Finger Motion Modeling For Bionic Fingers

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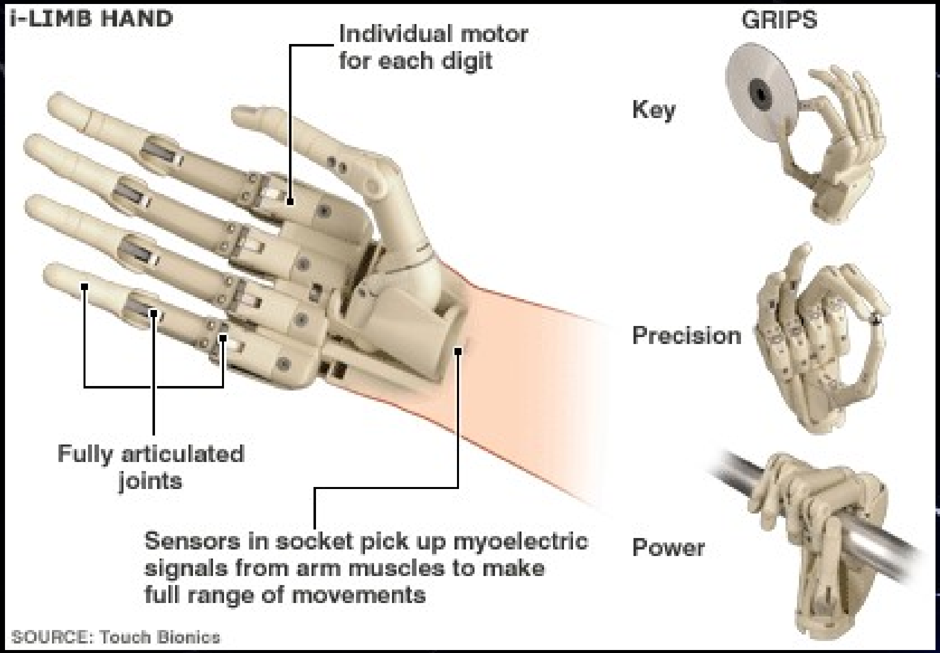
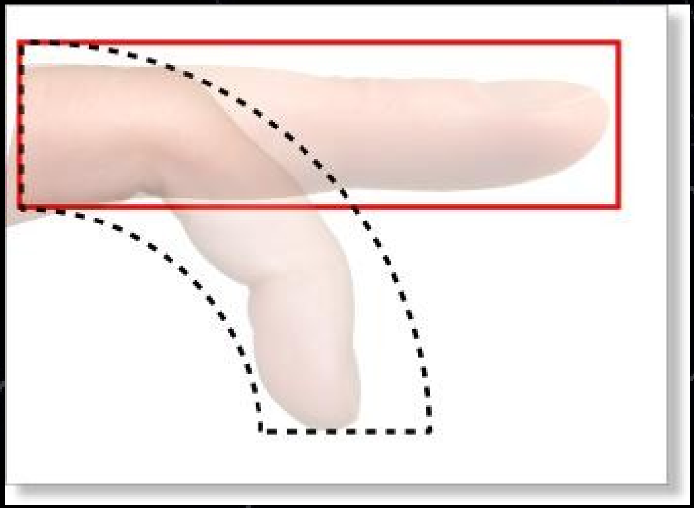
What are Bionic Fingers?

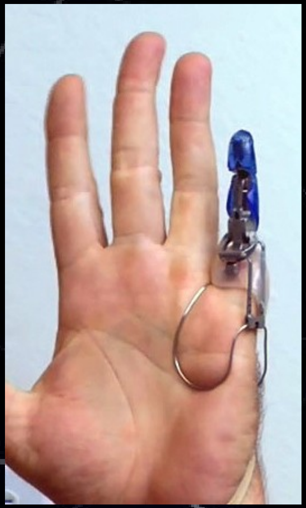
- Mechanically engineered prostheses
- Replaces missing fingers.



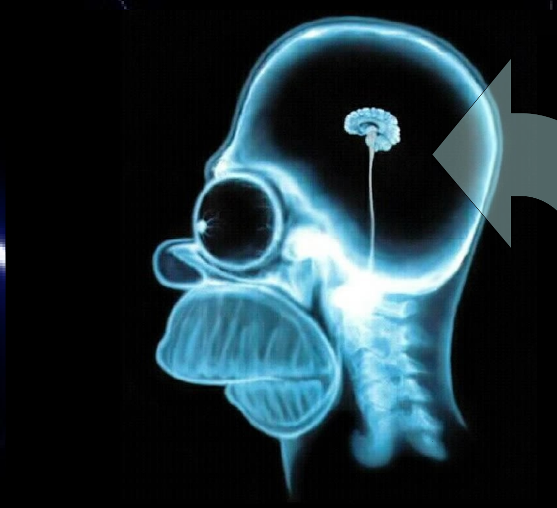
Why Model Finger Motion?



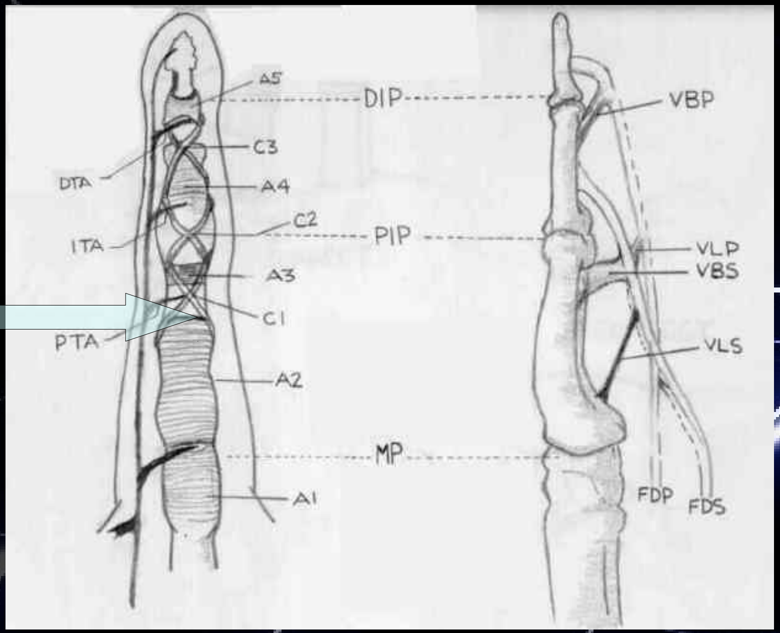
- Determine forces needed to create required movement

