ME 599/AA 546/EE 546: **Biology-inspired robot control**

Lecture 12

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Goals:

- introduce learning segment of course
- introduce paper6
- 2nd half of term project presentations

UNIVERSITY of WASHINGTON

Office Hours this week

- normally: Thurs 2:30-3:30 in MEB321
- this week: Thurs 1:30-2:30 in MEB321

recap: mechanical intelligence (weeks 1-4)

Engineered control systems typically use tight feedback control to regulate motion

- example: Honda Asimo. It hunches to walk. 20x power usage of humans

In biological systems, mechanics and control and evolved simultaneously

- result: sometimes desirable behavior can be engineered to occur *without* neural feedback
- simpler, more efficient, robust to failure
- "mechanical intelligence"

Examples from the readings

- Jindrich2002: cockroaches perturbed by cannons don't change their gait
- Collins2001: a robot that walks without any motors at all!
- Fuller14: simplifying the sensing problem by relying on dynamics
- Werfel14: collective output using tight coupling between mechanics and behavior
- Sam Burden (guest speaker): theory on mechanical intelligence

upcoming: reflexive/learning control

Engineered control systems typically contain a *model* of the system being controlled

- examples: model of inertia of the car for cruise control; a map of the environment
- valid approach for simple systems/environments
  - problems if more complicated or unpredictable
  - examples: turbulent flow, friction, complex environments

Biological systems instead find *input-output* mappings to achieve satisfactory performance

- "reflexive control" or "model-free control"

Examples from the readings

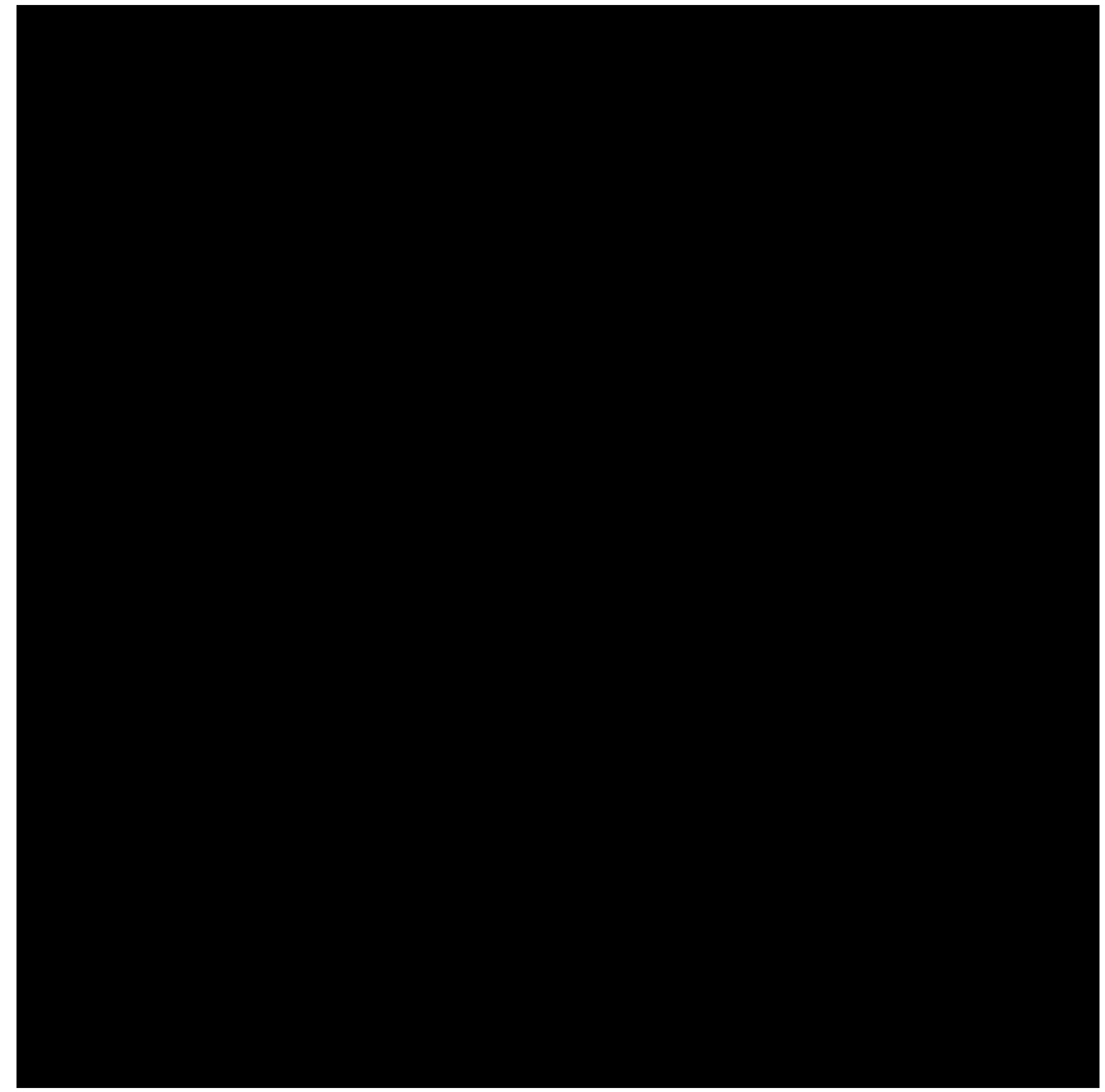
- McLeod1996: fielders don't estimate a ball's trajectory, they just follow it
- Braitenberg1984: simple reflexes can produce complex behavior

(upcoming:)

