# Towards the development of dynamic hand orthosis without conventional joints

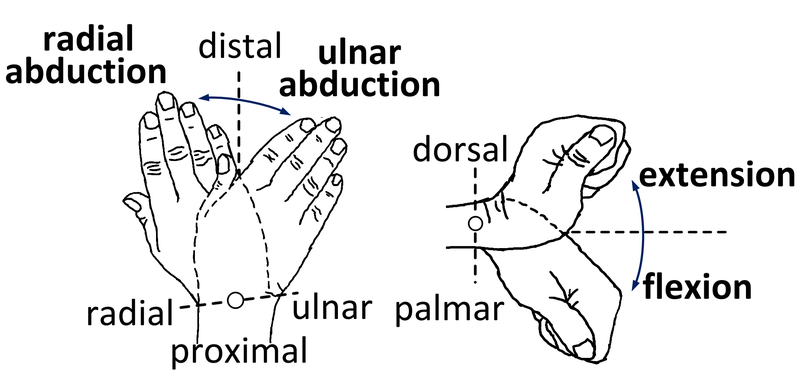
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## Abstract

The human hand is an exceptionally complex anatomical region with 31 degrees of freedom. Among these, the four degrees of freedom in the wrist are particularly important for facilitating the hand's multiaxial mobility. To effectively replicate this mobility in dynamic orthoses, a specific design is required that accurately mirrors the natural multiaxial movements of the hand and wrist. One promising solution is the use of compliant tensegrity structures as the core framework for such orthoses. This work highlights the essential aspects of developing such an orthosis, including simulative calculations, experimental measurements, and the accurate capture of hand anatomy. The proposed methodology provides a solid foundation for the design of initial prototypes of tensegrity-based hand orthoses.

## Human Hand

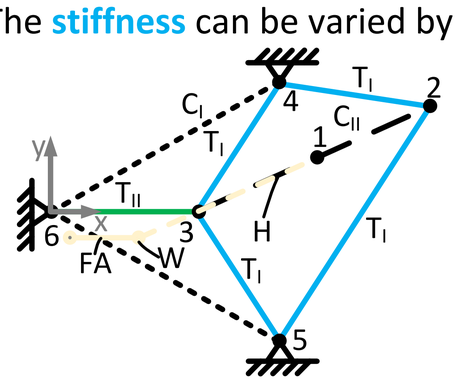
- **8** carpal bones, **5** metacarpal bones and **14** phalanges
- **2** degrees of freedom



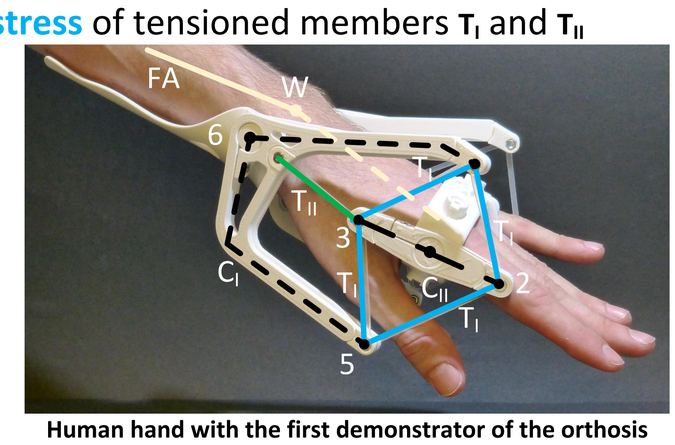

**Range of motion of the human hand with respect to the two main rotational movement possibilities.**

## Hand Orthosis

- Multiaxial mobility of the hand and orthosis:
  - **without the use of conventional joints**
  - with the help of a **single flexible structure**
- The **stiffness** can be varied by adjusting the **prestress** of tensioned members $T_I$ and $T_{II}$




**2-dimensional tensegrity structure of the orthosis**




**Human hand with the first demonstrator of the orthosis based on the described concept**

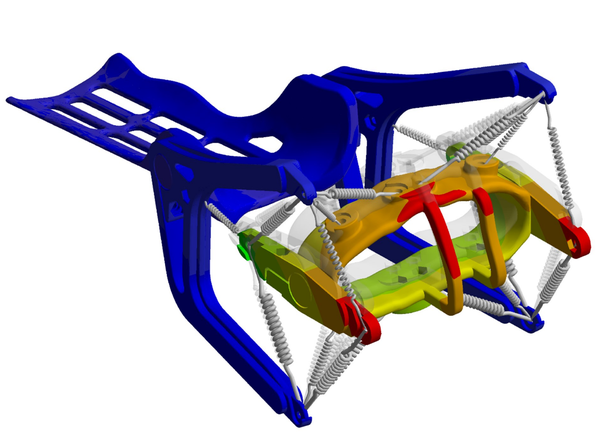
## Mechanical Model and Simulations

- Tensioned members properties (inital length and stiffness) have significant influence on the resulting body reactions → Characterization needed
- Formfinding (equilibrium determination) is the basis for all characterization
- Geometric Nonlinear Static FEA is used for characterization