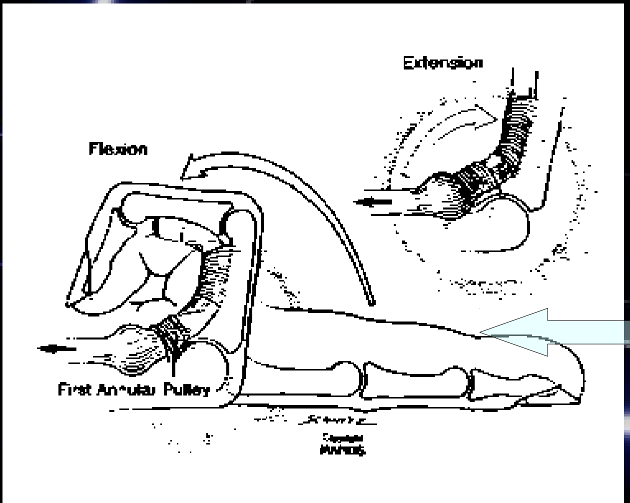


How the Finger Works?

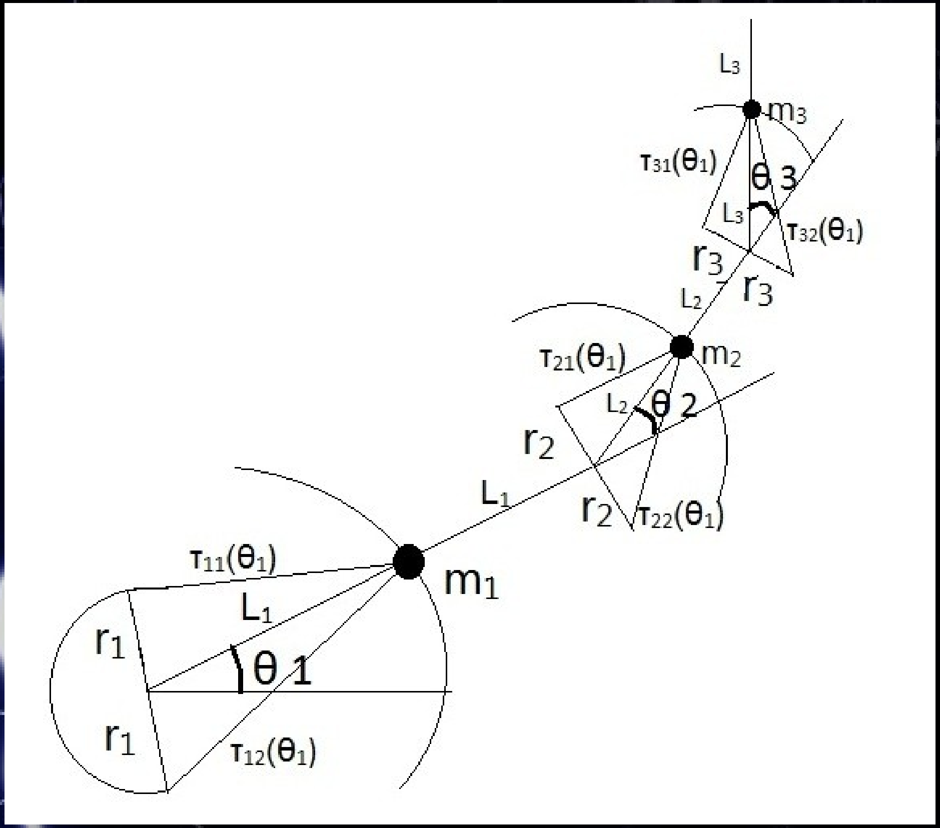


- Eyes
- Brain
- Tendons
- Action





Modeling Approach



- r: radius of joint
- θ: angle between horizontal and center of phalanx
- L: length of phalanx
- M: center of mass
- T (θ): tension force

Equations

Force

First Phalanx

$$sin(\alpha_1)(T_{11} - T_{12}) - sin(\theta_2 - \theta_1)(cos(\alpha_2)(T_{21} + T_{22}) + cos(\alpha_3)cos(\theta_3 - \theta_2)(T_{31} + T_{32}))$$

Second Phalanx

$$sin(\alpha_2)(T_{21} - T_{22}) - sin(\theta_3 - \theta_2)cos(\alpha_3)(T_{31} + T_{32})$$

Third Phalanx

$$sin(\alpha_3))(T_{31} - T_{32})$$

Equations cont.

Acceleration

First Phalanx

$$\ddot{u}_1 = \tau_1(\theta_1)L_1\ddot{\theta}_1$$

Second Phalanx

$$\ddot{u}_2 = \tau_2(\theta_2)(2L_1cos(\theta_2 - \theta_1)\ddot{\theta}_1 + 2L_1sin(\theta_2 - \theta_1)(\dot{\theta}_1)^2 + L_2\ddot{\theta}_2)$$

Third Phalanx

$$\ddot{u}_3 \cdot \tau_3'(\theta_3)) = 2L_1(cos(\theta_3 - \theta_1)\ddot{\theta}_1 + sin(\theta_3 - \theta_1)(\dot{\theta}_1)^2) + 2L_2(cos(\theta_3 - \theta_2)\ddot{\theta}_2 + sin(\theta_3 - \theta_2)(\dot{\theta}_2)^2) + L_3\ddot{\theta}_3$$

Equations cont.

