Inference of computational models of the fingers' tendinous networks through sparse experimentation

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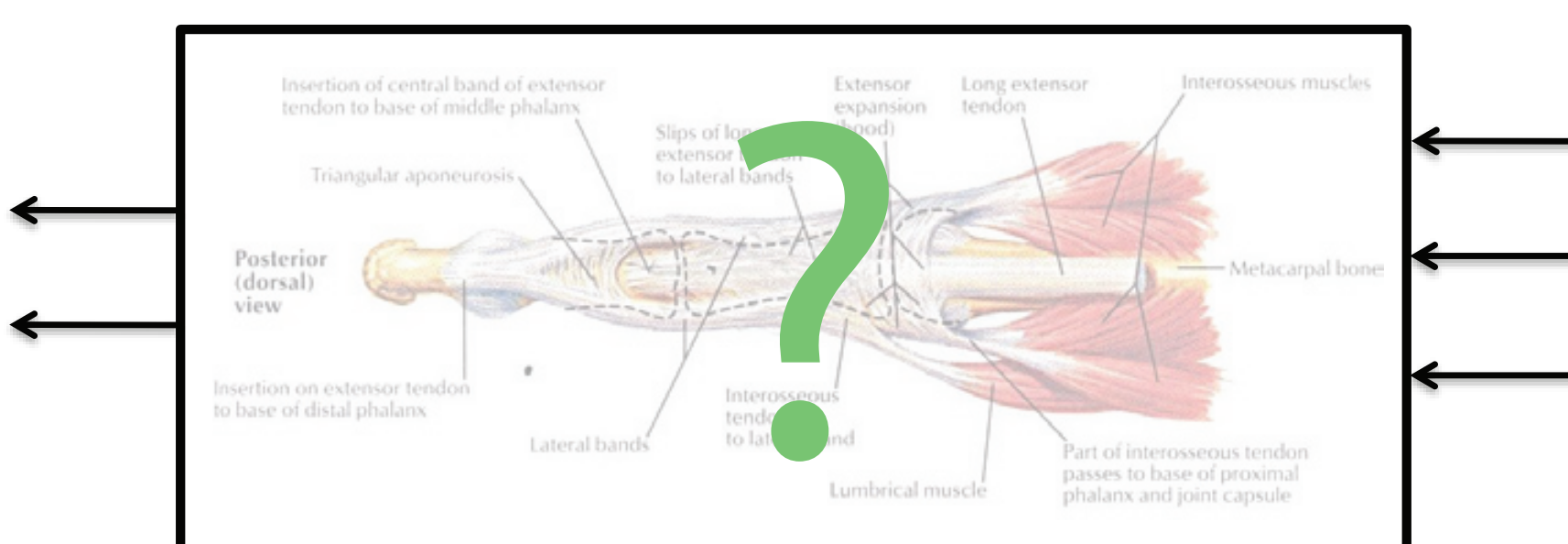[3]Sibley School of Mechanical and Aerospace Engineering, Cornell University

