Preliminary Results from Functional and Usability Assessment of the WiGlove - a Home-based Robotic Orthosis for Hand and Wrist Therapy after Stroke

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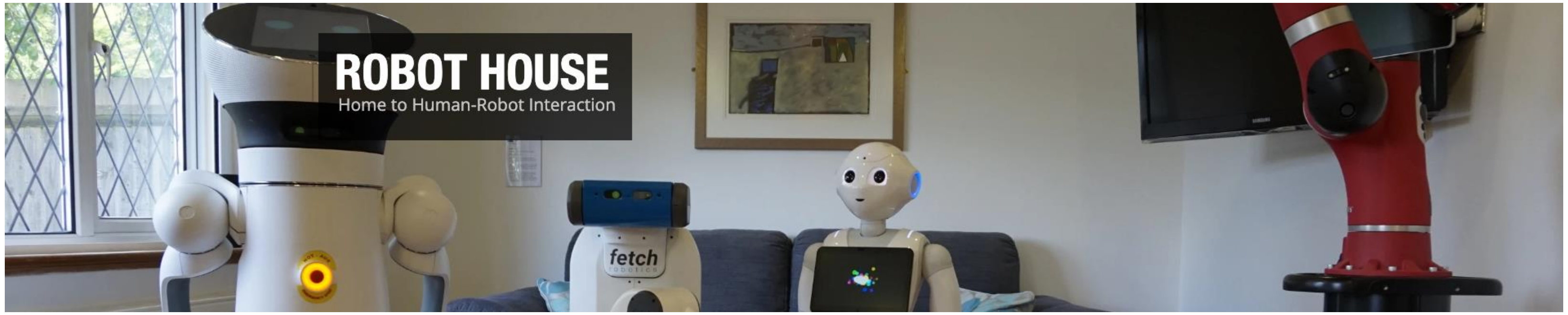
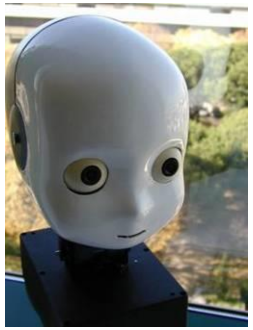
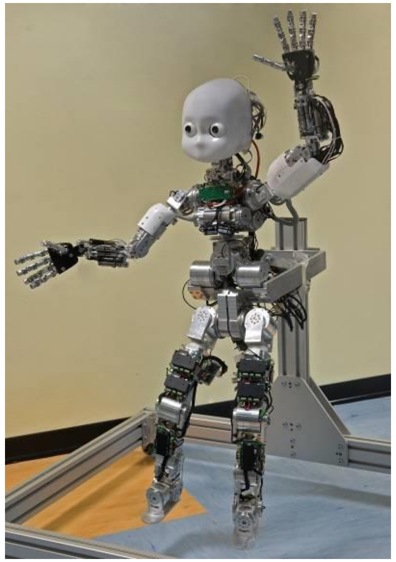
Dr Vignesh Velmurugan is a research fellow in educational robotic companions at the University of Hertfordshire, UK. He has a PhD in Rehabilitation Robotics from the above university for his work on the user-centred development of a rehabilitation robot for hand and wrist rehabilitation. He received his masters degree in Advanced Robotics from the Ecole Centrale de Nantes, France and the Warsaw University of Technology. He has a bachelors degree in Mechanical Engineering from the College of Engineering, Guindy, Anna University, India.

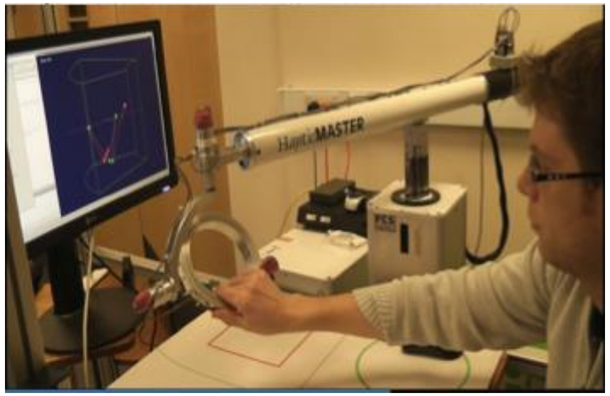
His current research focuses on robots for education and robotics for post-stroke therapy. In addition, his interests include assistive robotics, human-centred design in healthcare robotics and human-robot interaction.





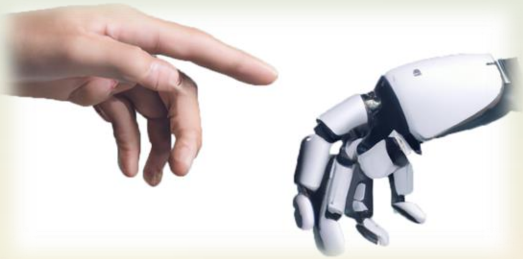
Robots in UH **Robot House** and Robotics Research Group

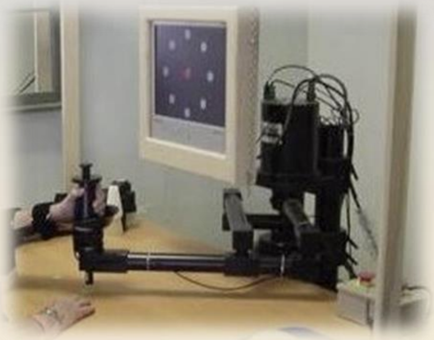




Introduction

Home-based rehabilitation using robots





MIT-Manus

Objective

- Facilitate safe home-based therapy
- Provide the ability to interact with games during training
- Allow the fingers and wrist to be trained together
- Provide support to perform ADL by countering abnormal synergies

