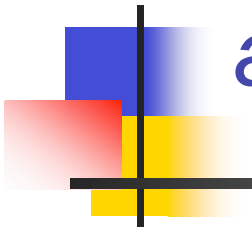

# Stability:
## *How it relates to why things go wrong and what can be done about it*

**CSSA Conference**

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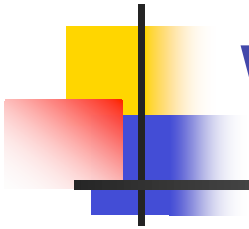
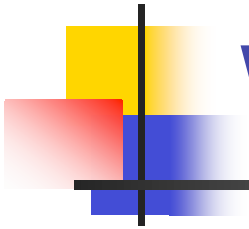
Department of Mechanical and Aerospace Engineering,
UCSD

April 21, 2007



# When things go wrong

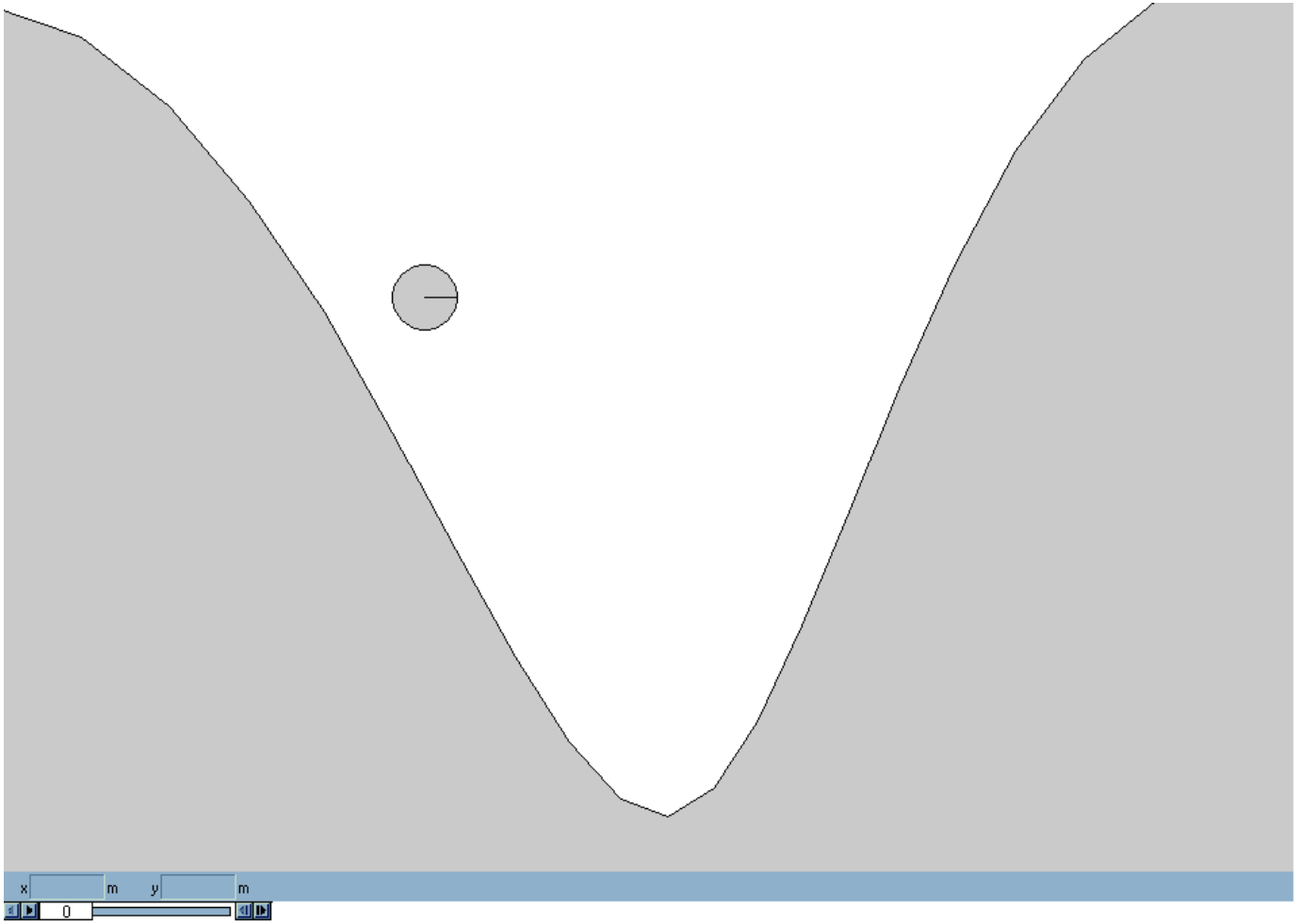
- Often when things go wrong in biological, mechanical, mechatronic, electronic, and other systems it can be shown that the system moved outside some range of normal operation
  - A human being ‘operating’ within a normal range of energy, health, fitness, age, terrain, etc can stand and balance very well
    - Put the person on a pitching boat and all bets are off!
  - Human temperature compensation for a variety of environments
  - Systems interacting can cause undesirable effects - ever see a CRT monitor in a magnetic field?
  - Many plane crashes have occurred because of HCI errors such as too much critical information being presented simultaneously or too quickly, or incorrect color contrast, or in the wrong place



