A tracking-based approach for handling control signal constraints

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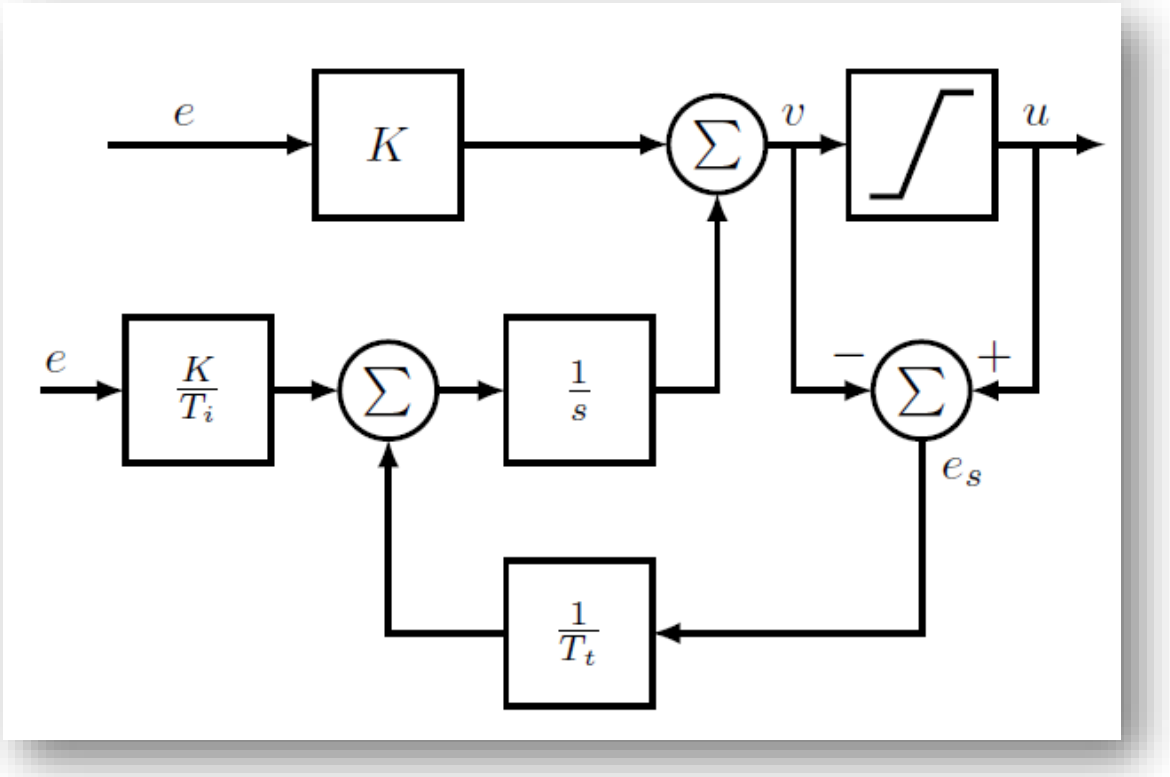
Background

- In many applications of control to computer & communication systems the control signals correspond to some resource that should be shared between a number of users/clients/processes
- For example,
  - Network bandwidth
  - CPU capacity
  - .....
- Limited resource → constraint on the sum of the control signals