Background

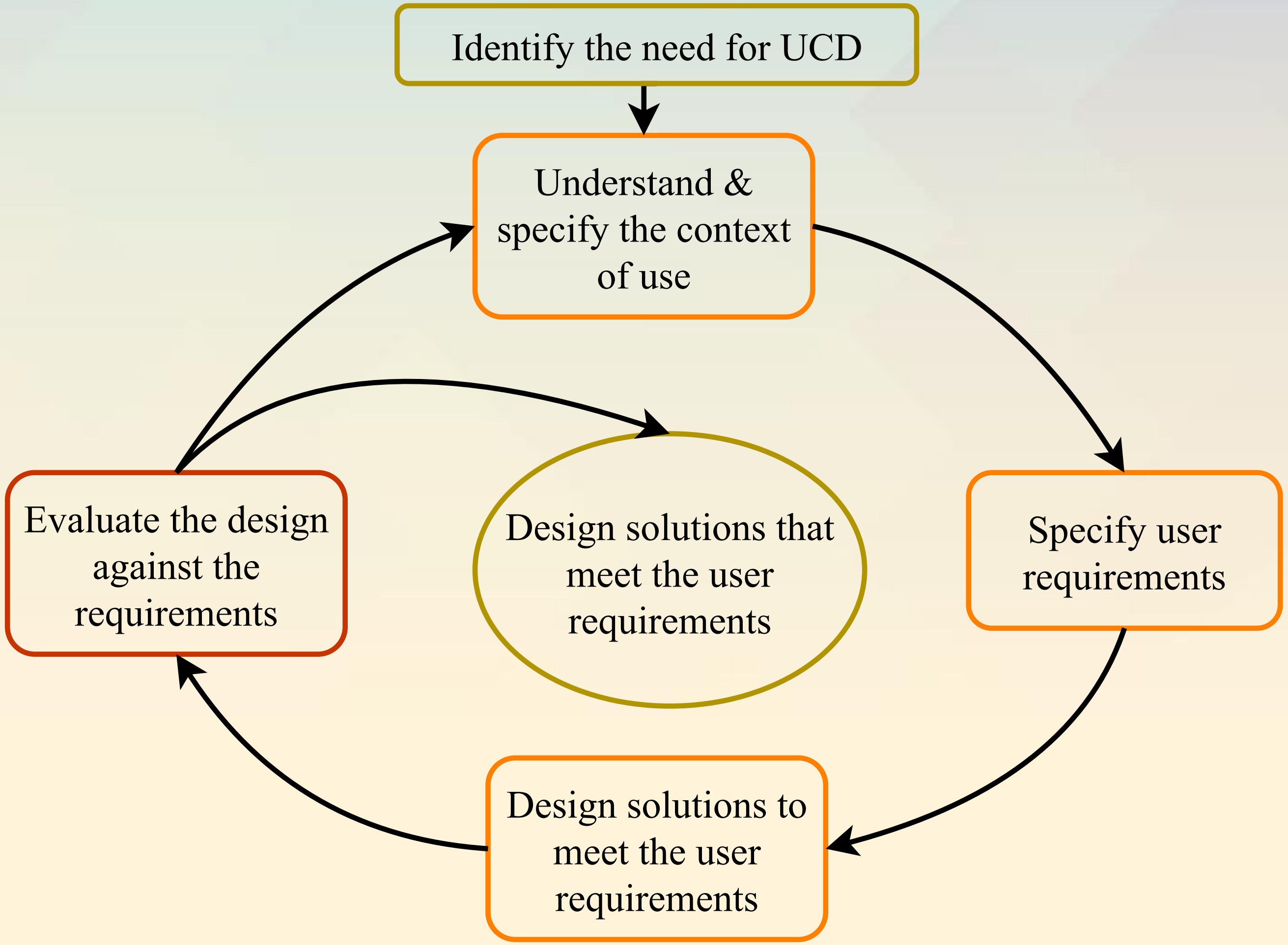
- Hand impairments in stroke survivors
- Impact on Activities of Daily Life
- State of the art
  - Functional and Usability limitations

Hyperflexion of Wrist and Fingers (Yap *et al.*, 2016)

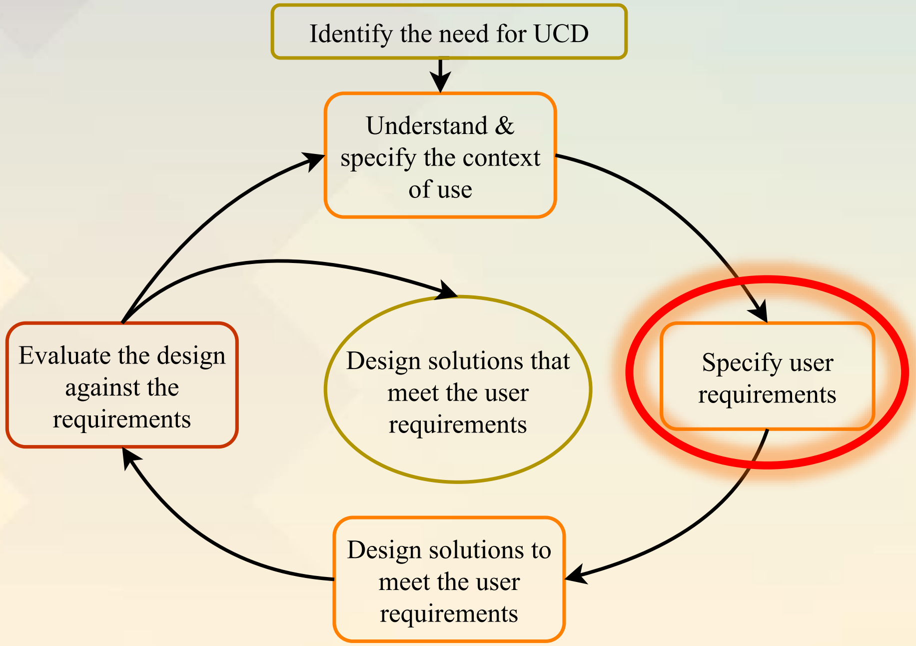
Table I: Orthotic devices used for the rehabilitation of the wrist and fingers together