F=ma

First phalanx

$$m_1 L_1 \ddot{\theta}_1 = sin(\alpha_1)(T_{11} - T_{12}) - sin(\theta_2 - \theta_1)(cos(\alpha_2)(T_{21} + T_{22}) + cos(\alpha_3) cos(\theta_3 - \theta_2)(T_{31} + T_{32}))$$

Second Phalanx

$$2L_1 cos(\theta_2 - \theta_1)\ddot{\theta}_1 + 2L_1 sin(\theta_2 - \theta_1)(\dot{\theta}_1)^2 + L_2\ddot{\theta}_2 = sin(\alpha_2)(T_{21} - T_{22}) - (cos(\alpha_3)(T_{31} + T_{32}) sin(\theta_3 - \theta_2))$$

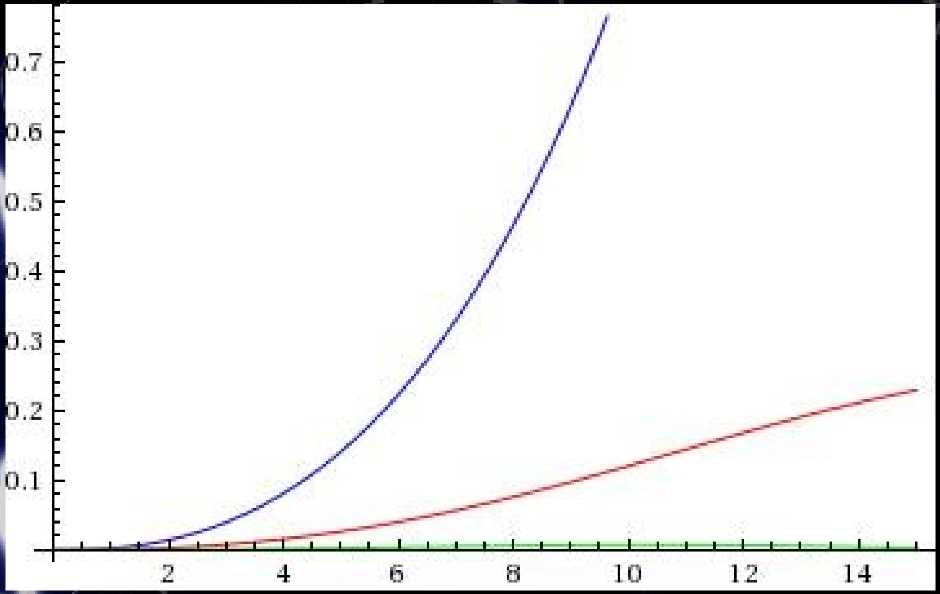
Third Phalanx

$$m_3(\ddot{u}_3 \cdot \tau_3'(\theta_3)) = (F_3 \cdot \tau_3(\theta_3))$$

Solving

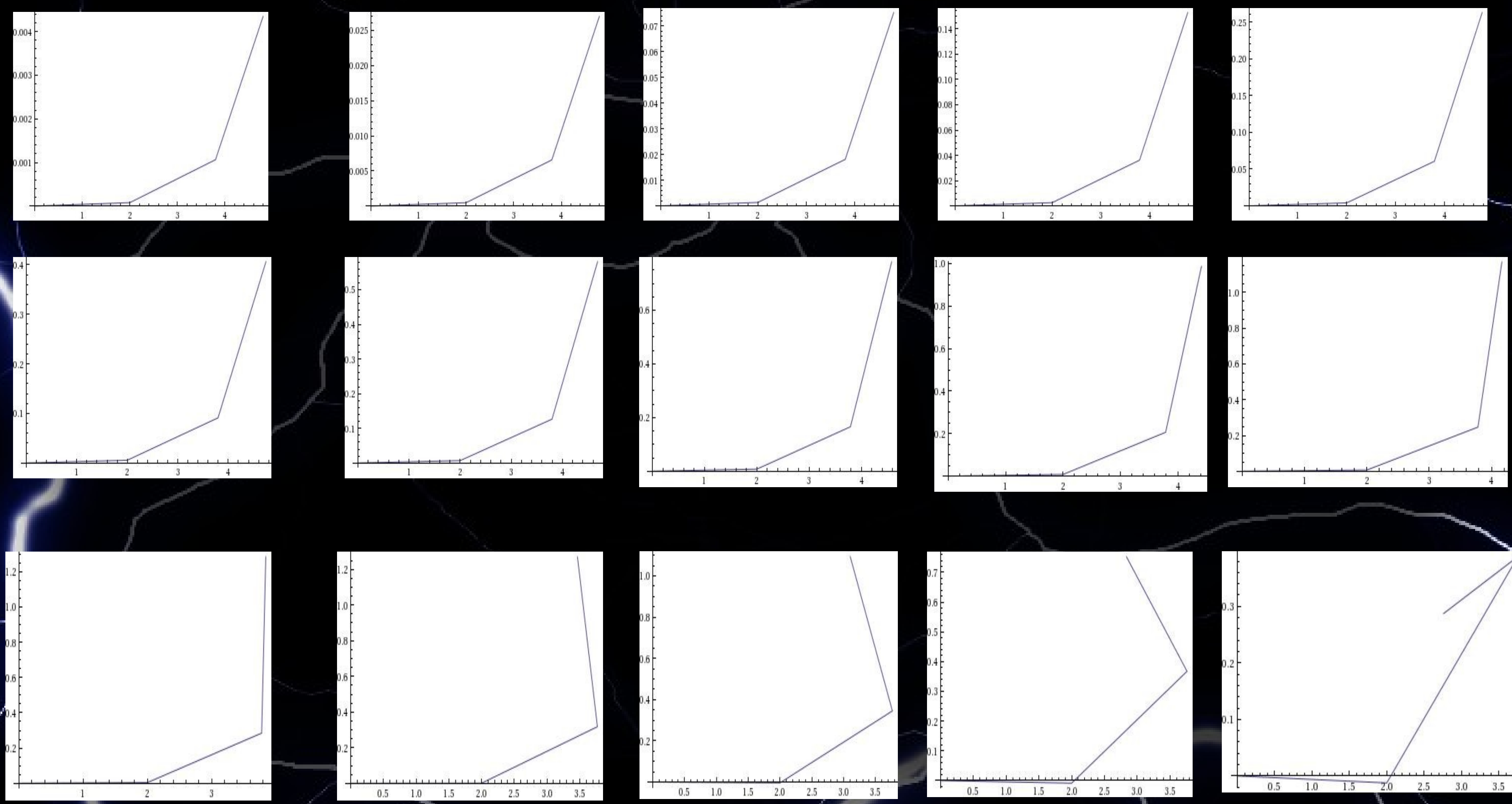
- Newton's Third Law of Motion
- Mathematica
- Numerical Differential Equations w/ initial conditions
- Change of theta in time
- Trail and Error
- Time Simulations