Introduction

• Tendons in the fingers form complex networks of interconnections.
• Any damage to these networks results in dysfunction.
• Accurate computational models inferred from experimental data will help us understand their role in manipulation and changes upon damage.
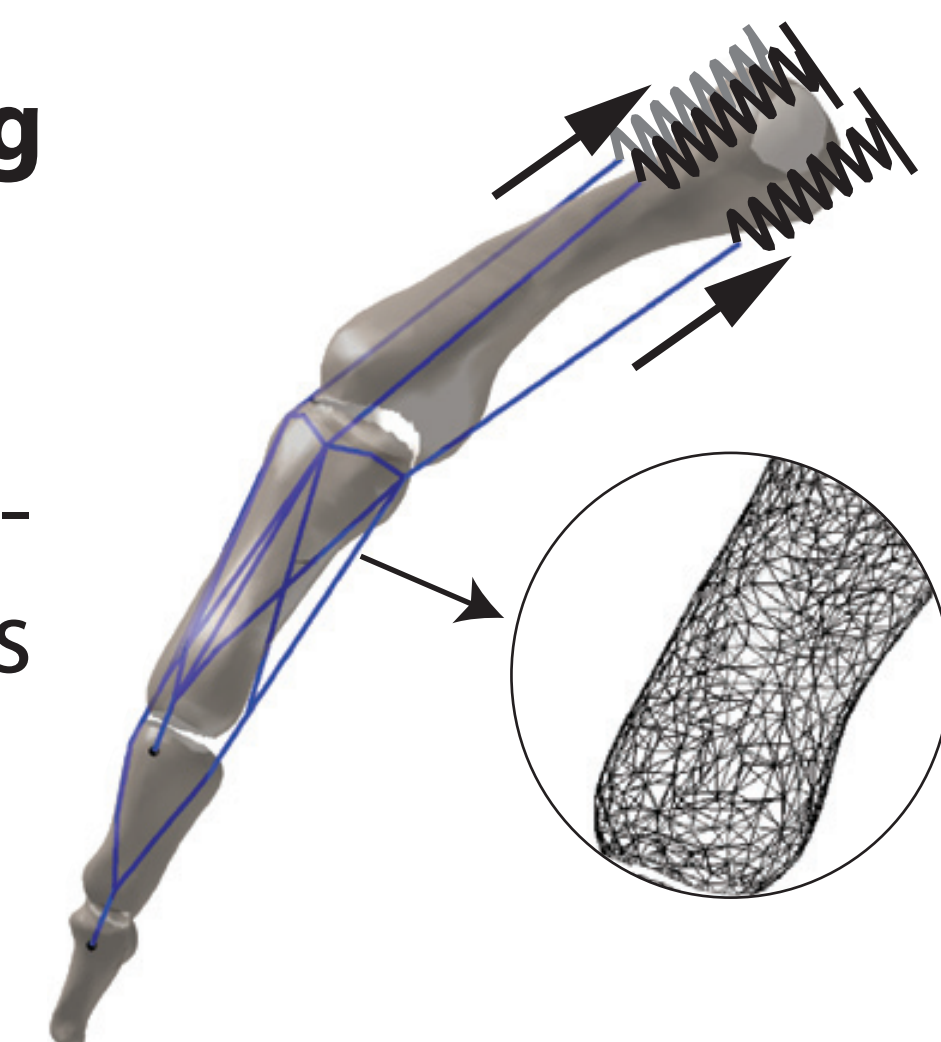• This will also enable better robotic and prosthetic hands.