Device Name	**Mode of Operation**	**Assisted Degrees of Freedom**	**Suitability for home-based**	**Wireless/Wired**	**Interaction with games**
Hand Mentor (Kutner *et al.*, 2010)	Active	2 (1 for fingers + 1 for wrist)	The peripherals of the actuation mechanism makes it unsuitable	Wired	No
HWARD (Takahashi *et al.*, 2005)	Active	3 (1 for fingers, 1 for thumb, 1 for wrist)	The peripherals of the actuation mechanism makes it unsuitable	Wired	No
SCRIPT Active Orthosis (Ates *et al.*, 2015)	Passive	6 (1 per finger + 1 for wrist)	Study showed that the bulky size, unsafe and complicated appearance prompted the user's to deem it less suitable	Wired	Yes
SCRIPT Passive Orthosis (Amirabdollahian *et al.*, 2014)	Passive	6 (1 per finger + 1 for wrist)	Studies showed that it was suitable home environment	Wired	Yes
(Ito *et al.*, 2011)	Active	18 (3 per finger + 4 for thumb + 2 for wrist)	Active actuation with multiple motors could lead to potential risk factors and therefore require supervision, complicated and unsafe appearance	Wired	Yes (VR)

Methodology - User Centred Design



Identification of User Requirements

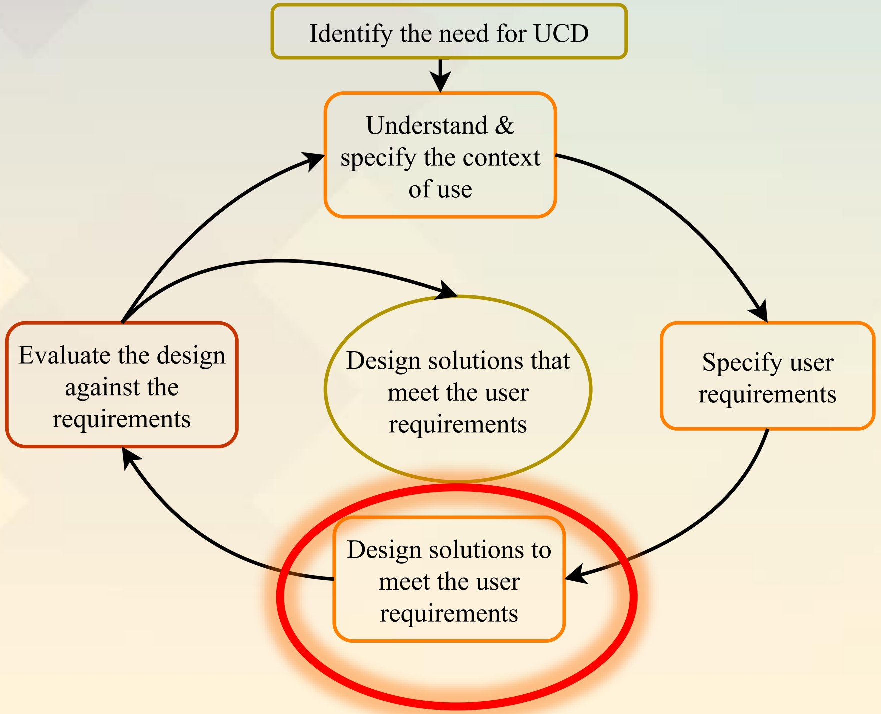


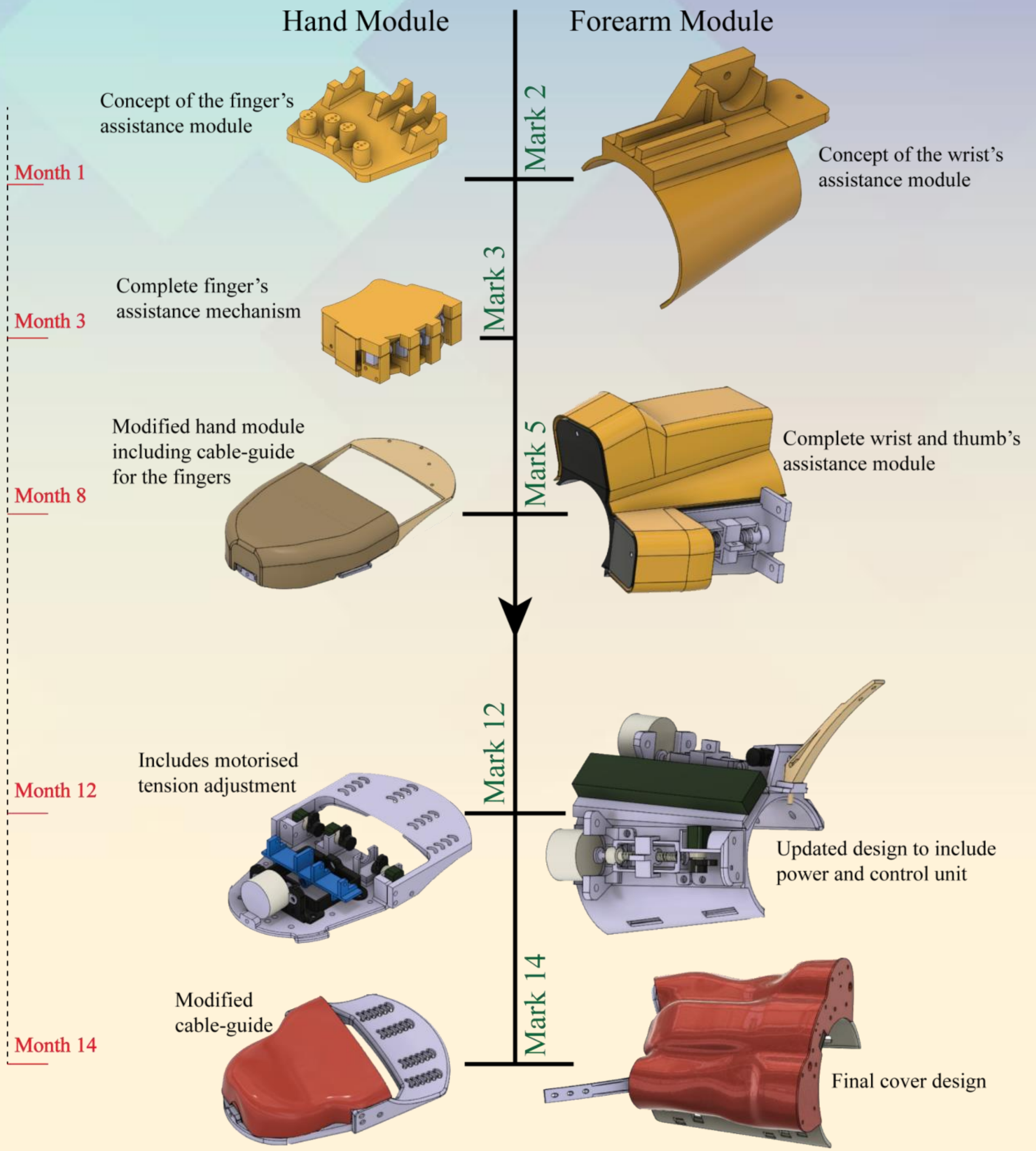
Functional requirements

- Adjustable functional assistance.
- Range of Motion (RoM) required for Activities of Daily Life (ADL).
- Does not hinder any of the natural range of motions of the joints.
- Self-aligning centre of rotation (CoR).
- Measurement of finger and wrist motion.
- Accommodate different hand dimensions.
- Visual and tactile transparency.