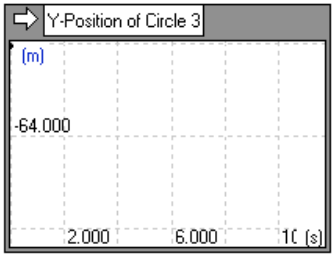
# What is (in)stability?

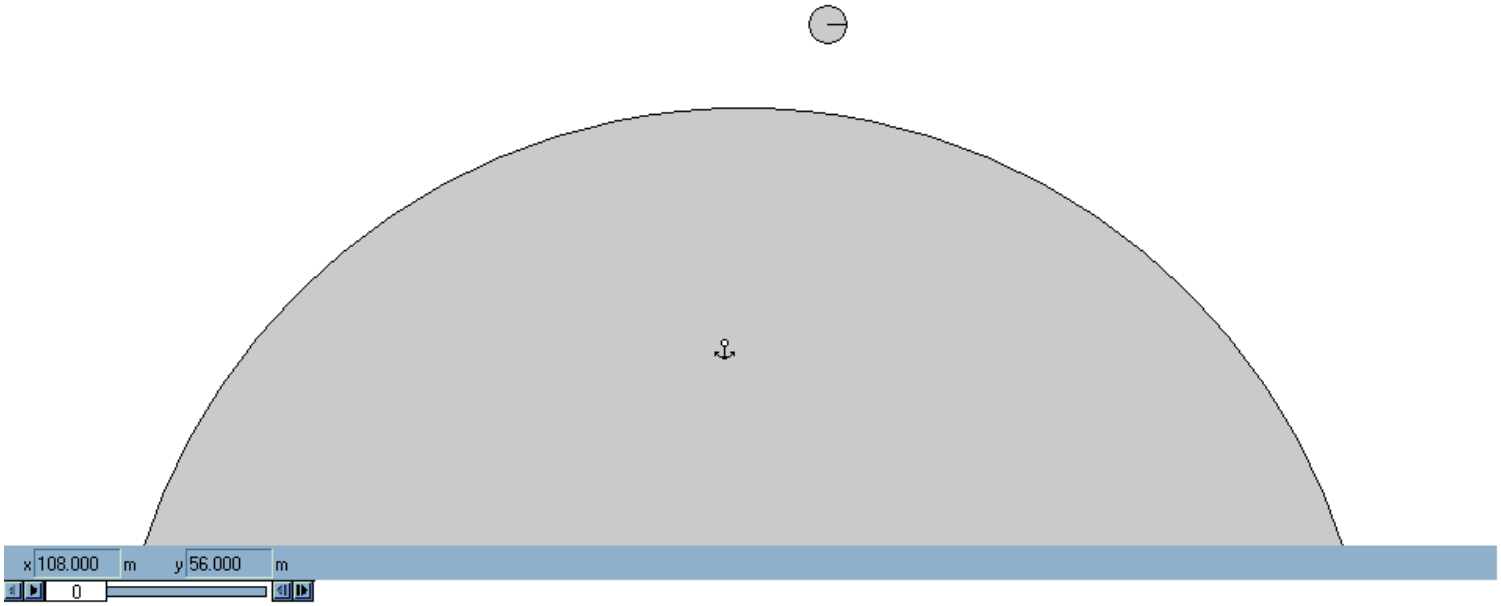
- ***Stability = "The ability of a system to approach one of its equilibrium points once displaced from it"*** ***(Tewari, 2002)***
- Consider the ball on a hill example
- Demos…
  - Tacoma narrows bridge
  - HCI failure - JSF crash
  - Child learning to walk
  - Learning to ride a bike
- Defining context

