IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

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DEPARMENT OF ELECTRICAL ENGINEERING

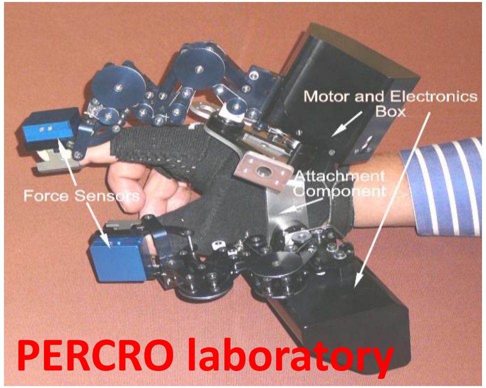
Introduction to Robotic Hand Exoskeleton

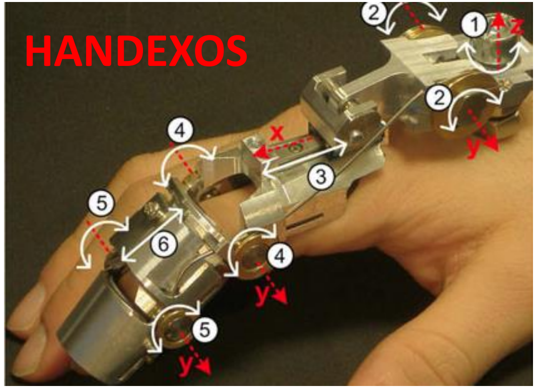
Outline

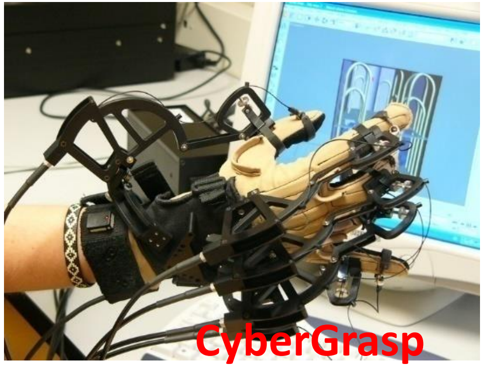
1. Definition
2. Classification
3. Design Challenges
4. Conclusion

Hand Exoskeletons

Hand Exoskeleton -*Wearable Interactive system for the Hand*







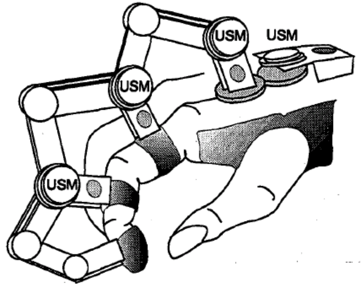
Classification of Hand Exoskeletons based on Power Transmission Method

1. Hand Exoskeletons employing Mechanisms

2. Hand Exoskeletons employing Cables

3. Hand Exoskeletons employing Cables and Mechanisms

1. Hand Exoskeletons employing Mechanisms

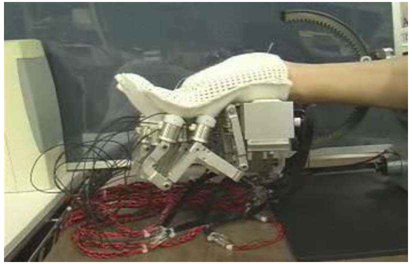


Degrees of Freedom: Four per finger

Actuation: Semi Direct Drive Mechanism by Ultrasonic motors

Sensing: Force and Position sensors

Ref: **B. H. Choi and H. R. Choi, "A semi direct drive Hand Exoskeleton using Ultrasonic Motors", Proc. IEEE International Workshop on Robot and Human Interaction, Pisa, Italy, 1999**



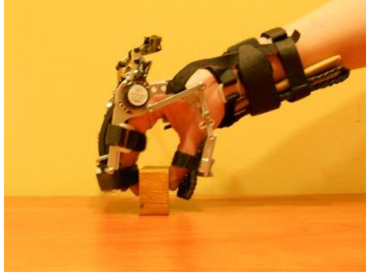
Degrees of Freedom: 18 (3 for each finger, 4 for thumb)and 2 for wrist

