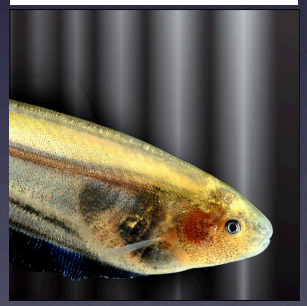
Introduction to System Identification for Neural Systems

Lecture 1:
Modeling & Identifying Neurosystems

Systems I Have Studied



- Human
  - Standing balance / posture control
  - Running
- Weakly Electric Fish
  - Midbrain neurons

What if you wanted a model of a human flying

Like balance, flying is a sensorimotor stabilization task.

Modeling Approach

Use a flight simulator with an autopilot that mimics the brain of a real pilot.

Model Complexity Varies

Most autopilots ... trivialize human controller

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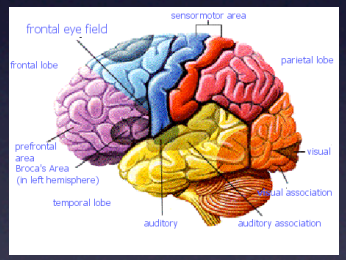

Autopilot behaving human ... trivializes variability in pilot population

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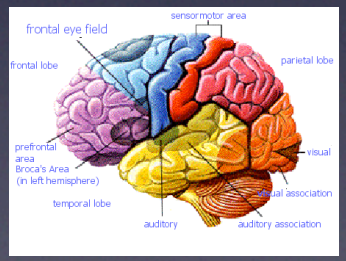

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Good model

For each pilot, System ID tells you the states of knobs and switches.

Need #1:
Simple Behavior

Yes!

No!

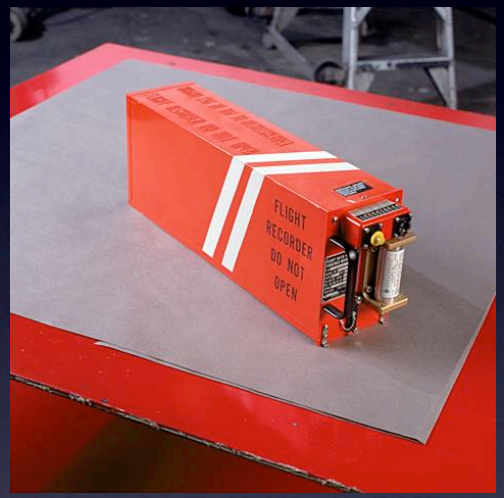
“Need” #2: Input

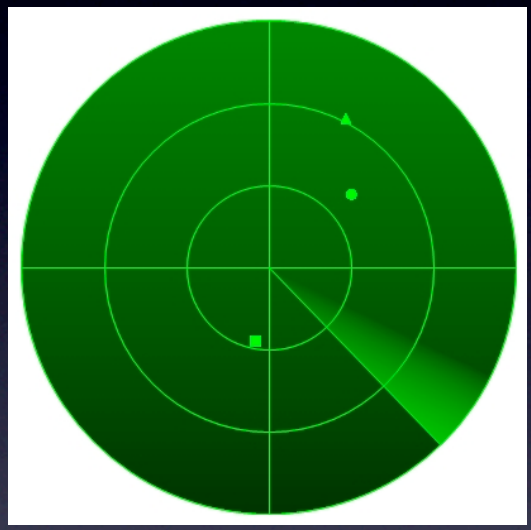
Balance: Move platform & visual surround

Flight: Change the wind

Need #3: Data

Flight:





Balance:

Need #4: Parameterized Model

Flight:

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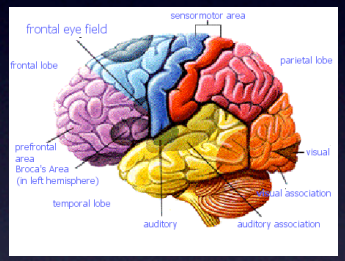

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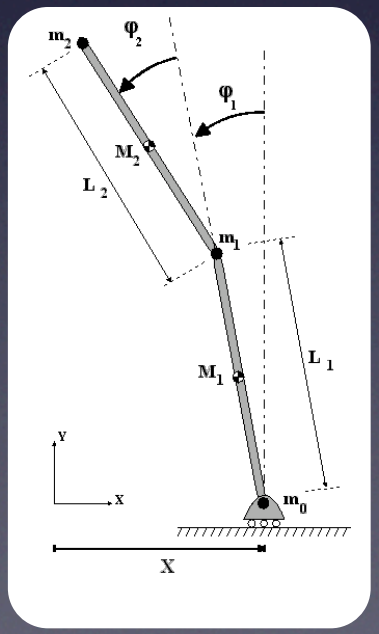
Balance:



