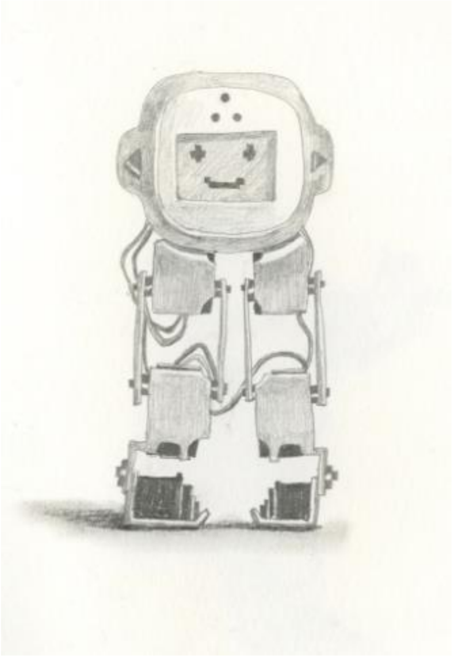
Robotics Studio MECE 4611
Fall 2021, Assignment 1



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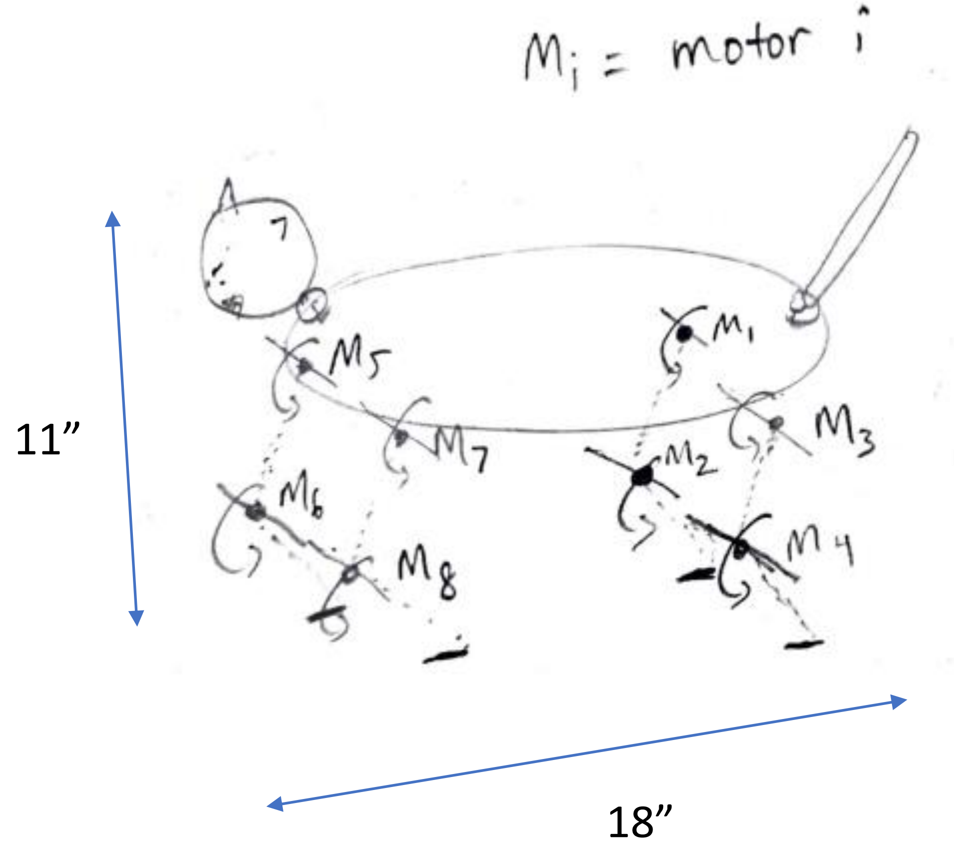
wx2214, mp3942

