Spasticity Quantification

Preliminary Report

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for client Dr. John Engsberg

What is Spasticity?

Spasticity: A velocity dependent resistance to passive stretch

Cerebral Palsy (CP): 1/500 children are affected. Of those, 80% experience spasticity (NIH, 2014)

Physiofunction, 2013

How do you measure it?

Modified Ashworth Scale

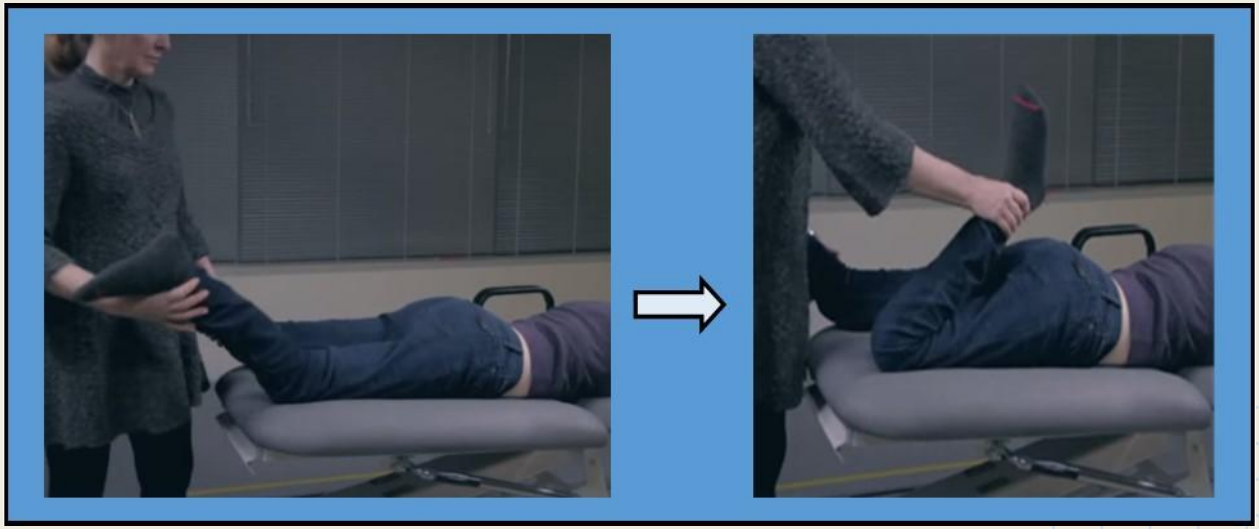
Grade	Description
0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch or by minimal resistance at the end of the range of motion (ROM) when the affected part(s) is moved in flexion or extension
1+	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM
2	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
3	Considerable increase in muscle tone, passive movement difficult
4	Affected part(s) rigid in flexion or extension
9	Unable to test

American Academy of Orthotists and Prosthetists, 2013

How do you measure it?

Modified Ashworth Scale:

1) Physician stretches leg over range of motion at varying velocities
2) Subjectively rank spasticity on scale of 0 to 4



SCIREproject, 2014

Why do we need to measure it?

- Treatment is a spectrum from physical therapy to invasive surgery
- Measure of spasticity necessary for objective treatment planning