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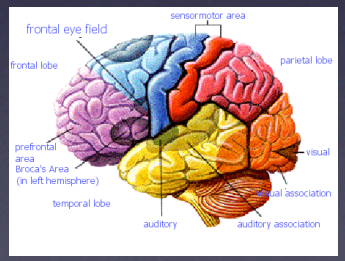

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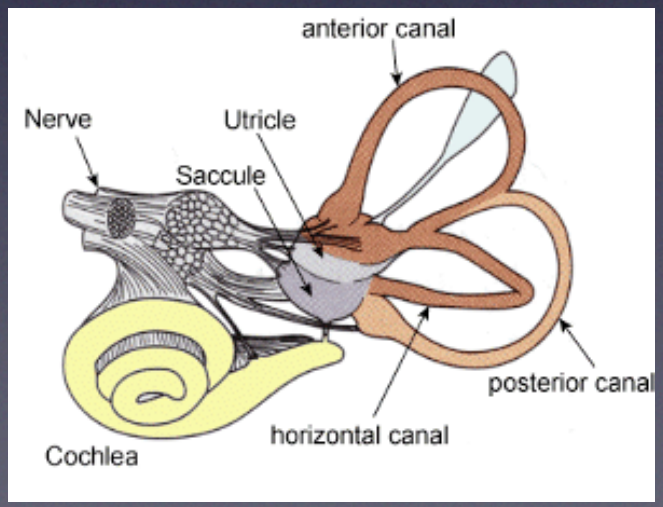
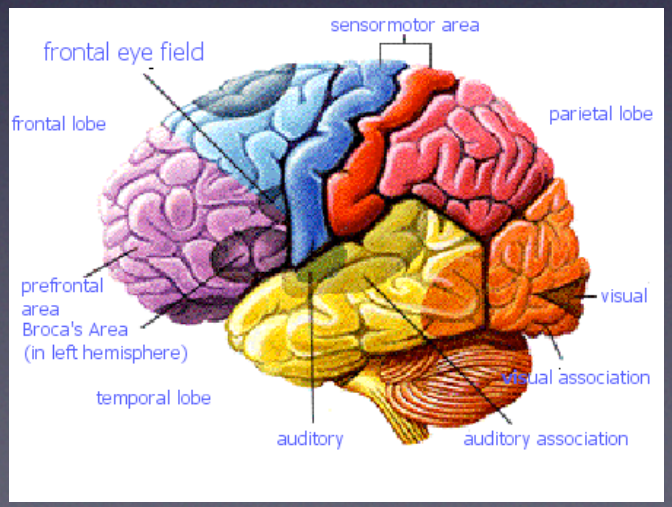
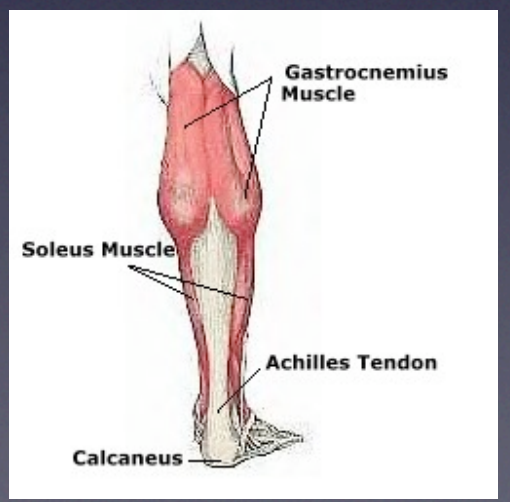
Need #5: Statistics of Noise

Noise is any input you do not know.