Actuation: By Direct drive mechanism of the motors

Sensing: Force Sensors are embedded in the fixtures

Ref: **H. Kawasaki et al., "Development of a Hand Motion Assist Robot for Rehabilitation Therapy by Patient Self-Motion Control", Proceedings of the IEEE 10th Int. Conf.on Rehabilitation Robotics, 2007, pp. 234-240.**

1. Hand Exoskeletons employing Mechanisms (cont'd)



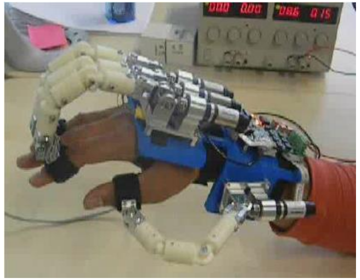
HandSOME

Degrees of Freedom: 1 Passive

Actuation: Passive Actuation by Series Elastic Cords

Sensing: Force and Torque sensors

Ref: **Brokaw et al. , "Hand Spring Operated Movement Enhancer", IEEE Trans. Neural Systems and Rehabilitation Engineering, vol. 19, no. 4, pp. 391-399, Aug. 2011.**



Hexosys-II Exoskeleton

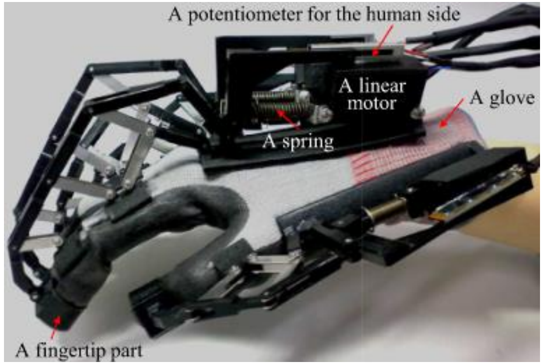
Degrees of Freedom: 4 (1 Active)

Actuation: Under actuation by electric motors

Sensing: Force sensors

Ref: **Iqbal et al., "HEXOSYS II – Towards realization of light mass robotics for the hand", Proceedings of the IEEE 14th Int. Multi topic conference, 2011, pp. 115-119.**

1. Hand Exoskeletons employing Mechanisms (cont'd)



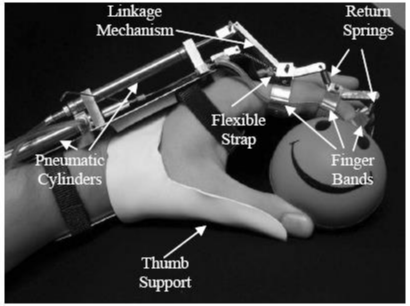
Degrees of Freedom: 3 DOF for each finger (F/E)

Actuation: Series Elastic Actuator Mechanism (small linear actuator, motor driver, spring and POT)

Sensing: Pressure sensors

Ref: Brokaw et al. , "Hand Spring Operated Movement Enhancer", IEEE Trans. Neural Systems and Rehabilitation Engineering, vol. 19, no. 4, pp. 391-399, Aug. 2011.

2. Hand Exoskeletons employing Cables



Degrees of Freedom: Two

Actuation: Pneumatic Pistons actuating a cabling system

Sensing: EMG signals used to obtain intent of the user

Ref: M. DiCicco, L. Lucas and Y. Matsuoka, **"Comparison of Control Strategies for an EMG Controlled Orthotic Exoskeleton for the Hand",** Proc. 2004 IEEE Int. Conf. on Robotics & Automation, 2004, 1622-1627.

Degrees of Freedom: Four DOF for one finger

Actuation: The ends of the Bowden cables are attached to a pulley which is moved by a DC motor with transmission gears

Sensing: Hall Sensor and Force Sensor

Ref: **A. Wege and G. Hommel, "Development and Control of a Hand Exoskeleton for Rehabilitation of Hand Injuries", International Conference on Intelligent Robots and Systems, 2005, 3046-3051**

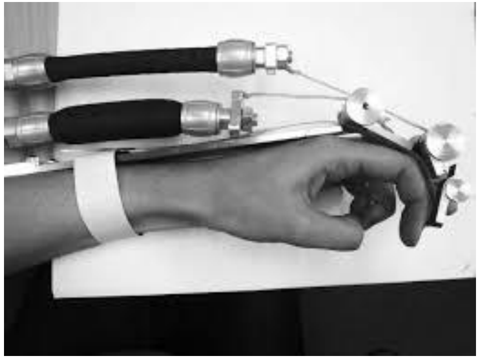
2. Hand Exoskeletons employing Cables (cont’d)

Degrees of Freedom: Two

Actuation: Electric actuators with a cabling system

Sensing: EMG signals used to obtain intent of the user

Ref: Mulas et al. , **“An EMG controlled exoskeleton for hand rehabilitation”,** Proc. 9th IEEE Int. Conf. on Rehabilitation Robotics, 2004, pp. 371-374.