# Stable point in a system

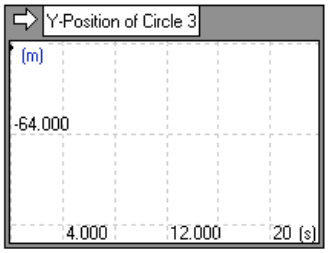


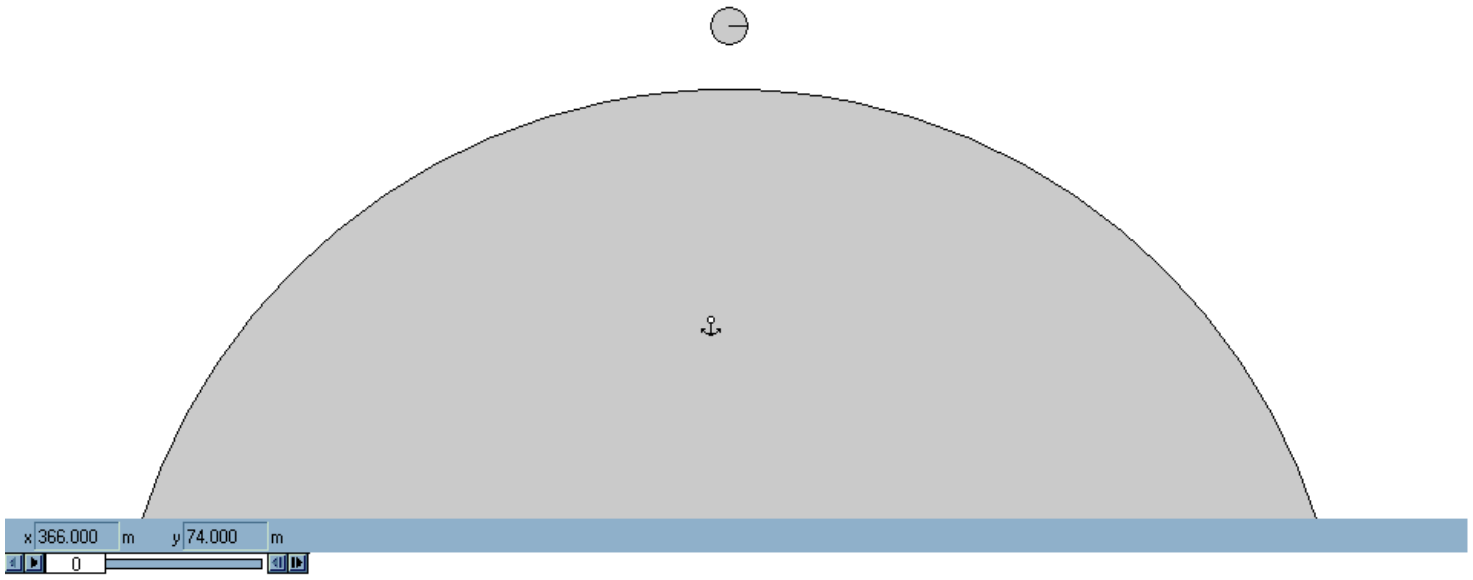
# Unstable point in a system



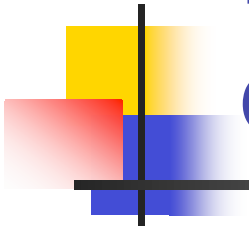
# Conditionally stable point in a system



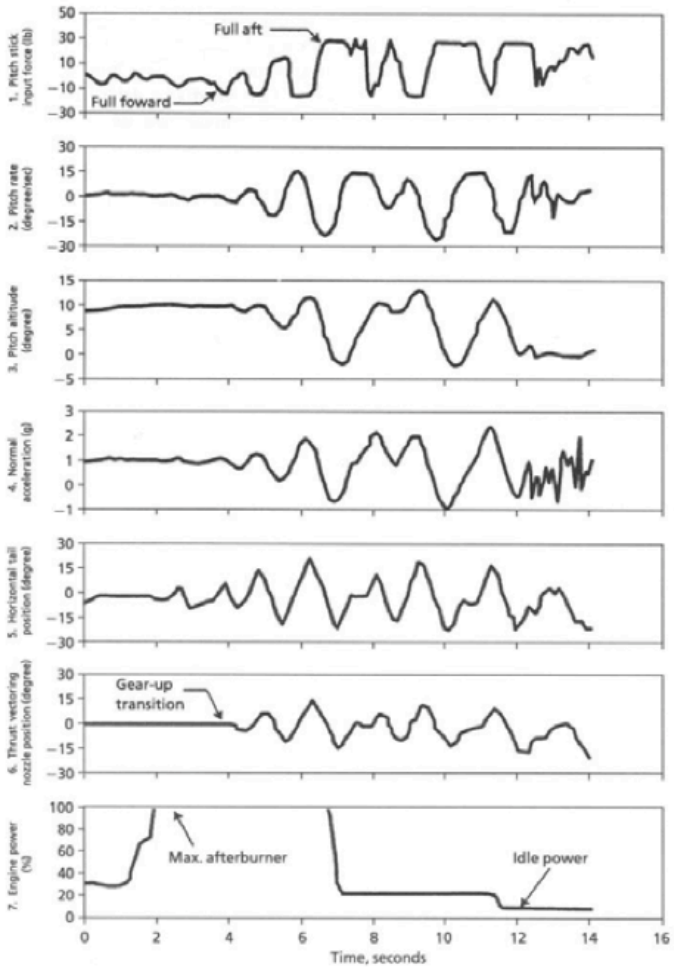
# How can a 42mph wind destroy a bridge capable of withstanding 120mph winds?!?

