Wearable Rehab Technology for Automatic Measurement of Patients with Arthritis

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***Abstract*—this paper outlines the initial ideas surrounding the development of an accurate hand measuring tool to assist Medical clinicians and Rheumatologists in the accurate measurement of finger and thumb movement of the human hand. Clinicians rely heavily on invasive x-rays or manual evaluation methods which are dependent on training and can vary between observers. Angle measuring instruments, tape measure and grip strength dynamometer are used to assess the joint range and function of a patient to determine their hand function. Self questionnaires used determine a persons ability to perform daily tasks are open to interpretation problems.**

***Index Terms*—Rheumatoid Arthritis, Assisted Technology, Healthcare Technology, Medical Informatics**

I. Background

RHEUMATOID Arthritis (RA) is a disease which attacks the synovial tissue that lubricates the joints of the human skeleton. This systemic condition affects the musculoskeletal system, including bones, joints, muscles and tendons that contribute to loss of function and range of movement and difficulties in performing activities of daily living (ADL). Treatment for hand RA is determined by Clinicians and Occupational Therapists (OT) using invasive techniques such as x-rays or manual techniques using a Health Assessment Questionnaire (HAQ), angle measuring instrumentation, tape measure and grip strength dynamometer. Clinicians and Therapists aim to quickly diagnose and treat those with this debilitating disease through treatment programs and education [1]. Treatment options include manual therapy, electrotherapy, injection therapy, and physiotherapy. Patients are educated in Joint Protection (JP) techniques, altering working methods, energy conservation and the use of assistive devices to reduce load and effort required for everyday tasks. Previous research has shown that altering working methods significantly reduces activities within ADL [2]. Hand therapy research has also identified a role for strengthening hand exercises in the management of RA. A combination of strengthening and mobilizing exercises with advice on JP improves hand function and grip strength in an individual with RA more than stretches or JP alone [3].

II. Occupational Therapy Assessment

Swelling, deformity and pain are common symptoms of hand arthritis. Currently a patient who has suspected hand RA is examined by an OT to quantify joint range and determine hand function for the prescription of suitable treatments and education. A time consuming examination assesses the clinical appearance of hands and fingers using a goniometer, a tape measure, a Health Assessment Questionnaire and a grip strength dynamometer. A goniometer measures flexion, extension, adduction and abduction of the metacarpophalangeal (MCP), Proximal interphalangeal (PIP) and Distal interphalangeal (DIP) joints of the fingers and thumb in degrees. It also determines thumb-index finger web space angle and Palmar abduction. A tape measure determines thumb-index finger web space and Distal Phalanx-palm distance in centimetres. The HAQ contains questions that determine a patients ability to perform daily tasks. Statistical techniques are applied to patients responses and the outcome measures their daily functionality level. A grip strength dynamometer measures the patients power grip of the intrinsic and extrinsics in kg and indicated grip strength is compared to a grip strength scale. All measurement outcomes are recorded in handwritten form to assist in future assessments. Outcomes are influenced by the Clinicians training and experience and can vary between observers.

III. Summary of Data Gloves to Date

This project involves the development of an intelligent computing system to assist medical clinicians with the accurate angle measurement of digits in the human hand. Two gloves that are typically used for gaming purposes have been evaluated for development of a glove measurement system; the 5DT data glove 14 ultra [4] and the X-IST Dataglove HR1 [5] (see Figure 1).

A. 5DT Data Glove 14 Ultra

The 5DT data glove 14 Ultra is a single layer glove made from stretchable lycra. Each glove finger contains two fibre optic bend sensors, with an additional sensor between fingers allowing finger flexure and finger abduction measurements. The glove connects to a host computer via the USB for signal and 5 volt power provision. Each finger sensor has a flexure resolution of 12 bit A/D and a minimum dynamic range of 8 bits to provide a minimum 75 Hz sampling rate and 200 Hz per finger tracking [6].

B. X-IST Dataglove HR1

The X-IST data glove is made from a two layer glove. The inner layer is constructed from stretchable lycra. Sensors

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Fig. 1. a) 5DT dataglove; b) X-IST dataglove HR1

are attached onto the top of it. The inner layer is covered with an outer glove which protects the sensors and associated electronics from the outer environment. There is a choice of two outer layer versions: a rubber coated or a lyrca / elasthan version which is thinner and more stretchable than the rubber version [7]. Each bend sensor has a flexure resolution of 10 bits and a sampling range of 100-200 Hz dependent on filter settings.

All sensor post processing is carried out by the ADBox24 sensor processor that connects to the glove and to the USB port of a host computer. The sensor processor converts the 24 channel signals from the data glove to digital using an analogue / digital convertor. Two 15 port connections can accommodate either two gloves simultaneously or additional sensors for each part of the finger. Sensors are wired through high flex silicone cables. Two cables then run to the ADBox24 and plug into port 1 and 2. The 5DT data glove is more accurate, comfortable, and easier to communicate with than the X-IST data glove. It has bend sensors on each finger for the measurement of finger flexure. The additional sensor between each finger provides finger abduction measurement.

IV. What the System Will Provide

The aim is to develop a new system to aid medical clinicians in the accurate measurement and diagnosis of patients with RA. This system will consist of a wearable glove measurement tool and a 3D interface that will display accurate quantifiable data on a patients flexion, extension, adduction and abduction finger and thumb joint movements in degrees and as a 3D image. Data should be recorded and electronically stored for future comparisons on historic movement range of a patient over time. Key indicators will assist the clinician to make an informed prognosis including:

- The degree of deformity of the hand and stiffness of the moving finger joints
- A shift in the position of the fingers in relation to the direction of the thumb by measuring web space
- The amount of joint swelling using a volumetric system
- The system records the minimum, maximum and average values of a number of tests

V. System Benefits

The proposed system will be the first ambulatory system to monitor joint stiffness at home. The symptom of difficulty in moving a joint will be measured rather than the limitation of finger joint movement. The rate of joint movement at different times of the day will be measured. This will provide a better understanding of early morning joint stiffness which is a common ailment of RA.

The system will measure the time taken to perform repetitive finger-palm flexion and opposition touch exercises and provide positive feedback to the patient. Specific programs of exercise will be assessed for benefit using historical hand joint data. The clinician will observe time taken to perform hand exercises and determine if exercise has any quantifiable benefit to the patient.

VI. Conclusion

This is a new research project that will encompass current interface and system developments from earlier work [8]. A customized interface has been developed for the presentation of glove data in a user friendly format. Finger movements from each finger are displayed in real time in numerical and graphical form as shown in Figure 2.

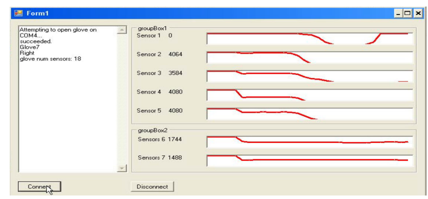

Fig. 2. Interface processing information from each sensor 1-5 (fingers) and 6-7 (2-axis tilt sensor) on the data glove

A 3D hand model has been created using the 3D Max application as shown in Figure 3. Sensor data harvested from the data glove enables an accurate animated sequence of hand movements to be displayed in 3D.

Fig. 3. Animated hand using sensor data from glove

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