Degrees of Freedom: 1 for prototype I and 2 for II

Actuation: Through Pneumatic muscle actuator

Sensing: Force Sensors

Ref: **E. Matheson and G. Brooker, “Augmented Robotic Device for EVA hand manoeuvres”, Acta Astronica, vol. 81, pp. 51-61, 2012.**

2. Hand Exoskeletons employing Cables (cont'd)

Degrees of Freedom: Four(F/E of each finger excluding the pinky)

Actuation: Electric actuators with a cabling system

Sensing: Force and Flex sensors

Ref: D. Popov et al. , **"Portable Exoskeleton Glove With Soft Structure for Hand Assistance in Activities of Daily Living",** IEEE/ASME Trans. on Mechatronics, vol. 22, no. 2, pp. 865-875, 2017.

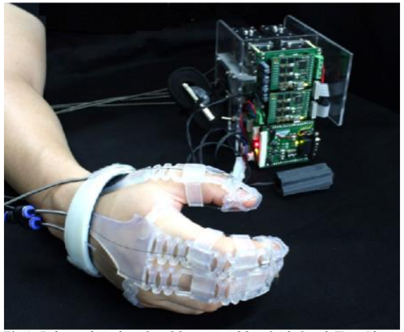


Fig 1. Polymer-based tendon-driven wearable robotic hand (Exo-Glove

Exo-Glove Poly

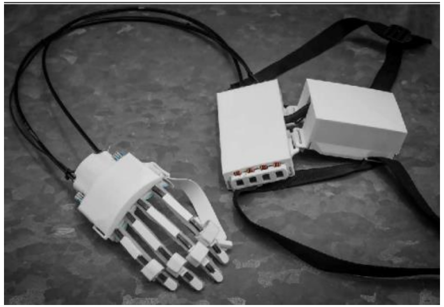
Degrees of Freedom: 1 (F/E of the IF, MF and Th)

Actuation: By 2 DC Motors

Sensing: Force Sensors (Load cells and Pressure sensors)

Ref: **B. B. Kang et al., "Development of a Polymer-Based Tendon-Driven Wearable Robotic Hand", IEEE Int. Conf. on Robotics and Automation (ICRA), 2016, pp. 3750-3755.**

2. Hand Exoskeletons employing Cables (cont'd)

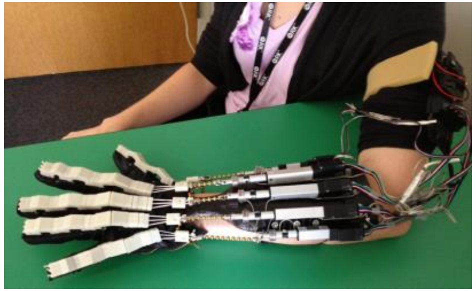


Degrees of Freedom: Four(F/E of each finger excluding thumb)

Actuation: DC Linear Actuators

Sensing: Position and Force sensors

Ref: Nycz et al. , **"Design and Characterization of a Lightweight and Fully Portable Remote Actuation System for Use With a Hand Exoskeleton",** IEEE Robotics and Automation Letters, vol. 1, no. 2, pp. 976-983, 2016.