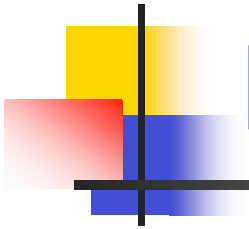
# Resonance (unmodelled dynamics) can lead to instability



- The wind excited a natural resonance mode of the bridge
  - similar to a child pushing a larger person on a swing - if they push at the right timing
  - Consider the ball on the hill example - the wind pushed the bridge closer and closer to that unstable point, until failure occurred
- But how does this relate to Cognitive Science?

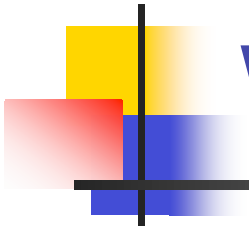
# An HCI example of instability



# HCI? Why?

- Vectored exhaust
  - Gear down, no vectoring
  - Gear up, vectoring
  - Vectored exhaust low fly-by
    - In April 1992, during flight testing after contract award, the first YF-22 prototype crashed while landing at Edwards air force base in California. The test pilot, Tom Morgenfeld, was not injured and the cause of the crash was found to be a flight control software error that allowed and created a pilot-induced oscillation.



# Why are humans so stable?

- Built into biomechanics
  - Recall that as we move our muscles at higher and higher speeds, they produce less and less force
- Very advanced methods of control, incorporating dynamic feedback systems
  - Feedback control tends to have a stabilizing influence
  - We learn from when we're born
    - Baby learning to stand and walk

# But what happens when one of these stabilizing systems goes wrong?

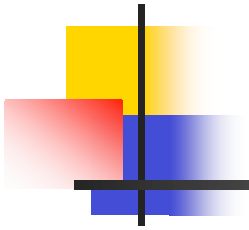
- The brain does its best!
  - Compensation schemes
- Problems manifest such as Parkinson's disease
- Sometimes system coupled with an artificial system can lead to things going wrong (such as PIO)

# What can we do about it?

- Discover and implement treatments
  - Research and development of therapies, drug treatments, rehabilitation, and other interventions
- Help person's brain find a workaround
  - Example of individual with balance issues
    - From 'The man who mistook his wife for a hat'
  - Use intuitive knowledge of feedback to give a new input to the patient and teach them to use it or to bypass a damaged system

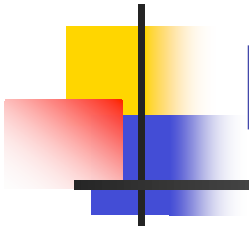
# What else can we do?

- Work with plasticity of the brain to bring about re-learning lost functionality
  - U. Alberta studying how babies learn to walk on a treadmill, applying to patient rehab. strategies



# Instability in artificial systems

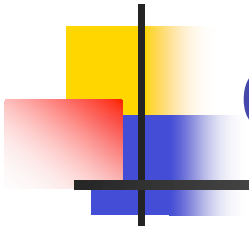
- Analysis methodologies
  - Stability analysis
    - Linear systems - by deriving a mathematical representation of the system in state space or transfer function form, it is simple to compute stability properties
    - Nonlinear systems - much more difficult, because small changes in inputs can result in explosive instabilities, but all is not lost



# Linear stability analysis tools

- Eigenvalues of the A matrix tells you immediately information about the behavior of a linear system
- Poles and zeros of a transfer function form another way to analyze stability properties
- BIBO stability - it can be shown for some systems (open or closed-loop) that they hold this property

# Incorporating this into cognitive models



- The basic concept of stability analysis can be applied to any system
  - Look for the parallels in the behavior with models that exist
  - Measure the behavior through experiments and simulation
  - Create a model, analyze its properties and create a static or dynamic compensation scheme which can be used to predict and eliminate or attenuate instabilities