Finger in Three parts

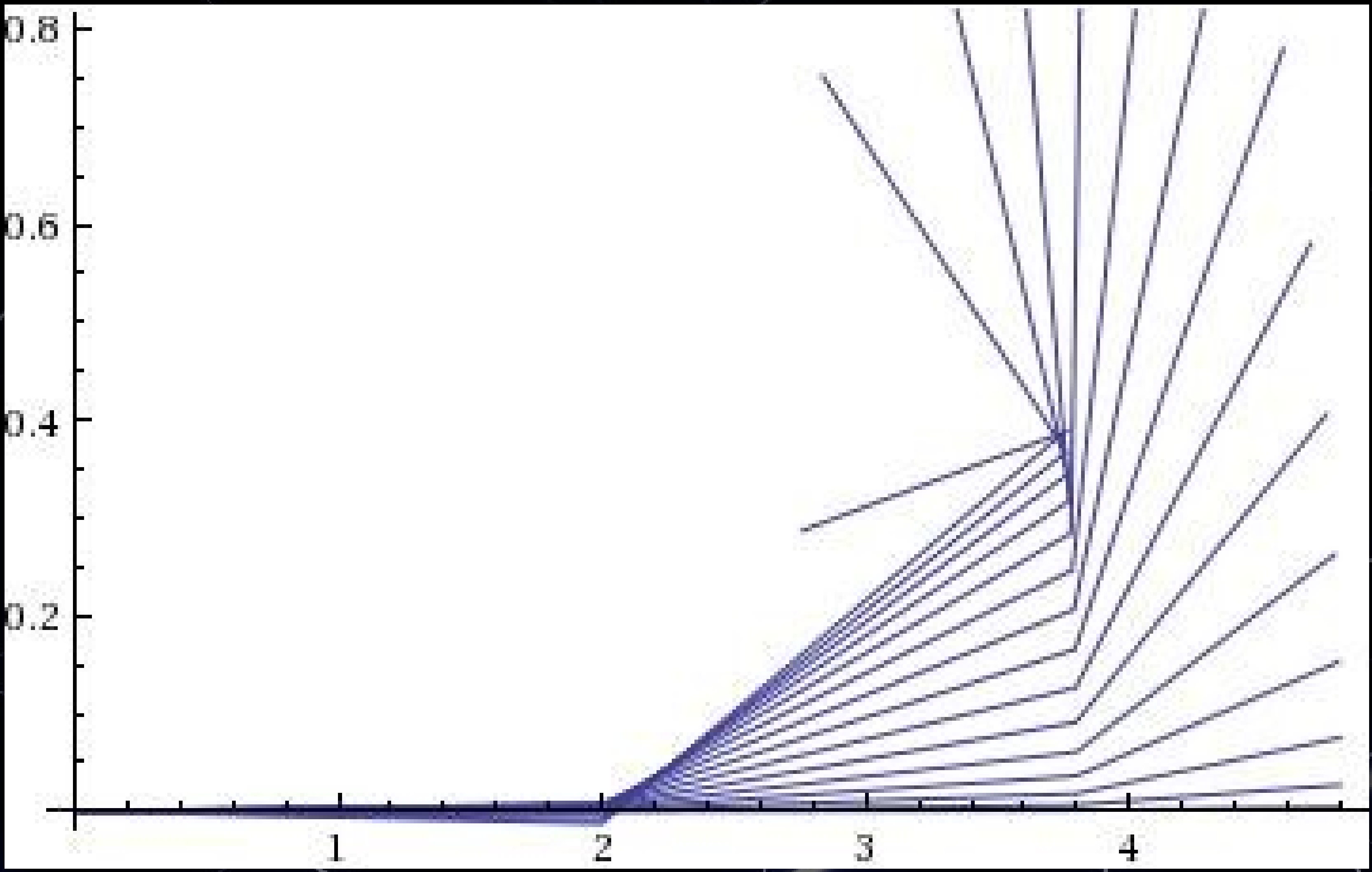


- Blue- 3rd phalanx
- Red- 2nd phalanx
- Green- 1st phalanx

Finger motion due to time

