

# Research Challenges in Feedback Computing: An Interdisciplinary Agenda

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## Early Challenges...

More Recent Research...

Emerging Challenges...

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## Challenge:

### Software Models as Dynamic Systems

- In control theory, the concept of dynamic systems (informally) refers to systems where state variables evolve over time
- These systems can be described by difference or differential equations
- Feedback Computing (formerly FeBID) was born out of the realization that *software is a dynamic system*

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## Challenge:

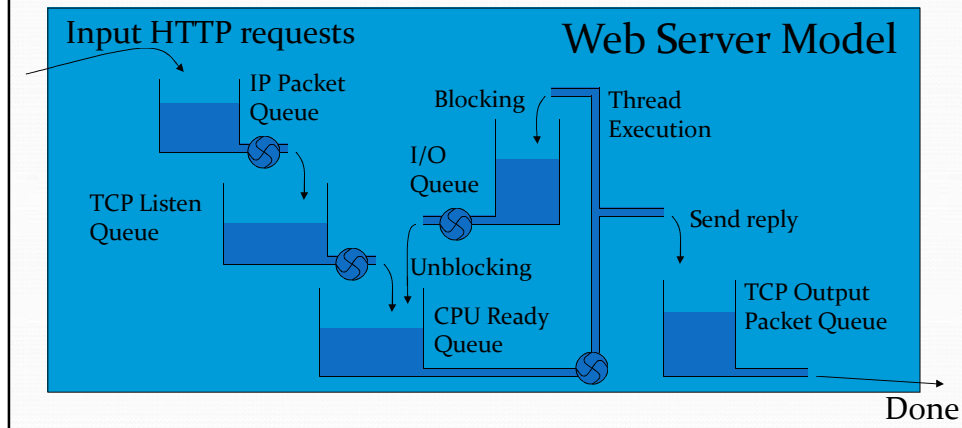
### Software Performance Control

- Ensuring stability of individual software feedback control loops
  - Delay control
  - I/O rate control
  - Utilization control
  - ...
- Dynamic models of queuing systems
- Linear approximations of software
- Control middleware

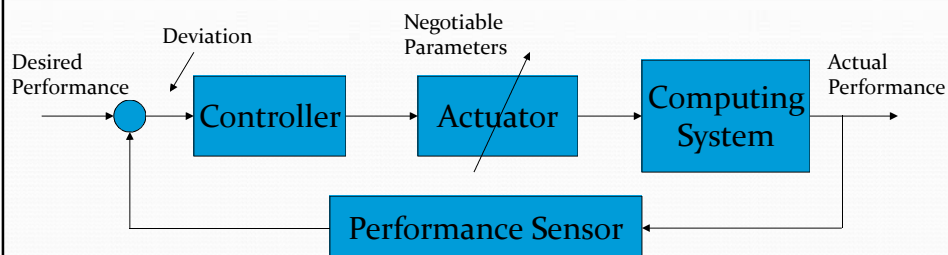
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## Early Example (15 years old): Web Server Modeling

Web servers can be modeled by difference equations!



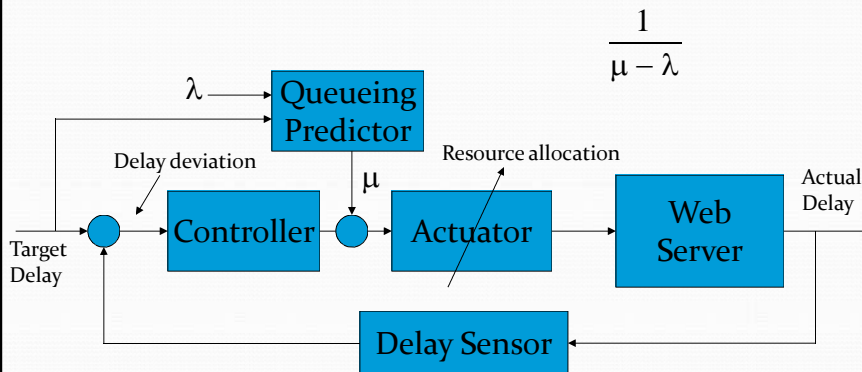
## (15 year old) Example: Control of Computing Systems



- Software is modeled by *differential equations* relating performance and resource allocation
- Sensors measure performance
- Actuators reallocate resources