Modern Control Solution

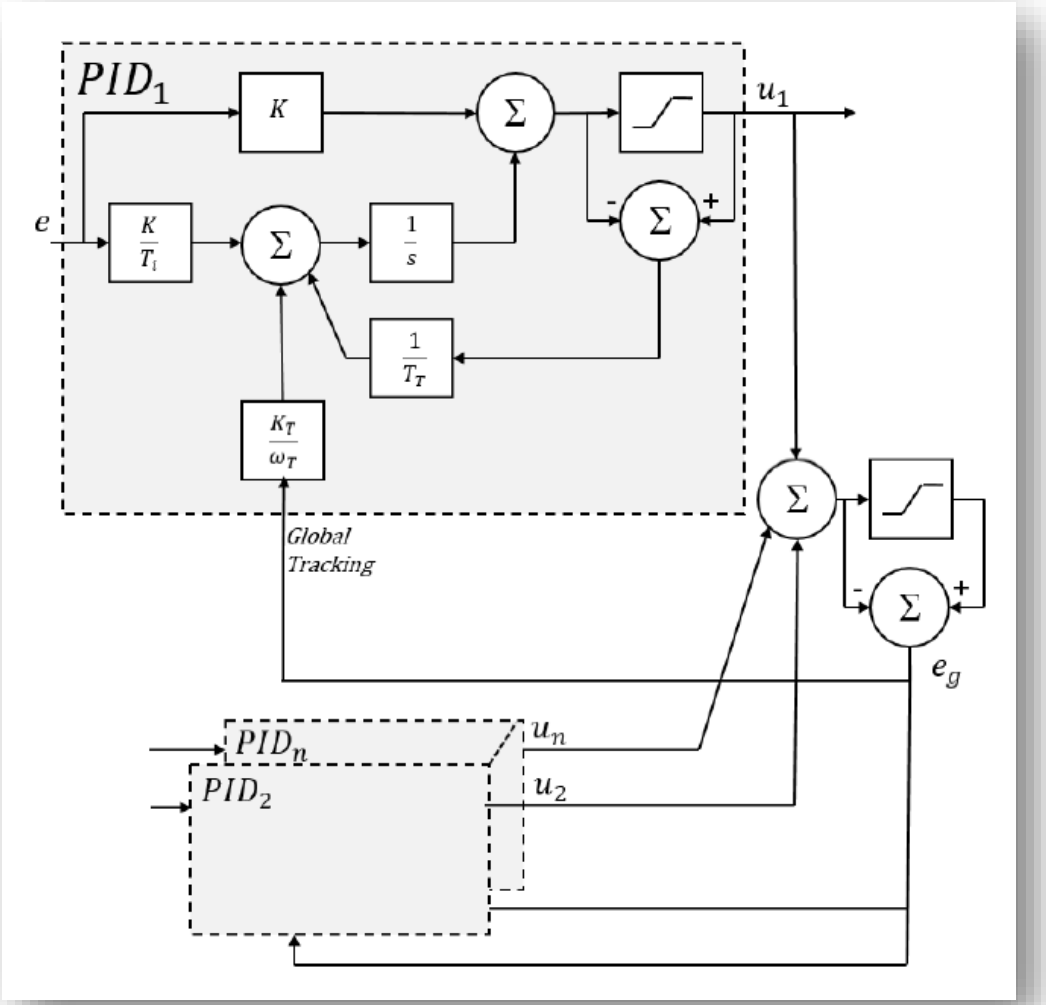
- Model-Predictive Control
  - Can express global control signal constraints
- However,
  - In most cases simple PI(D) controllers are sufficient
  - Want to have a decentralized solution
- Research Questions
  - How can we combine classical decentralized PI(D) control with global control signal constraints?
  - How can we prioritize?

