FLEXIBLE CARBON NANOCOMPOSITE SENSORS: VALIDATION USING ROBOTICS AND VIRTUAL REALITY (VR)

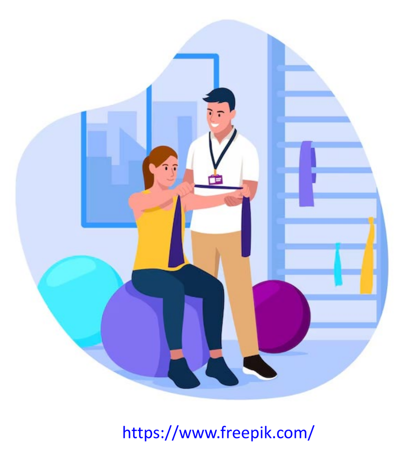
University of Delaware | CENTER FOR COMPOSITE MATERIALS

Dr. Amit Chaudhari[1], Prof. Erik T Thostenson[1,2,3]

University of Delaware | Center for Composite Materials[1] | Department of Mechanical Engineering[2] | Department of Materials Science and Engineering[3]

Introduction

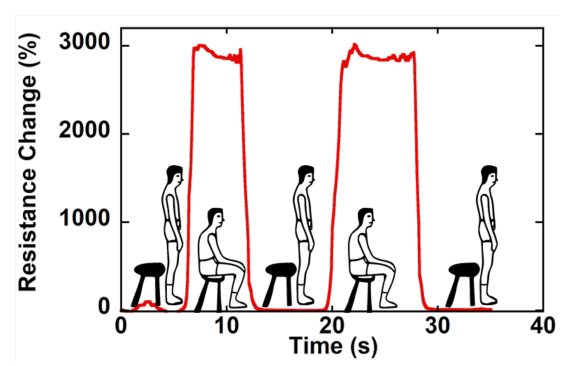
- **Physiotherapy** is typically conducted in a **clinical settings** and movement is recorded by **physiotherapist** manually,
  - Difficult to monitor over **long-time intervals**
  - Monitoring is not conducted during **day-to-day activities**



- The ability to **monitor exercise movements** of a joint offers opportunity to provide **feedback or intervention remotely** to enhance exercise effectiveness and improve the **recovery** process.

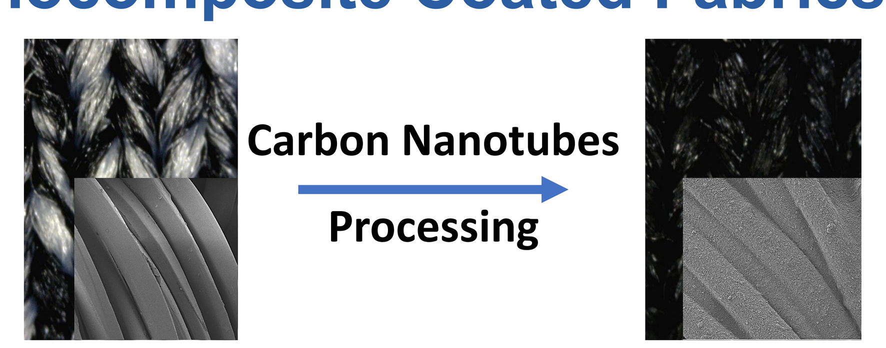
Our overarching goal is to **develop functional garments** capable of accurately capturing kinetic and kinematic data from **patients** during **at home physiotherapy exercise**.

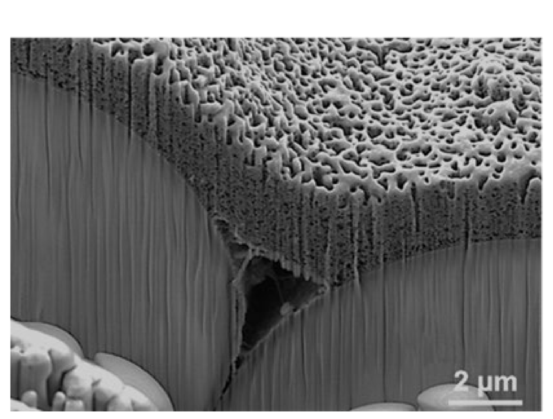
Textile-based sensors based on fiber/fabric level integration to monitor elongation and curvature (e.g. joint rotation)



