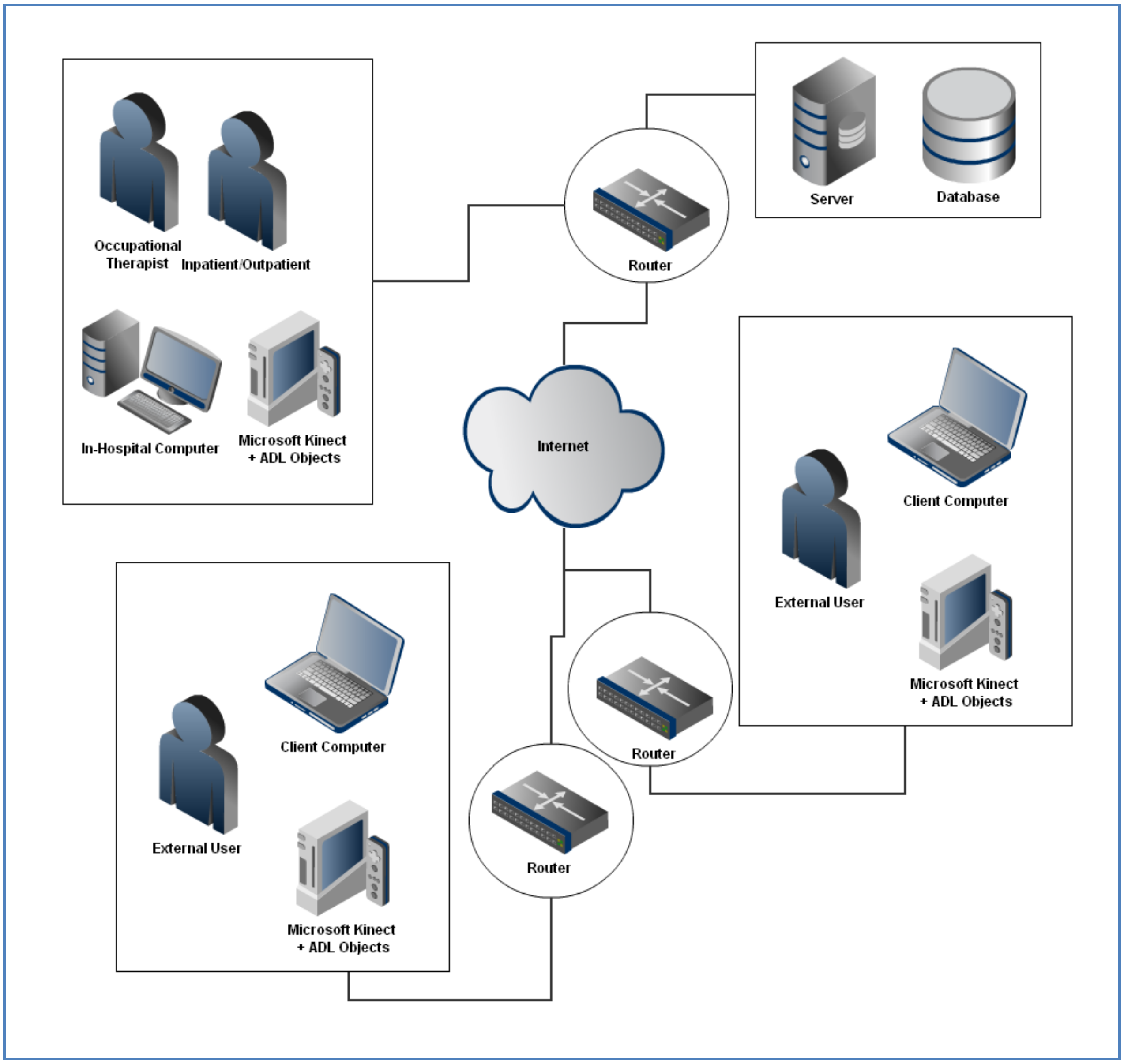

Figure 2 – Overall System Diagram

The proposed system has been developed with the vision of its inclusion in a large scale telerehabilitation system, where patients are able to interact using various tools (e.g. virtual reality, haptic interfaces, etc.); the prototype described in this paper will be the base for the development of this large scale system. This will provide quantitative feedback for the assessment of patients (helping therapists interpret at what stage a patient is currently at, as well as providing motivation for the patient), whilst also allowing for the creation of highly effective personalised care plans.