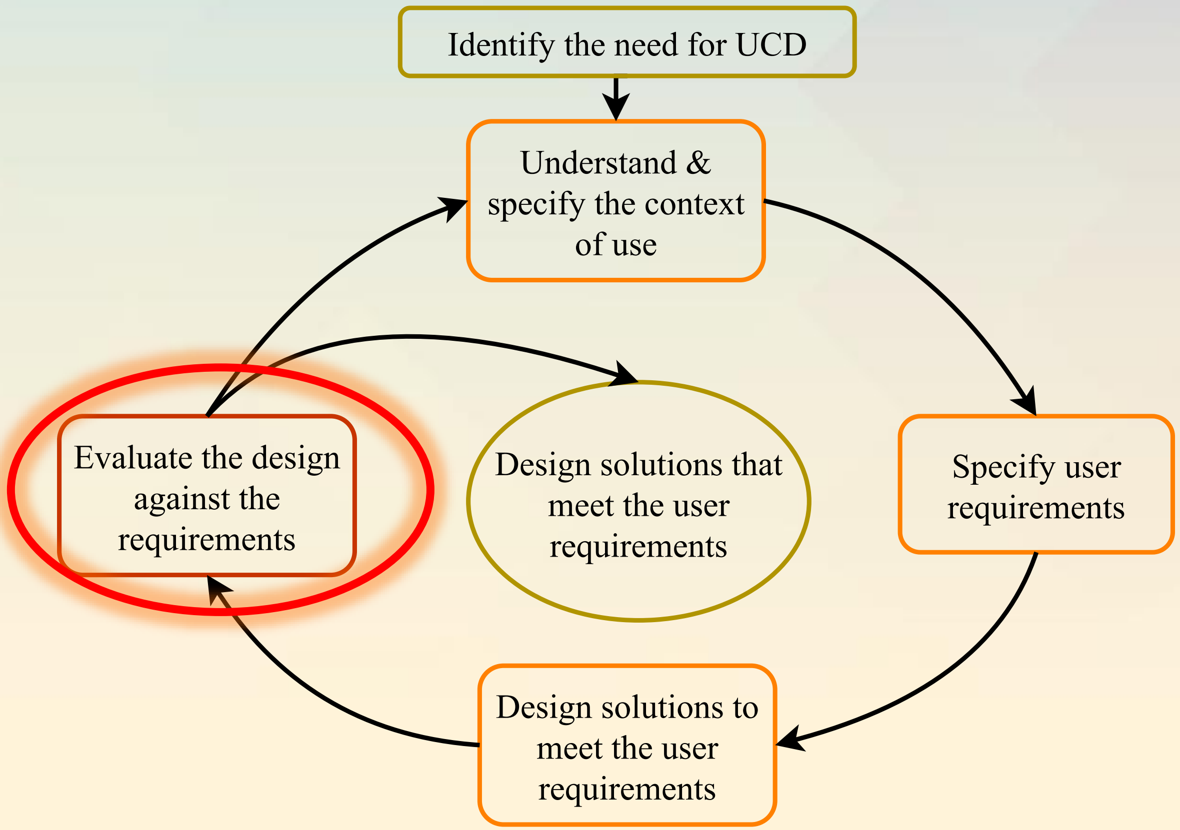
Usability requirements

- Ease of donning/doffing..
- Safe to use at home.
- Smaller space requirement and increased mobility.
- Require relatively less technical proficiency.
- The cost of the robotic orthosis should be affordable.


Identify the need for UCD
Understand & specify the context of use
Specify user requirements
Design solutions to meet the user requirements
Evaluate the design against the requirements
Design solutions that meet the user requirements


Hand Module
Forearm Module
Month 1
Month 3
Month 8
Month 12
Month 14
Mark 2
Mark 3
Mark 5
Mark 12
Mark 14
Concept of the finger's assistance module
Concept of the wrist's assistance module
Complete finger's assistance mechanism
Modified hand module including cable-guide for the fingers