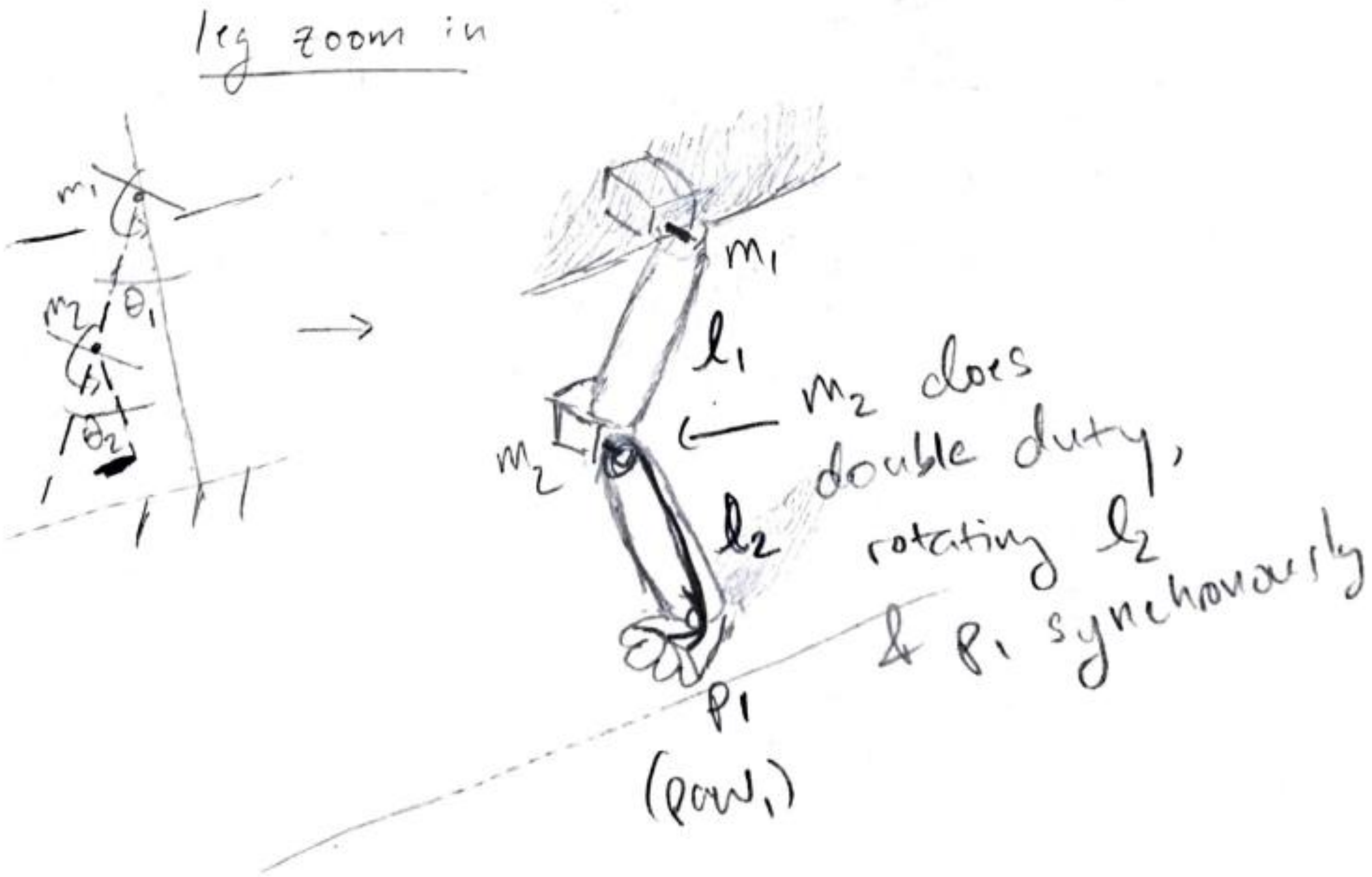
Submission Date: 9/21/2021 at 11:00 PM

Grace Hours Gained: 1

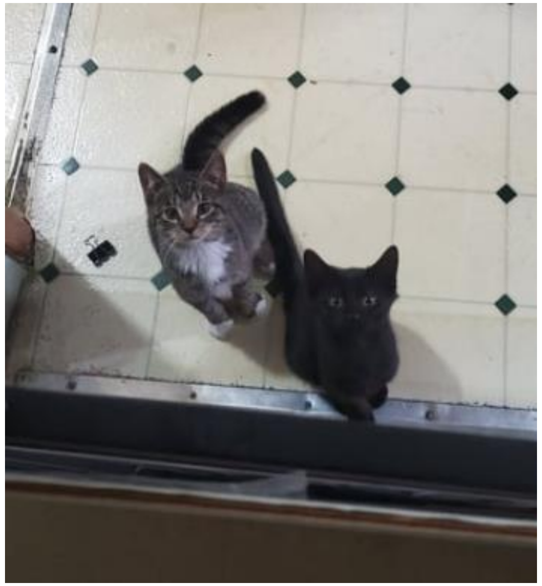
Grace Hours Remaining: 97

Concept 1 - Little Kitten





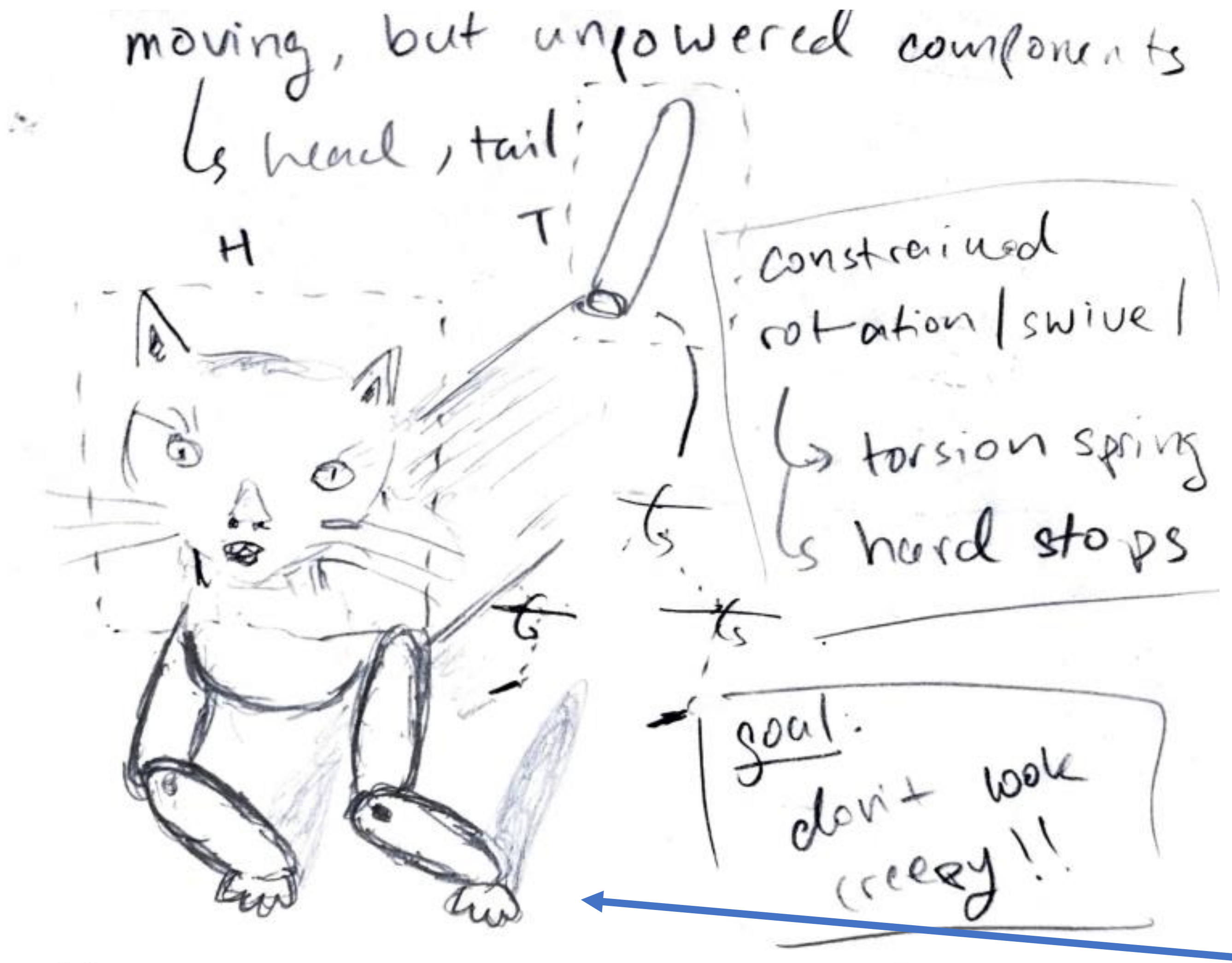
Concept 1 - Inspiration

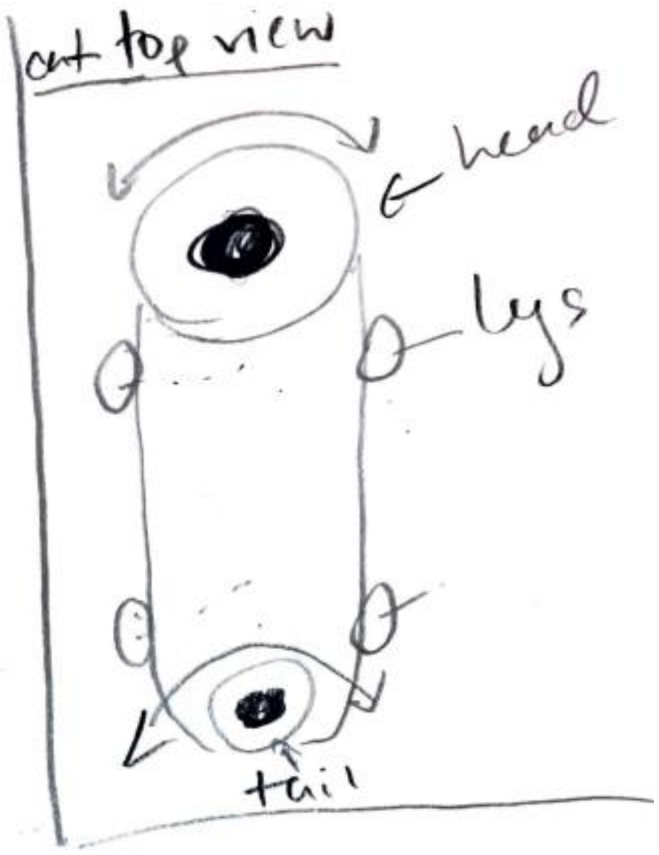


My cats, when they were kittens. I want another kitten and for it to stay a kitten forever.

They would probably hate this robot.

