Computational Method to Study Tendinous Interactions Across Fingers

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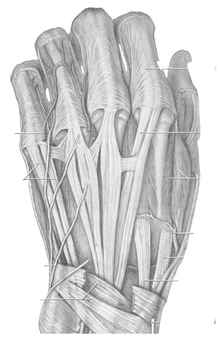
Introduction: Role of the Juncturae Tendinum

1. Tendinous interconnections distribute forces across fingers but their contribution to enslavement is not clear [1].
2. Combining computational modeling with direct actuation of cadaveric tendons will help us understand this without interference from the neuromuscular system [2].

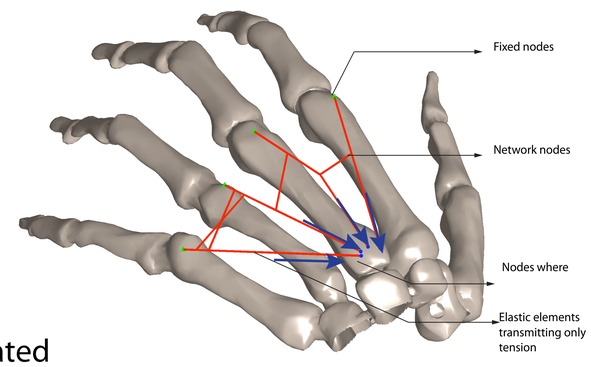


The Juncturae tendinum

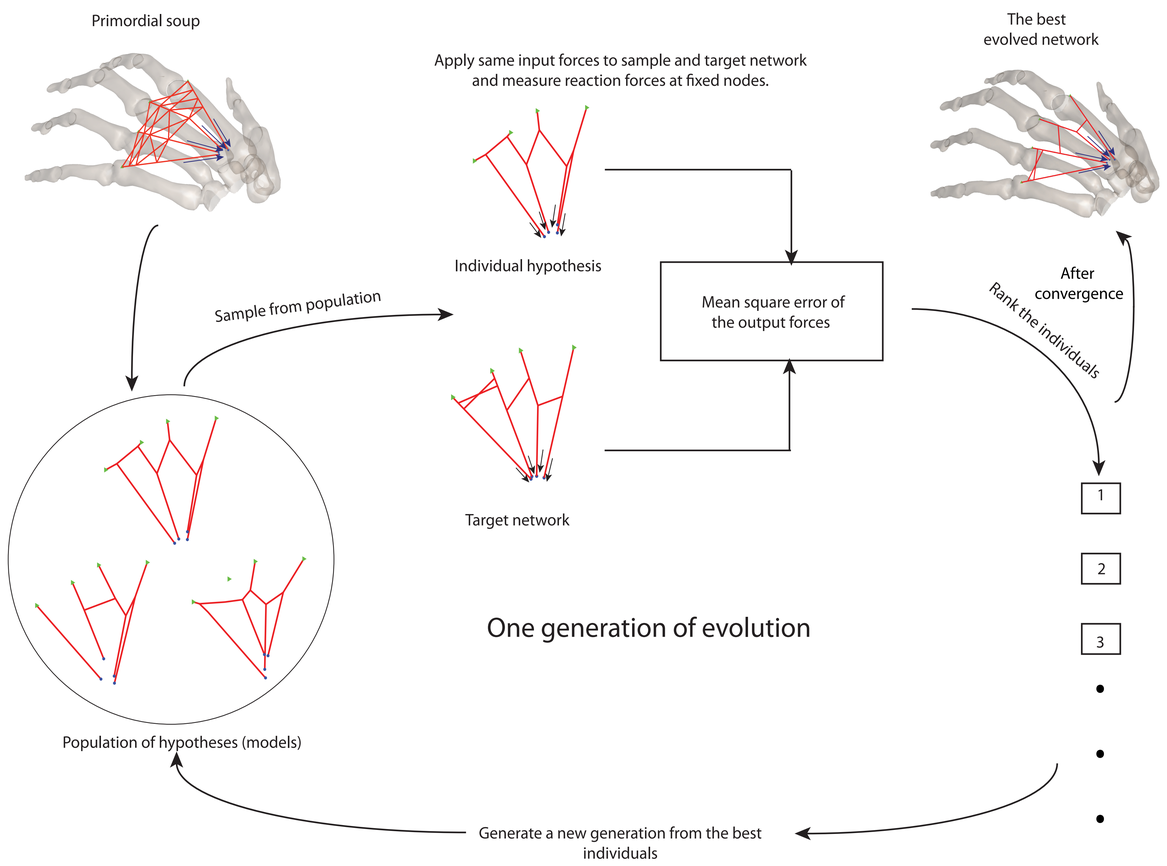
Grant, J. C. B. and J. E. Anderson (1978). "Grant's atlas of anatomy", Williams & Wilkins.