Complete wrist and thumb's assistance module
Includes motorised tension adjustment
Updated design to include power and control unit
Modified cable-guide
Final cover design

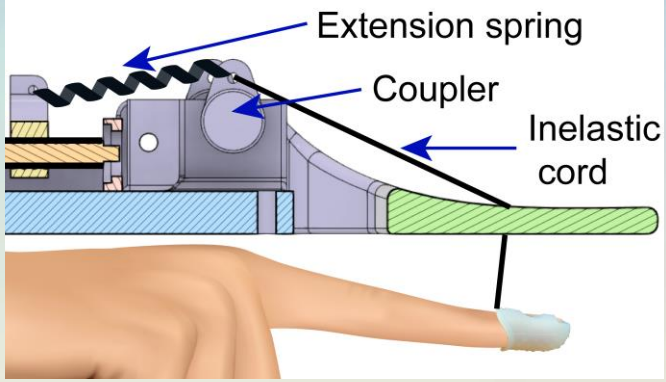
Functional and Usability Evaluations

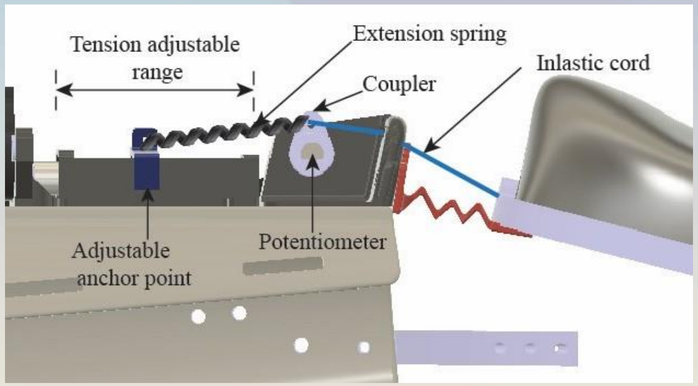


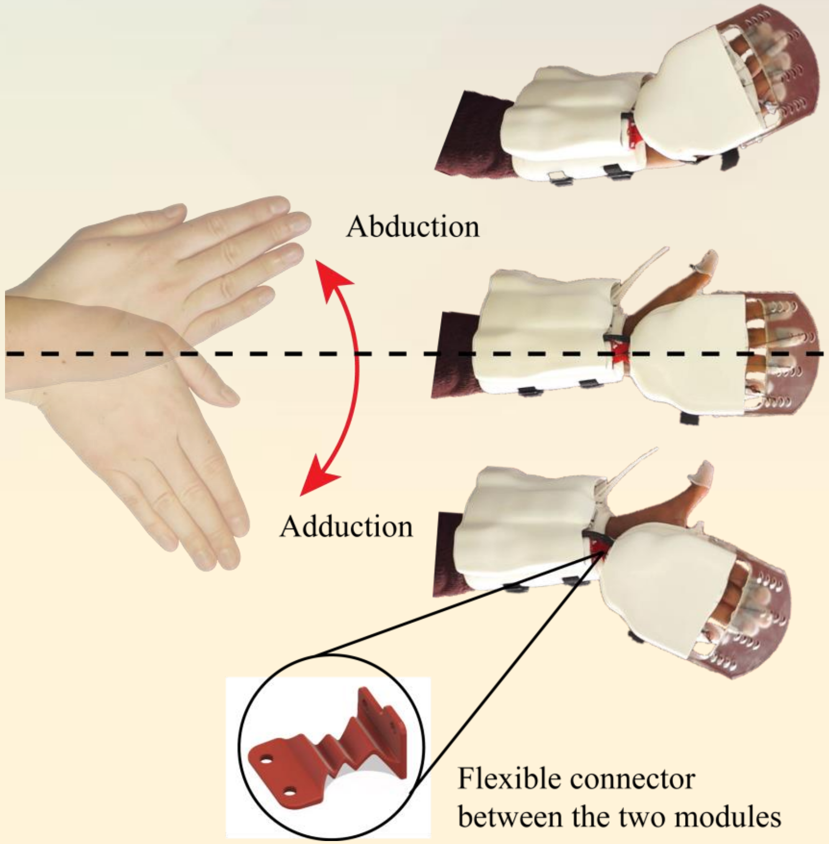
The WiGlove

Functional requirements

- **Adjustable functional assistance.**
  - **Passive extension assistance**
  - **Motorized tension adjustment**
- **Does not hinder any of the natural range of motions of the joints.**
- **Self-aligning centre of rotation (CoR).**
- **Accommodate different hand dimensions.**
- **Visual and tactile transparency.**
- Range of Motion (RoM) required for Activities of Daily Life (ADL).
- Measurement of finger and wrist motion.