Andrusko, 2013

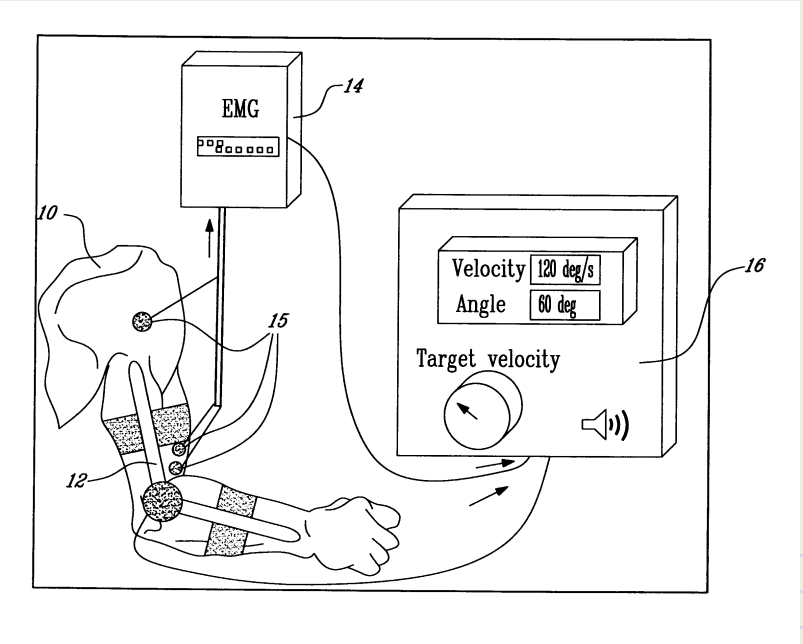
Project Scope

Design a device or software needed to measure the three major parameters that factor into spasticity: range of motion, velocity, and force

Existing Solutions - Electromyography Measurements (EMG)

EMG

- **Test**:
  - EMG electrodes and goniometer used on joint
- **Results**:
  - output real-time velocity and angle measurements
- **Limitations**:
  - Fickle system, precise setup. Some setups are static tests for a dynamic process



Patent US20080312549 A1

Existing Solutions - Objective Spasticity Measure

Ansari, N. 2007:

- **Test**:
  - Move arm through constant force, measure velocity reduction
- **Results**:
  - Patients with higher spasticity have a higher reduction in velocity
- **Limitations**:
  - Study fails to accurately measure patients in upper ranges of spasticity
  - Measuring instantaneous velocity with high degree of accuracy is difficult in clinical setting

Existing Solutions - Objective Spasticity Measure

Peng, Q. 2011:

- **Test**:
  - Move ankle joint up and down through its range of motion, measuring force and orientation
- **Results**:
  - Plot force vs. angle and observe “catch”
- **Limitations**:
  - Provided comprehensive data, but failed to arrive at measurable scale to quantify degree of spasticity

Existing Solutions - Objective Spasticity Measure

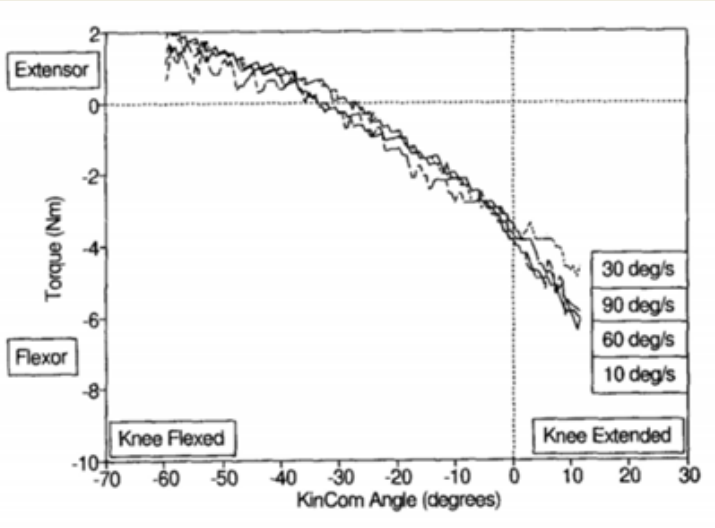
Engsberg, J. 1996:

- **Test**:
  - Rotate leg about the knee joint at constant velocity, tracking the force required through entire range of motion. Calculate total work done by leg at various velocities
- **Results**:
  - Normal patients: 0
  - Spastic patients: >0
  - More spastic → higher rating