Netter, F. Atlas of Human Anatomy, 3rd edition, pp 447-453

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Wilkinson et al. 2006
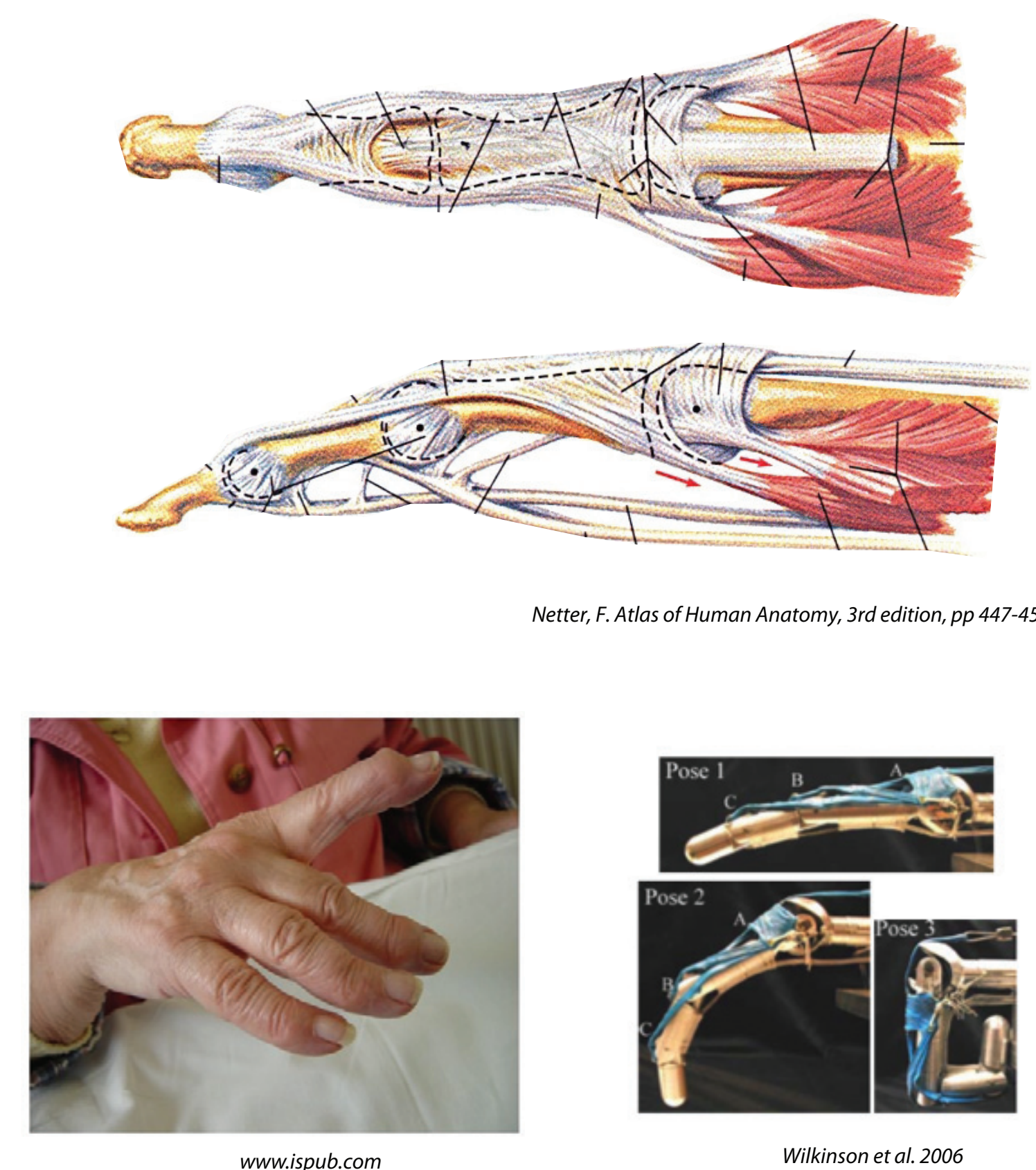
Methods