X-Glove

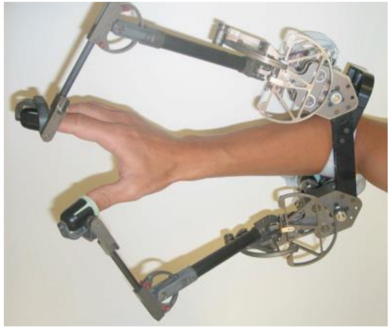
Degrees of Freedom: 5 (F/E of each digit)

Actuation: By 5 DC Linear Actuators

Sensing: Position Sensors

Ref: **K. M. Triandafilou et al., "Effect of Static versus Cyclic Stretch on Hand Motor Control in Subacute Stroke", Int. J Neurorehabilitation Eng, vol. 1, no. 4, pp. 1-5, 2014.**

3. Hand Exoskeletons employing Cables and Mechanisms

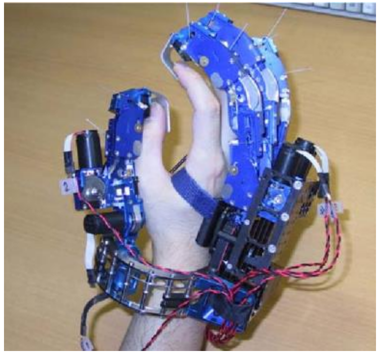


Degrees of Freedom: Six (3 actuated DOF for each finger mechanism) → to track any movement of the finger tips

Actuation: Electric actuators with cables and pulleys

Sensing: Force feedback through haptics interface

Ref: A. Frisoli et al. , **“Kinematic Design of a two contact points haptic interface for the thumb and index finger of the hand”,** Trans. of the ASME-Journal of Mechanism Design, vol. 129, pp. 520-529, 2007.



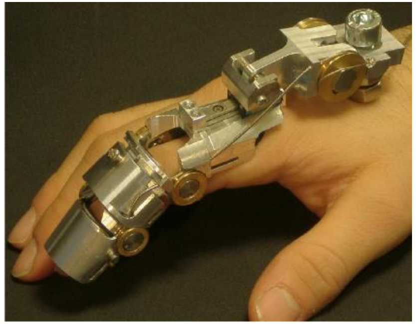
Degrees of Freedom: 5 DOF

Actuation: Electric actuator

Sensing: Force and Position sensors

Ref: **Nakagawara et al., “An Encounter-Type Multi-Fingered Master Hand Using Circuitous Joints”, IEEE-ICRA, 2005, pp. 2667-2672.**

3. Hand Exoskeletons employing Cables and Mechanisms (cont'd)



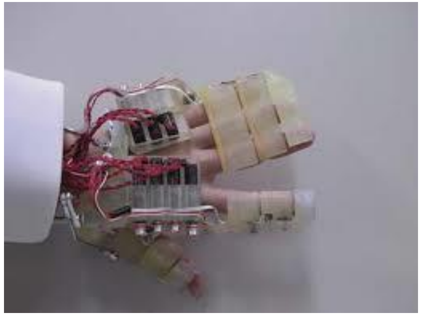
HANDEXOS

Degrees of Freedom: 3 Active DOF(F/E of MCP, PIP and DIP joints) and 3 Passive DOF (1 rotational (A/A of MCP joint and 2 translational joints (dis. b/w MCP – PIP & PIP–DIP

Actuation: Electric actuators with cables and pulleys

Sensing: Force and position sensors

Ref: A. Frisoli et al. , **"Kinematic Design of a two contact points haptic interface for the thumb and index finger of the hand",** Trans. of the ASME-Journal of Mechanism Design, vol. 129, pp. 520-529, 2007.



Degrees of Freedom: 8 DOF (3-IF, 3-(MF,RF,LF), 2-Th)

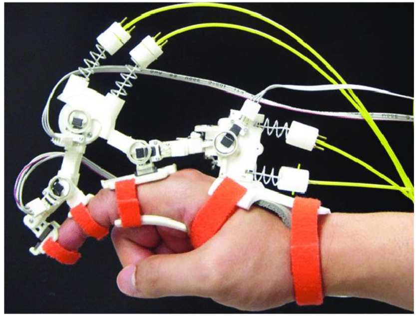
1 Motor for Thumb opposition (CMC) & 1 Motor for coupled MCP and IP joint

Actuation: Electric actuator

Sensing: Force sensor

Ref: **Hasegawa et al., "Five Fingered Assistive Hand with Mechanical Compliance of Human Finger", IEEE-ICRA, 2008, pp. 718-724.**

3. Hand Exoskeletons employing Cables and Mechanisms (cont'd)



Degrees of Freedom: 2 DOF

Actuation: DC motors with Bouden cables

Sensing: Angle sensors

Ref: P. Agarwal et al. , **"An index finger exoskeleton with series elastic actuation for rehabilitation: Design, control and performance characterization",** The Int. Journal of Robotics Research (IJRR), vol. 34, no. 14, pp. 1747-1772, 2015.