Potential Applications	Required Properties
Virtual physiotherapy	Repeatability
Exercise feedback	Consistency with angle change
Joint movement	Angle prediction

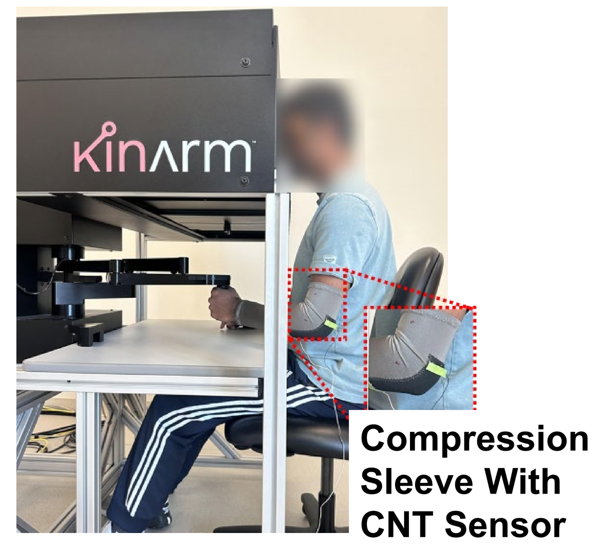
Nanocomposite Coated Fabrics





- A thin and porous film of nanotubes and polymer is created on the substrate
- Ability to coat **non-woven, woven,** and **knit fabrics**
- **Comfortable to wear** – No significant change in texture, feel or breathability of fabric after coating

