ME 20N: Haptics: Engineering Touch
Autumn 2017

Week 4: Mechatronics

Allison M. Okamura
Stanford University

Announcements

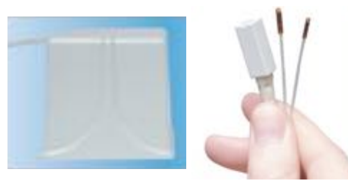
- Continue to bring your laptop and power cord (and USB converter, if needed) to class for the rest of the quarter.
- If you need to adjust the mechanics of your Hapkit, please do this before Thursday
- Try to get checked off on **Lab 4** by the end of class Thursday
- Note: No Thursday office hours due to Alumni lecture

Hapkit Sensor

Allison M. Okamura
Stanford University

sensor types

- magnetic
- optical
- acoustic
- inertial
- **mechanical**
  (our focus, since these are the sensors typically integrated with the actuator in kinesthetic haptic devices)


magnetic: TrakStar, Ascension


optical: Polaris, NDI


optical: Microsoft Kinect


acoustic: ultrasonic proximity sensor, BiF

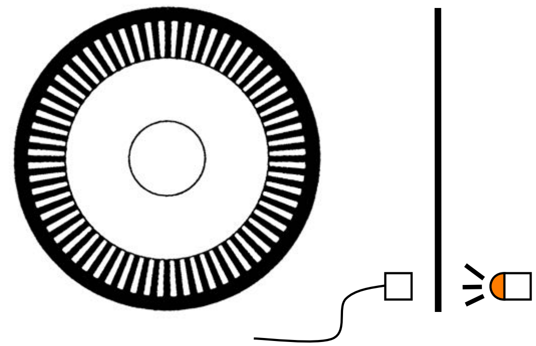

inertial: wearable IMU, MotionNode


mechanical: Faro arm

mechanical trackers

- ground-based linkages most commonly used
- joint position sensors
  - digital: optical encoders are most common
  - analog: magnetic sensors and potentiometers are most common

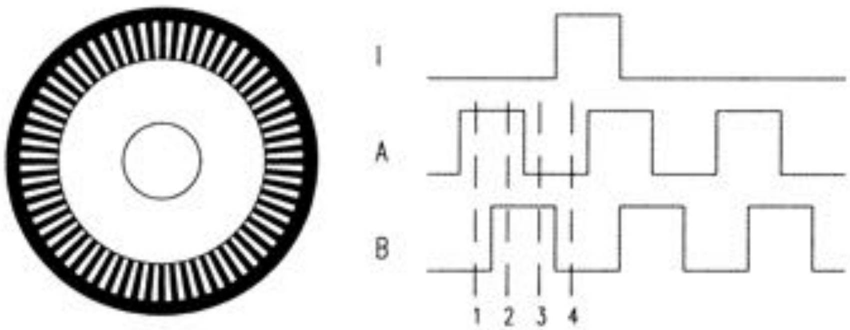
Encoders



- how do they work?
  - Typically, a focused beam of light aimed at a matched photodetector is interrupted periodically by a coded pattern on a disk
  - In our case, the rotation is sensed by magnetic signals instead of light
  - Produces a number of pulses per revolution (Lots of pulses = high cost)
- quantization problems at low speeds
- absolute vs. referential

Encoders

- phase-quadrature encoder



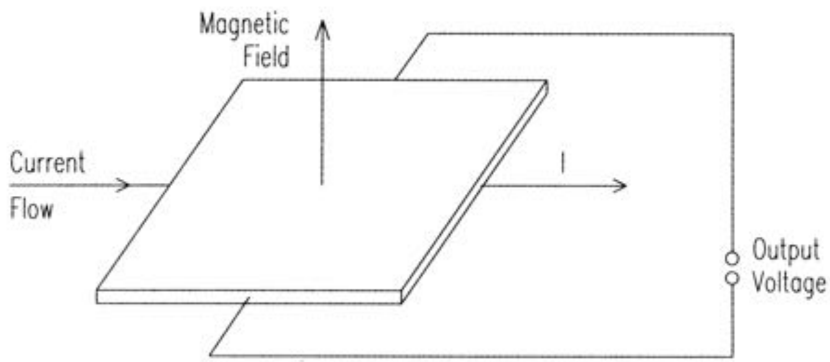
State	Ch A	Ch B
S_1	High	Low
S_2	High	High
S_3	Low	High
S_4	Low	Low

- 2 channels, 90° out of phase
  - –allows sensing of direction of rotation
  - –4-fold increase in resolution

Hall-Effect Sensors

How do they work?

a small transverse voltage is generated across a current-carrying conductor in the presence of a magnetic field



(Discovery made in 1879, but not useful until the advent of semiconductor technology.)