Inspiration: Tracking-Based PID Anti-Windup



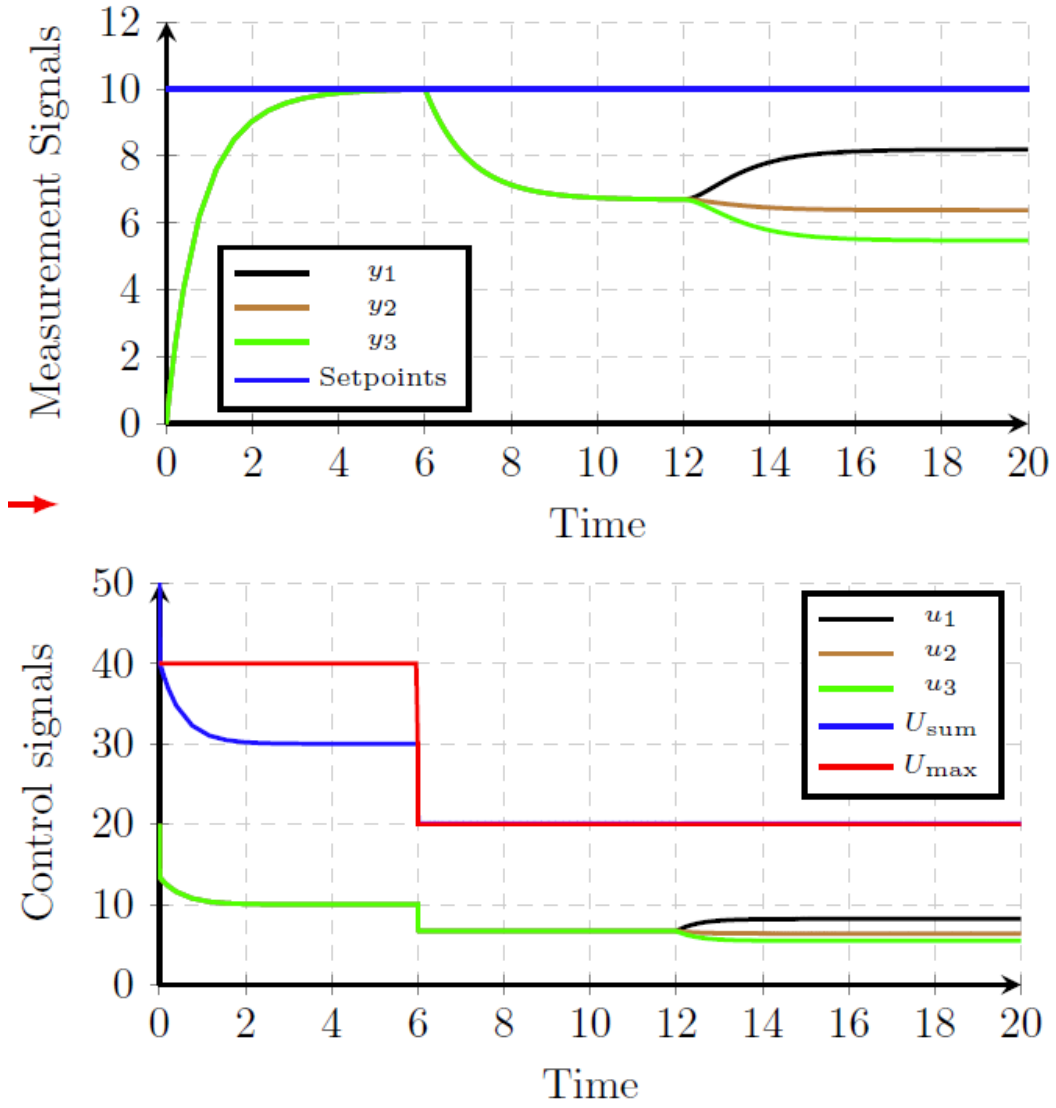
Tracking for Control Signal Constraints

- K_T - Global scaling gain
- ω_T - priority or weight
  - Decides the relative importance among the control loops
  - Large → the loop will not be affected so much
  - Small → the loop will be affected much



