Systems Neuroscience CISC 3250

Motor control

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JMH 328A

Classes of motion

Voluntary

Somatic		Skeletal muscle
Autonomic	Sympathetic Fight or Flight	Smooth muscle
	Parasympathetic Resting state	Cardiac muscle

Involuntary

2

Pathways to motion in (typically) 2 synaptic steps

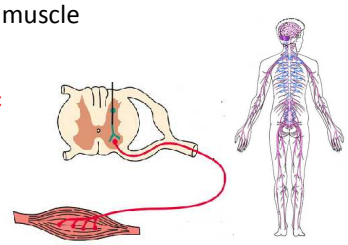
0 Command from primary motor cortex (M1)

1 Synapse onto neuron in spinal cord/cranial nerve

2 Synapse onto muscle

Efferent – motor message **out**

Afferent – perceptual message **in**

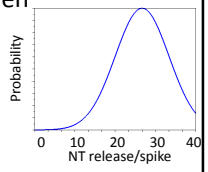


3

Precise motion in an imprecise world

Imprecise neurons

- Efferent signal for motion will present variable number of NT molecules per spike
- Number of spikes may vary between movement repetitions



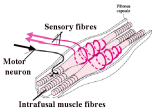
Unreliable world

- Wind blows while you pick up a bag
- You trip on unseen object while walking

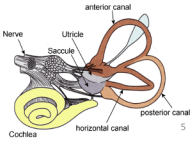
4

Monitoring body motion

- Seeing body move (covered in earlier lecture)
- Skin stretch (covered in earlier lecture)
- Muscle stretch/contraction – muscle spindles



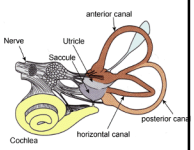
- Head rotations – inner ear; semi-circular canals

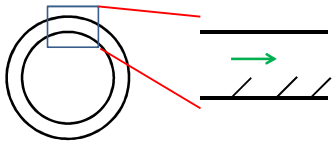


5

Vestibular system

Three canals on left and right side of head: anterior, posterior, horizontal



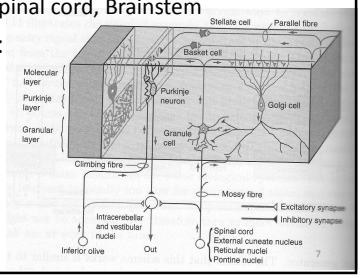


1. Head rotates
2. Fluid flows
3. Hairs displaced

6

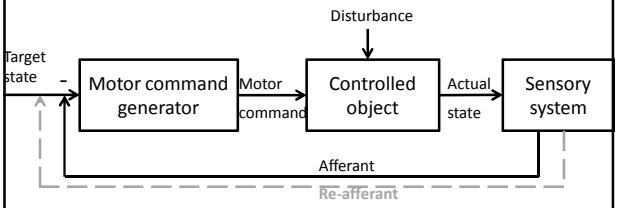
Adjusting motion with the cerebellum

- Compare motor commands to actual motion
- Cerebellar inputs:
  - Climbing fiber from Inferior Olive (brainstem)
  - Mossy fiber from Spinal cord, Brainstem
- Cerebellar outputs:
  - Purkinje cells – inhibition to brainstem



Control theory

Correcting errors in motion

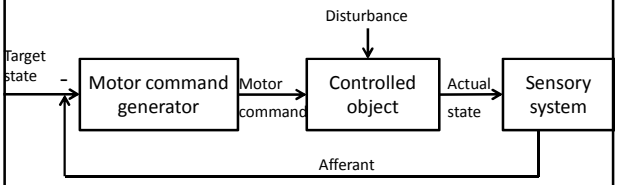


Afferant – muscle sensors

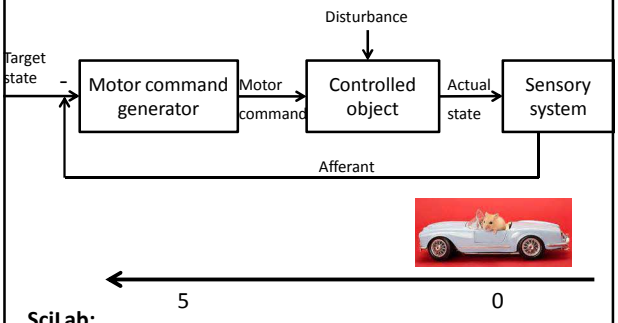
Re-afferant – visual sensors

Motor command generation

swing leg forward -> rotate leg using muscle force



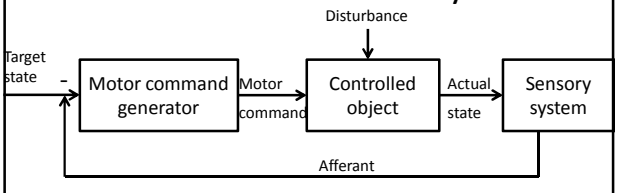
Motion with basic feedback system



SciLab:

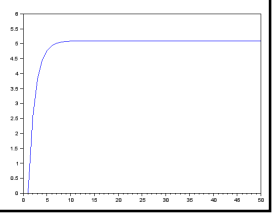
bodyPosition=feedbackSim(5,0.5,0,50);

Motion with basic feedback system



SciLab:

bodyPosition=feedbackSim(5,0.5,0,50);