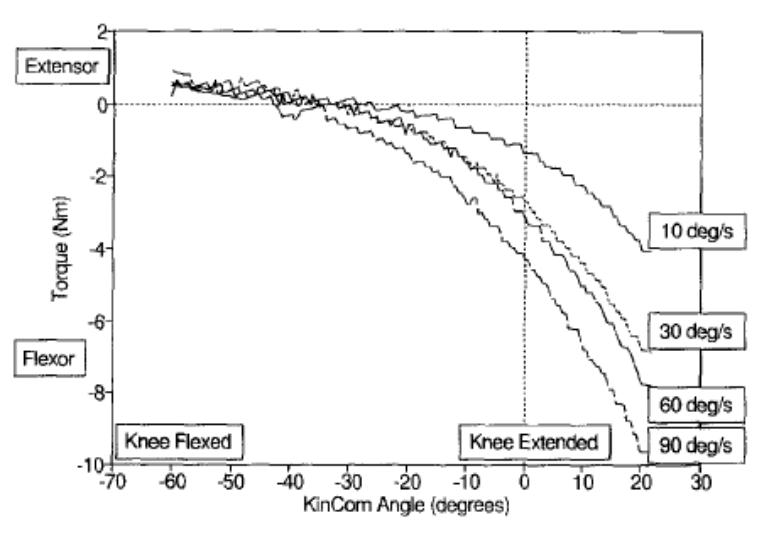
KinCom Corporate Website, 2011

Objective Spasticity Measure

Engsberg 1996 (cont)



Non-spastic Patient Torque-Angle graph, for different angular velocities



Spastic Patient Torque-Angle graph, for different speeds

Design Requirements

Characteristic	Specification
Weight	Less than 1 kg
Size	No larger than 21.6 cm x 19 cm x 5 cm
Cost	Less than $200
Portability	Easily transported between patient rooms Does not need constant external power supply
Battery Life	Must not require charging over a period of 8 hours

Design Requirements

Characteristic	Specification
Ease-of-Use	Will not require more than 10 minutes of training for a physician to effectively use.
Usage Time	Length of test for a single joint should not take more than 5 minutes
Data Storage	Less than 0.3 megabytes per test
Accuracy	Able to differentiate between different levels of spasticity more accurately than the Modified Ashworth Scale
Precision	Less than 10% error between repeated trials of the same patient on the same joint

Data Transmission[1]

	Bluetooth	Wi-Fi
Frequency	2.4GHz	2.4, 3.6, 5 GHz
Cost	Low	High
Bandwidth	Low (800 Kbps)	High (11Mbps)
Hardware Requirement	Bluetooth adaptor	Wireless adaptors
Range	5-30 meters	32 meters indoors
Power Consumption	Low	High
Bit-rate	2.1 Mbps	600 Mbps

1. "Bluetooth vs. Wi-Fi." *Bluetooth vs Wi-Fi*. http://www.diffen.com/difference/Bluetooth_vs_Wifi

Preliminary Analysis - Data Transmission Calculations

Data Transmission Speed:

- 300kb of data per test
- 800kb per second bandwidth (Bluetooth)
- 300/800 = 0.375 seconds for data transmission

- 11,000kb per second bandwidth (Wireless)
- 300/11,000 = 0.027 seconds for data transmission