2.1.2 – Inpatient/Outpatient Software

The proposed system provides continual assessment for persons with stroke, from an inpatient/outpatient setting, through to rehabilitation from a remote location (telerehabilitation). In order to achieve this initially, assessment data must be taken from within the hospital environment.

For maximising user acceptance, the system has been designed in a way whereby it shall not alter current therapist practice; the only intervention the occupational therapist will have to make is to place the patient by themselves in front of the camera and initiate the system.

After this intervention has been made, the Kinect device will now track only the patient's skeleton, continually measuring ROM in the patient's upper limbs. At this point, the patient's skeleton will be displayed on the screen and the therapist is free to continue their standard rehabilitation session. Standard objects that are used in the session will now have accelerometers attached to them in order to measure rotational data.

Once the occupational therapist has concluded a therapy session, they may return to the system and end the session. At this point, the prototype system will generate a range of data detailing information about flexion/extension at the elbow joint; abduction and adduction at the shoulder joint and pronation/supination in the forearm. The specific outputs are detailed below.

2.1.2.1 – Current Session ROM

The therapist shall have access to separate graphs which detail the angles the specified joints were at throughout the current session, acting as a real time goniometer.

2.1.2.2 – Overall ROM Data

Once the session is completed the system will store the minimum and maximum ROM at each joint during the session. Using this data in combination with data from previous sessions, the occupational therapist will be able to view graphs which detail the ROM the patient has and is capable of achieving at each specific joint over time, demonstrating whether the patient has made progress or not.

2.1.2.3 – ADL Data

An alternative use for the data has been developed following opinions from occupational therapists, stating that functional outcomes are useful, and results should not be presented purely in the form of graphs. Therefore, using data from the book ‘Measurement of Joint Motion (17)’, which details required ROM for certain ADL tasks, an additional ADL task section has been developed. This section takes the ROM that the patient is capable of achieving at each specific joint and compares this with the ROM that is required to carry out specific ADL tasks, therefore, evaluating and generating a list of ADL tasks which the patient is capable of achieving.

2.1.3 - Telerehabilitation Software

This partition of the proposed system allows for the patient to continue rehabilitation once they have left the inpatient/outpatient setting. This section works in a similar manner to the former, however, an automated approach is now taken, allowing the patient to continue therapy with minimal concern.

The amount of interventions required by the patient has been minimised as much as possible. Currently, once the patient switches the machine on, the software automatically starts, presenting a screen which asks the patient to stand back. At this point in time they are also asked to press the ‘on button’ on each ADL object (this could be avoided in future circumstances by having these devices permanently on charge).

The patient’s skeleton is then displayed on screen, as in the inpatient/outpatient version of this software. However, in disparity with the inpatient/outpatient software, a video is displayed. Here, it is demonstrated to the patient how to carry out three ADL tasks (pouring water and drinking, combing of the hair and picking up a telephone). These tasks have been selected as they require the greatest ROM according to ‘Measurement of Joint Motion (17)’. This allows the system to calculate the patient’s maximum flexion/extension at the elbow joint; abduction and adduction at the shoulder joint and pronation/supination in the forearm. This data is now transmitted to the hospital where the therapist is able to view the results, using the same outputs described in sections 2.1.2.1, 2.1.2.2 and 2.1.2.3 of this paper.

3.1 – Further Work

This system has been developed with the idea of being the base for a large scale telerehabilitation system for persons who have suffered a stroke. Therefore, additional work must be performed in order to carry this idea forwards.

However, additional work must be performed on the prototype described in this paper before this larger picture is attainable. The system must be developed into a full scale system, in which a greater number of joints and movements are measurable. Research must also be performed, to attain the required ROM for a larger number of ADL tasks, so therapists can view what the patient is capable of achieving. Data used in producing total ROM at each joint over time could also be analysed and extrapolation applied in order to predict patient recovery (time and recovery level).

For the next stage of research, the authors of this paper now intend to test the proposed proof-of-concept system within UK healthcare to prove efficacy.

4.1 – Conclusion

This system has the potential to provide the base to a new telerehabilitation system within healthcare. This system proposes that continual data be taken throughout a patient's rehabilitation, from the inpatient/outpatient setting through to the remote; providing useful data to the therapist, whilst presenting the capability of producing personalised care plans through telerehabilitation for the patient.

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