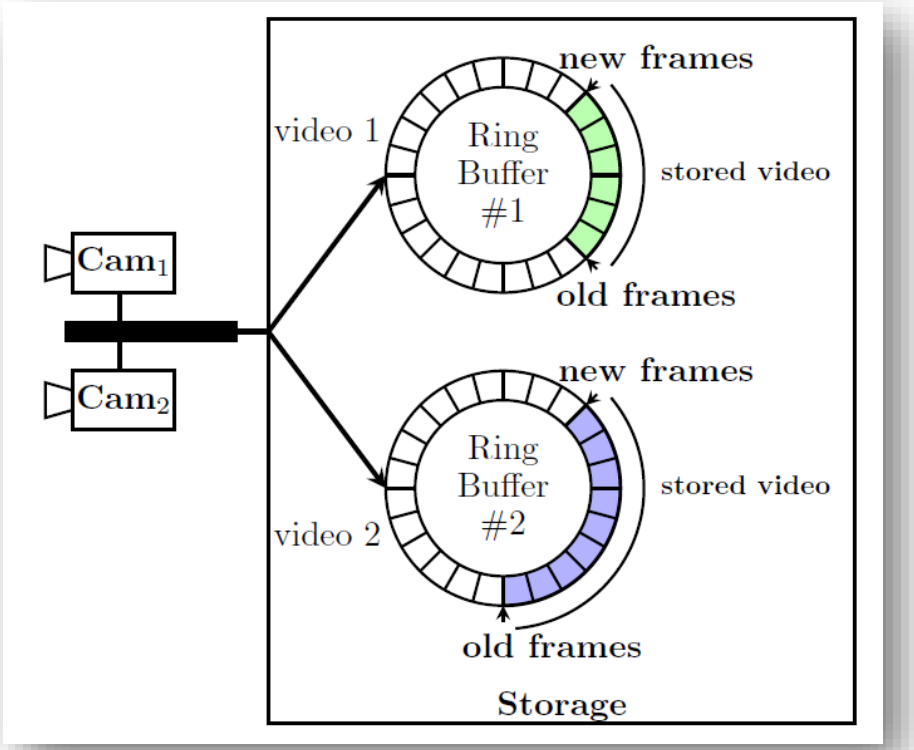
Simple example

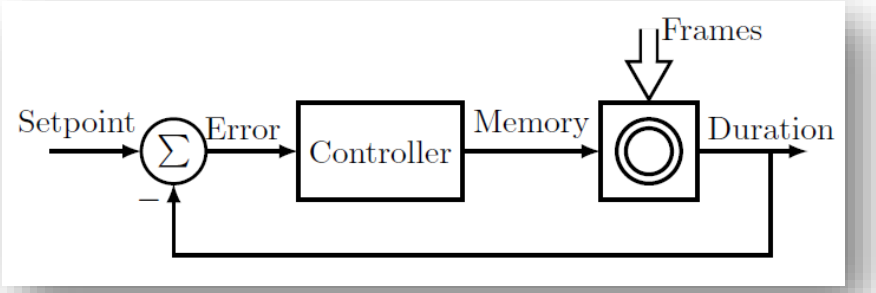
- Three identical first order systems controlled by three identical PI controllers
- $t = 6$ Constraint activated
- $t = 12$ Priorities changed
  - Black - high
  - Green - low



Camera Storage

- Multiple H.264 video streams sharing the same storage disk space (limited resource)
- Stored in separate ring buffers
- Want to control the stored video duration, i.e., the amount of past video stored in memory for each camera
- Control signal = the amount of disk space allocated to each camera