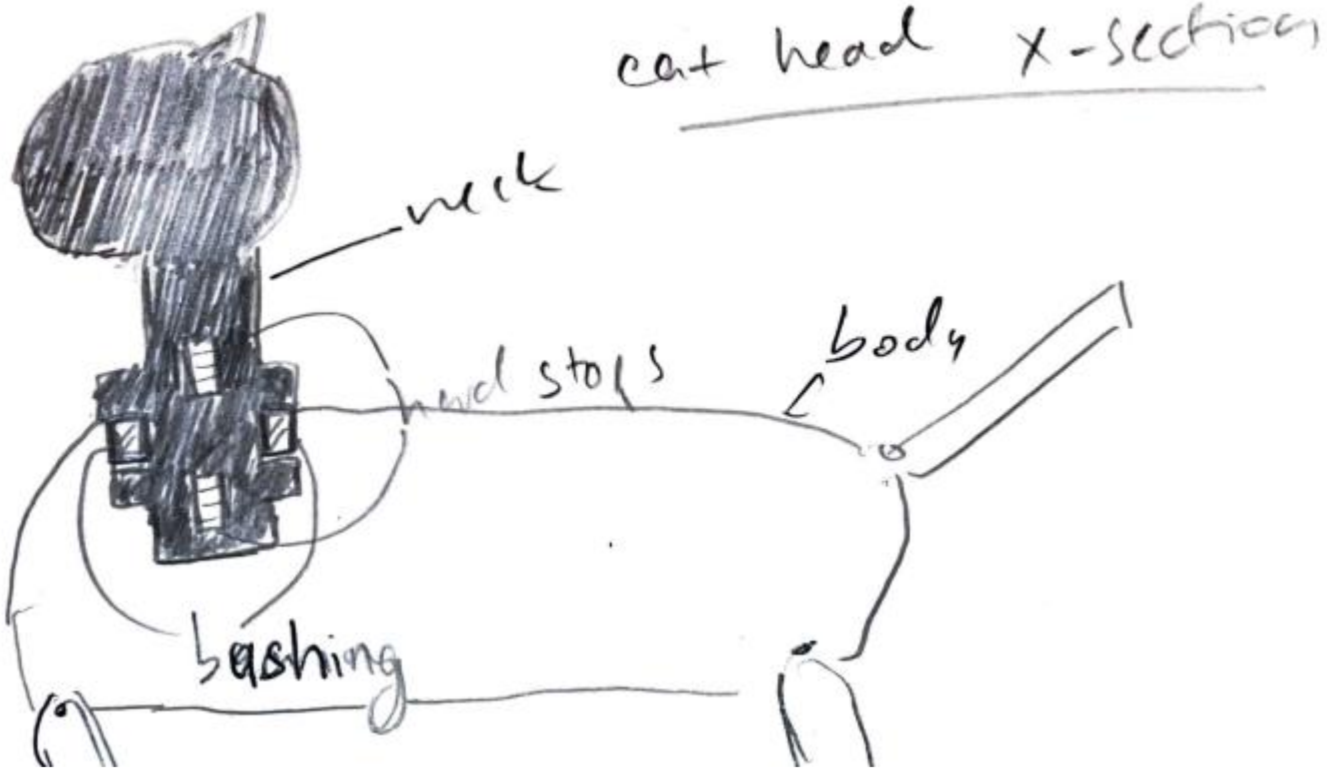
Concept 1

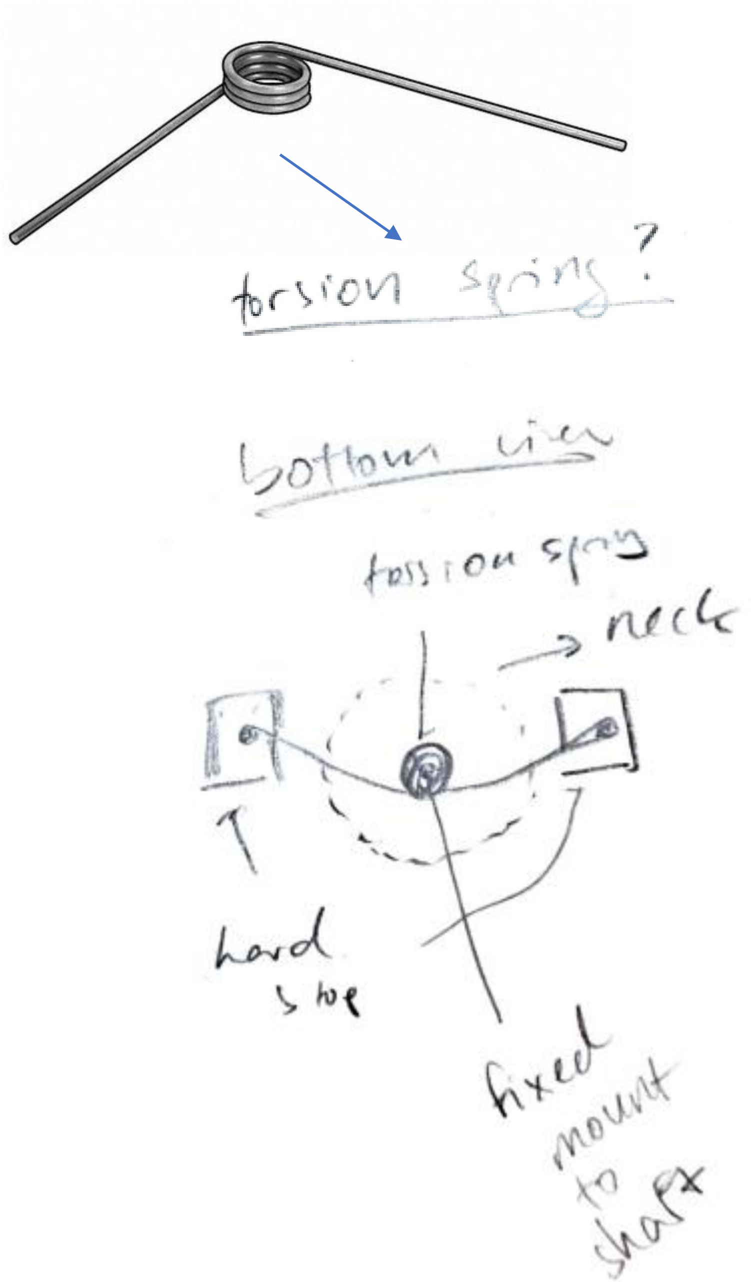




This face looks really creepy, so I already failed to achieve my goals.

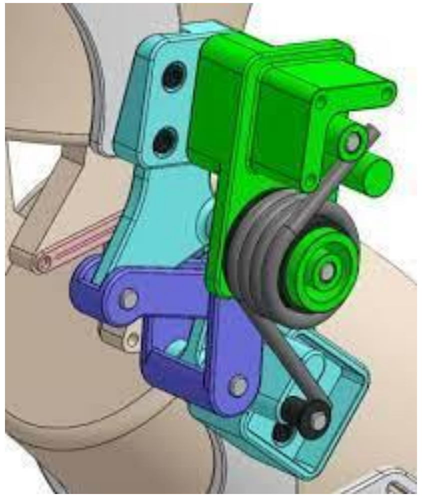
Concept 1 – Passive Joints

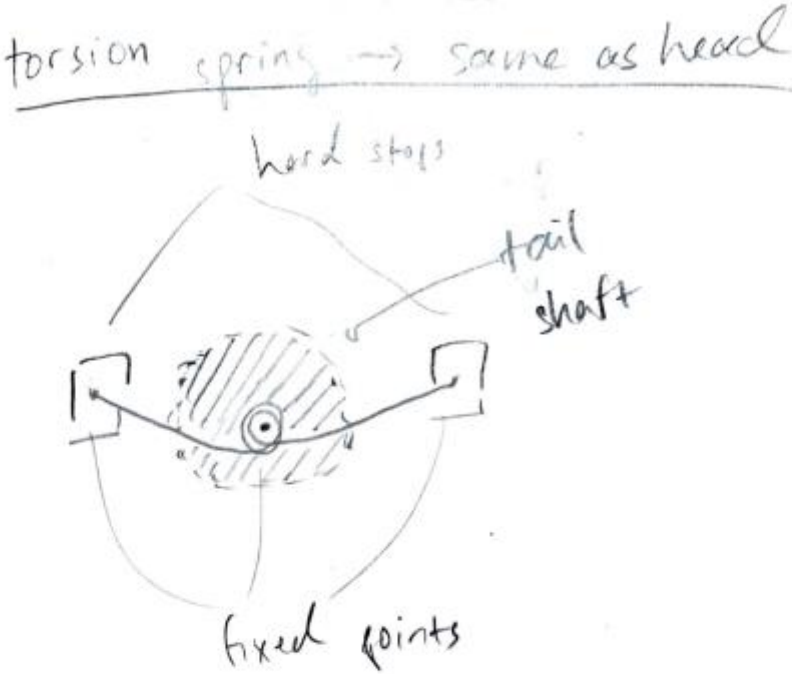




All 8 motors are allotted toward the legs, but I still want the head and tail to swivel a little bit. The plan is to constrain their rotation with hard stops and dampen the rotation with a torsion spring.

Concept 1

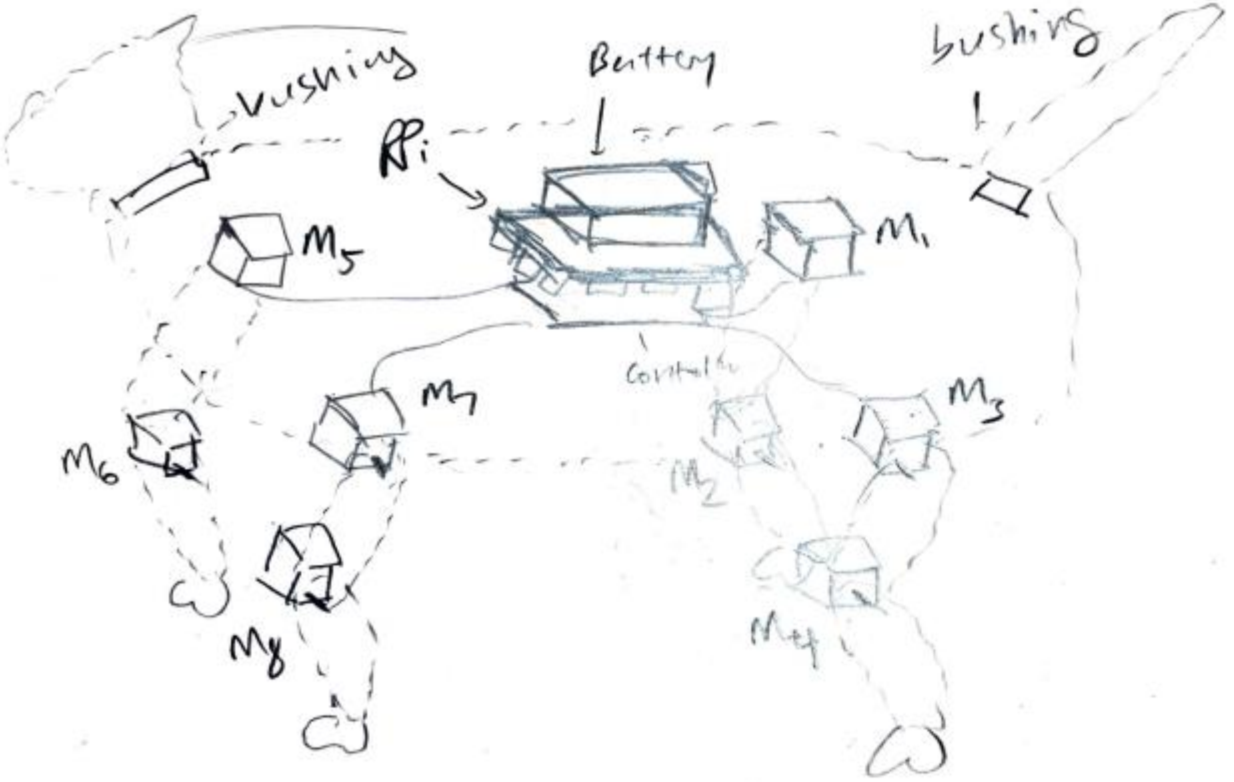




“Passive knee exoskeleton using torsion spring for cycling assistance”, Chaichaowarat et al. (2017)

Concept 1

component view



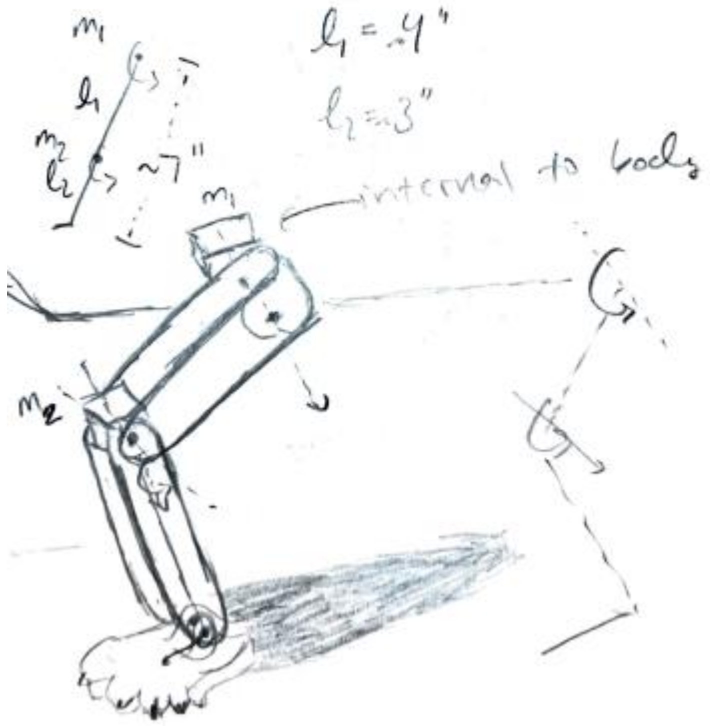
Concept 1

Actual size:

emulate a small kitten

↳ 4-5 lbs ~ 2 kg

each leg is ~7"