Motion strategy

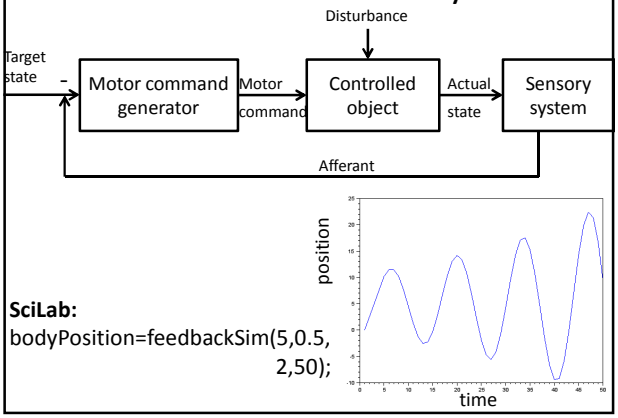
Move = 1/2 x (**T**arget-**C**urrent)

	t=1	t=2	t=3	t=4	t=5
Sense	0	2.5	3.75	4.38	4.69
Move	+2.5	+1.25	+.63	+.31	...
Actual	0	2.5	3.75	4.38	4.69

Target: 5

t=1 Start at 0

Motion with basic feedback system



SciLab:
bodyPosition=feedbackSim(5,0.5, 2,50);

Motion strategy

Move = 1/2 x (**T**arget-**S**ensed)

	t=1	t=2	t=3	t=4	t=5	t=6
Sense	0	0	0	2.5	5	7.5
Move	+2.5	+2.5	+2.5	+1.25	0	-1.25
Actual	0	2.5	5	7.5	8.75	8.75

Desired: 5
t=1 Start at 0
2 time point sensation delay

14

Expanded control theory

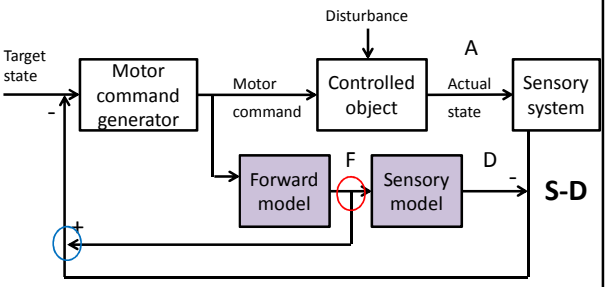
Challenge: Waiting for afferent feedback is slow

Solutions:

- Anticipate typical motion progress – **forward model**
- Account for typical motion progress from the beginning – **inverse model**

15

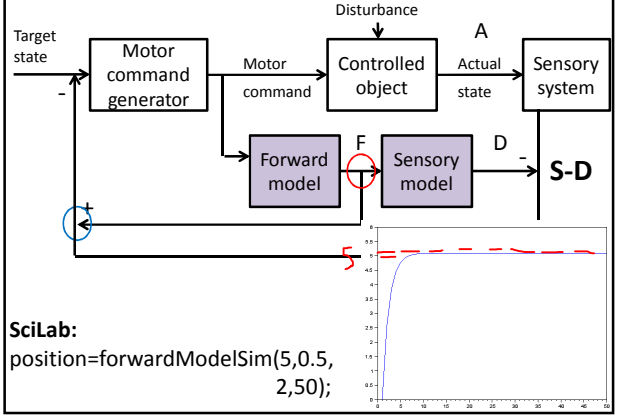
Forward model



- Adjust motion based on predicted position
- Adjust predicted error based on actual position
- Adjust models (over longer experience)

16

Motion with forward model



SciLab:
position=forwardModelSim(5,0.5, 2,50);

Motion strategy

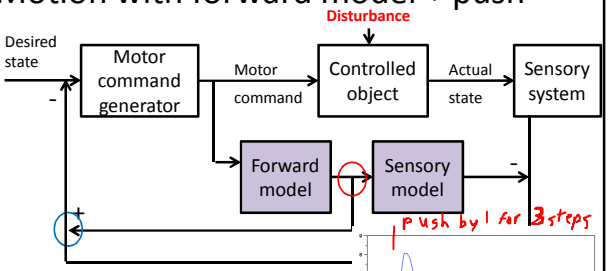
Move = 1/2 x (**T**arget-(**F**orward+**S**ensed-**D**elay))

	t=1	t=2	t=3	t=4	t=5	t=6
Sense	0	0	0	2.5	3.75	4.38
Move	+2.5	+1.25	+.63	+.31	+.16	+.08
Forward	0	2.5	3.75	4.38	4.69	4.85
Delay	0	0	0	2.5	3.75	4.38
Actual	0	2.5	3.75	4.38	4.69	4.85

Target: 5
t=1 Start at 0
2 time point sensation delay

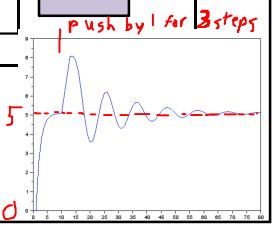
18

Motion with forward model + push

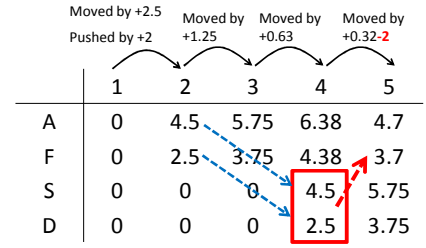


SciLab:

```
position=forwardModelSim(5,0.5,
                         2,50,
                [zeros(1,10) 1 1 1
                 zeros(1,37)]);
```



desired location = 5 starting location = 0 sensory delay = 2
push forward by 2 at time 1 no other



	1	2	3	4	5
A	0	4.5	5.75	6.38	4.7
F	0	2.5	3.75	4.38	3.7
S	0	0	0	4.5	5.75
D	0	0	0	2.5	3.75

Compare model motion and actual motion after 2 time step delay

20