Range of Motion required for Activities of Daily Life – Goniometric Measurement

- Verifies that the WiGlove does not block any of the Natural RoM necessary to perform ADL.
- Extension of fingers (MCP) are blocked to prevent accidental hyperextension

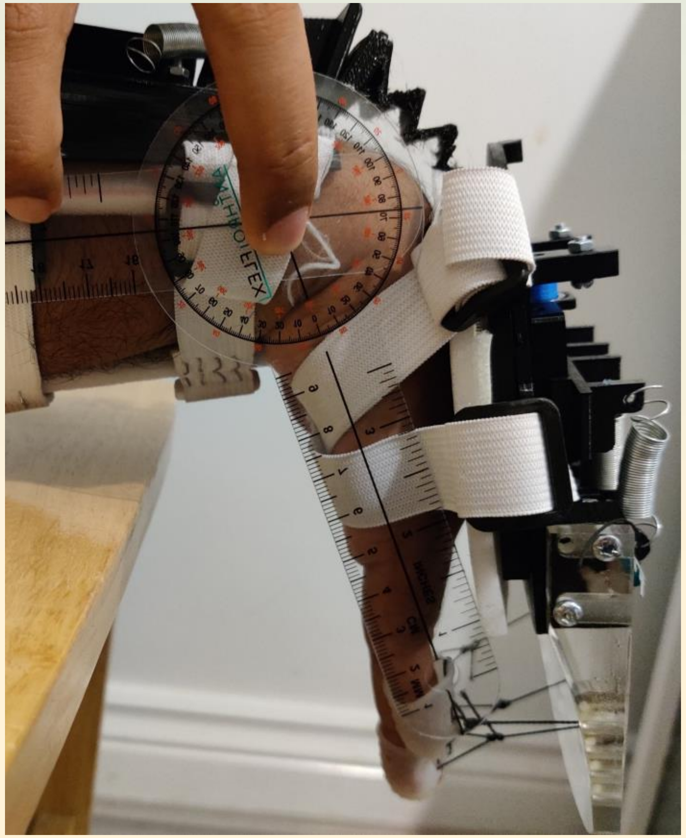
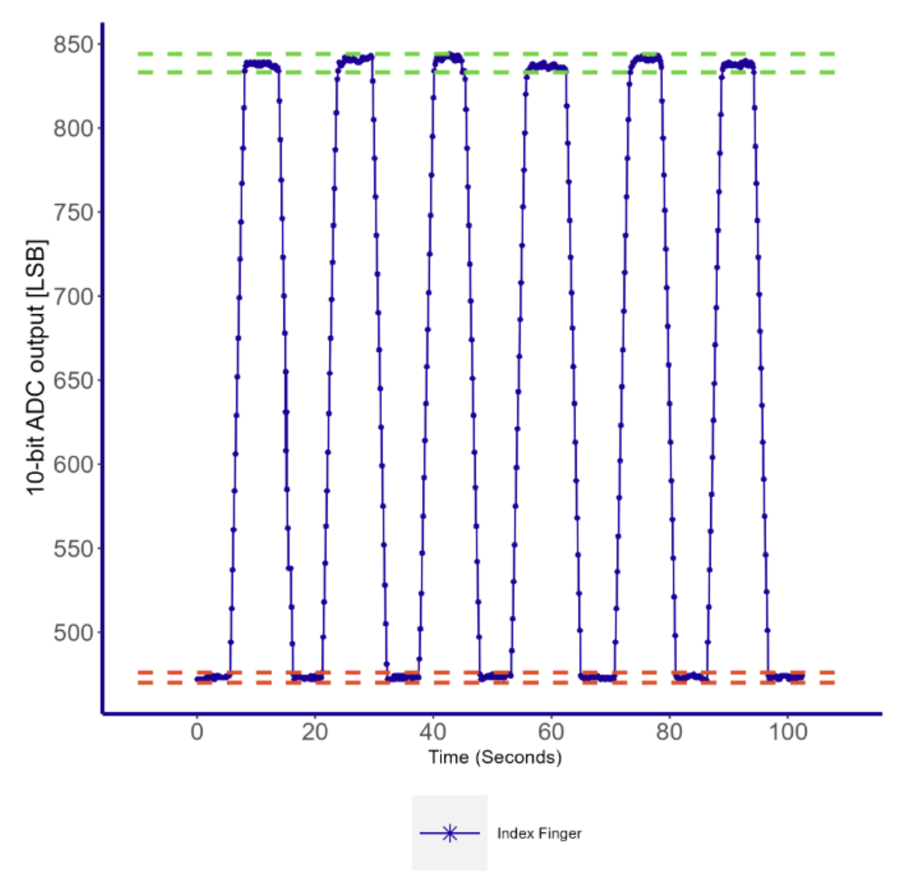