Estimated weight = **~5 lbs**
Paw thickness = ~0.5”
Entire leg weight = ~8 oz. (0.5 lb)
L2 + paw weight = ~4 oz. (0.25 lb)

Leg length = ~7.5” (0.625’)
L2 + paw length = ~3.5” (0.29’)

Max ω (L1 or L2) = ~20 rpm (2.9 rad/s)
F_r = mv^2/r = 0.082 lbf (whole leg), 0.019 lbf (L2 + paw)
F_g = ma (assumed holding force—just combatting gravity—of fully extended leg parallel to the ground)

Defining dynamic torque as torque in motion (F_g + F_r)

τ = rFsin(ϑ)
Max holding torque on motor 1: **0.3125 ft-lb**
Max dynamic torque on motor 1: **0.3750 ft-lb**
Max holding torque on motor 2: **0.0725 ft-lb**
Max dynamic torque on motor 2: **0.0957 ft-lb**

$$P = \tau\omega$$

$$\tau = \frac{P}{\omega}$$

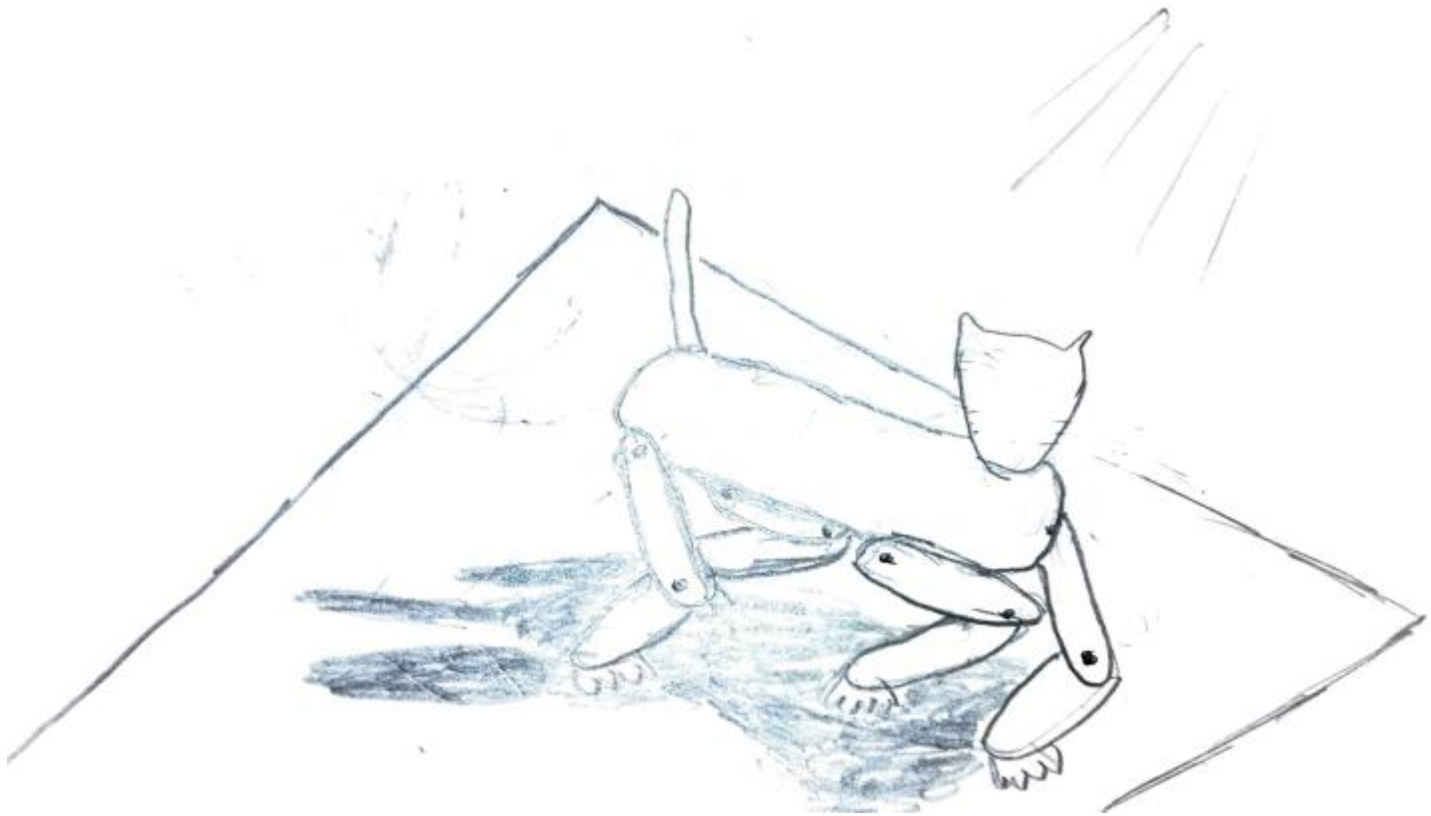
$$\omega = \frac{2\pi RPM}{60}$$

Max power from m1: **1.06 W**
Max power from m2: **0.28 W**
Per leg power draw: **1.34 W**
Whole robot (4 legs): **5.32 W**

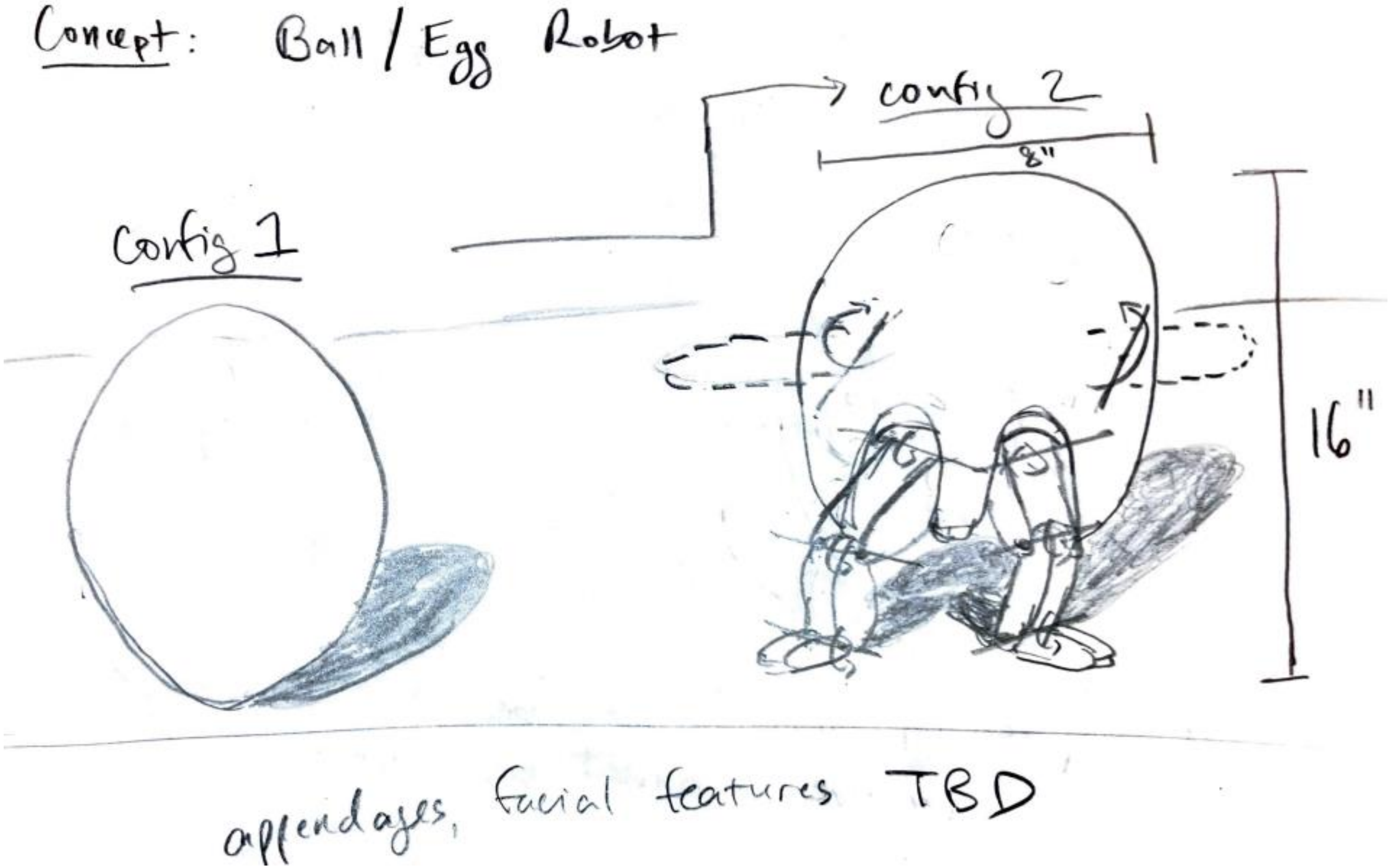
Each motor is within its 6 W envelope, and the robot is within the 30 W battery envelope.