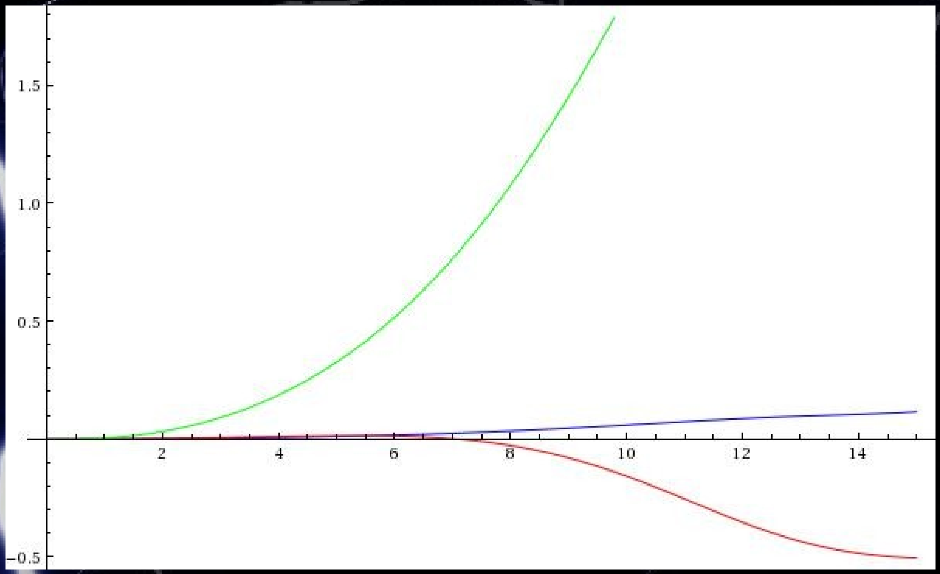


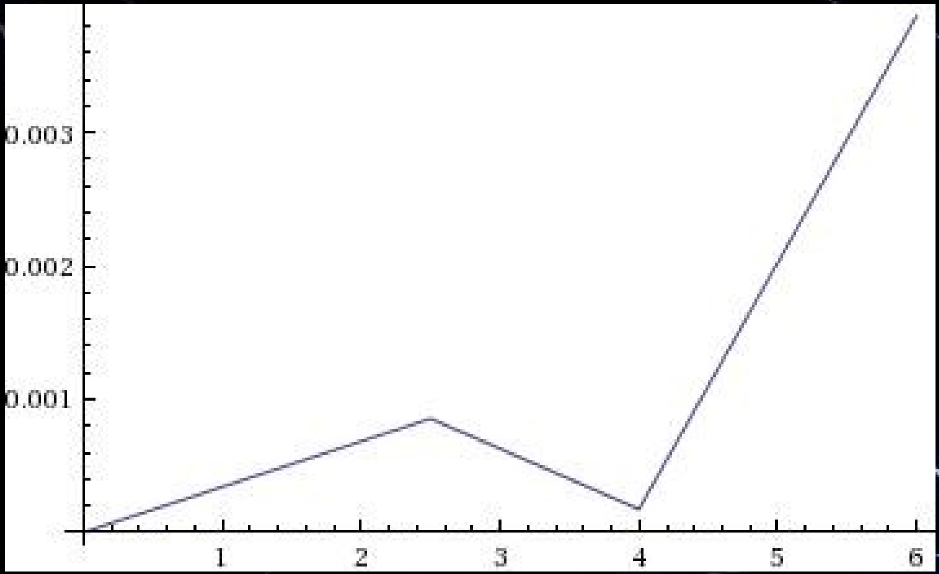
First attempt at Finger Bending



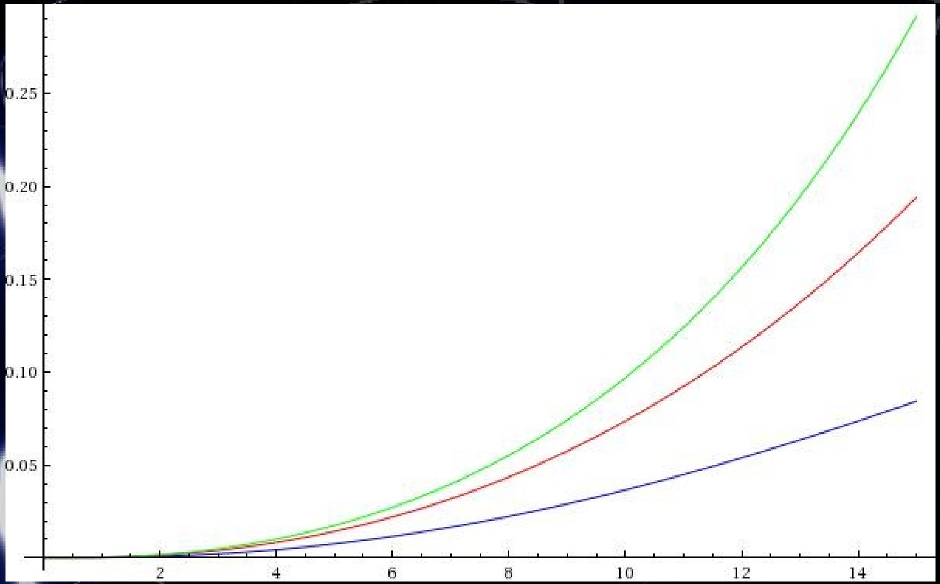
Finger Gone Wrong

It's Broken!!!