Inference of computational models from input-output data
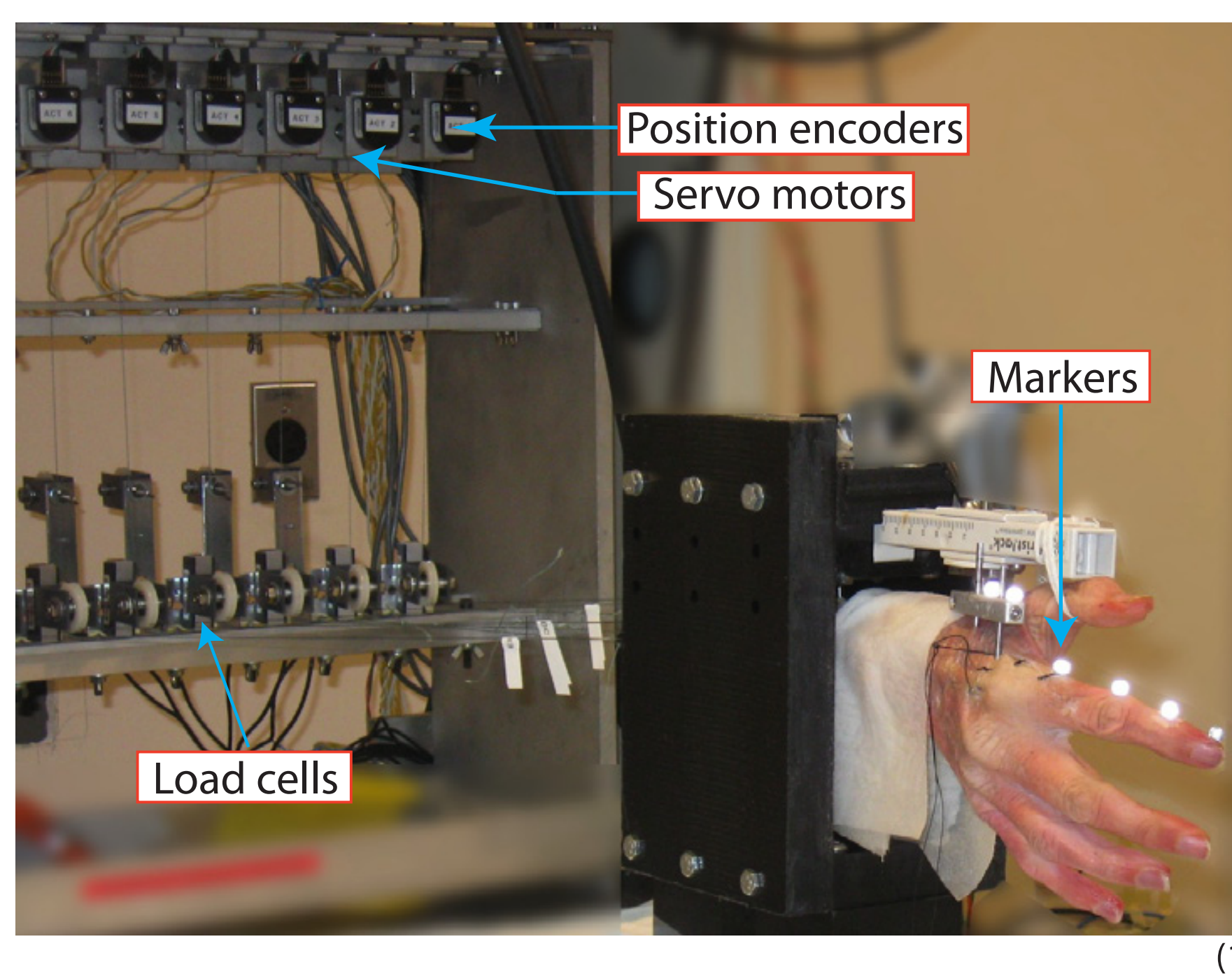