Concept 1

With a small-kitten-scale, robot should be able to balance on 2 paws at a time



Concept 2 – Unfolding Ball/Egg

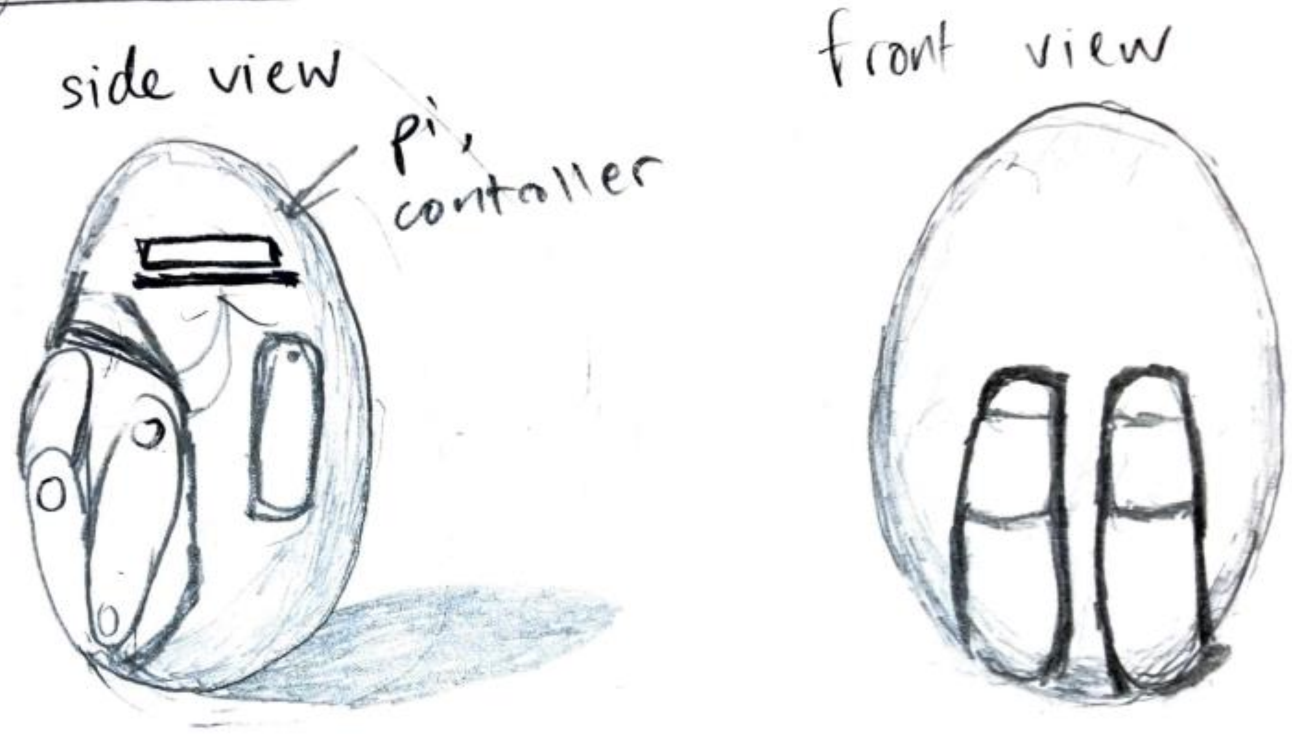


Concept 2 – Real world inspirations

Diabotical, video game

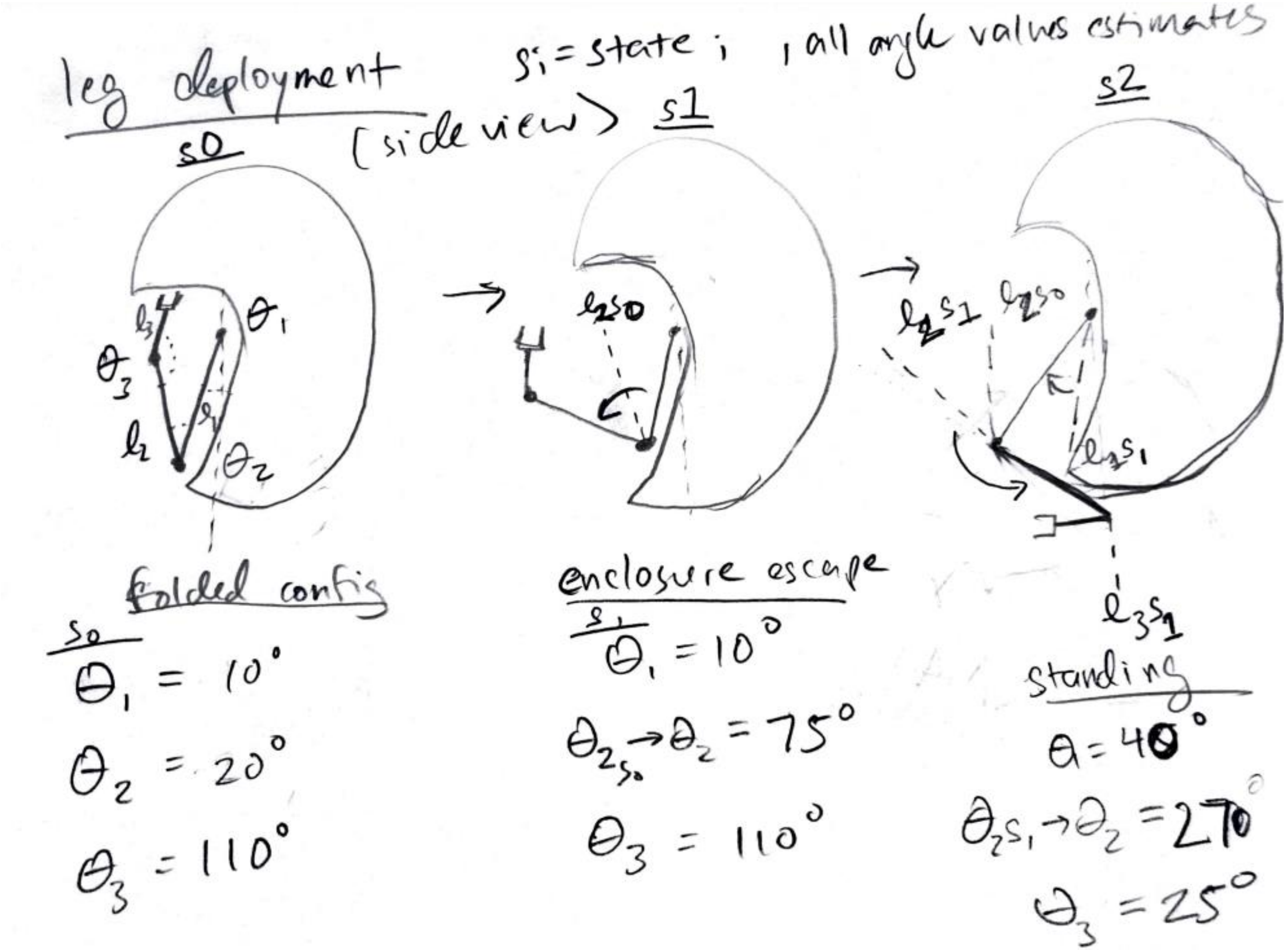
Concept 2

Folding mechanism



note: probably would not be self-righting / require manual orientation

Concept 2



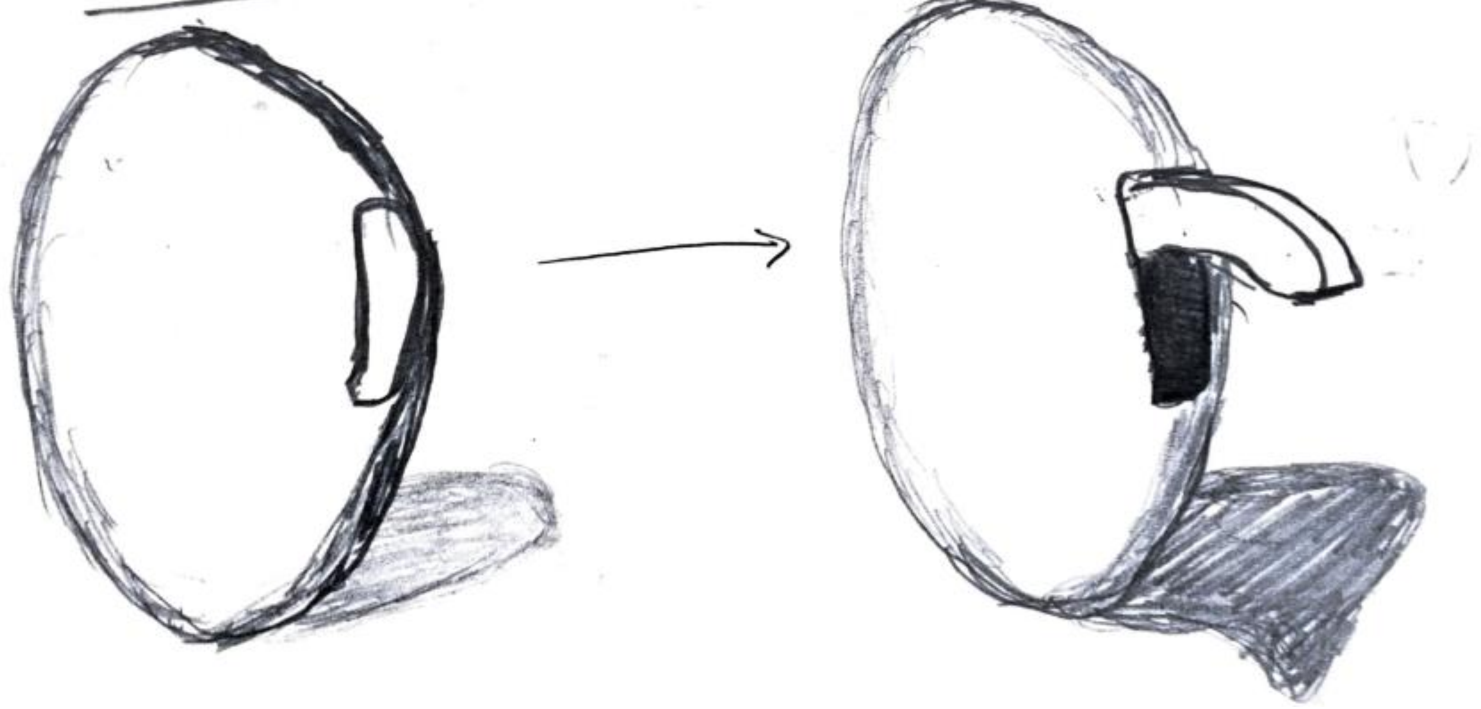
leg deployment
(side view)
s_i = state i , all angle values estimates
s0
s1
s2
folded config
s_0
$\theta_1 = 10°$
$\theta_2 = 20°$
$\theta_3 = 110°$
enclosure escape
s_1
$\theta_1 = 10°$
$\theta_{2_{s_0}} \to \theta_2 = 75°$
$\theta_3 = 110°$
standing
$\theta = 40°$
$\theta_{2s_1} \to \theta_2 = 270°$
$\theta_3 = 25°$