Hall-Effect Sensors

$$V_h = \frac{R_h I B}{t}$$

V_h = Hall voltage

R_h = Hall coefficient

I = Current

B = Magnetic flux density

t = Element thickness

- amount of voltage output related to the strength of magnetic field passing through.
- linear over small range of motion (need to be calibrated)
- affected by temperature, other magnetic objects in the environments

measuring velocity

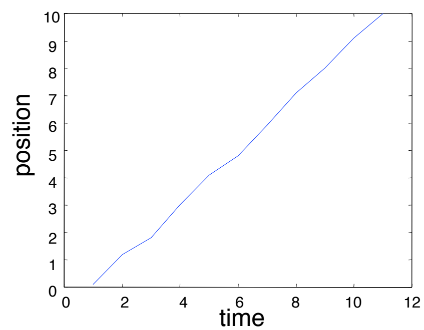
- differentiate position
  - advantage: use same sensor as position sensor
  - disadvantage: get noisy signal
- alternative
  - for encoders, measure time between ticks

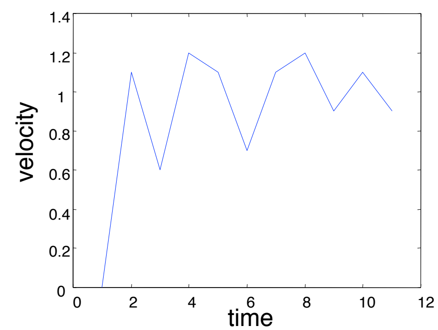
discrete differentiation

- many different methods
- simple example:
  - average 20 readings = P1
  - average next 20 readings = P2
  - where t is the the period of the servo loop

$$V = \frac{P1 - P2}{t}$$

- differentiation increases noise
- usually need to filter





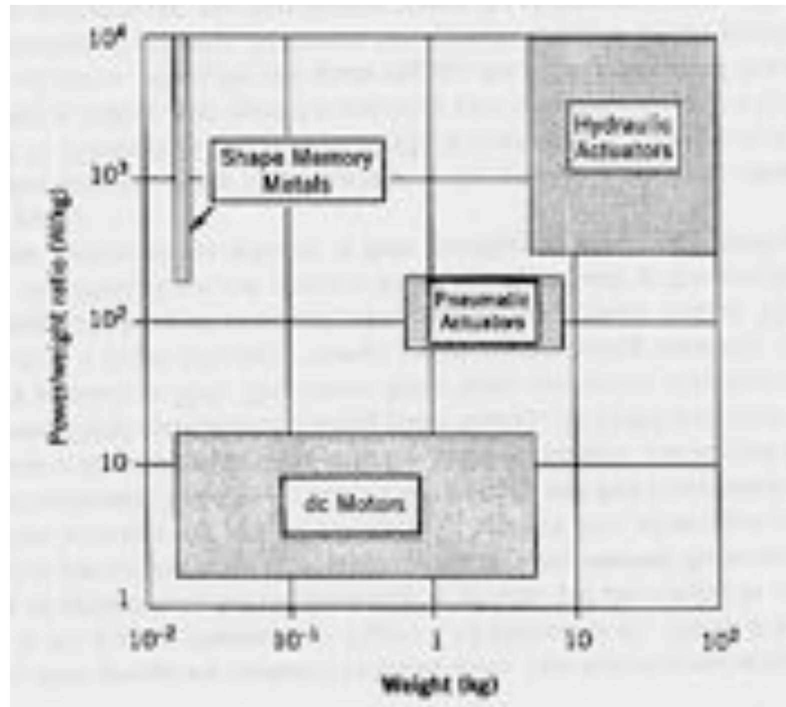
Hapkit Actuator

Allison M. Okamura
Stanford University

Actuator types

For kinesthetic haptic devices, the actuator of choice is the electric motor, specifically:

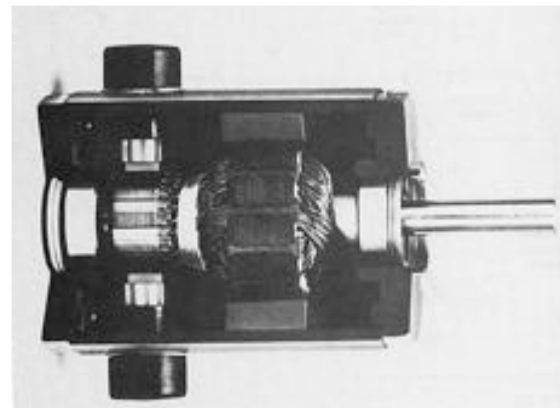
- DC (direct current)
- Brushed
- PM (permanent magnet)



Burdea

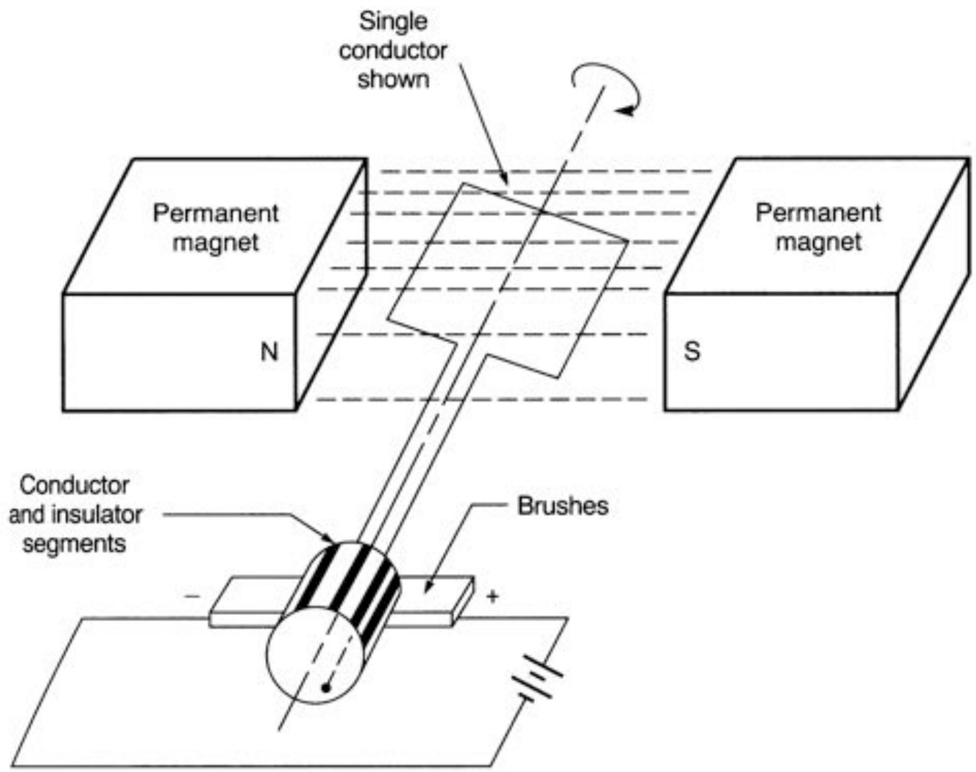
PM DC brushed motors

- Rotating *armature* with coil windings is caused to rotate relative to a permanent magnet



- Current is transmitted through brushes to armature, and is constantly switched so that the armature magnetic field remains fixed.