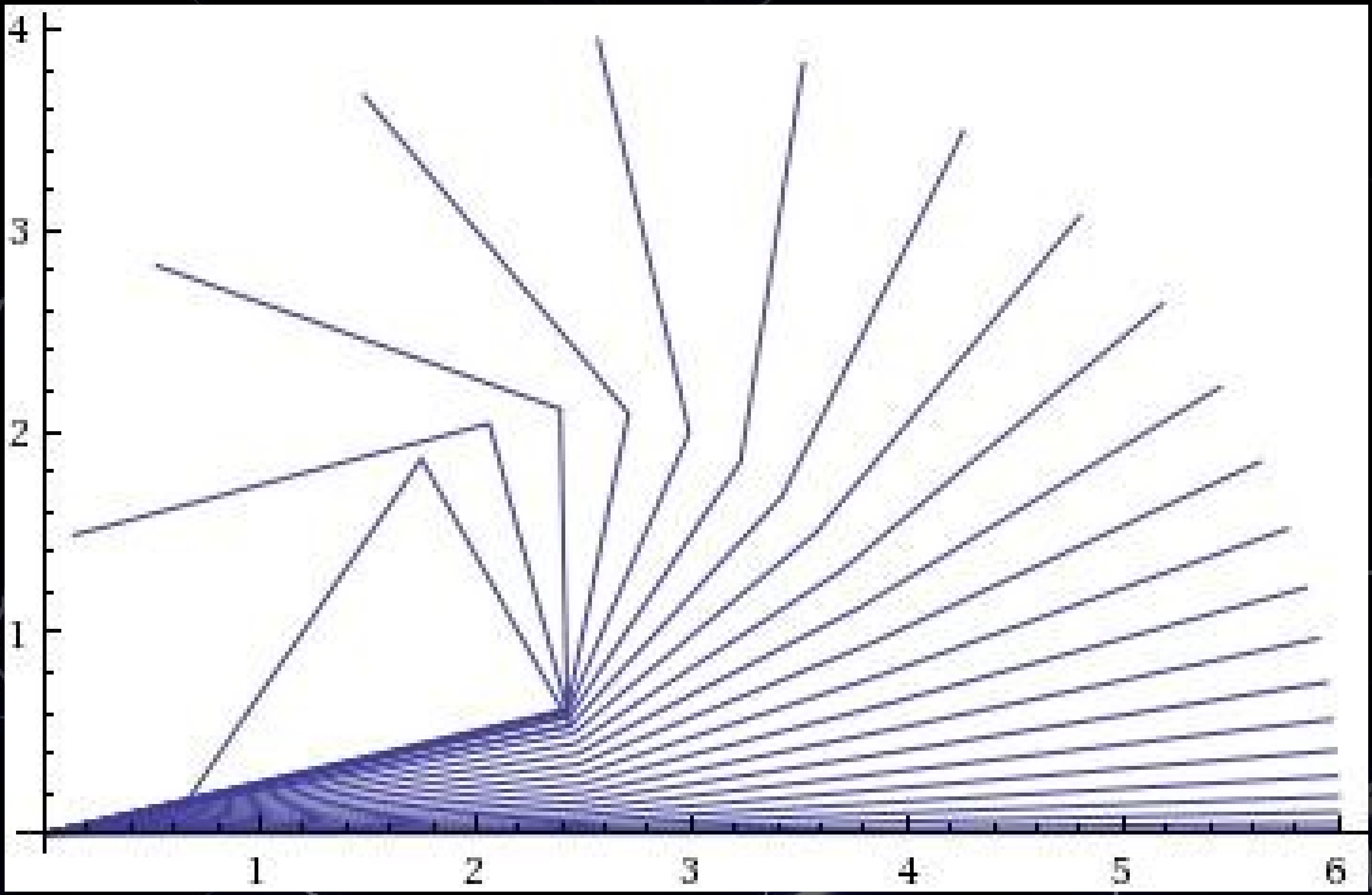


Change of Inputs for Better bend



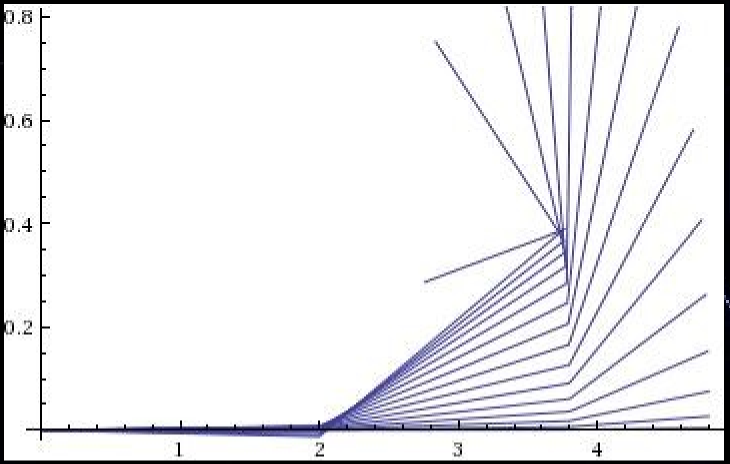
- Green- 3rd phalanx
- Red- 2nd phalanx
- Blue- 1st phalanx

Better Bend

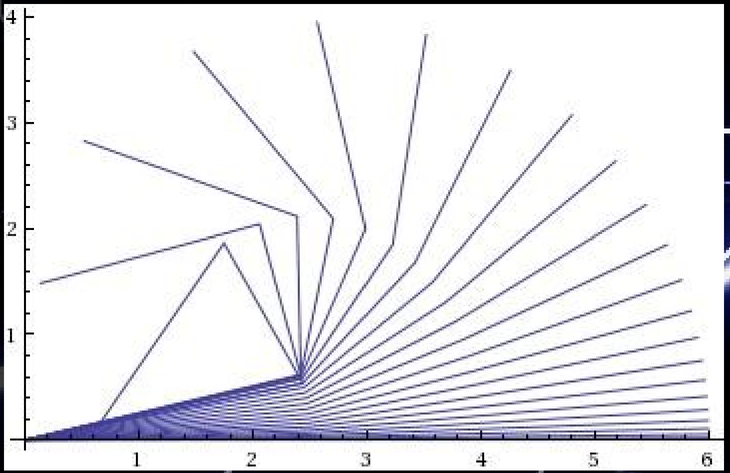


What Changed?

- The length of the phalanges.