Computational modeling environment

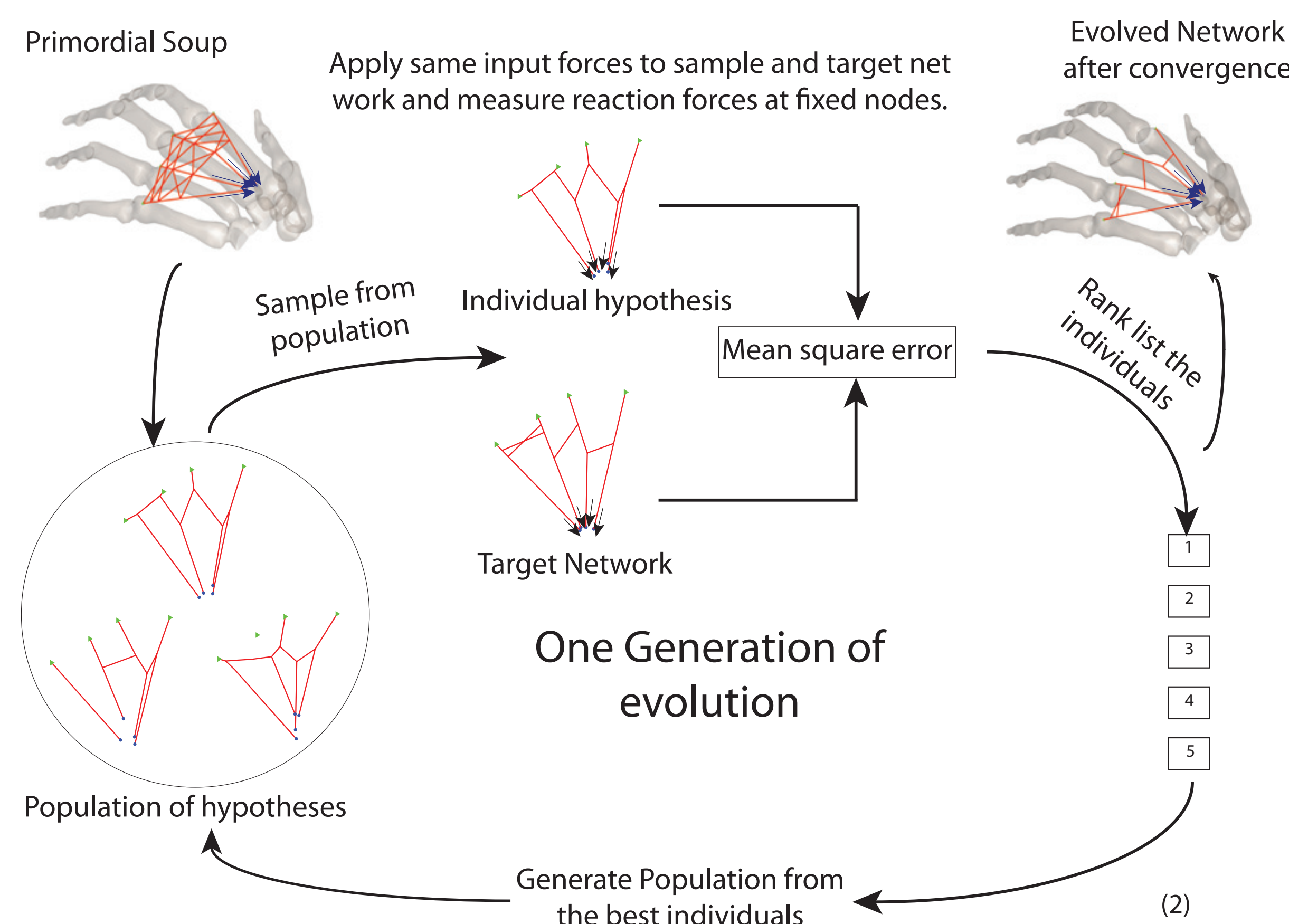Finite Element Analysis Simulator to model interactions of elastic networks on bones.