Concept 2

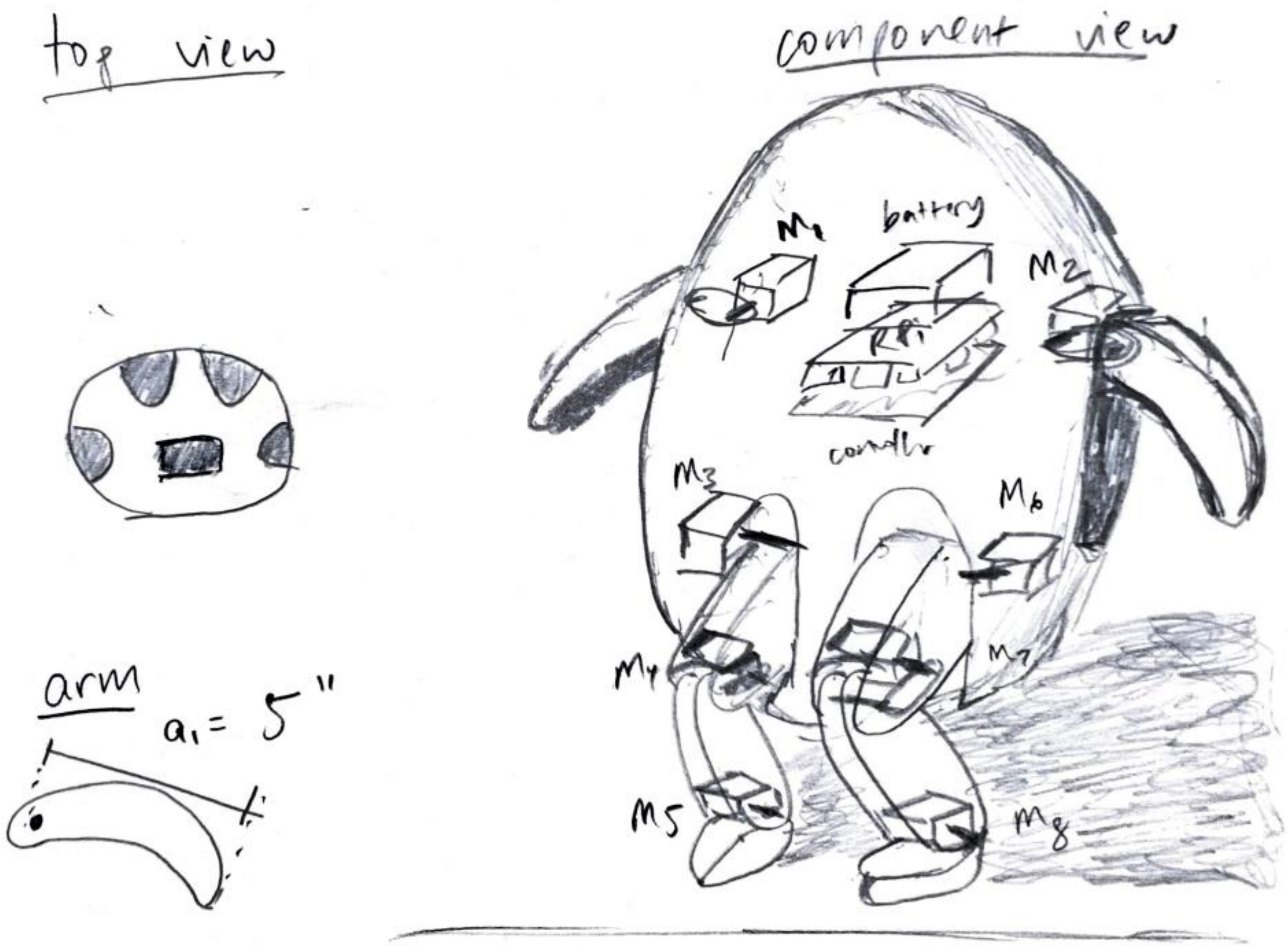
arm deployment (much simpler)

top right perspective

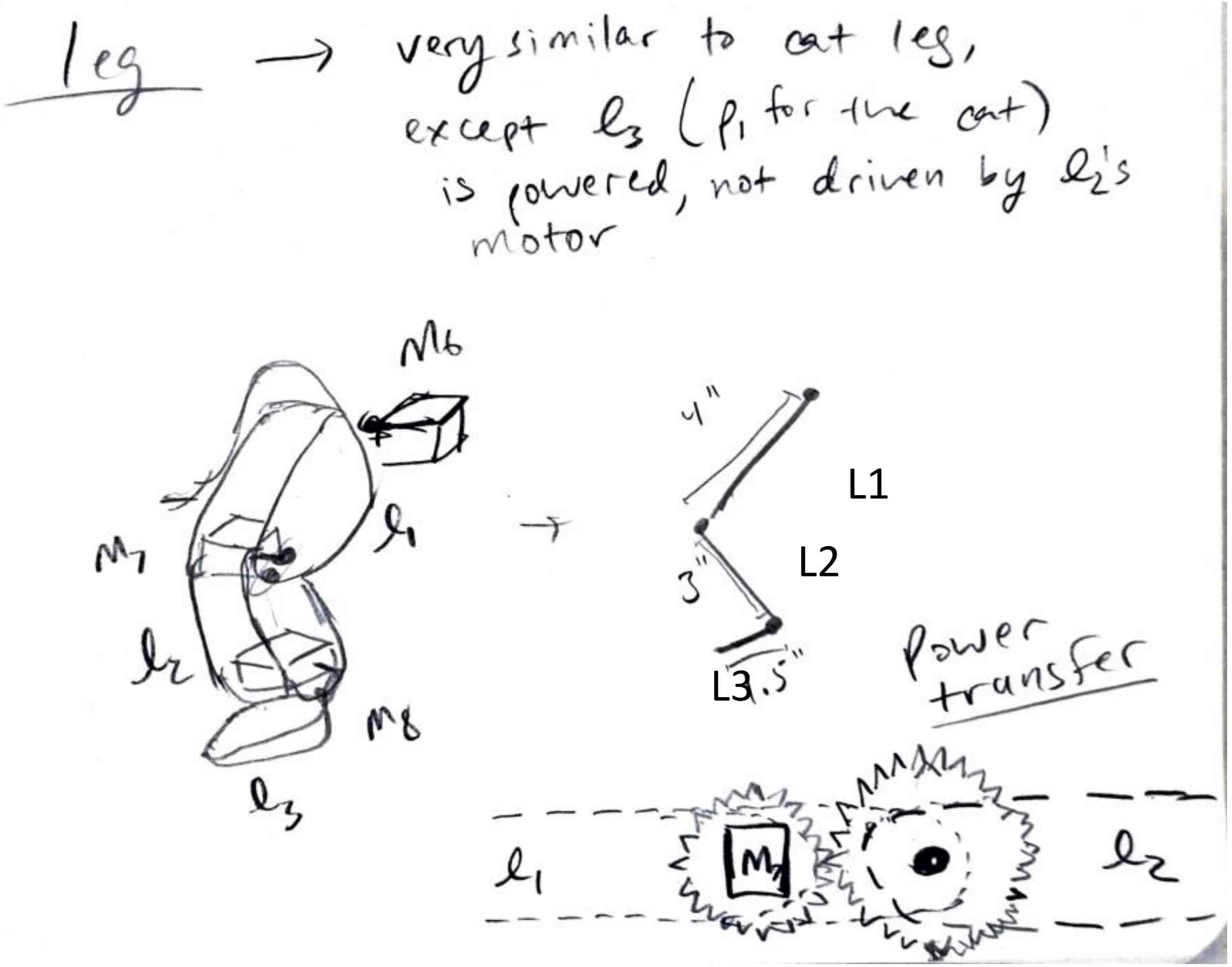
folded unfolded



Concept 2


top view
component view
M1
battery
M2
RPi
controller
M3
M6
M4
M7
M5
M8
arm
a1 = 5"

Concept 2 - Calculations



Robot weight = **~5 lbs**
Entire leg weight = ~10 oz. (0.5 lb)
L2 + L3 weight = ~6 oz. (0.25 lb)
L3 weight = ~2 oz.
Arm weight = ~3 oz.