KinArm® Robotic Test Setup



Mechanically Controlled

In Plane Movement

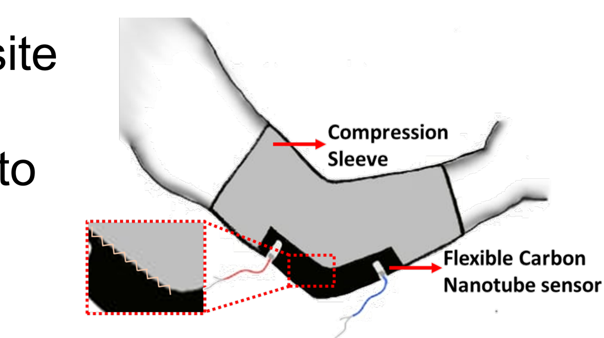
Hand **Driven by Robot**

Predefined Motion

No Change in Posture

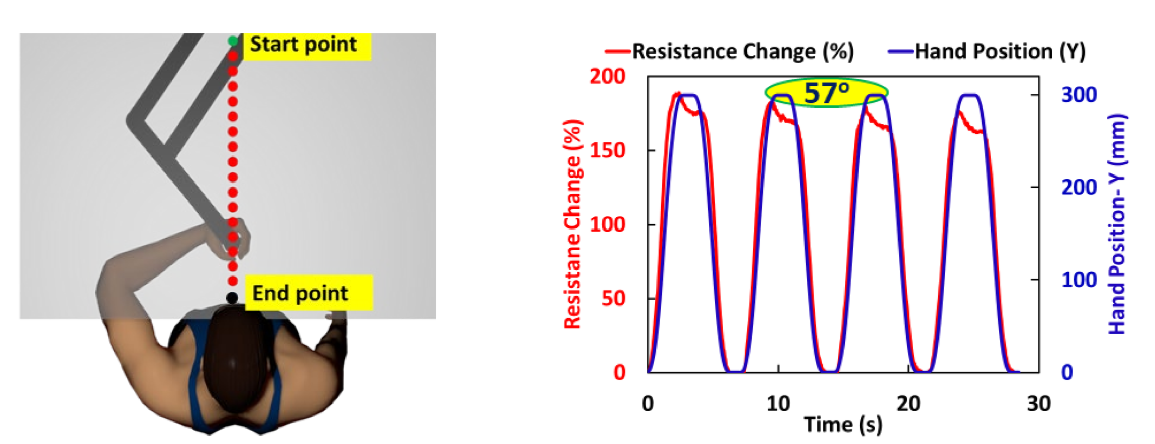
No Manual Effort

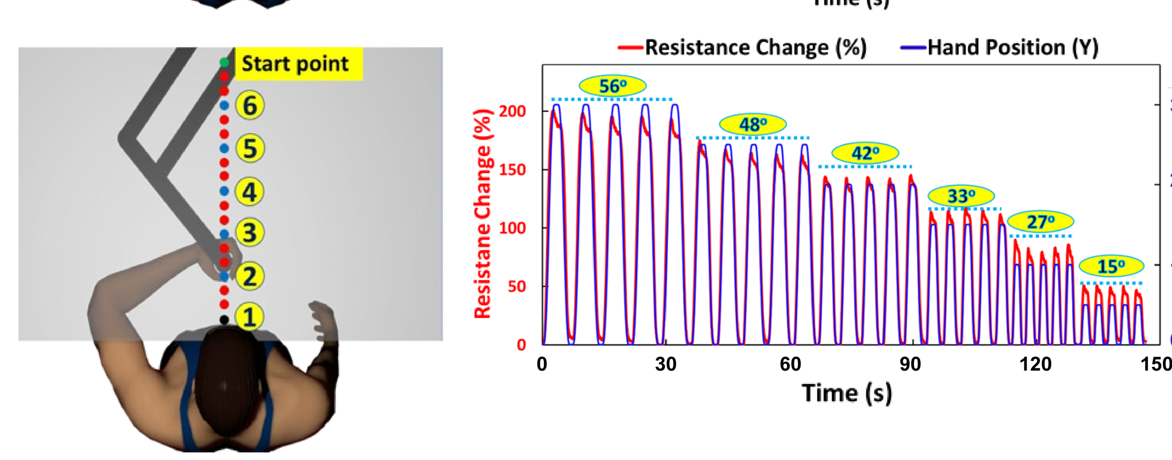
- Carbon nanotube composite coated **Knit fabric**-based elbow sensor is attached to the **compression sleeve** using **zig-zag sewing**



Sensor Response to Linear Movement

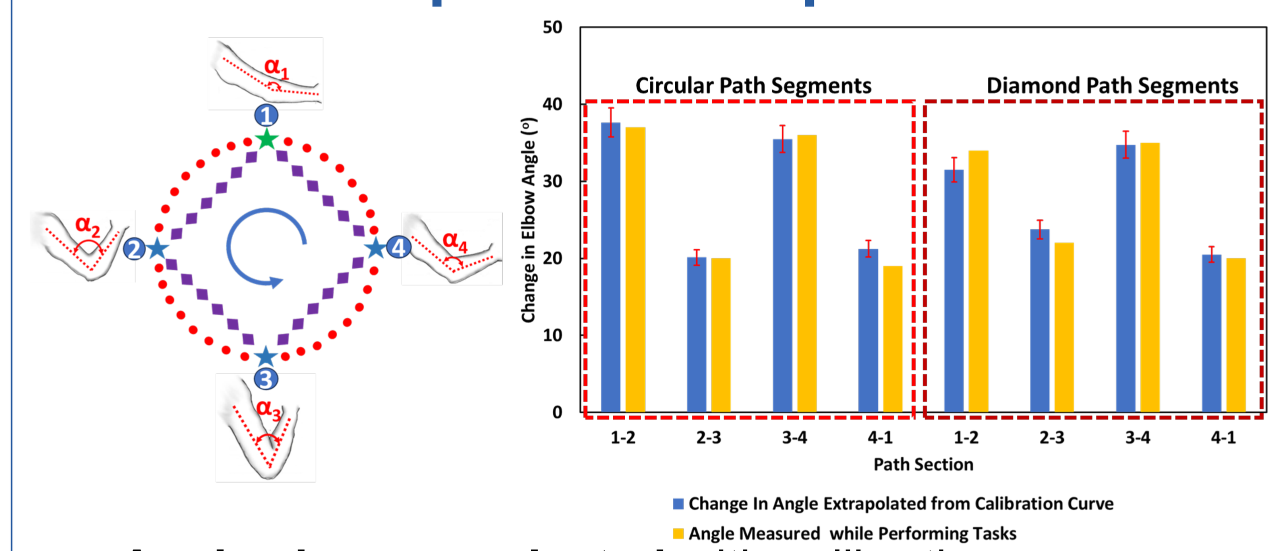
- A ***constant displacement straight-line motion*** task is created to validate the sensor ***repeatability*** under constant amplitude movement of the arm
- A ***variable amplitude straight-line motion*** task is created to validate the sensor's response with the ***variation*** in the elbow angle