Preliminary Analysis: Components of Spasticity

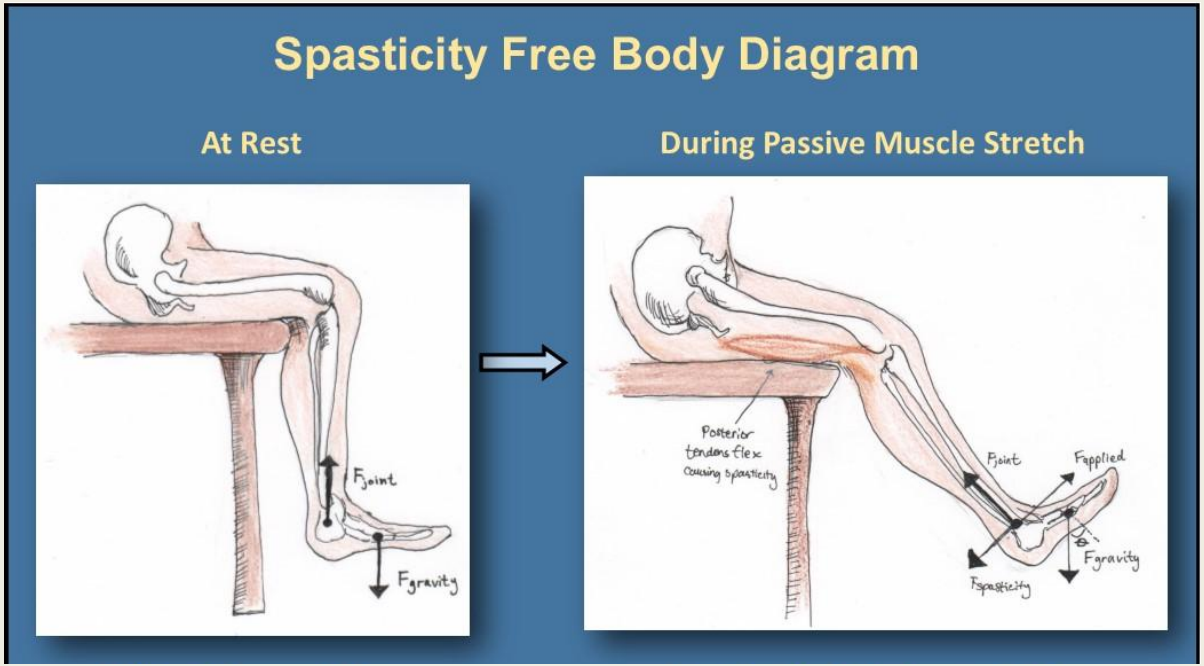
Range of Motion

Velocity

Force

University of Maryland Rehabilitation and Orthopedic Institute, 2008

Preliminary Analysis

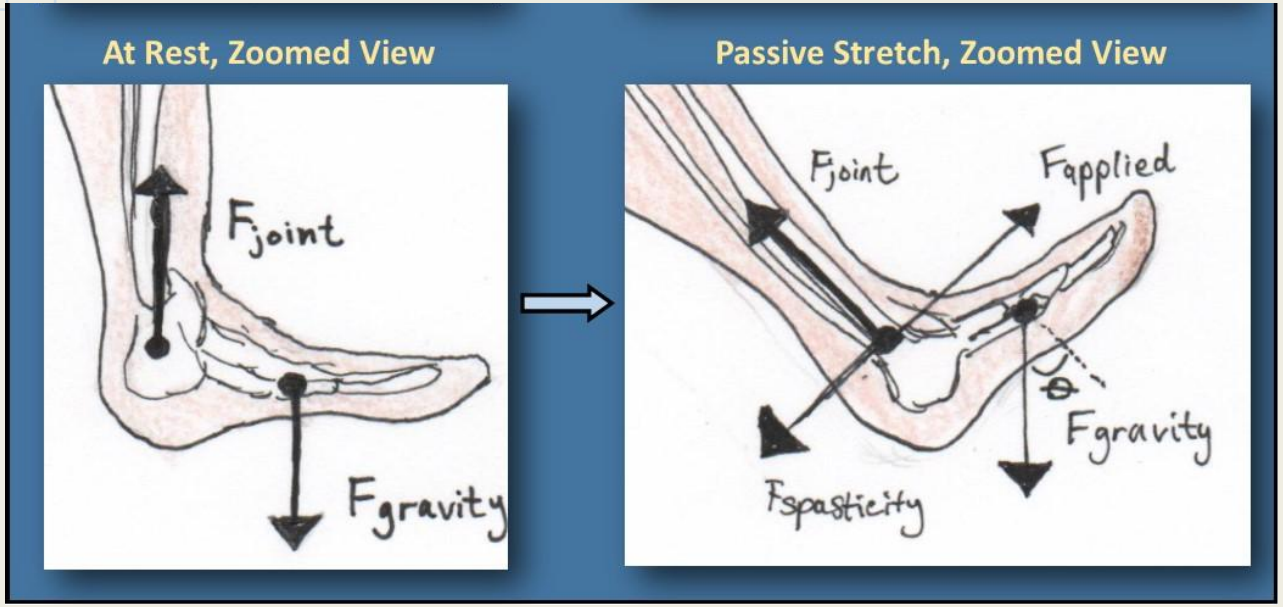


$$F_{gravity} = F_{joint} \quad (1)$$

$$F_{gravity}*\cos(\theta)=F_{joint} \quad (2)$$

$$F_{spasticity}+F_{gravity}*\sin(\theta)=F_{applied} \quad (3)$$

Preliminary Analysis