**A**: Formfinding (stiffness = 0.1 N/mm; inital length = 35 mm)

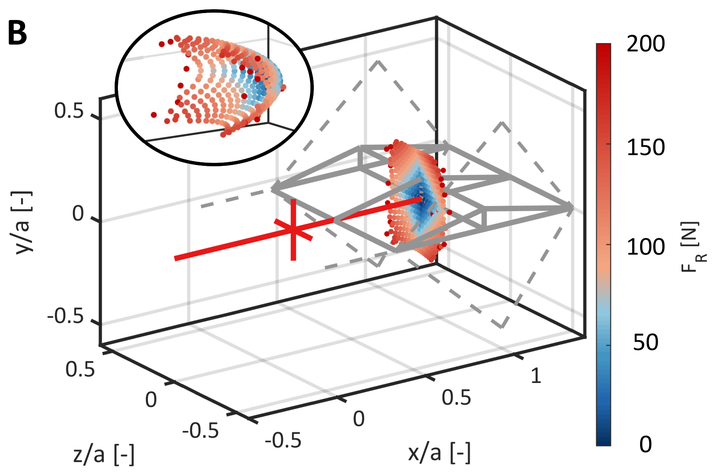
**B**: Flexibility plots visualize deflection vs. joint forces
- maximum deflection from equilibrium position with resulting joint forces of each deflection

**A**



**A: Formfinding of 3-dimensional orthosis using ANSYS (transparent = random initial position, blue to red: deformation from inital to equilibrium positon)**

**B**

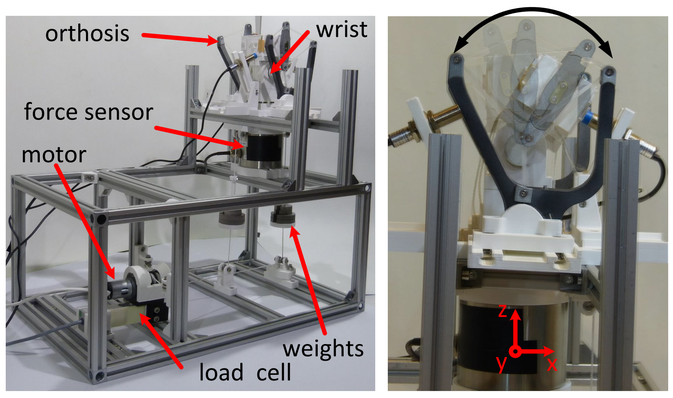



**B: Characterization of 3-dimensional orthosis using MATLAB (tensioned members: stiffness = 0.1 N/mm; inital length = 35 mm, blue to red dots: coresponding joint forces)**

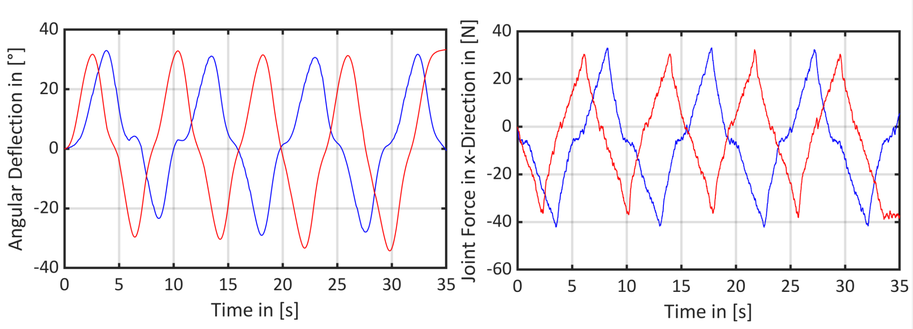
## Experimental Setup

**Objective:**
- Characterization of the orthosis → overall orthosis stiffness; prestress of the tensioned members
- Influence on the wrist → joint forces during movement

**Implementation:**
- movable orthosis element $C_{II}$ with a cable-guided actuator system
- 6 component force sensor for joint forces and load cell for cable forces

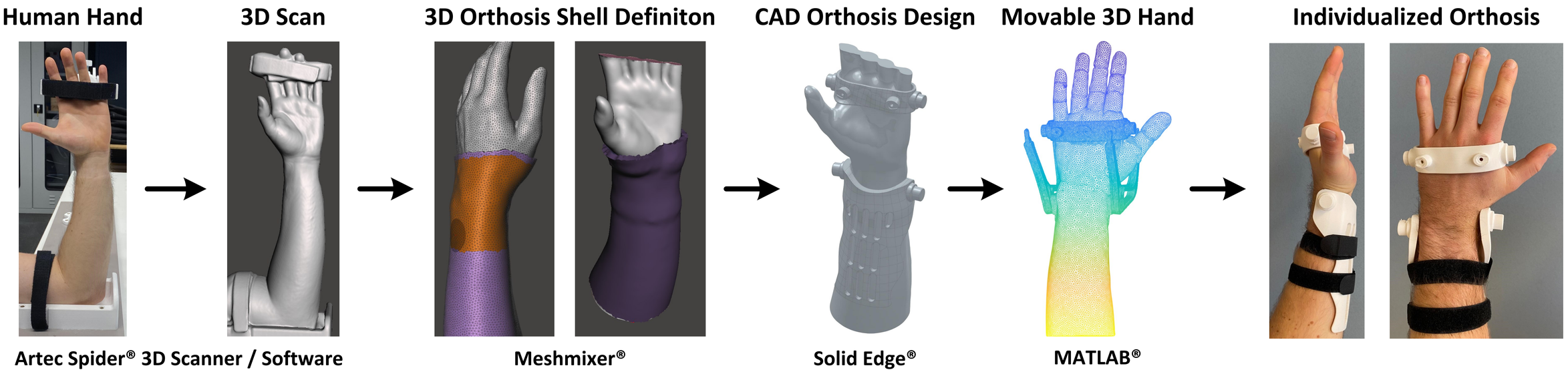



**Test rig for the experimental orthosis characterization**




**Exemplary results for flexion / extension movement of orthosis**

## Digitization of the Human Hand Surface




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The authors gratefully acknowledge the support of the German Research Foundation (DFG) through the Priority Program SPP 2100 “Soft Material Robotic Systems” (Projects: BO4114/3-2, ZE714/14-2)