- The elbow angle change between the start and end points is ~ 53°, and **sensor's response** (~180% resistance change) is **repetitive for multiple cycles**
- Sleeve **resistance changes** with **change in amplitude** of straight-line motion
- **Stable** and **repeatable** response for each amplitude cycle

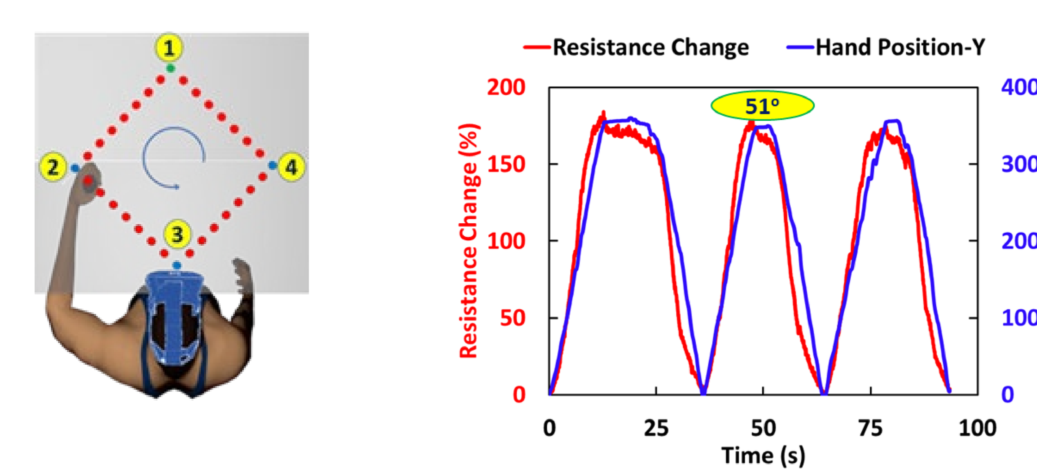
Sensor Response to In-plane Motion

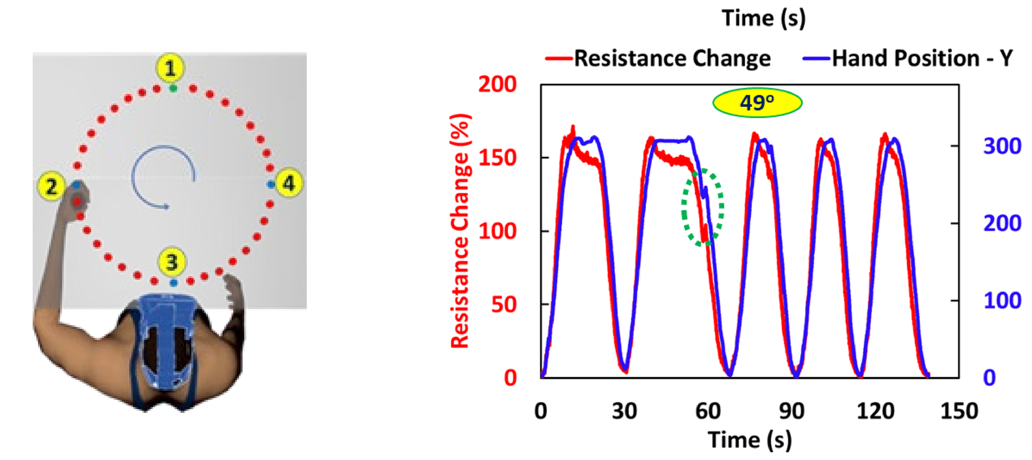


- **Angle change projected** with calibration curve was in close **comparison** to **angle measured** during exercise