DC motor components



DC motor terms

- Cogging/torque ripple

  - tendency for torque output to ripple as the brushes transfer power

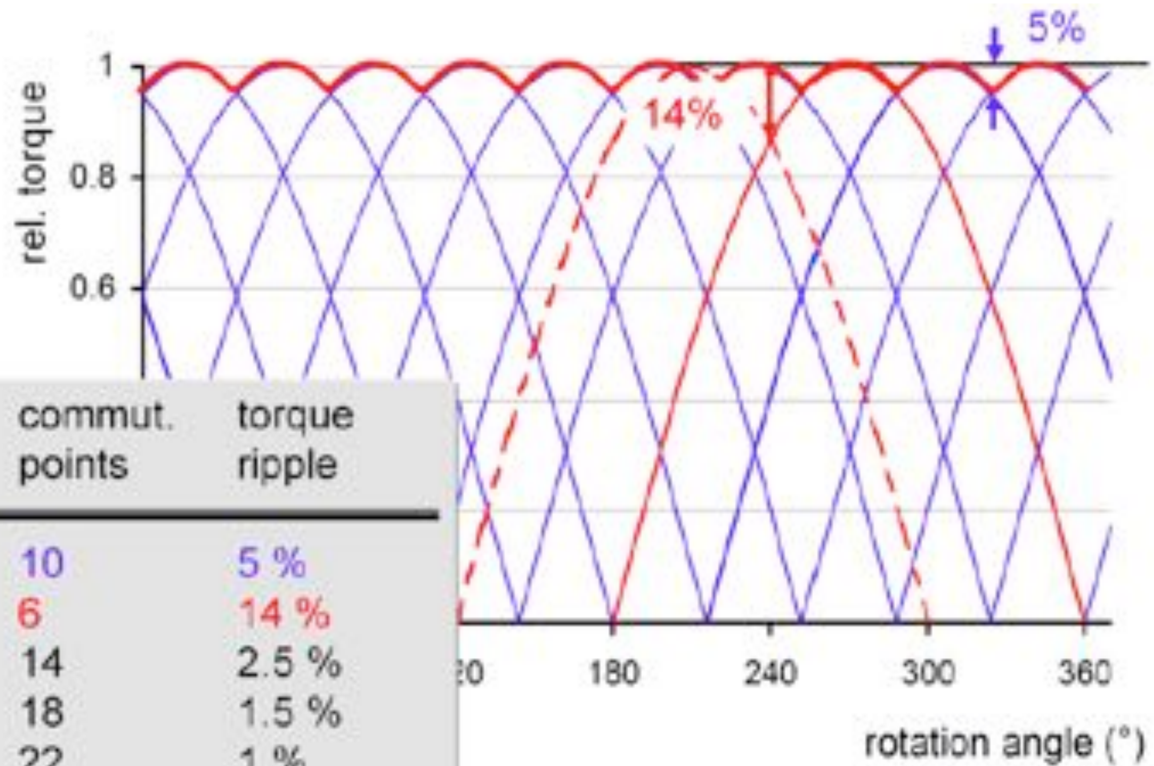
- Friction/damping

  - caused by bearings, brushes, and eddy currents

- Stall torque

  - max torque delivered by motor when operated continuously without cooling

Torque ripple



commutator segments	commut. points	torque ripple
5	10	5 %
6	6	14 %
7	14	2.5 %
9	18	1.5 %
11	22	1 %
13	26	0.75 %

http://www.maxonmotorusa.com/

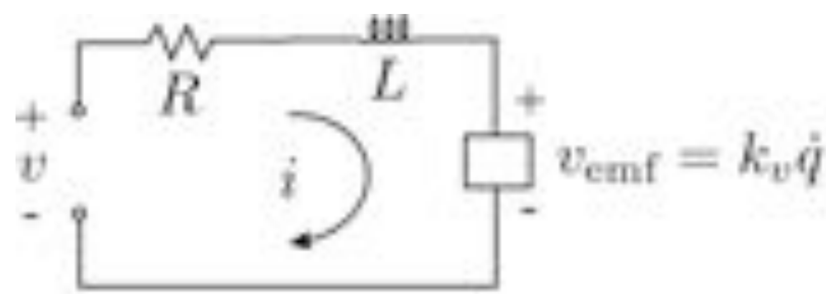
Motor equations

- Torque constant k_T $\tau = k_T i$
- Speed constant k_v $v_{\text{emf}} = k_v \dot{q}$

- Dynamic equations

$$v = L\frac{di}{dt} + Ri + v_{\text{emf}}$$

$$m\ddot{q} + b\dot{q} = \tau$$

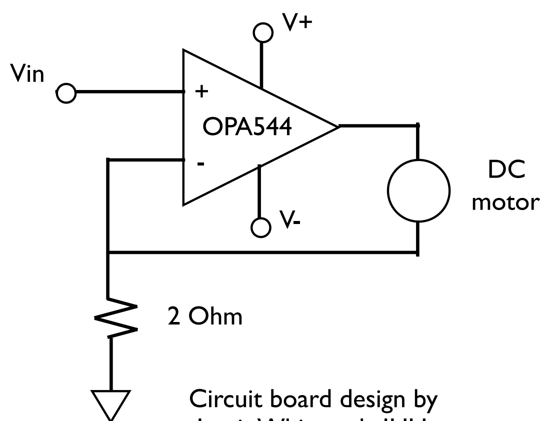


Motor amplifier types

current amplifier

(voltage controlled current source VCCS)