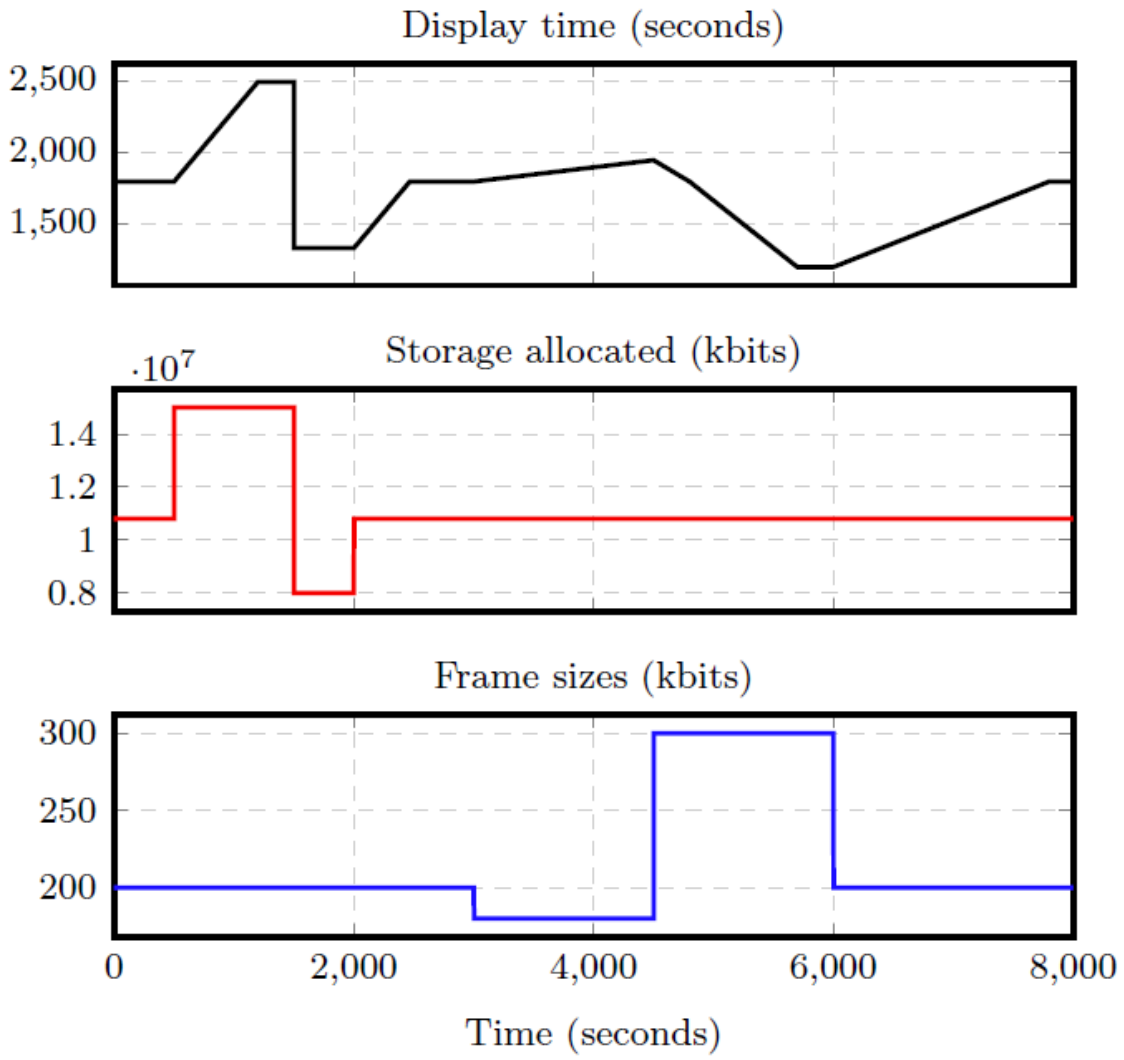
Open Loop Behavior

- Saturated integrator where the gain depends