CYBER GRASP

Degrees of Freedom: 5 DOF

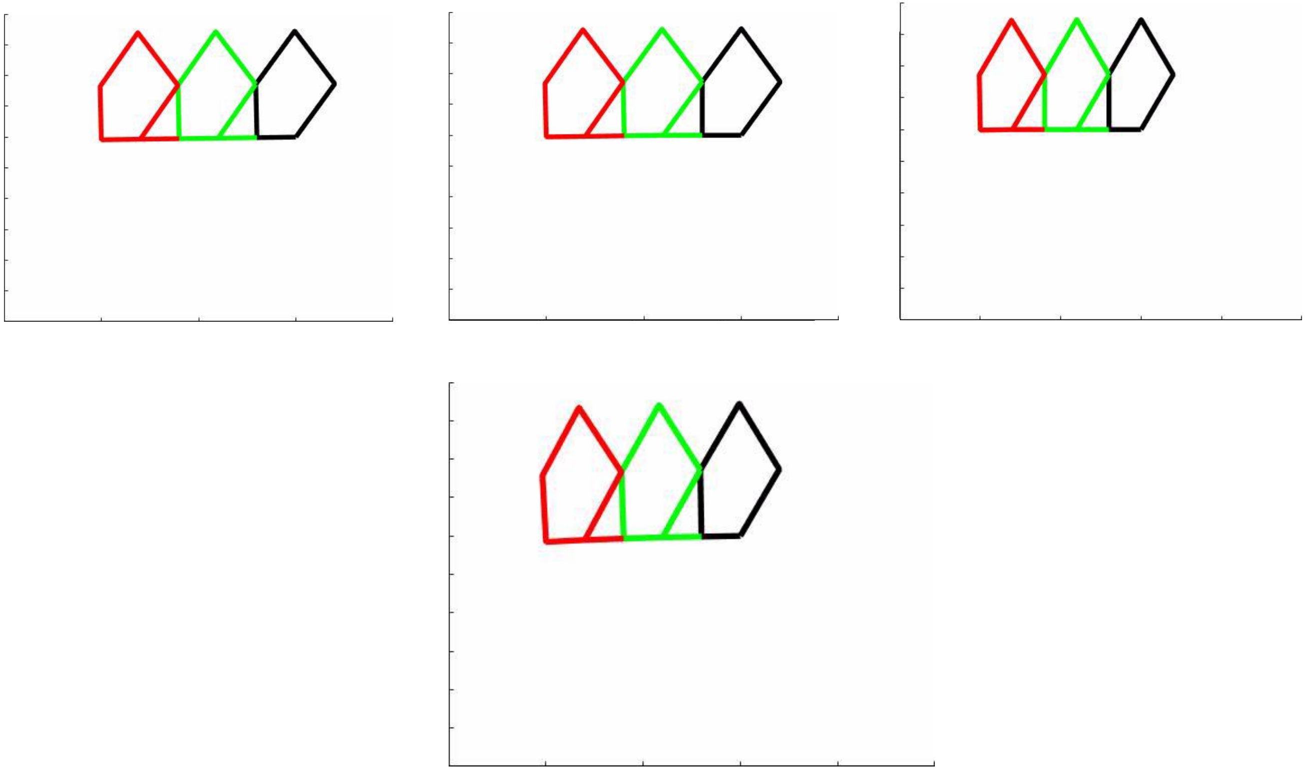
Actuation: Electric actuator

Sensing: Force feedback through haptic interface

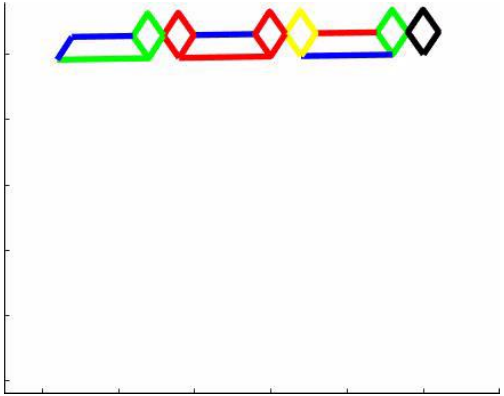
Ref: **Cyber Glove Systems. Cyber Grasp. 2016. http://www.cyberglovesystems.com/.**