Needs

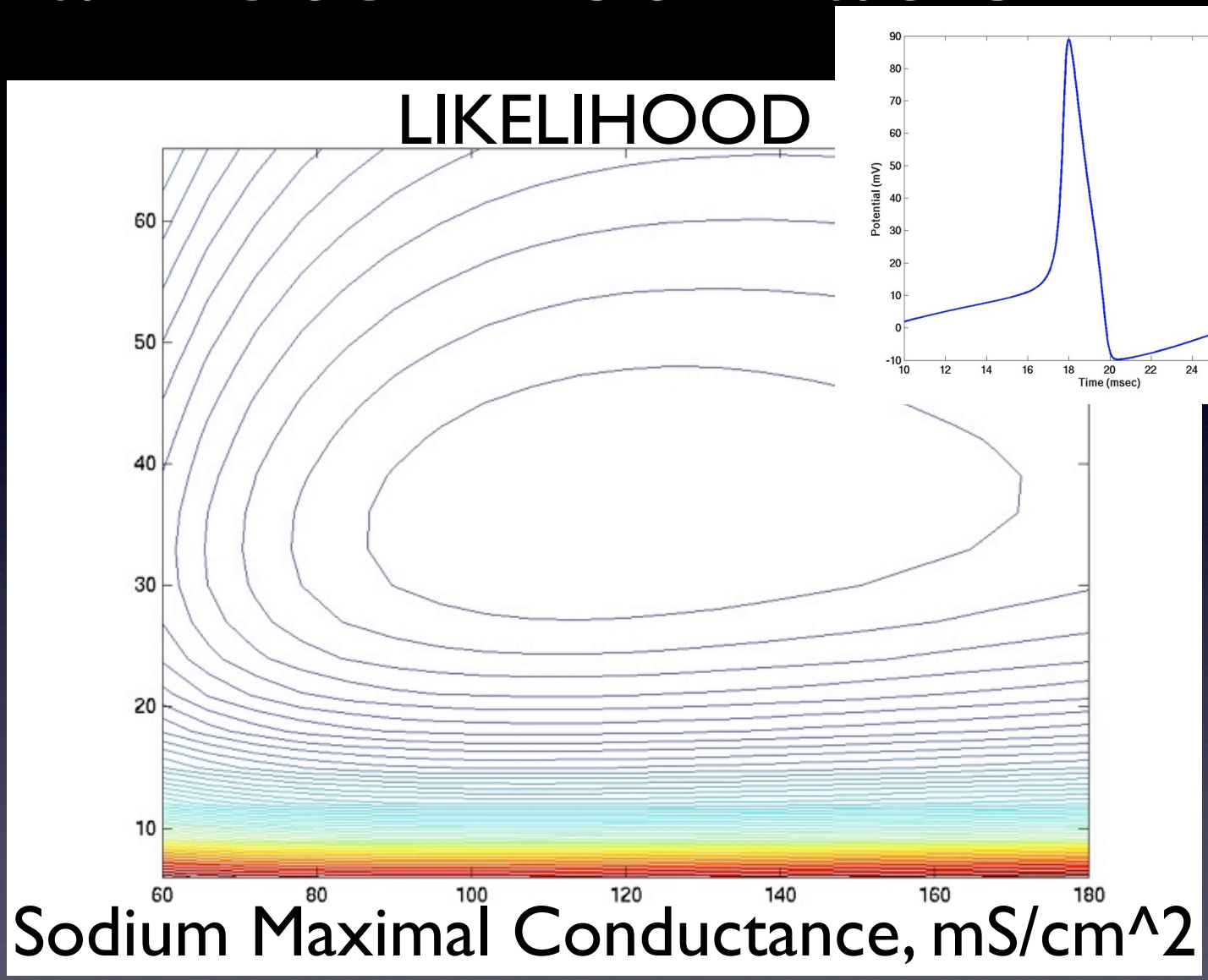
1. Simple Behavior to Be Studied
2. Known Inputs to System During Behavior
3. Data Collected During Behavior
4. Parameterized Model of System ...
5. Including Statistics of Noise (Unknown inputs)

System Identification: Infers the Values of Parameters (Knobs & Switches) and/or Decides If the Model Fits the Data