on the frame size

+

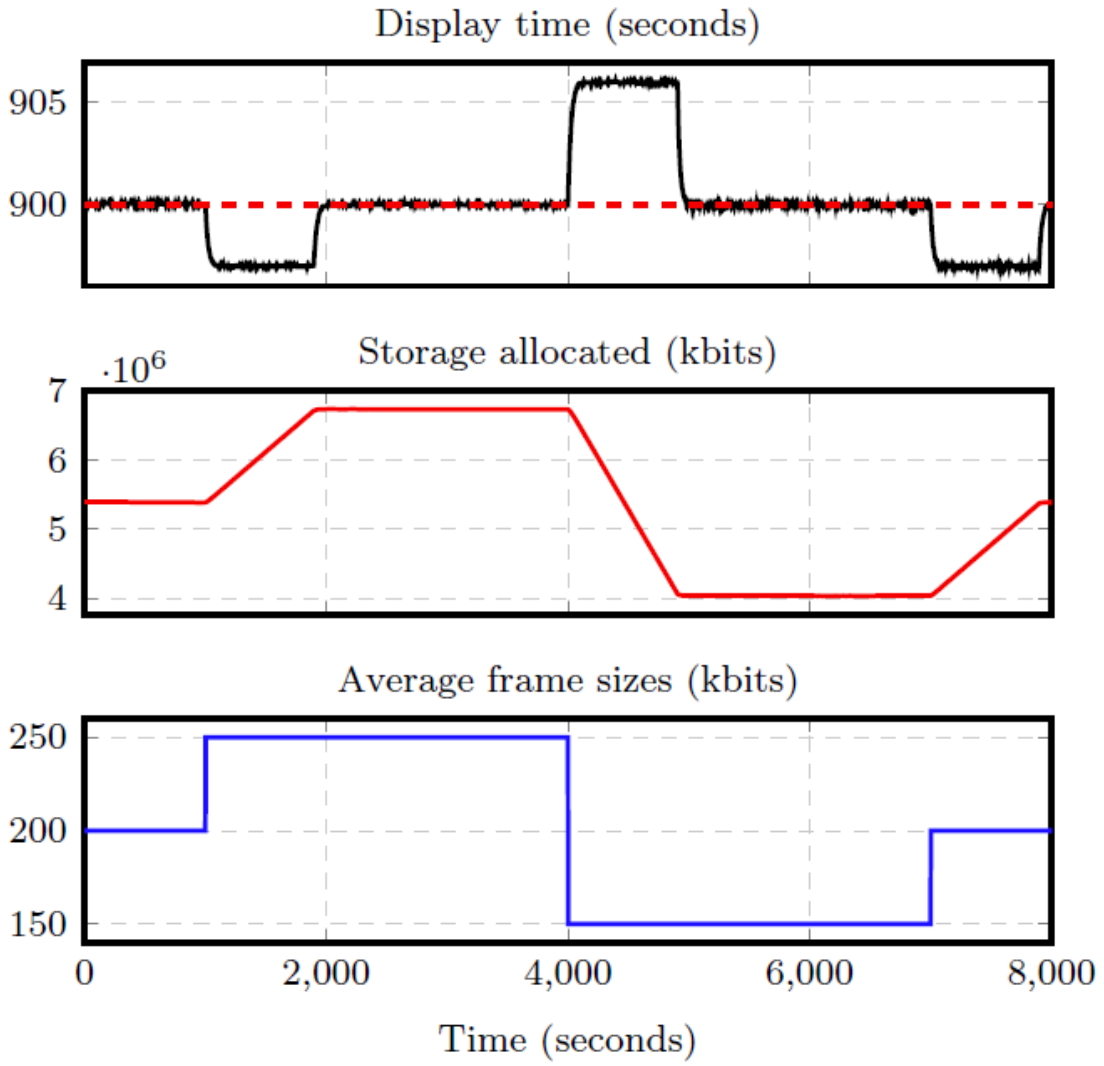
- Instantaneous change when data is flushed