directly controls current
current = torque (good!)
expensive



Circuit board design by
Louis Whitcomb, JHU

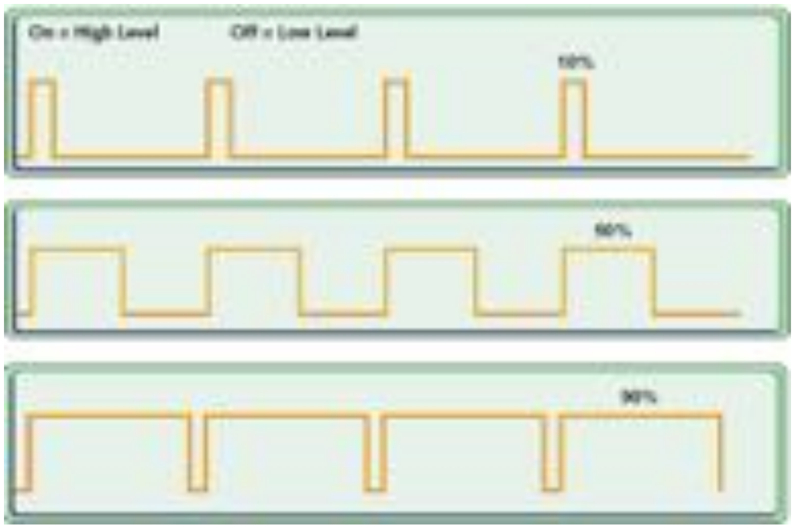
voltage amplifier

(voltage controlled voltage source VCVS)

indirectly controls current
current depends on several factors
less expensive

ardumotor shield (https://www.sparkfun.com/products/9815) and Adafruit
TB6612 1.2A DC/Stepper Motor Driver Breakout Board

Pulse width modulation



http://www.barrgroup.com/

assumes that the average signal is a constant signal

duty cycle is the proportion of ***on*** time to the ***period***

useful if you do not have a D/A converter
to send analog signals to the motor circuit

switching frequency must be much faster than the
mechanical dynamics of the system

Motor in your Hapkit

Pololu MP 12V Motor

Dimensions

Size:	[illegible]
Weight:	[illegible]

General specifications

Gear ratio:	[illegible]
Free-run speed @ 6V:	[illegible]
Stall current @ 6V:	[illegible]
Stall torque @ 6V:	[illegible]
Free-run speed @ 12V:	[illegible]
Free-run current @ 12V:	50 mA
Stall current @ 12V:	2100 mA
Stall torque @ 12V:	[illegible]
Lead length:	[illegible]
Motor type:	[illegible]
Encoders?:	[illegible]

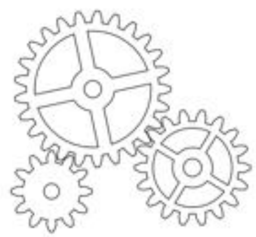
Notes:

[illegible]

