Digit-Ease

Smart Glove System for ambulatory measurement of joint range of motion and stiffness

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Background

- Rheumatoid Arthritis (RA) is a disease that attacks the joints of the human skeleton (see Fig. 1).
- In 2011, RA affected up to 500,000 of the UK population and starts between the ages of 40-50. It is commoner in women [1].
- Around 20,000 new cases of RA are diagnosed every year in the U.K [2].
- Four out of ten people give up their job within five years of diagnosis.
- Joint stiffness is a common complaint of RA sufferers.

Figure 1 – finger joints affected by RA disease

Figure 2 – example of goniometer used for ROM measurement

- RA is currently diagnosed by clinicians and therapists using x-rays and manual evaluation methods including a goniometer (Fig 2), tape measure and visual evaluation.
- Measures flexion, extension, abduction and adduction of finger joints.
- Joint Stiffness is currently measured using a Disease Activity Scale and the Health Assessment Questionnaire.
- Difficult to record the onset of stiffness with this equipment as it occurs most frequently in the morning at home.

Materials and Methods

Digit-Ease project is a smart glove system integrating sensors, processors, wireless technology and algorithms to empirically measure Range of Motion and assess the progression of joint stiffness.

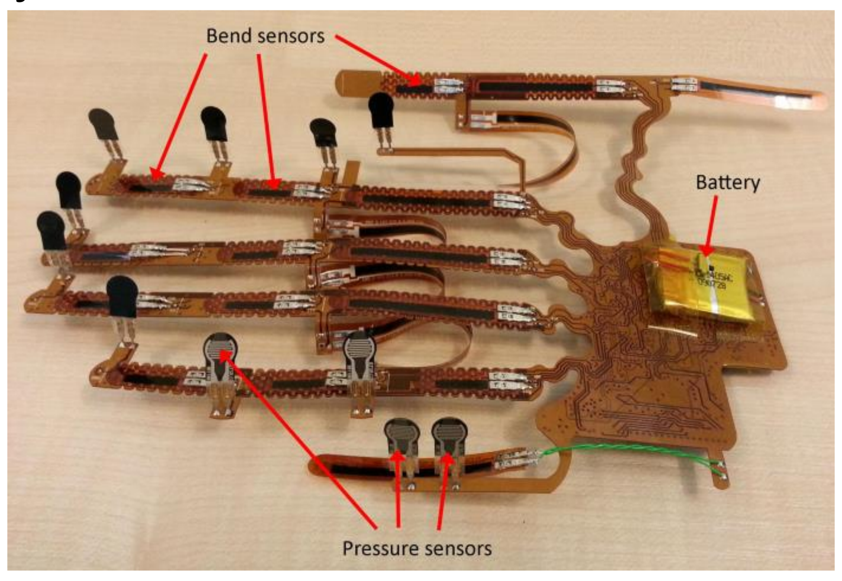

Figure 3 – Image of new glove

Auto-calibrating

- New glove containing multiple accelerometers, bend sensors and force sensors eliminates the need for calibration (Fig. 3)
- Glove is automatically calibrated using Neural Network and accelerometer inputs from glove (Fig. 4)[3]

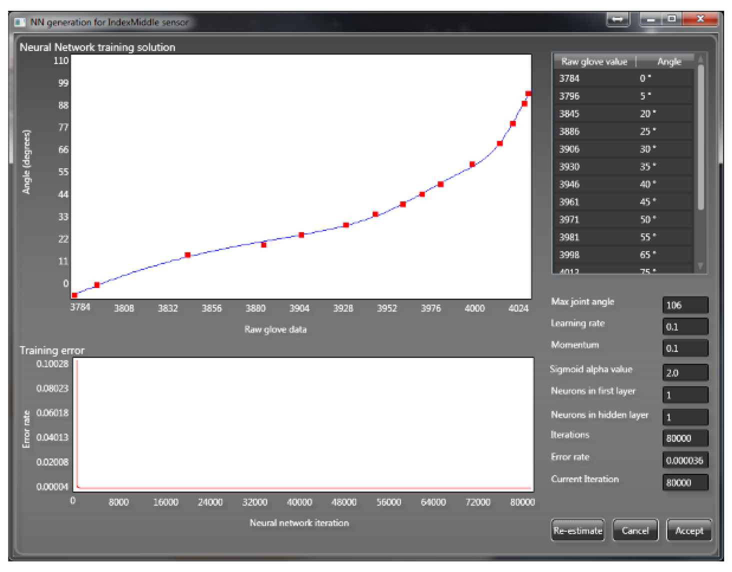

Figure 4 – screen shot of Neural Network application used for auto-calibration of glove sensors