Experimentation

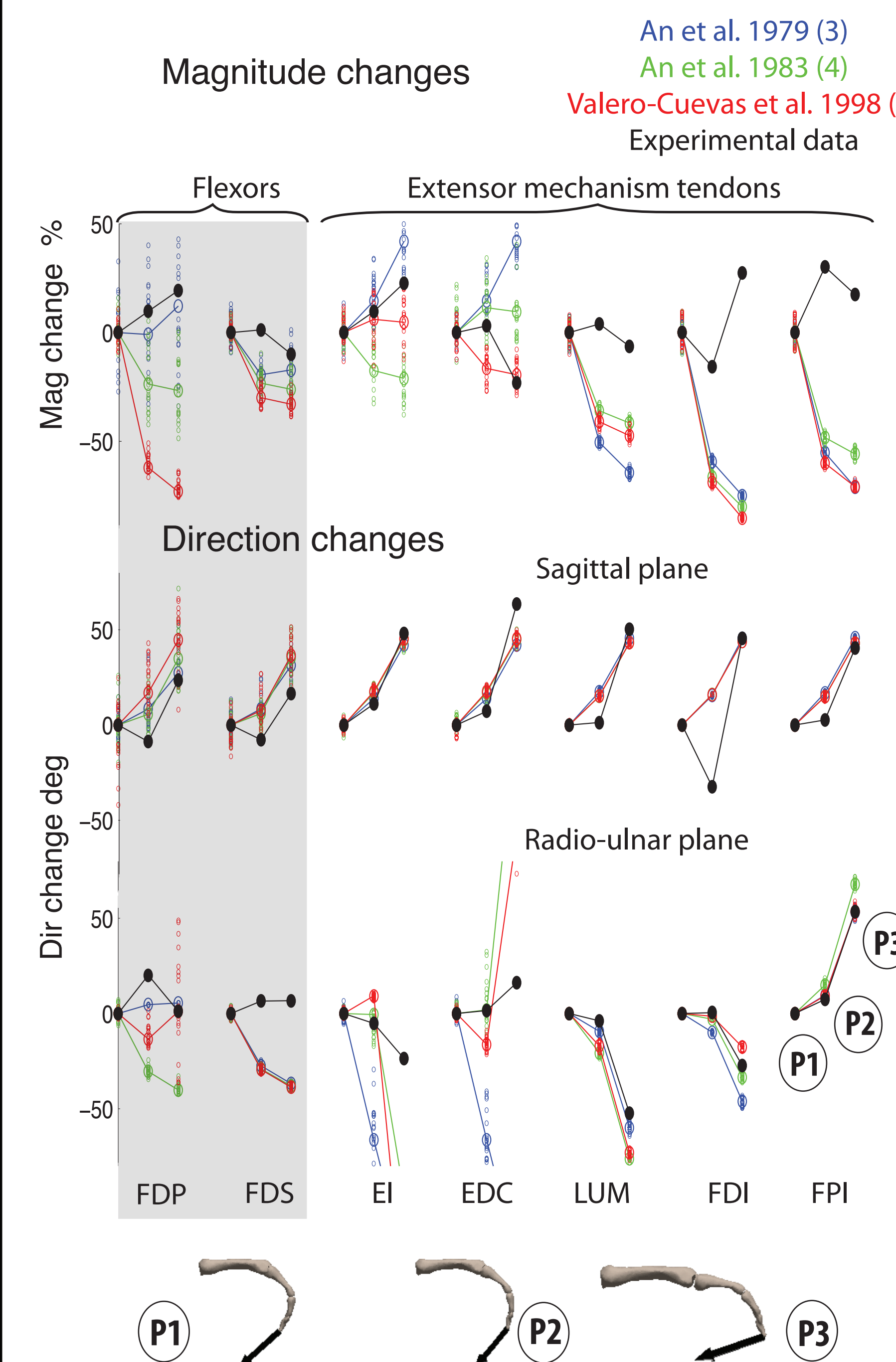Actuation of the seven tendons of a cadaveric index finger using a real time control system.
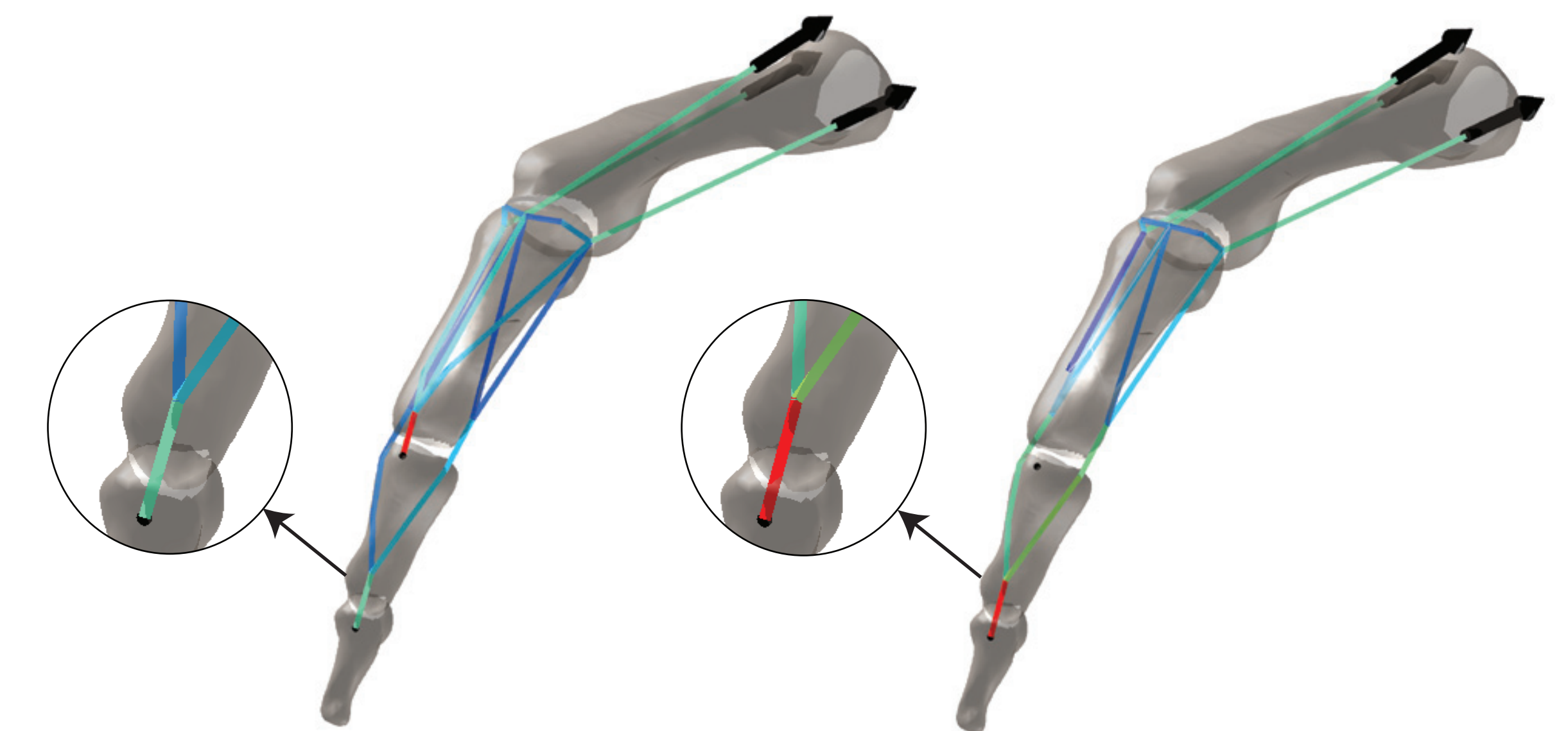