Leg length = ~8.5” (0.708’)
L2 + L3 length = ~4.5” (0.375’)

Max ω (L1/L2/L3) = ~20 rpm (2.9 rad/s)
F_r = mv^2/r = 0.115, 0.037, 0.004 lbf (whole leg, L2+L3, L3)
F_g = ma (assumed holding force—just combatting gravity—of fully extended leg parallel to the ground)

τ = rFsin(ϑ)
Max holding torque on motor 1: **0.443 ft-lb**
Max dynamic torque on motor 1: **0.521 ft-lb**
Max holding torque on motor 2: **0.141 ft-lb**
Max dynamic torque on motor 2: **0.154 ft-lb**
Max holding torque on motor 3: **0.016 ft-lb**
Max dynamic torque on motor 3**: 0.016 ft-lb**
Max holding torque on arm motor: **0.079 ft-lb**
Max dynamic torque on arm motor: **0.088 ft-lb**

$$P = \tau\omega$$

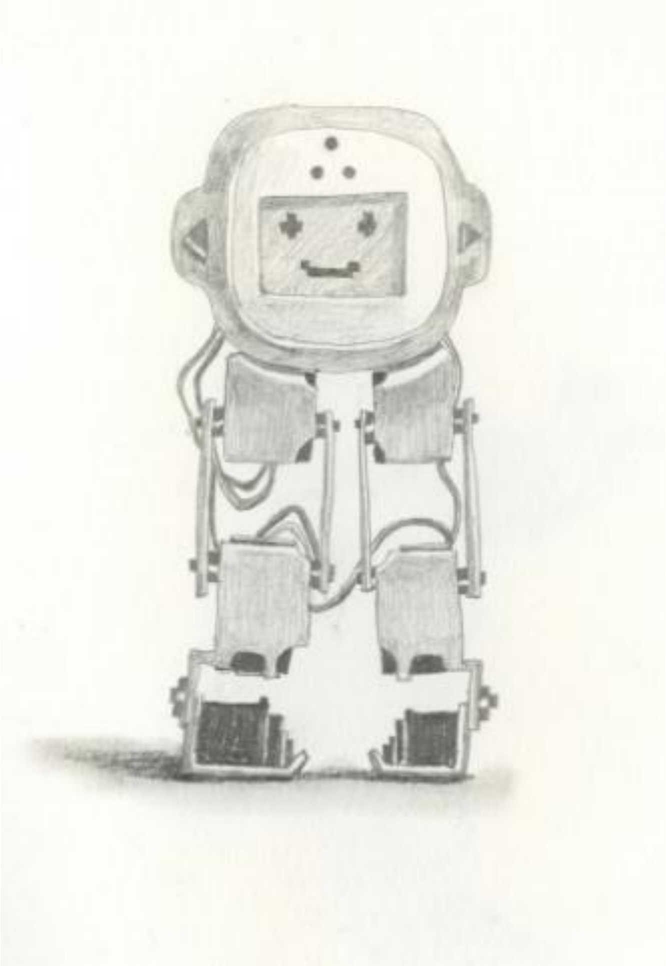
$$\tau = \frac{P}{\omega}$$

$$\omega = \frac{2\pi RPM}{60}$$

Max power draw from m1: **1.48 W**
Max power draw from m2: **0.44 W**
Max power draw from m3: **0.05 W**
Max power draw from arm motor: **0.12 W**
One side total: **2.09 W**
Both sides: **4.18 W**

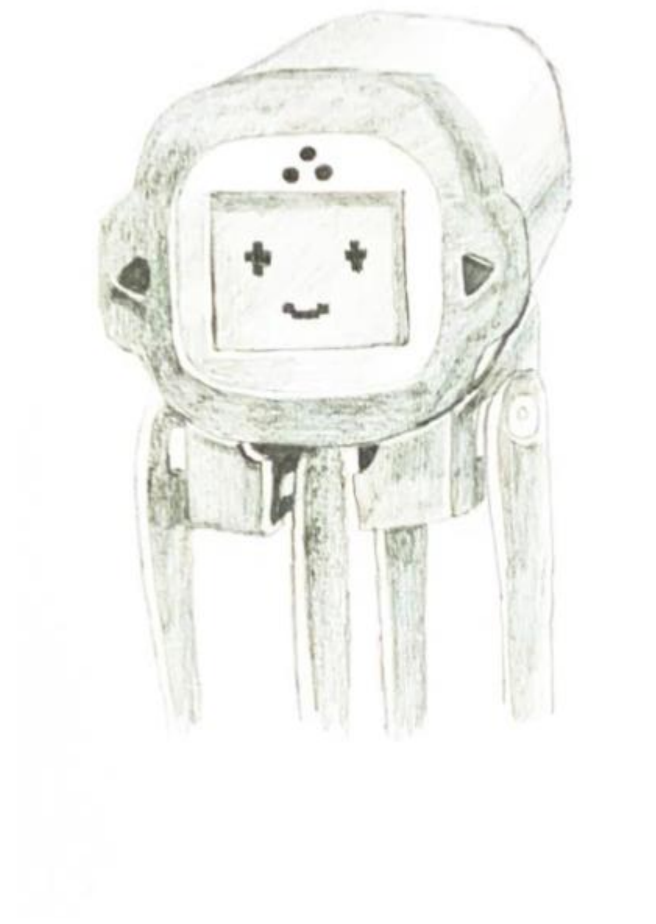
All motors are well within the individual 6W power envelope, and the robot is well within the 30 W battery power envelope.