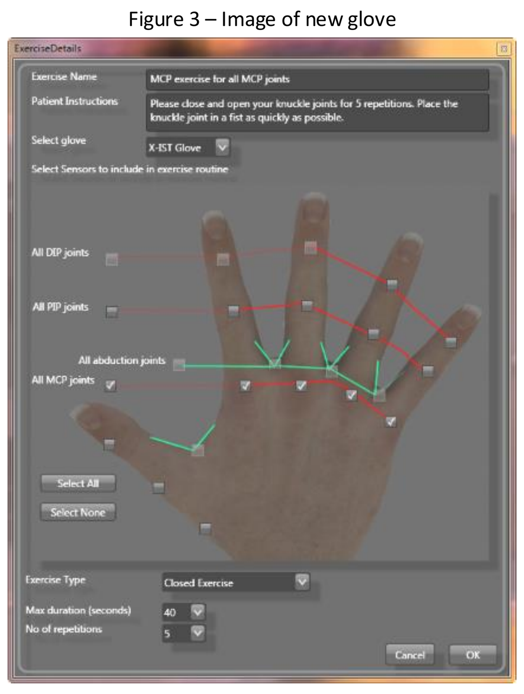

Figure 5 – creating a new objective

Patient access at home

- Clinician assigns objective from the objective bank to the patient or creates a new tailored one (Fig. 5).
- Patient attends clinic session and completes an objective routine. This is used as a baseline for comparison to future objectives.
- Patient logs into system and selects objective routine. Patient shown 3D hand movement during objective progression (Fig. 6)

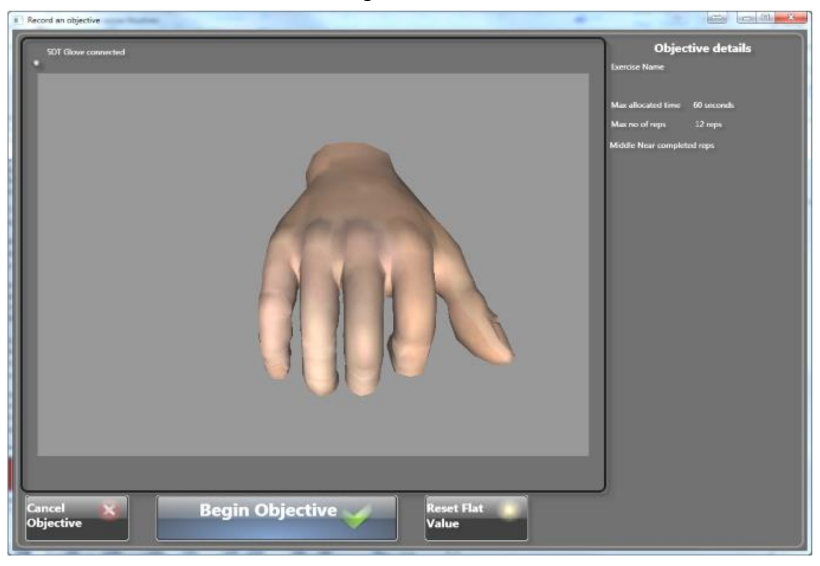

Figure 6 – 3D hand moves in tandem with patient movement in glove. Provides feedback to patient on objective progression

Figure 7 – Comparison of several objective repetitions

Cloud-based analysis

- Clinician can compare individual repetitions from several objectives completed by the patient (Fig. 7).
- Objective routine is uploaded to a cloud database. Clinician can immediately view completed objective routine statistics and a 3D image as it happened at the patients home (Fig 8).

Figure 8 – Playback of movement recorded by the patient at home

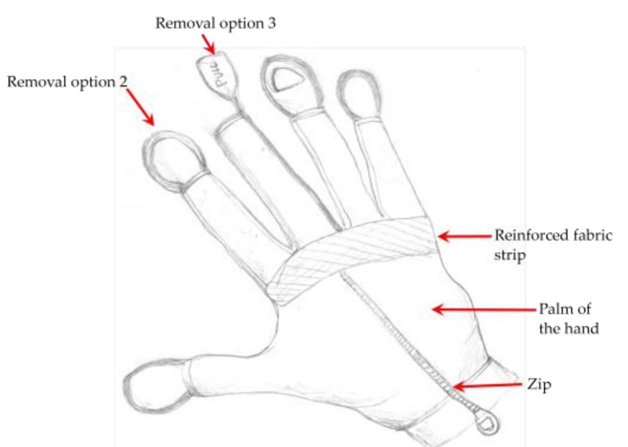

Figure 9 – sketch showing design concepts for easy glove removal

Figure 10 – implementation of glove concept shown in Figure 9

Glove structure design

- Physical attributes of the glove structure has been modified to allow easier donning and doffing and to protect glove circuitry from unintentional stretching.
- Using a zip on the underside of the glove relieves pressure across the knuckle joint.
- Using lightweight fabric strips along each fingertip reduces pulling force during removal.