Position encoders
Servo motors
Markers
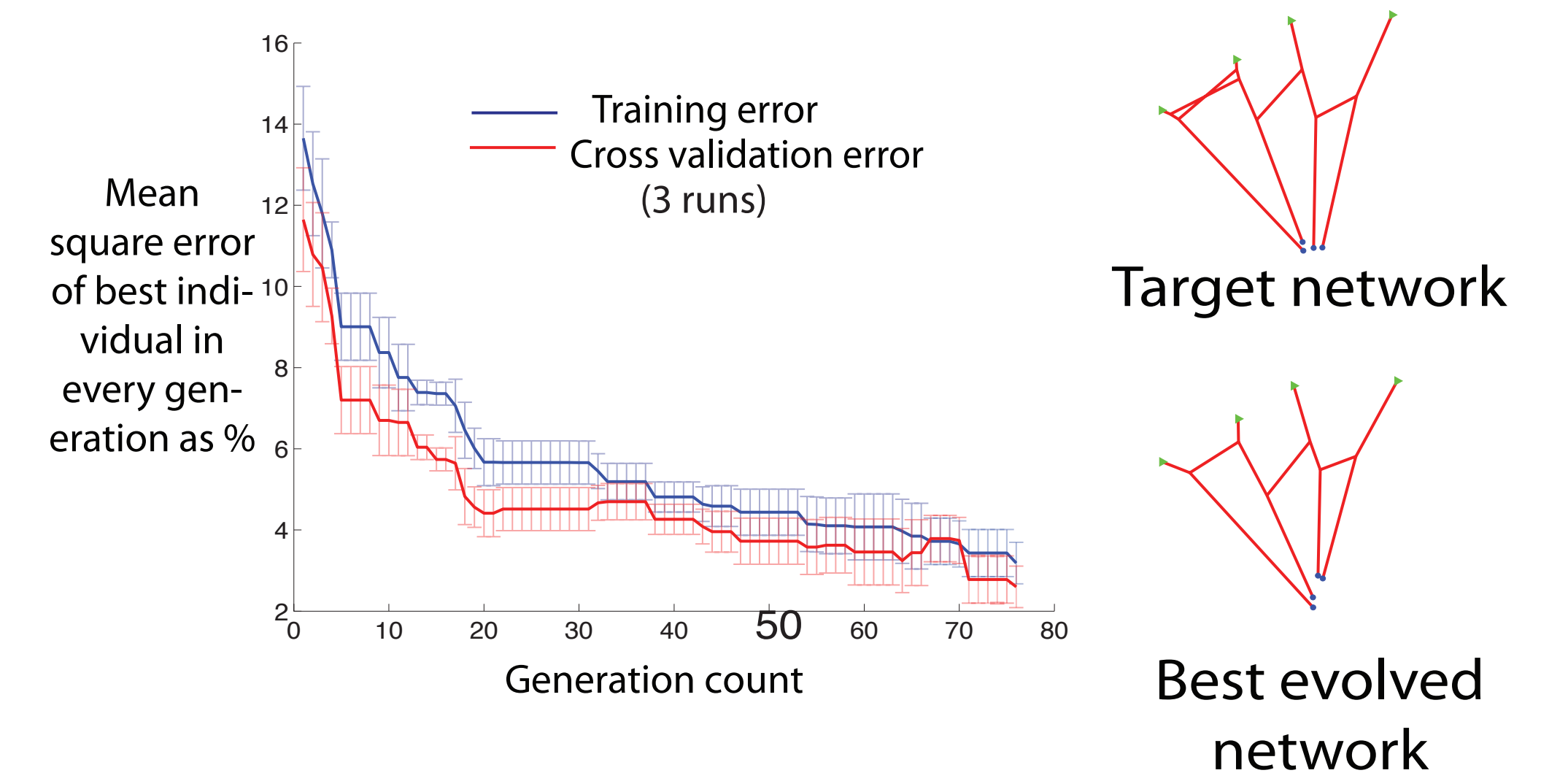Load cells