Table II: Range of Motion Measurements

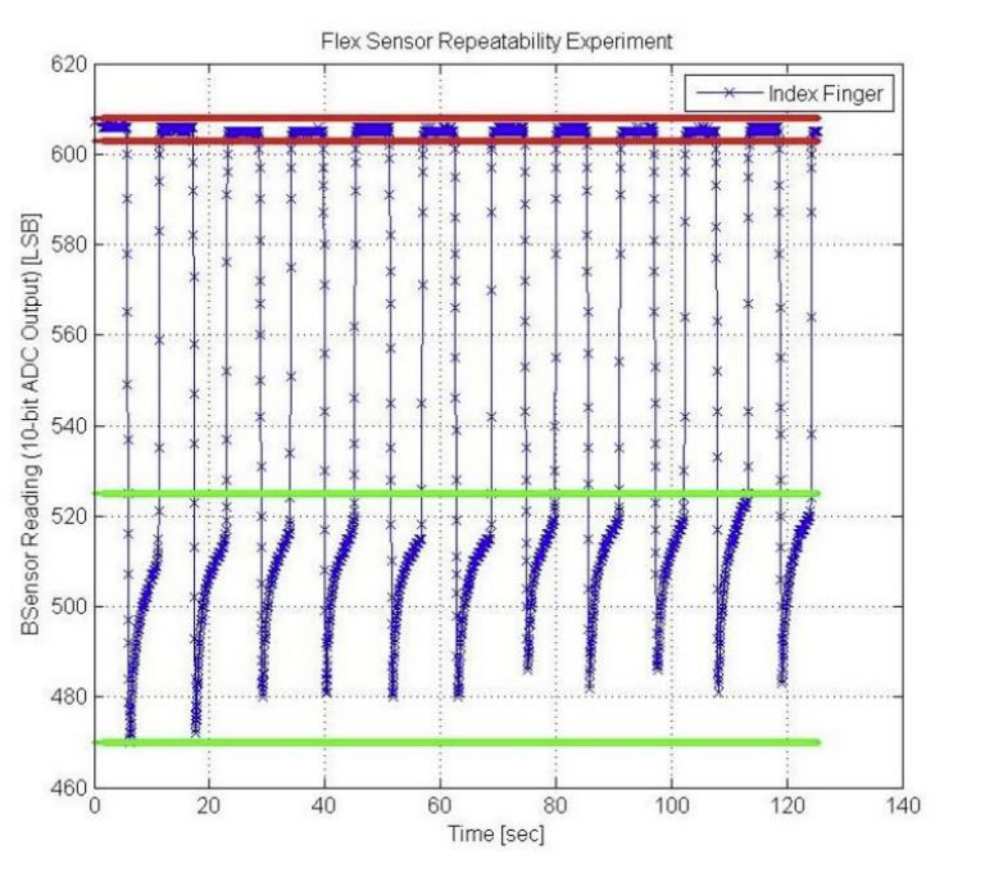
			Natural RoM	With SPO	With WiGlove	ADL
WRIST		Flex	76°	40°	74°	70°
		Ext	-58°	-20°	-52°	-60°
		Abd	28°	0°	25°	20°
		Add	31°	0°	31°	30°
THUMB	MCP	Flex	100°	60°	100°	100°
		Ext	0°	0°	0°	0°
		P Abd	50°	50°	50°	50°
	PIP	Flex	80°	15°	80°	80°
		Ext	40°	0°	0°	10°
FINGERS	MCP	Flex	90°	60°	90°	90°
		Ext	10°	0°	0°	10°
		Abd	25°	25°	25°	25°
		Add	0°	0°	0°	0°
	PIP	Flex	100°	80°	100°	100°
		Ext	0°	0°	0°	10°
	DIP	Flex	80°	15°	80°	80°
		Ext	0°	0°	0°	0°

Measurement of finger and wrist motion – Repeatability evaluation

- Repeated motions of flexion and extension for 5 seconds each. – The WiGlove demonstrates good repeatability compared to that of SCRIPT Passive Orthosis



WiGlove



SCRIPT Passive Orthosis

(Ates *et al.*, 2014)

Measurement of finger and wrist motion – Repeatability evaluation

Methodology

- Repeated motions of flexion and extension for 5 seconds each.
- Cylindrical grasps of 3 different diameters (Large = 84mm, Medium = 60mm, Small = 50mm)