- Cory2008: learning how to perform aggressive maneuvers from flight data
- Bongard2011: neural networks learning to walk
- Brooks1986: reflexive input-output loops can be layered to produce complex behavior
- Srinivasan1996: how bees use optic flow to navigate from the hive

Friday's reading: "Experiments in fixed-wing perching" by Cory and Tedrake (2008)

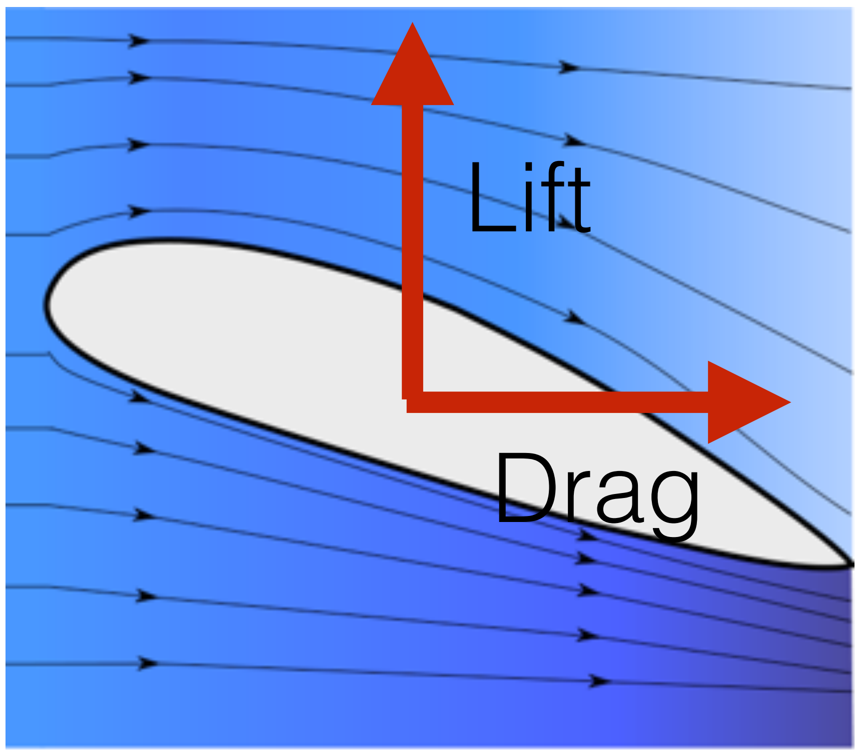
classic V/STOL
(vertical/short takeoff landing)
"classical approach"
but uses lots of energy



bird landing: high angle of attack,
unsteady flow hard to model,
efficient

perching on a wire

useful definitions

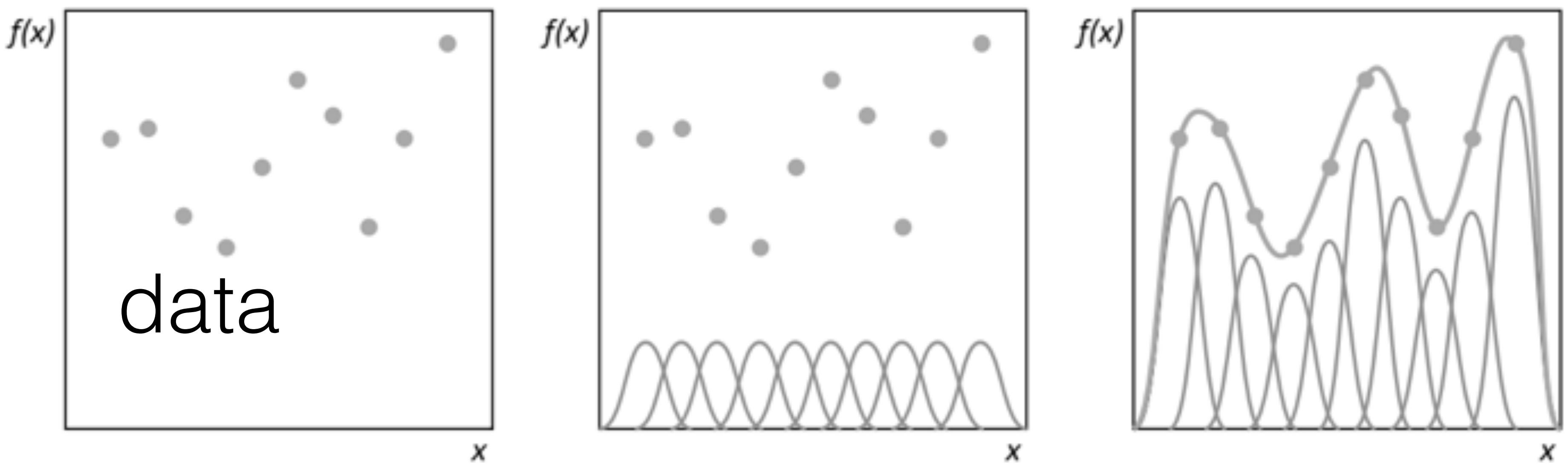


$$F_L = \frac{1}{2}\rho C_L S V^2$$

$$F_D = \frac{1}{2}\rho C_D S V^2$$

ρ	air density
C_L	coefficient of lift
C_D	coefficient of drag
S	wing area
V	wing velocity

machine learning background



function fit

$f(x) \approx \Sigma_i w_i \phi_i(x)$

“basis functions”

$\phi_i(x)$

$$C_L(\alpha, \varphi) \approx \Sigma_i w_i^{\alpha} \phi_i(\alpha) + \Sigma_i w_i^{\varphi} \phi_i(\varphi)$$

- section 5 “optimal control” - uses advanced topics in control theory. skim it, but but you’re not expected to understand it all