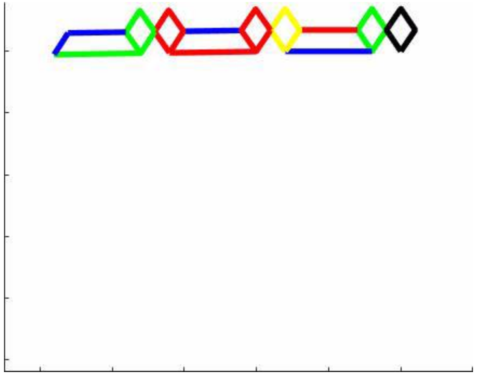
Cable driven mechanism	Direct drive mechanism
• Less number of actuators	• More number of actuators
• Control becomes simpler	• Control becomes tedious
• **Building:** cable driven actuation are easier to build and the bulky motors are not on the hand but next to the hand	• **Building:** motors with enough torque to move the finger joints with a smaller size are very rare Ultrasonic Motors 
• The hand part mechanical structure may be of less weight	• The hand part mechanical structure may be of more weight

Exoskeleton Simulations



Exoskeleton Simulations

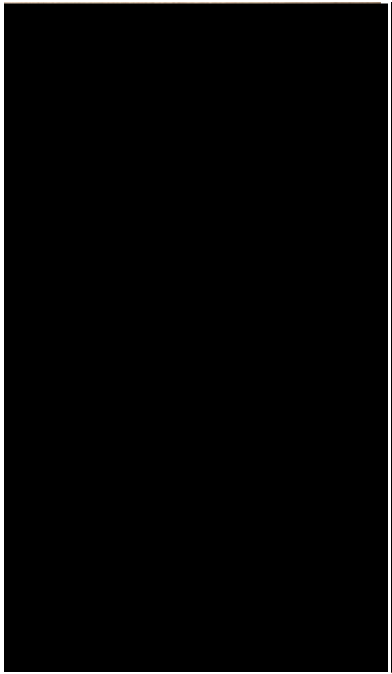




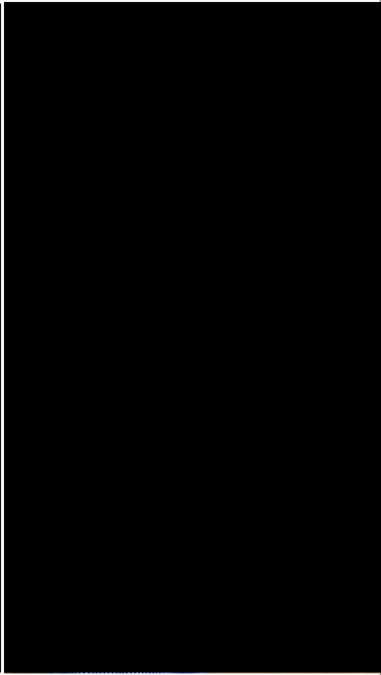
Pressing Issues and Design Challenges

- One of the most important requirements in the hand exoskeleton design is Safety → as any malfunction will be harmful to the wearer due to the direct contact with the limb.
- Mechanical Interface – Must be light weight and portable → "second skin" to the user.
- Must be comfortable, reliable and very durable.
- Must be facilitating – free-finger motions & task - oriented motions.