System ID Terminology

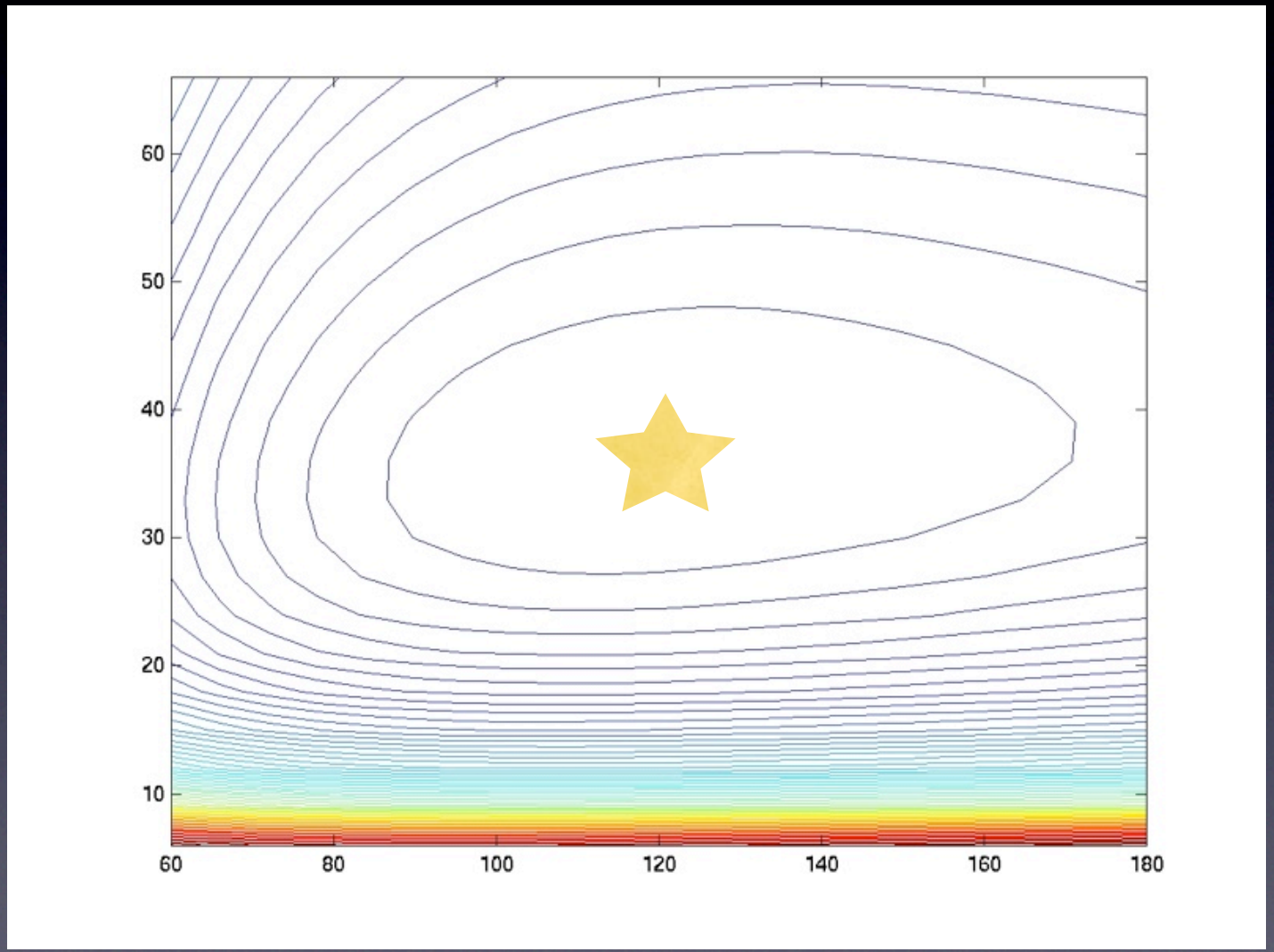
- Infer Position of Knobs: Parameter Estimation
- Infer Position of Switches: Model Selection
- Decide if Model Fits Data: Model Validation

Parameter Estimation

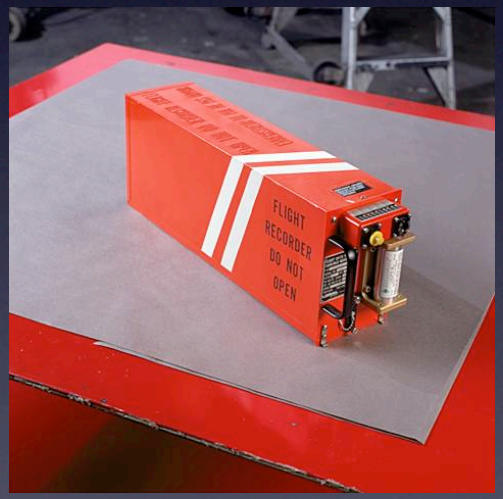


Objective Function Quantifying How Well Model Fits Data (As Two Knobs Vary)

