ECE 444 / ECE 544 / CS 444 / CS 544 Supervisory Control and Critical Infrastructure Systems

Session 22

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Many Other Control Options…

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Lecture 20

- Proportional, Integral, Derivative (PID)
  - fairly easy
  - taught in school
- On-off

Computing Applied for Control in ICS

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Lecture 20

- Local Control
  - measurements
    - local calculations] local control that is fast
  - Passing measurements to upstream controls - protocols, timing } slower
    - more data
    - larger system as whole
    - commands back
  - the farther they go
  - especially if human in loop

- modern control
  - state space approach
    - solve differential equations in matrix format (system)
      - true multivariable approach

primarily linear system →
- mathematical transformations to linearize

- model based (model predictive control)
  - using a model of the process to drive control system and improve speed & stability of response

- Control systems
  where the process is too
  difficult to model with
  simple equations/sets of equations

→ Fuzzy Logic
- Neural Network
- Stochastic
- Interval arithmetic
- Artificial intelligence/machine learning
- Statistics

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Computing Applied for ICS at Different Levels

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Lecture 20

- Communication infrastructure
  - characteristics? - Fast enough request/response timing for the process
  - Reliable delivery of data/commands
  - security
  - Bandwidth / Latency
- Supervisory Functions (at control centers)
  - optimization (cost, output, ..., reliability)
  - state estimation
  - contingency analysis (what if...)

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- Autonomous controls - react without human in the loop
  - cost
  - repetitive
- "Advice" for human operators ← preprocessed data or suggested options

Limitations of digital control

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Lecture 20

- Serial processing (Von Neumann bottleneck)
- Managing complexity - tracking bad data
- Real time computing
  - In real time system correct result means LOGICAL/mathematical correctness and timing of result

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- Real Time Response is application specific
  - Power Electronic converter switching at 15kHz
  - Traffic signal controller
    - 1-10 Hz
  - Power system SCADA 2-5 seconds
    → state estimation might be minutes
  - Water treatment facility
  - Pipeline (liquid or gas) - 10's of minutes or more

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Performance Criterias

U I Classifying Real Time

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Lecture 20

Soft Real Time
- allow frequent missed timing deadlines
  - Tasks are still executed correctly still have value (limited delay)
    - Airline reservation system

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Firm Real-Time
- Infrequent deadline misses tolerable <hurt quality of service (but at some point value of output is zero)
  → Video player

Hard Real Time
- missed deadline ⇒ system failure

Backup systems

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Reference Angle is not too Difficult in a Substation

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Lecture 21

- common clock reference to all devices in the station
  - └ IRIG-B
  - could define a reference for all measurements in station

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→ How about substation to substation?

Benefits of External Reference

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Lecture 21

- Phadke and Thorpe→ GPS clock signals
  - proposed over 30 years ago
- Slow adoption
  - 1996 Blackout in ~~west~~ western US
    - post event analysis
    - BPA – installed phasor measurement units
  - 2003

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→ Early applications were post event

→

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- more recent applications
  → model verification/improvement
- Identify modes of oscillation in system = improve stability
- Wide area control ~~system~~ schemes
- wide are protection

] consider consequences of loss of comms.