Virtual Reality Exercise Feedback

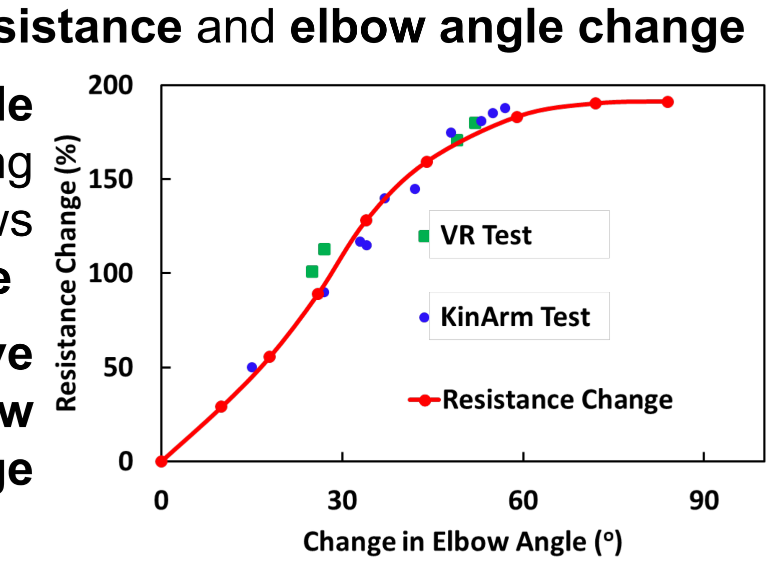
- A virtual model for the KinArm robot was designed in a **virtual reality** headset environment
- The resistance change for **diamond** and **circular** paths followed the **elbow angle change**
- **Mistake** made during circular movement captured by the **sensor response**





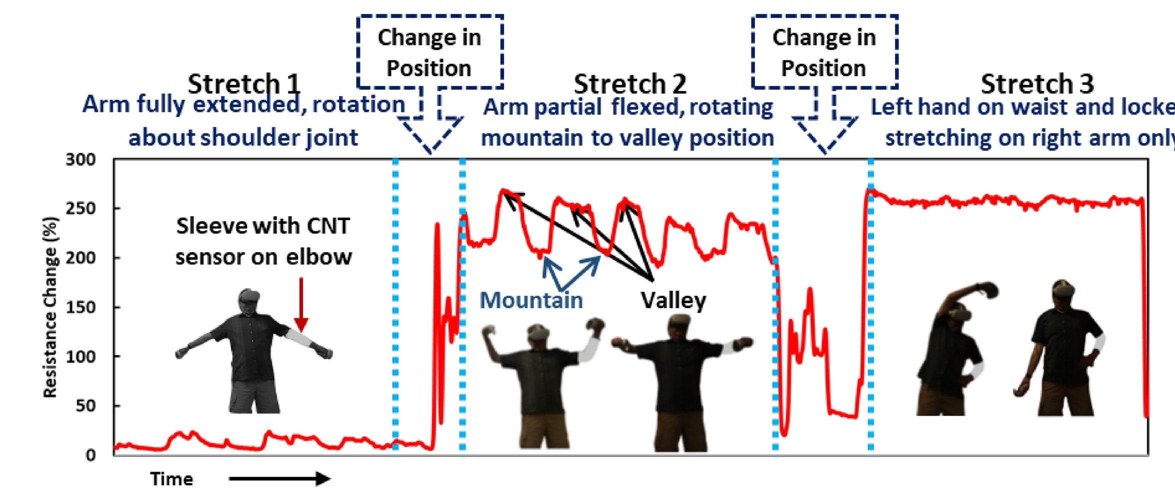
Sensor Response Validation

- A calibration curve was generated by manually measuring the **resistance** and **elbow angle change**
- **Elbow angle measured** during tests follows **calibration curve**
- **Calibration curve** can predict **elbow angle change** during **exercise**



VR Exercise Feedback

- A VR exercise was performed using a commercially available Meta Quest 2 VR gaming system and the sensor was integrated with sleeve to record the sensor response.



- Stretch 1 - arm rotated through the shoulder join, minimal/ no change in elbow angle and sensor response
- Stretch 2 - arms are flexed and resistance change by ~250 %. When arms are moved from mountain to valley position, ~ 50% resistance change is noticed, though visually no difference is visible
- Stretch-3, when hand with sensor is locked by positioning on waist, no response in the sensor during exercise
- The response of the sensor is dependent on the elbow angle change, irrespective of hand position and exercise

Conclusions and Future Work

- Knit fabric sensor's response is consistent with the change in elbow angle and repeatable
- Sensor can be used for VR based exercises feedback/ human machine interaction/ virtual rehabilitation/ human health support
- Future study is required to capture shoulder joint motion using multiple sensors

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