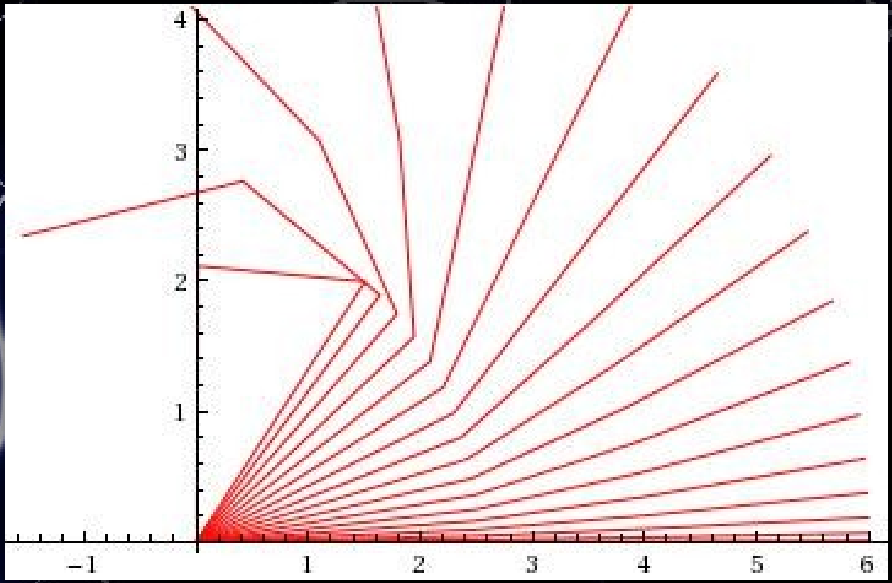
- From made up to more realistic numbers.



- m1=1;
- m2=.9;
- m3=.3;
- L1=1;
- L2=.9;
- L3=.5;
- a1=Pi/4.0;
- a2=Pi/4.0;
- a3=Pi/4.0;

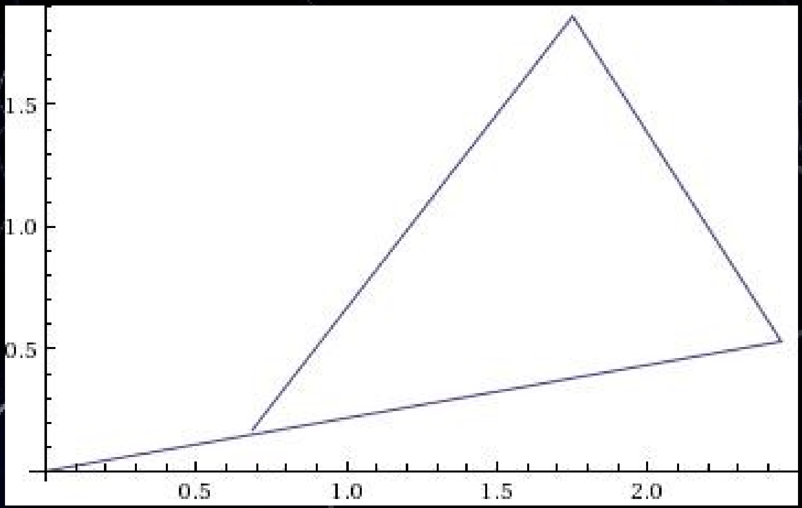
- m1=1;
- m2=.9;
- m3=.3;
- L1=1.25;
- L2=.75;
- L3=1;
- a1=Pi/4.0;
- a2=Pi/4.0;
- a3=Pi/4.0