- S-function block in Simulink

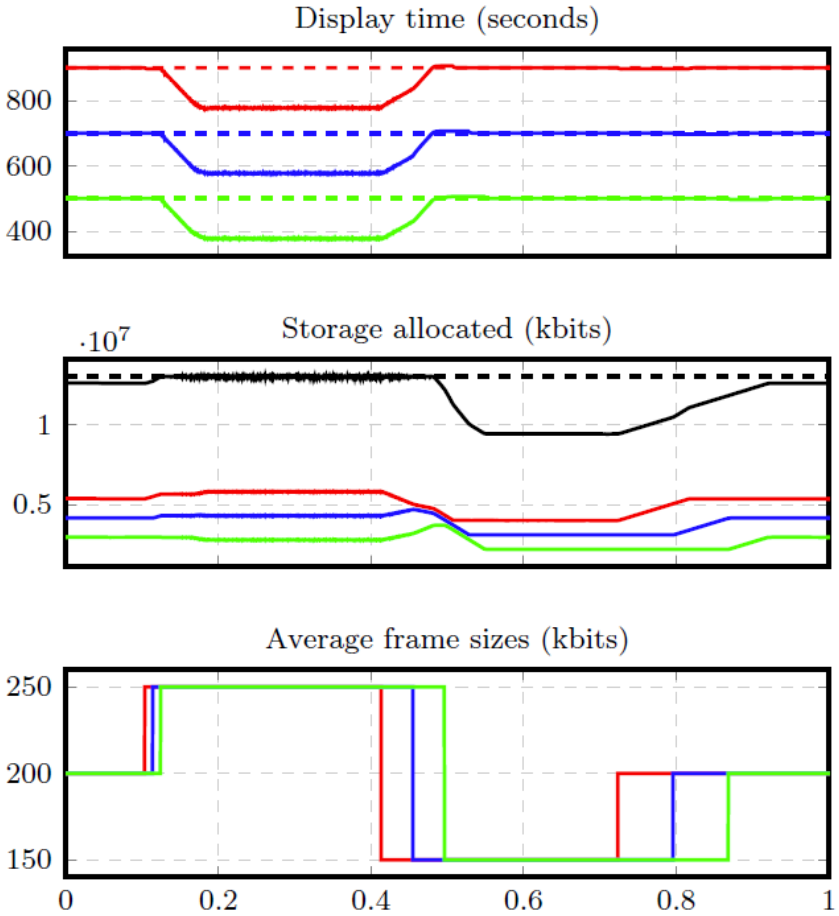


Closed Loop Behaviour

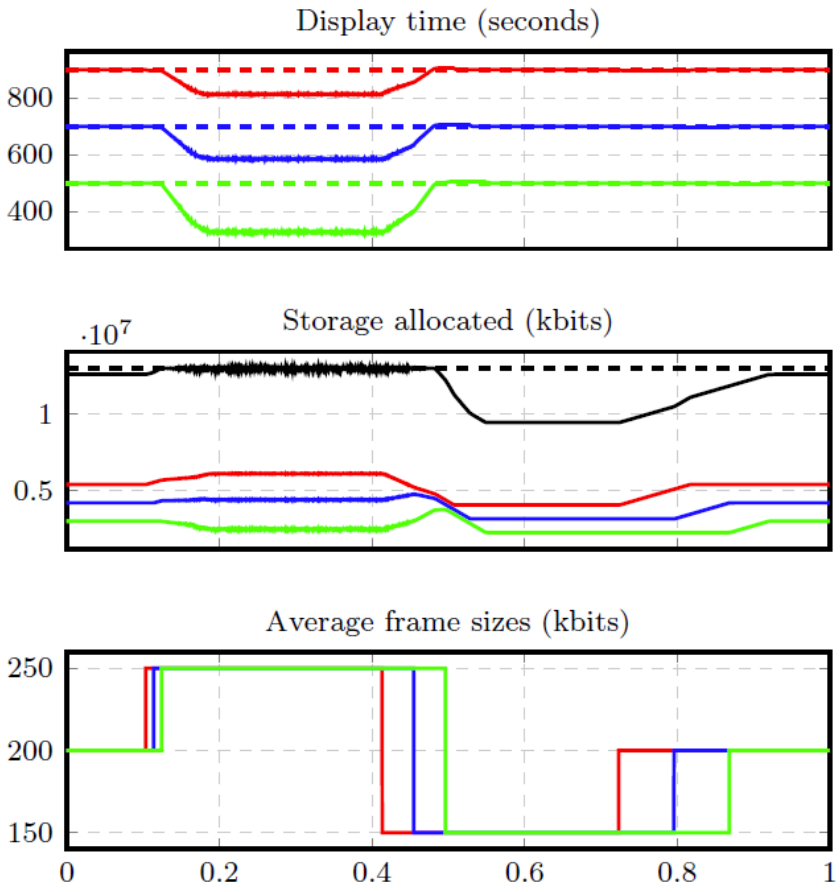
- PI controller
- No resource constraints



Three Cameras



Same priorities



Different priorities

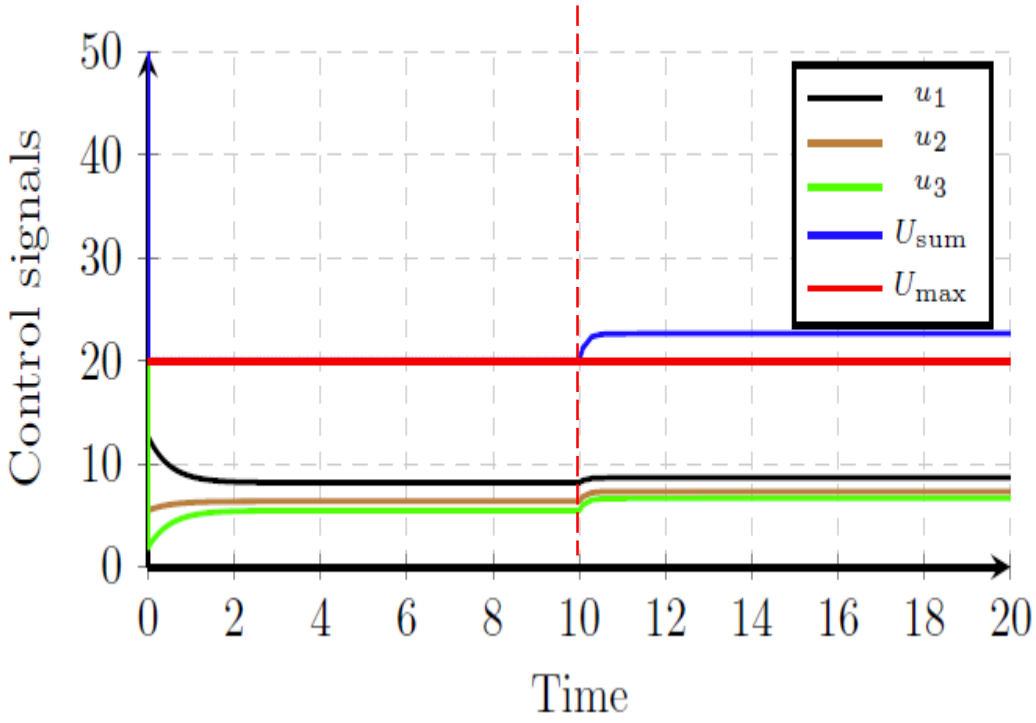
Does this always work?