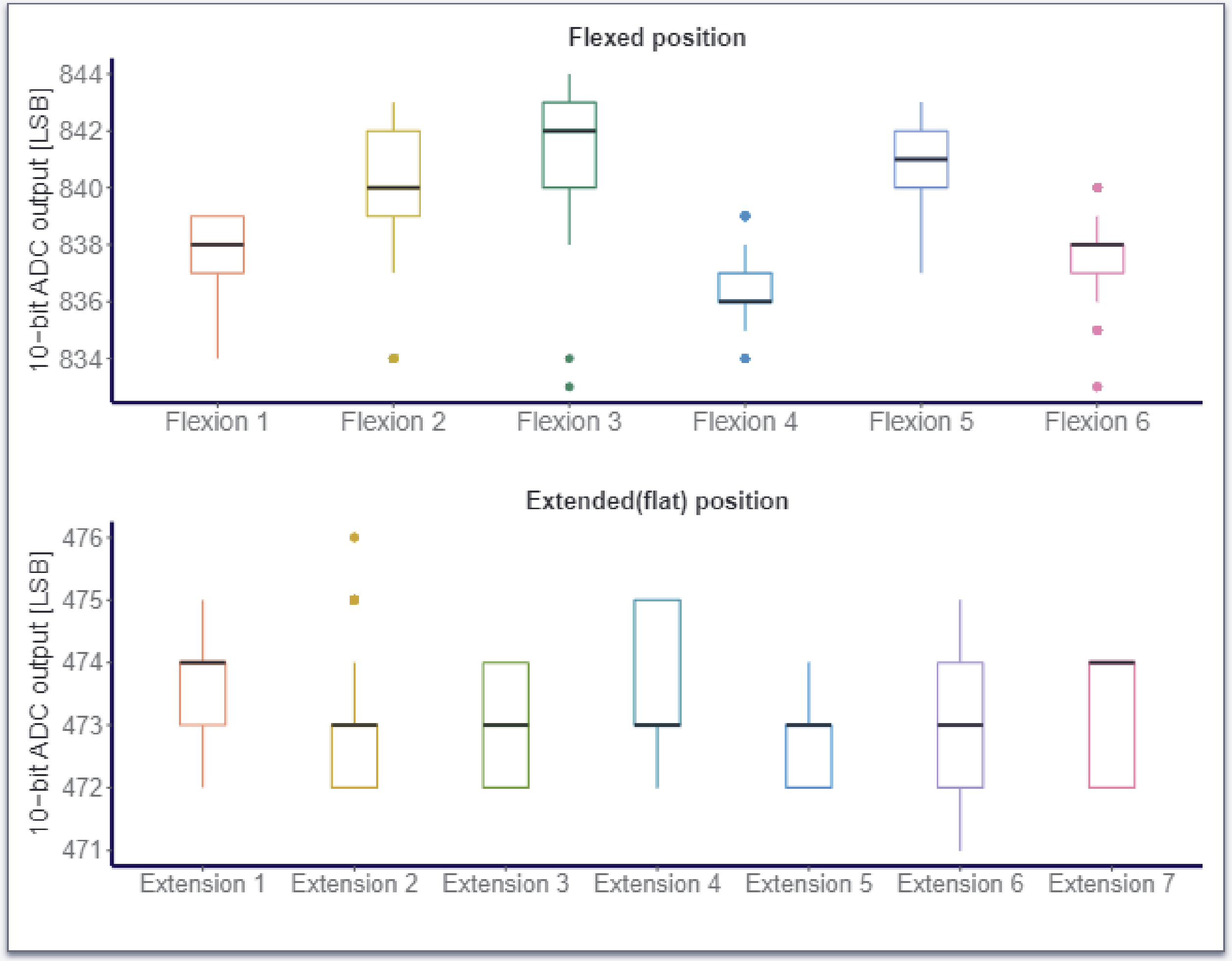
Results

Table III: Mean and standard deviations of the ADC output at different conditions expressed in Least Significant Bit [LSB]

		Closed fist	Large grasp	Medium grasp	Small grasp
Flexion	Mean	839	783	745	657
	SD	1	1	1	1
Extension	Mean	473	473	473	473
	SD	1	1	1	1

- Demonstrates ability to differentiate between different grasp sizes with good repeatability.

Boxplots of ADC values at completely flexed and flat positions



Home-based evaluation of usability requirements

- Two hemiparetic stroke survivors
- 6-weeks independent home-based usage.
- Flexion/extension exercises and playing games.
- Ethics protocol number: aSPECS/ PGR/ UH/ 05084 (1)

Characteristics	Participant A	Participant B
Gender	Male	Male
Age (years)	78	43
Time post-stroke (months)	15	27
Impaired hand	Left (Non-dominant)	Left (Non-dominant)
Baseline BBT (no. of blocks/60 secs)	0*	6
Baseline NHPT	0 pegs in 300 seconds	3 pegs in 300 seconds

* Modified version only counting the number of blocks picked and dropped.

Table IV: Summary of the participant's feedback on the WiGlove's usability

Requirement	**Participant A**	**Participant B**
RQ 7 - Ease of donning/doffing.	Unable to independently don and required assistance due to excessive tone in the shoulders. But was able to doff. "***Ease to remove finger caps and forearm***"	Was able to independently don/doff. "***it takes in a few sessions for me to wear it, So now like I'm doing it by myself, I don't need anyone's help.***"
RQ 8 - Safe to use at home.	Did not perceive any safety issues	Did not perceive any safety issues "***there is no safety issues, and it has small battery in the glove which is charged. There are no safety concerns.***"
RQ 9 - Smaller space requirement and increased mobility.	Found it easy to store and train at different parts of the house. "***When kids are coming, it's not a problem hiding it***"	Very portable. Trained at different parts of home and also took it to the office to train. "***You know storage is easy because that comes in two parts. You can always fold it***"
RQ -10 - Require relatively less technical proficiency.	Perceived it to be straightforward and easy to use.	Had some difficulty with donning the hand module in the beginning but otherwise found it easy to use

Challenges

- Unsupervised training – Distinct practices
- Effects of secondary interventions – Ethical dilemna
- Effect of the perception of family members

Participant B - "*Had it not been (my wife), I wouldn't have used the glove more often the way I have used it over the last few weeks. So she has always encouraged me to wear the glove and help me initially to wear the glove*"

Conclusions

- Demonstrates a user-centred design approach in the development of a rehabilitation robot for stroke survivors.
  - Functional and Usability Evaluation
- Presents promising evidence of the WiGlove's feasibility

Future Work

- Further clinical trials with more participants with varied impairment levels
- Further iterations of co-design process.

Thank you

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