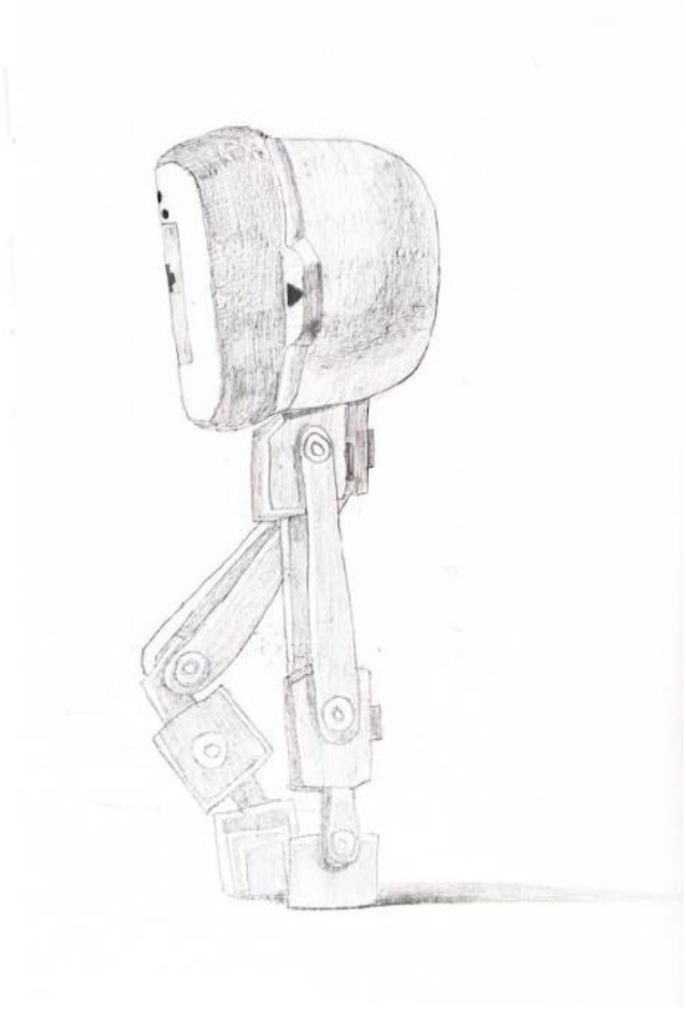
Concept 3 – Tamagotchi

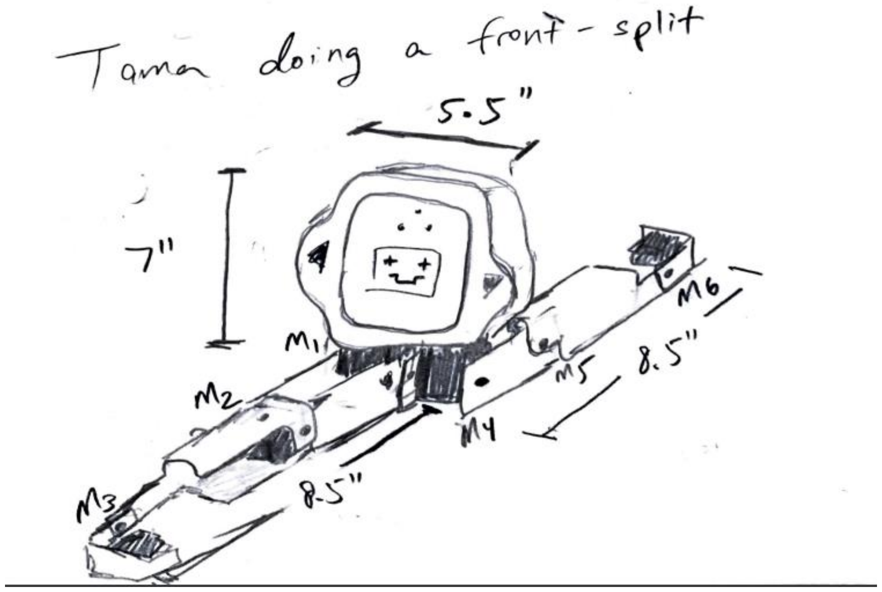


You can tell when Mimi joined the team…

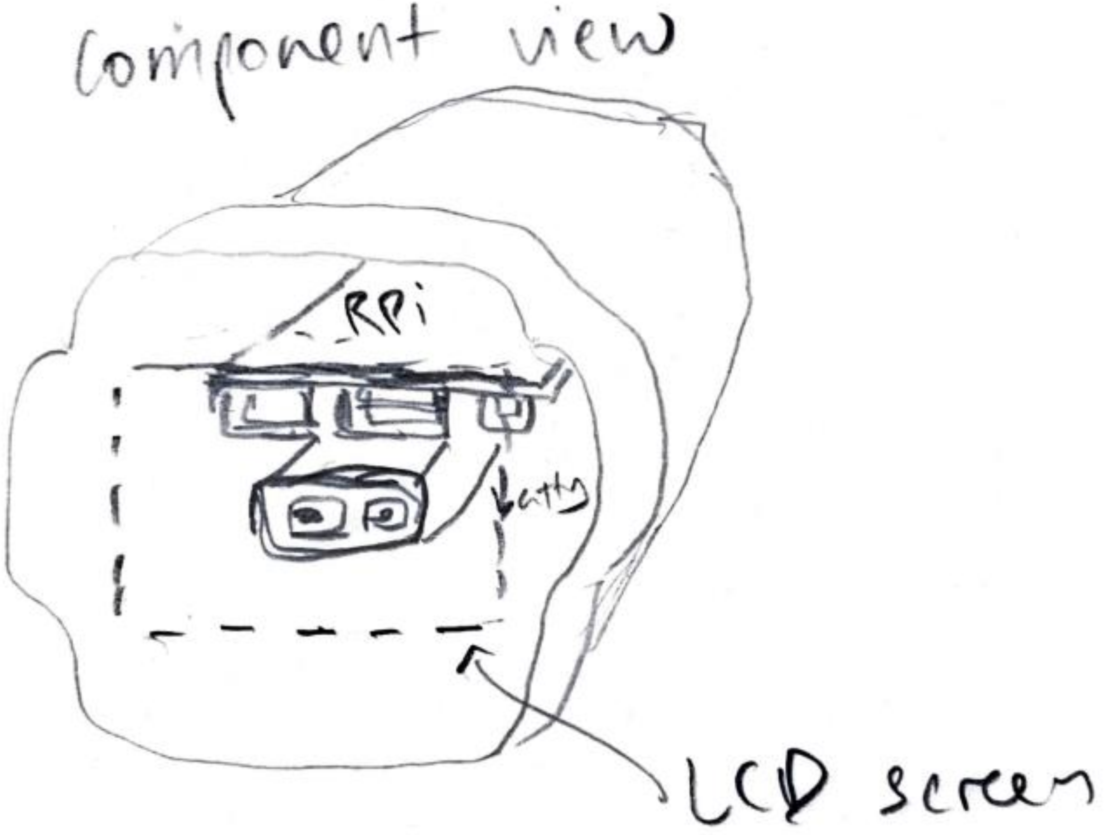
Concept 3 – Alternate views





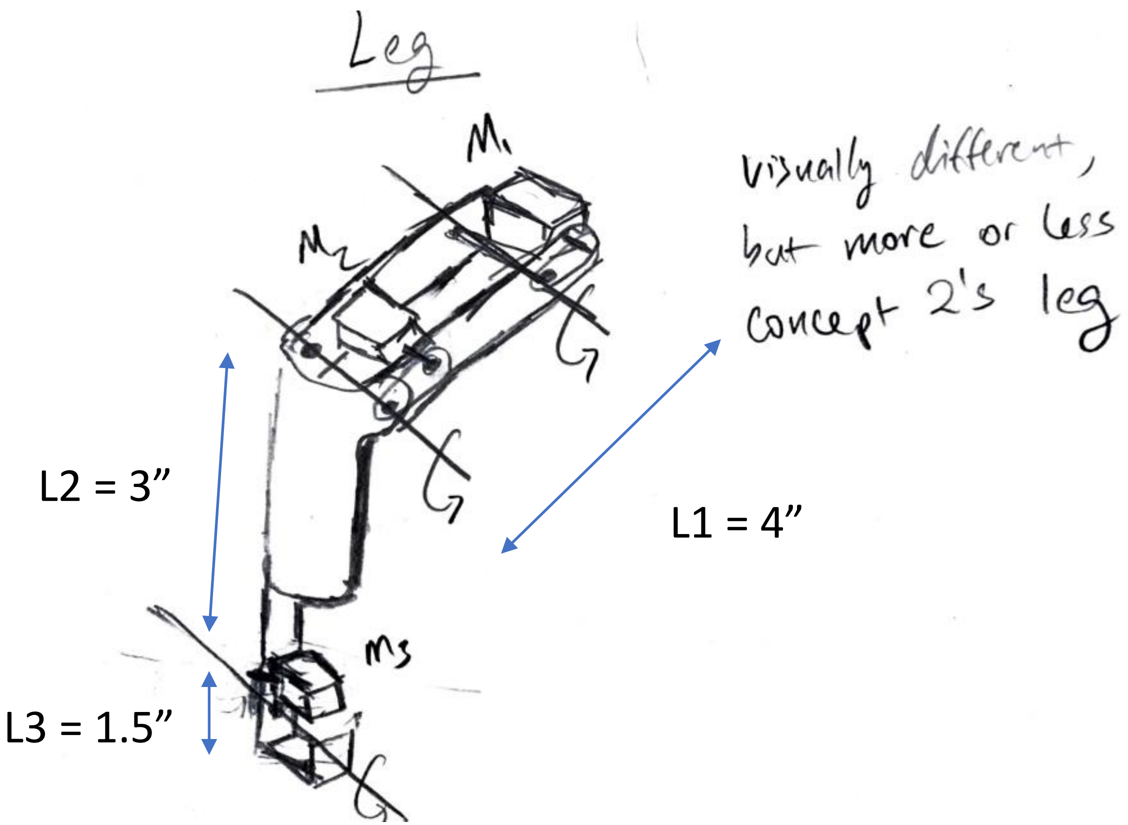


Concept 3 – Alternate views



Concept 3

Copying over from concept 2 because the legs are mechanically similar—these rough calculations apply approximately well to both concepts.



Robot weight = **~4 lbs**
Entire leg weight = ~10 oz. (0.5 lb)
L2 + L3 weight = ~6 oz. (0.25 lb)
L3 weight = ~2 oz.

Leg length = ~8.5” (0.708’)
L2 + L3 length = ~4.5” (0.375’)

Max ω (L1/L2/L3) = ~20 rpm (2.9 rad/s)
F_r = mv^2/r = 0.115, 0.037, 0.004 lbf (whole leg, L2+L3, L3)
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Max dynamic torque on motor 1: **0.521 ft-lb**
Max holding torque on motor 2: **0.141 ft-lb**
Max dynamic torque on motor 2: **0.154 ft-lb**
Max holding torque on motor 3: **0.016 ft-lb**
Max dynamic torque on motor 3**: 0.016 ft-lb**

Max power draw from m1: **1.48 W**
Max power draw from m2: **0.44 W**
Max power draw from m3: **0.05 W**
One side total: **1.97 W**
Both sides: **3.94 W**

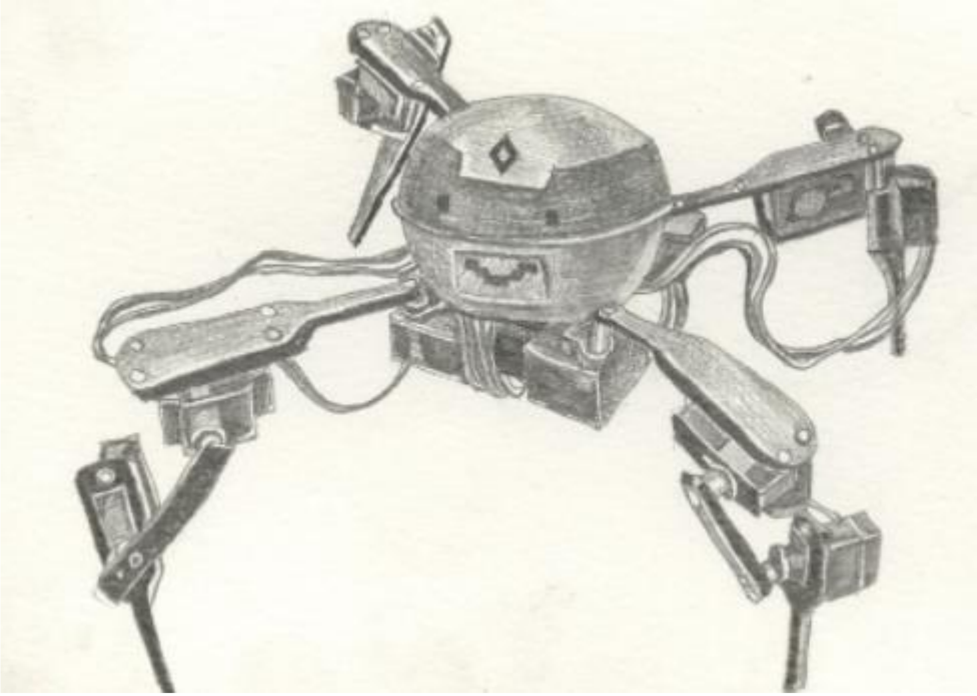
$$P = \tau\omega$$

$$\tau = \frac{P}{\omega}$$

$$\omega = \frac{2\pi RPM}{60}$$

All motors are well within the individual 6W power envelope, and the robot is well within the 30 W battery power envelope.

Concept 3 - Alternates



References

R. Chaichaowarat, D. F. P. Granados, J. Kinugawa and K. Kosuge, "Passive knee exoskeleton using torsion spring for cycling assistance," *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2017, pp. 3069-3074, doi: 10.1109/IROS.2017.8206146.