Figure 11 – Implementation of pull strips for easy glove removal

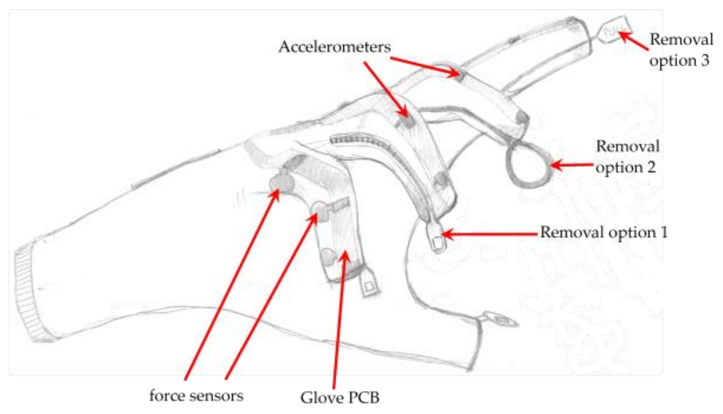

Figure 12 – sketch showing concept ideas for easy glove removal

Results

- Results show variance between repetition velocity (Fig. 13) and angular movement (Fig. 14) within objective.

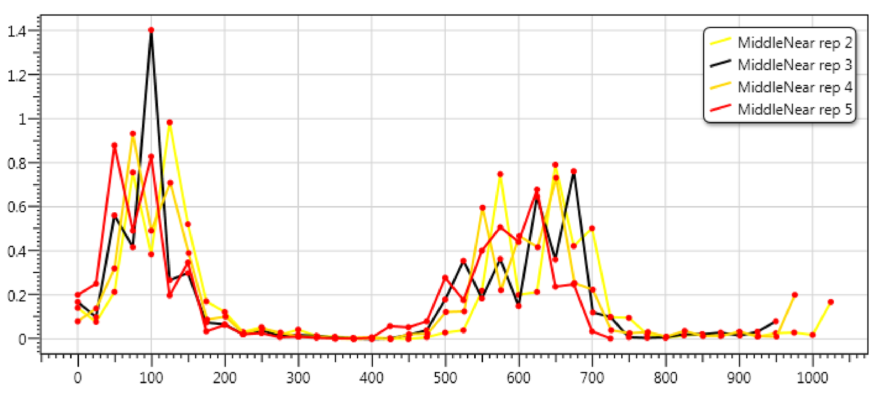

Figure 13 – velocity chart for middle MCP joint captured during an objective routine. Four repetitions are overlaid to compare variance in movement. Velocity is displayed in degrees / millisecond over time.

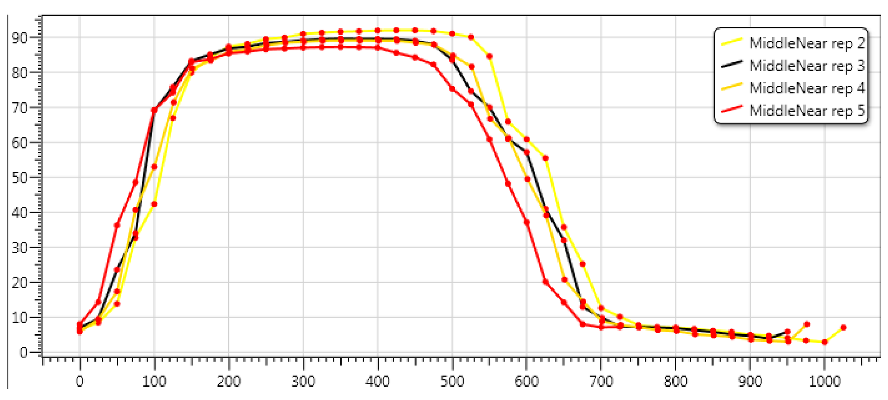

Figure 14 – angular movement chart for middle MCP joint captured during the same objective routine as demonstrated in figure 15. Four repetitions are overlaid to examine variance within each repetition. Angular motion is displayed in degrees over time.

Conclusion

- Digit-Ease is a Range Of Motion tool consisting of a wearable glove and a 3D interface.
- first ambulatory system to detect joint stiffness at home.
- Automatically calibrates glove using Neural Network and accelerometer data.
- Records minimum and maximum angular and velocity values during an exercise routine.
- Data is uploaded onto a database hosted in the cloud for immediate analysis by the clinician.
- Comparison of previous movement data provides indicators on improvement or decline.
- Determines the degree of deformity of the hand and stiffness of the moving finger joints.

References

[1] J. Y. Reginster: The prevalence and burden of arthritis. *Rheumatology* 2002, 41 (suppl. l):3-6, British Society for Rheumatology.

[2] Rheumatoid arthritis 'costs up to £8bn a year'. [http://www.independent.co.uk/life-style/health-and-families/health-news/rheumatoid-arthritis-costs-up-to-pound8bn-a-year-1931969.html].

[3] J. Connolly, J. Condell, K. Curran, and P. Gardiner, "A new method to determine joint range of movement and stiffness in rheumatoid arthritic patients.," Conference proceedings : Annual International Conference of the IEEE Engineering in Medicine and Biology Society., vol. 2012, pp. 6386–9, Jan. 2012.