Free-finger



Task-oriented



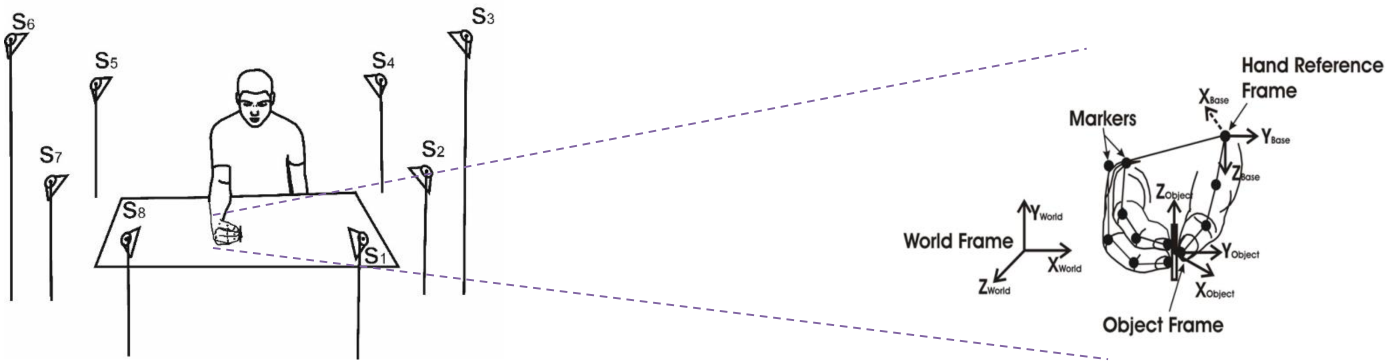
Pressing Issues and Design Challenges

- **Exceeding the range of motion should be avoided by implementing a mechanical stopper in the design itself.**

- **Anatomy of the human hand must be observed thoroughly before designing the hand exoskeleton.**

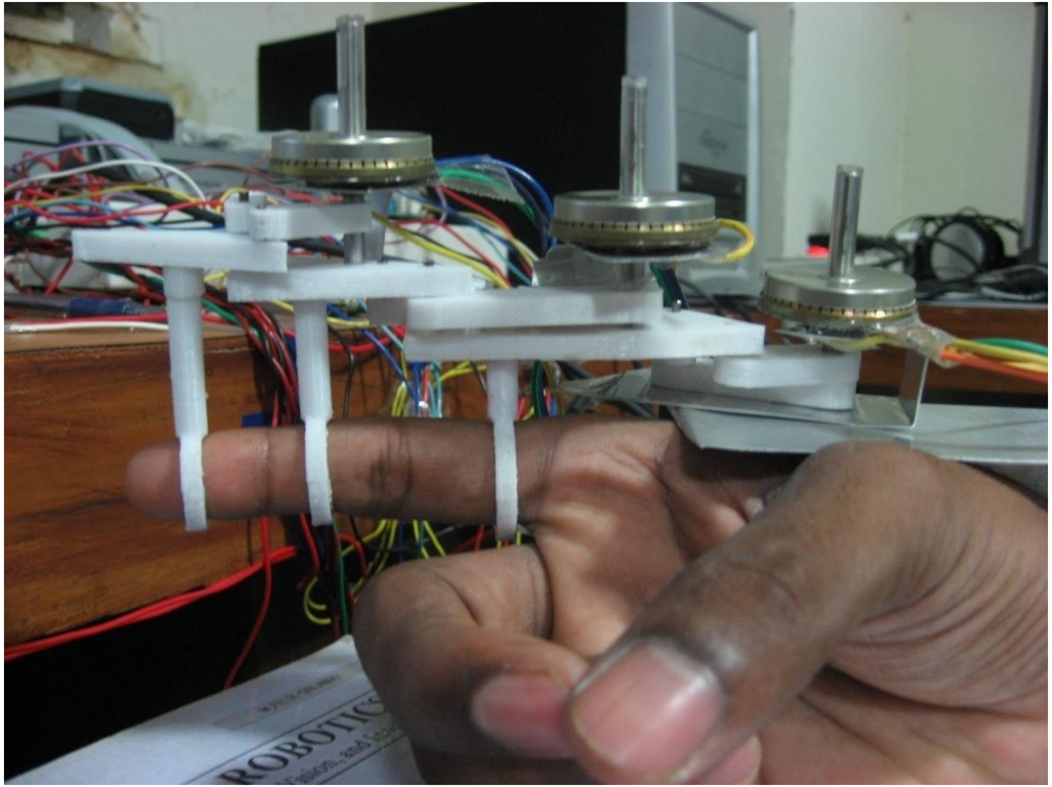
Phase-I

- Extraction of **3D finger motion data** using Motion Capture System



- **Developing hand exoskeleton system** with the extracted 3D data

- **Development of robust position and force control strategies** – Sensor fusion



Conclusions

- High power to weight ratio actuators with affordable costs and smaller size are necessary to develop a light weight and portable hand exoskeleton.

- A deeper understanding of human musculo-skeleton functions while performing ADLs will enlighten the design and control of the exoskeletons.

Thank You!