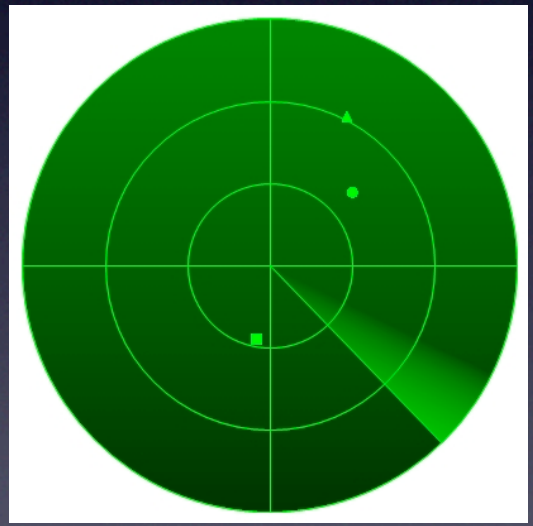
Optimization: Find Max



Hidden Variables Confound Likelihood Computation



Versus

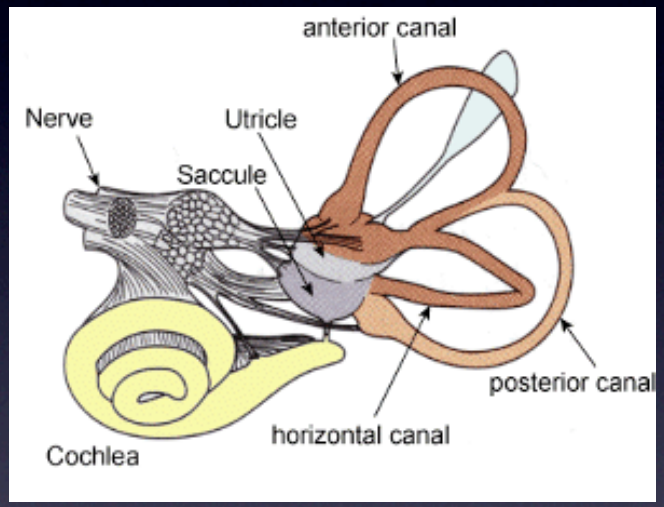


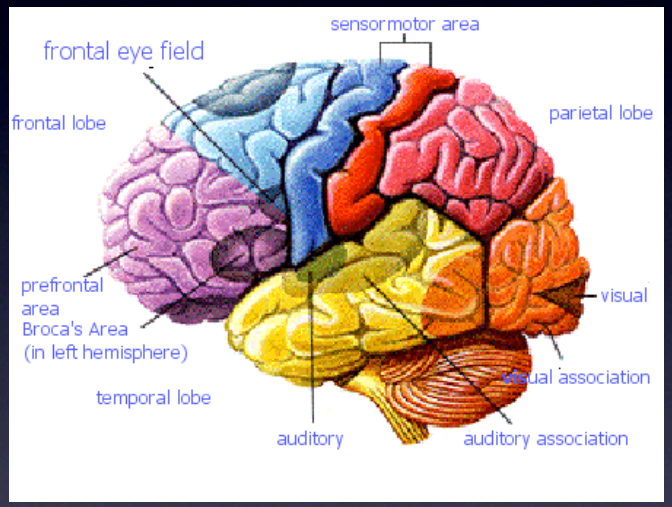
Solution: Bayesian Filtering

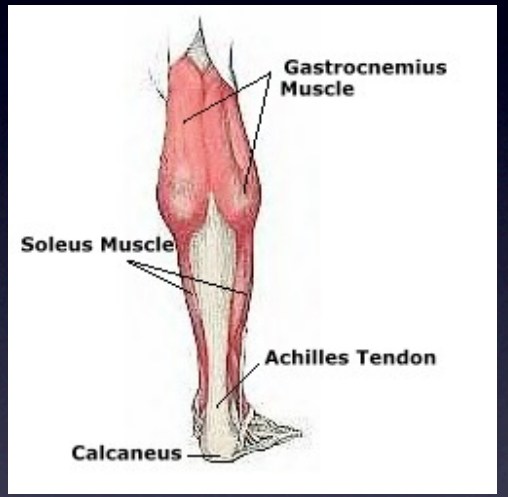
Diagnosis of Balance Deficits

Important problem impacting many lives

What Can Go Wrong With Balance?







Sensory

Central

Motor

Patient populations are heterogeneous!

Want Clinical Data

Useful for designing interventions
and monitoring progress

Enter Weakly Electric Fish

Tracking: Like Balance, Sensorimotor Stabilization

Prey Capture:

Courtesy Malcolm MacIver
Northwestern University

Jamming Avoidance