(1)

Estimation Algorithm

Primordial Soup

Apply same input forces to sample and target network and measure reaction forces at fixed nodes.

Evolved Network after convergence

Sample from population
Individual hypothesis
Mean square error
Rank list the individuals

Target Network

One Generation of evolution

Population of hypotheses

Generate Population from the best individuals

(2)

Results

Experimental evaluation of existing biomechanical index finger models

Magnitude changes

An et al. 1979 (3)
An et al. 1983 (4)
Valero-Cuevas et al. 1998 (5)
Experimental data

Flexors
Extensor mechanism tendons

Mag change %

Direction changes

Sagittal plane

Dir change deg

Radio-ulnar plane

P3
P2
P1

FDP   FDS   EI   EDC   LUM   FDI   FPI

P1   P2   P3

Simulating the effect of tendon ruptures on force transmission

Estimation of elastic tendon networks in 2D

Mean square error of best individual in every generation as %

Training error
Cross validation error (3 runs)

Generation count

Target network

Best evolved network

Conclusions and present work

• Experimental evaluation of existing biomechanical models in the literature calls for accurate data-driven models.
• To achieve this we have,
  – collected experimental data from cadaveric specimens.
  – designed a novel computational modeling environment .
  – developed novel structural inference algorithms.
• We are currently combining these to infer accurate computational models of the fingers' tendinous networks.

References
1. Valero-Cuevas et al. 2000, J. Biomech 33, 1601-1609, 2000.   **2.** Valero-Cuevas et al. IEEE Transactions on Biomedical Engineering 54, 1951-1963, 2007.   **3.** An KN, et al J Biomech 12, 775-788, 1979.   **4.** An KN, et al. J Biomech 16, 419-425, 1983.   **5.** Valero-Cuevas FJ, et al. J Biomech 31, 693-703, 1998.

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