https://www.pololu.com/product/3236/specs

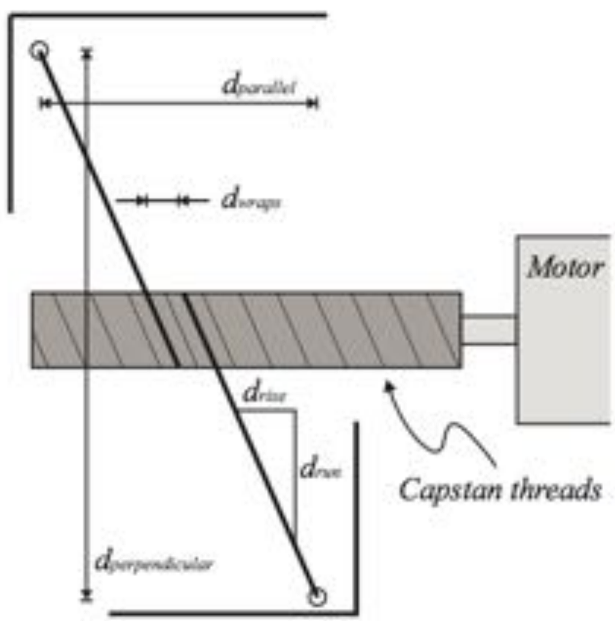
Transmission

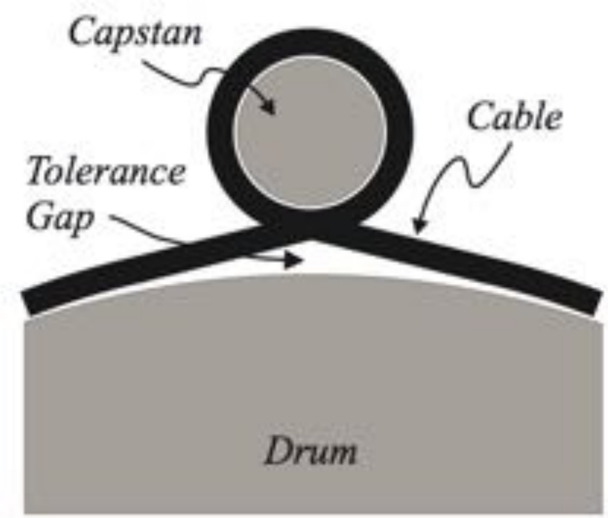
- Transfers/amplifies force/torque from motor
- You don’t want to feel or see the effects of the transmission!
- Types:
  - gears
  - belts/pulleys
  - capstan drive
  - none (direct drive)



Capstan drive

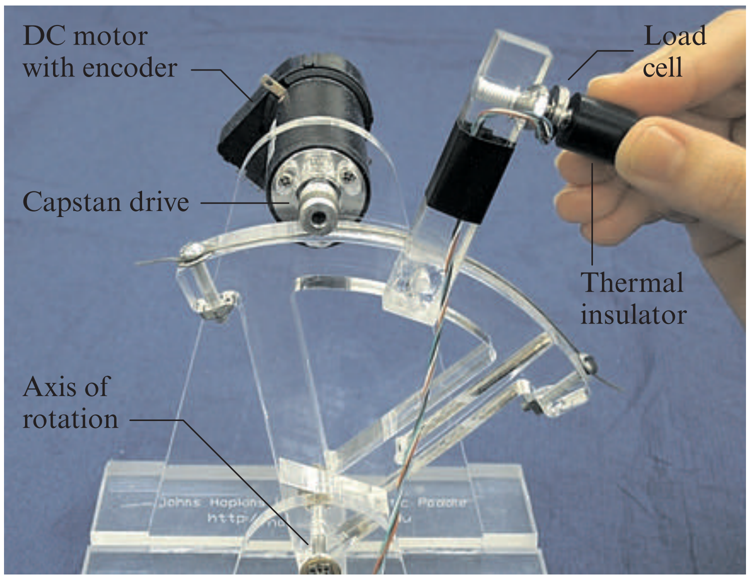
high transmitted force, low transmitted friction





Katherine Kuchenbecker

Capstan drive

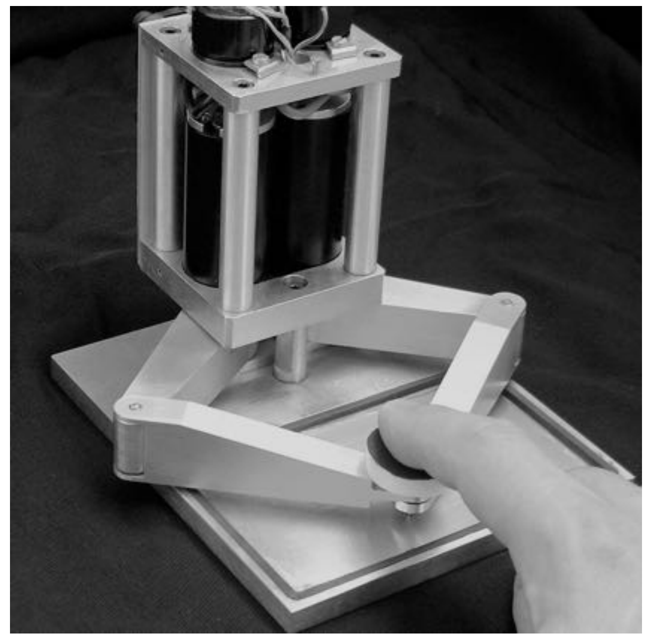


a version of the haptic paddle

Phantom Premium, SensAble Technologies

Direct drive

motors attached
directly to link(s)



Hayward (McGill)