$$F_{gravity} = F_{joint} \quad (1)$$

$$F_{gravity} * \cos(\theta) = F_{joint} \quad (2)$$

$$F_{spasticity} + F_{gravity} * \sin(\theta) = F_{applied} \quad (3)$$

Preliminary Analysis

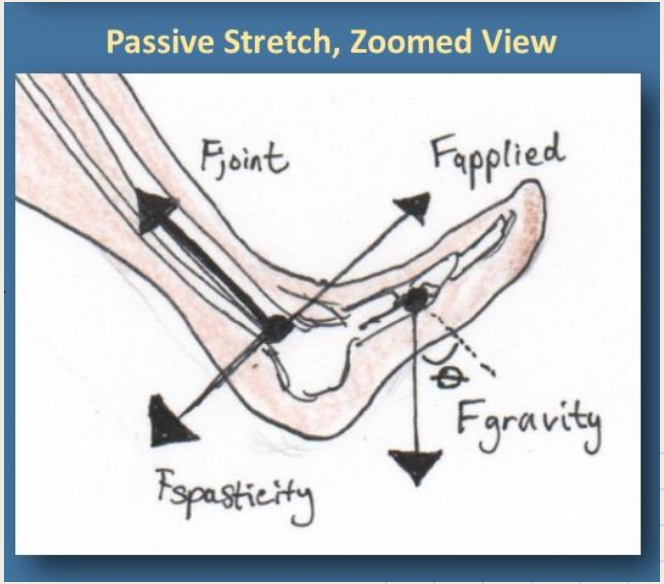
For a spastic patient's foot moving at an angular velocity of 60 deg/s extended at 70 degrees from vertical:

$F_g = (5.8\%)(25\ kg)(9.8\ m/s^2) = 14.21\ N$

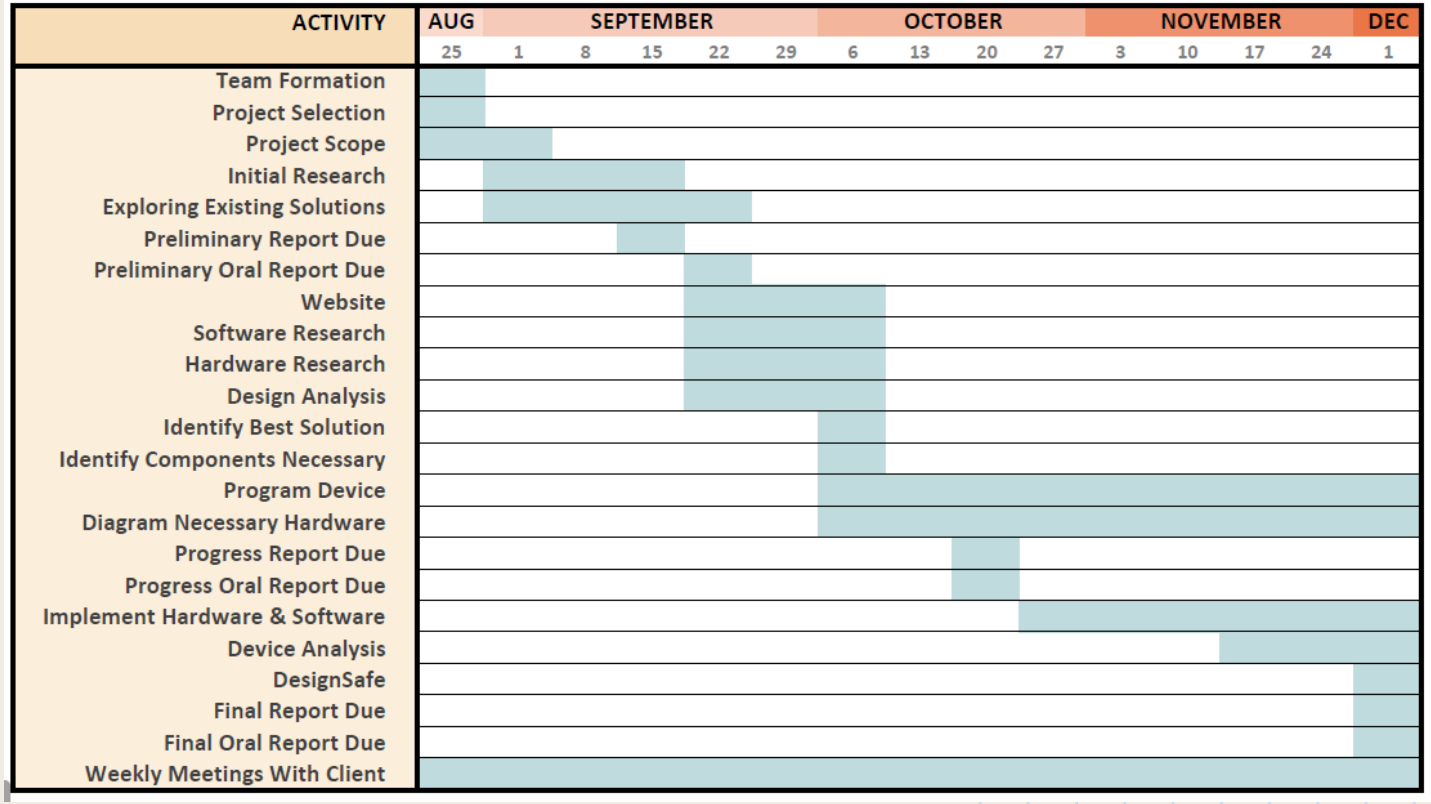
$F_{applied} = 26.67\ N$ (measured)