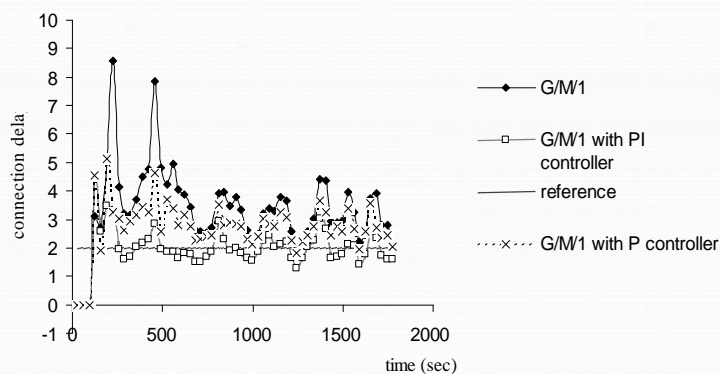
## A Case Study on Delay Control: Delay Control in Web Servers\* (2003)

- Average delay is inversely proportional to average flow (nonlinear control)
  - From queueing theory, delay =



\*This work is in collaboration with Lui Sha and Xue Liu

## Web Server Delay Control Experiment (2003)

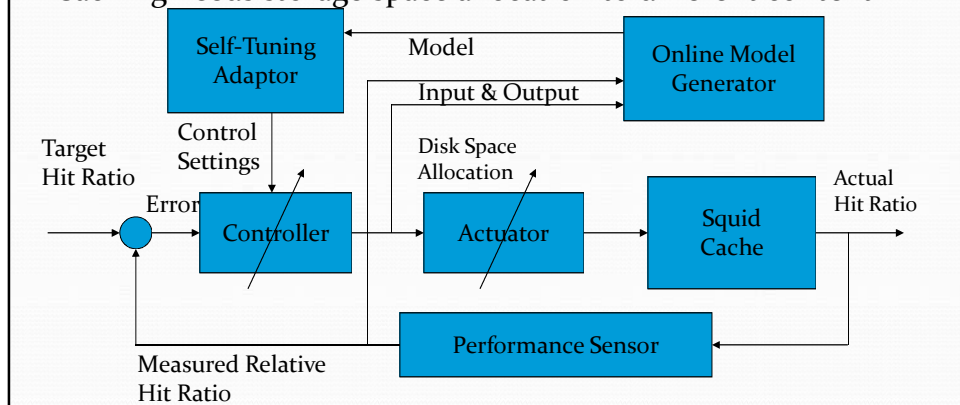


Graphs shown are a subset from Queueing Model Based Network Server Performance Control, by L. Sha, X. Liu, Y. Lu, T. Abdelzaher

\*This work is in collaboration with Lui Sha and Xue Liu

## Adaptive Control of Web Cache Hit Ratio (2003)

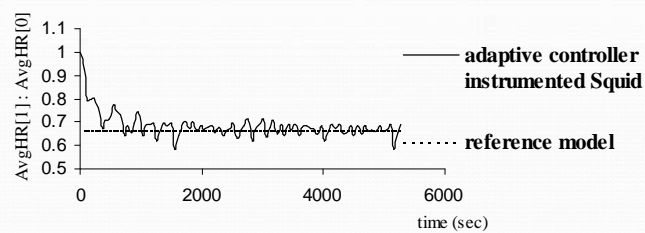
- Internet performance is improved by caching frequently requested content closer to clients
- Caching needs storage space allocation to different content



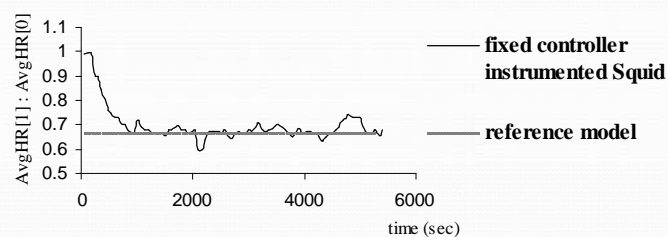
Courtesy of Ying Lu

## Adaptive Controller Performance for Synthetic Log

Experiment with Adaptive Controller



Experiment with Fixed Controller





# So, Is It All Done?

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# So, Is It All Done?

- Not quite...

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