Methods : Computational Estimation

1. We developed a finite element analysis solver to study force and displacement propagation through elastic tendinous networks on a plane.
2. Using a target topology, we generated data sets consisting of:
   - Inputs : Extensor muscle forces
   - Outputs : Extensor tendon forces
3. Using these input-output data, we estimated the target network.

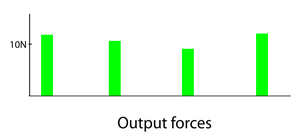


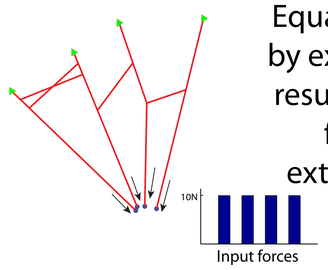
Estimation algorithm using evolutionary optimization



We used Stochastic Hill Climbing with learning by vectors of normal distributions [3].

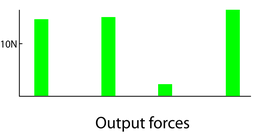
Simulation Results : Force Distribution in the Juncturae Tendinum

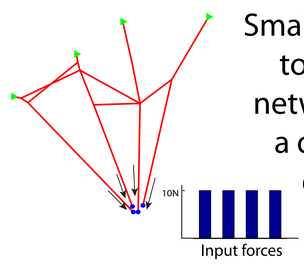




Equal forces applied by extensor muscles resulted in unequal forces to the extensor tendons.

Equal Force magnitude





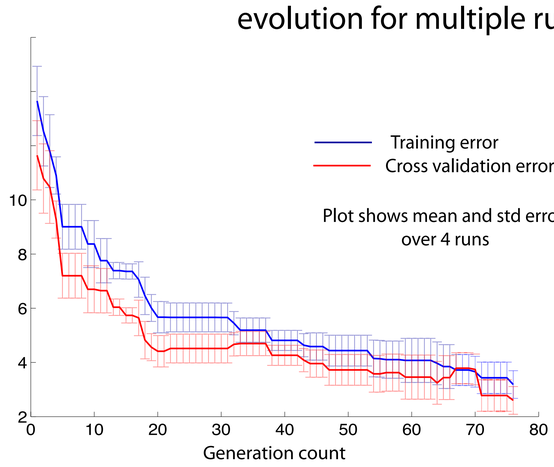
Small changes to the topology of the network resulted in a different force distribution.

Equal Force magnitude

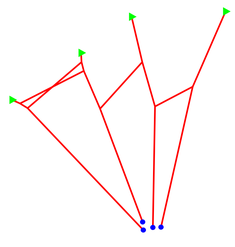
Hence extracting the correct topology is important!

Simulation Results : Estimation of the Target Network

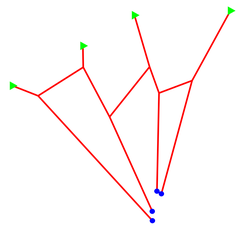
Estimation error across generations of evolution for multiple runs



Estimation converged to < 5% mean square error after around 75 generations of evolution (Population size : 100)



Target network



Best evolved network

Conclusions and Ongoing Work

1. Distribution of forces through the tendon network is sensitive to topology.
2. Our evolutionary computational approach can be used to effectively estimate topologies in real biological networks.
3. Next step : Estimate the topology of the juncturae tendinum using data from cadaveric hands.

References :

1. Schieber, M. H. and Santello, M., 2004,"Hand function: peripheral and central constraints on performance," J Appl Physiol, 96: 2293–2300
2. Valero-Cuevas, F. J., Anand, V. V., Saxena, A., Lipson, H., 2007, "Beyond Parameter Estimation: Extending Biomechanical Modeling by the Explicit Exploration of Model Topology," IEEE Transactions on Biomedical Engineering, 54(11) : 1951-1964
3. Rudlof, S., Köppen, M ,1996, "Stochastic hill climbing by vectors of normal distributions," Proceedings of the First Online Workshop on Soft Computing (WSC1) Nagoya, Japan

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