$F_{joint} = Fg*cos(70)$
$F_{joint} = 4.86\ N$

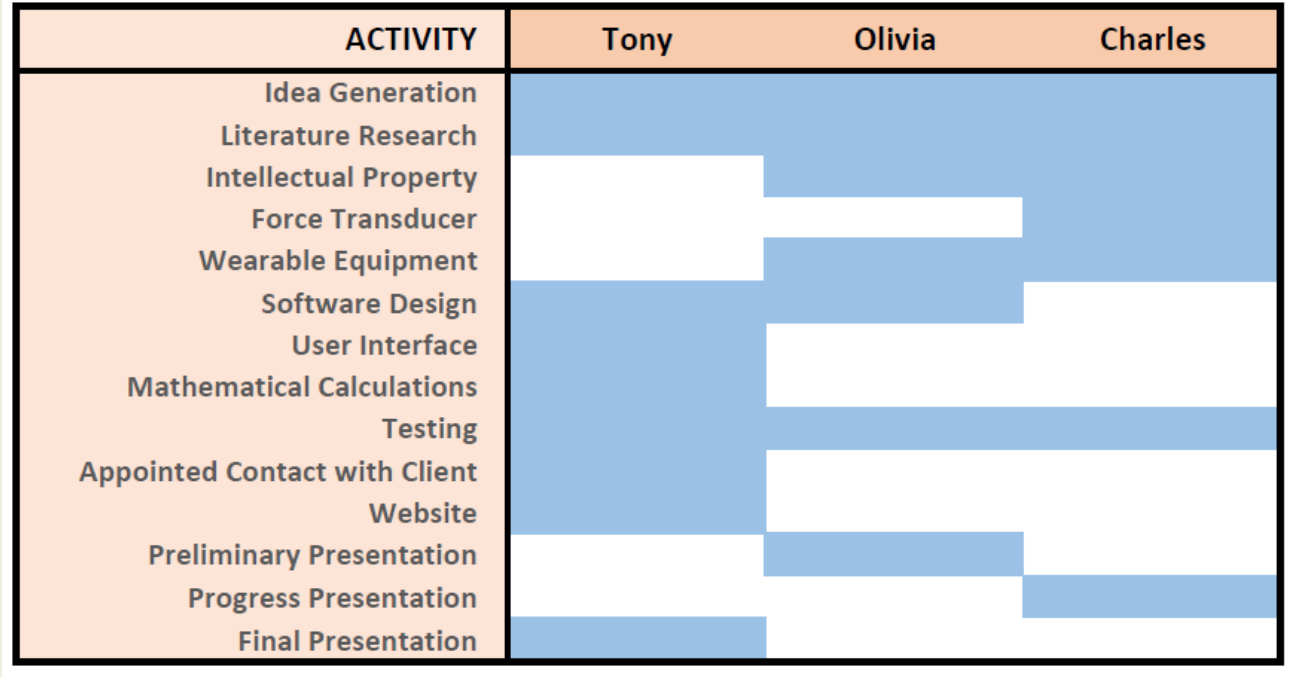
$F_{spastic} = F_{applied} - (F_g*sin(70))/2$
$F_{spastic} = 19.99\ N$



Design Schedule



Group Responsibilities



Acknowledgements

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