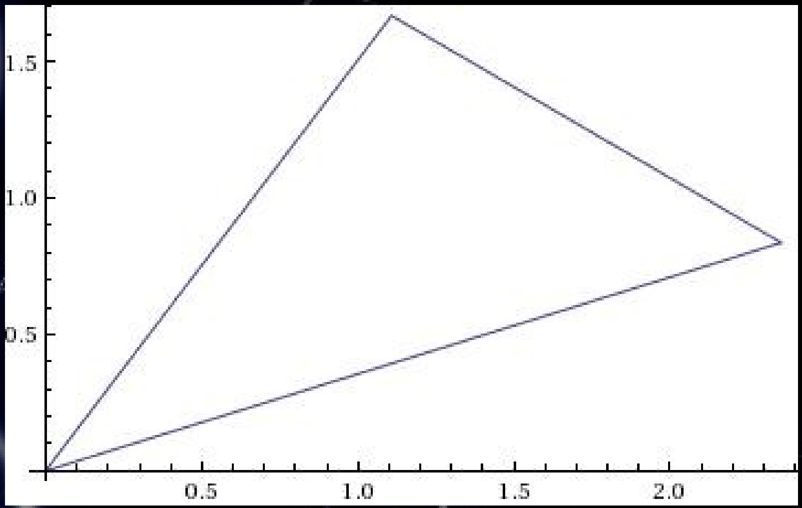
Trial and Error



- Adjust forces as needed
- Acquire best results

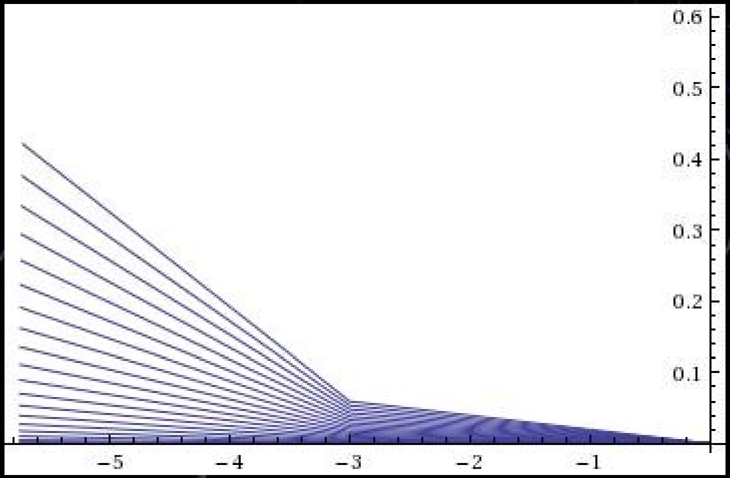
A Feedback Mechanism

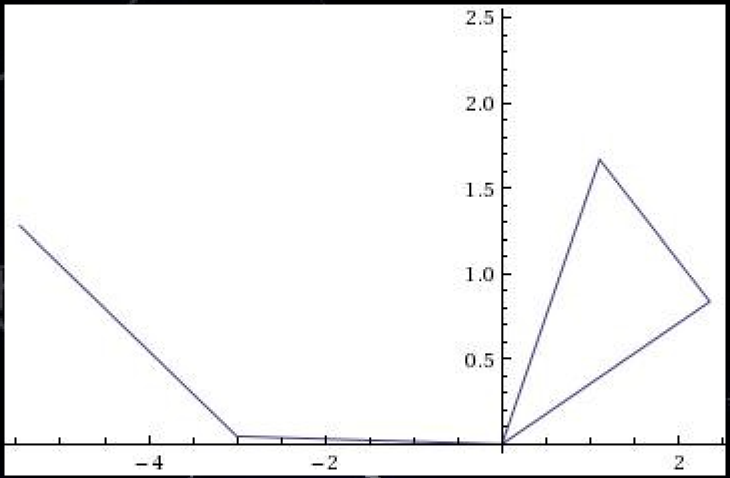




- Adjust forces until something goes wrong.
- Take position from a specific time.
- Use those positions as an initial condition.
- Repeat until best result is acquired.

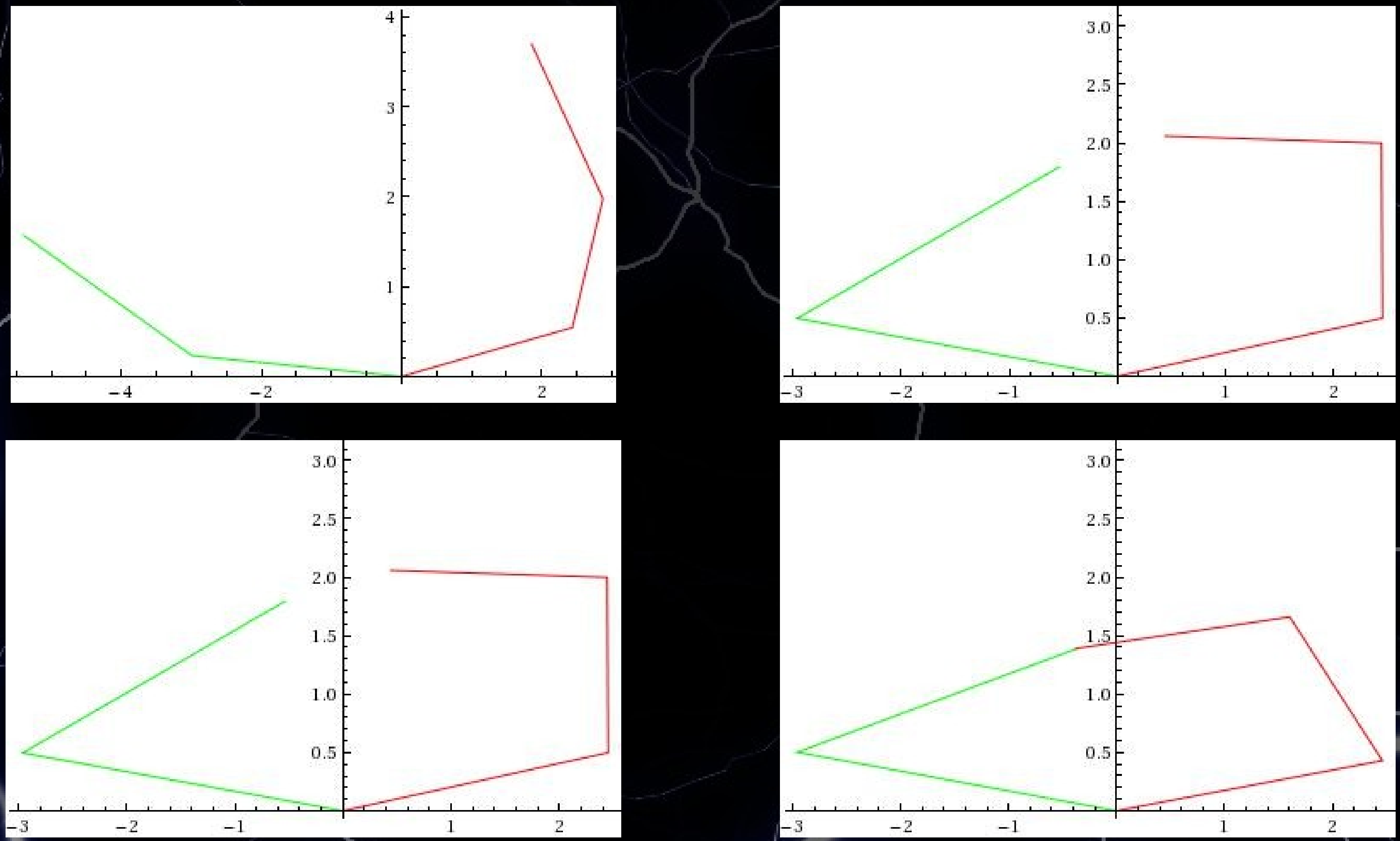
Thumb Incorporation





- Alter previous equations
- Change the angles to get a the thumb in the opposite direction.

Finger Thumb Touch



Conclusion

- Our model successfully calculates the movements due to forces on the phalanges.
- One benefit of our approach was that it is simpler.
- This project can be extended by finding a way to move the finger and thumb in space at any time.
- Also by picking a point in space and moving the finger to that point at a given time.

References

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