- No!
  - No guarantees → soft constraints and safety margins
  - Undesired equilibrium

$$\forall k, (K_k/T_{Ik})e_k + (K_T/\omega_k)e_g = 0$$

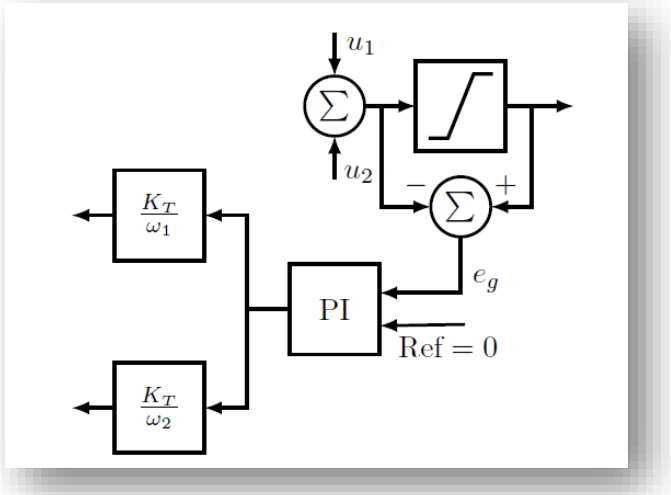
  - When tracking gain K_T is too small
  - Solution: Use sufficiently high tracking gain

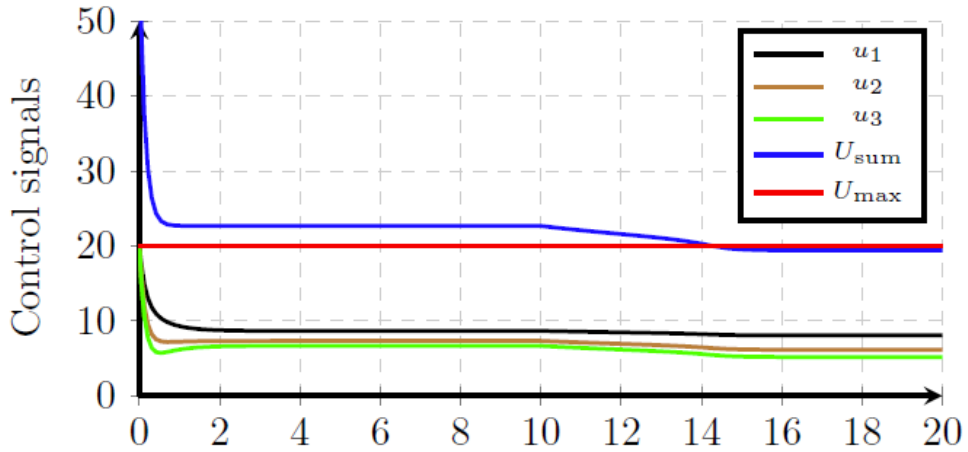
K_T decreased from 100 to 1



PI-Based Global Tracking Feedback

- The tracking gain can be interpreted as a P-controller
- Undesired equilibrium causes a stationary error
- PI control?
  - Can work if properly tuned





More information

- A. Martins, M. Lindberg, M. Maggio, K.-E. Årzén: ”Control-Based Resource Management for Storage of Video Streams”, IFAC World Congress 2020

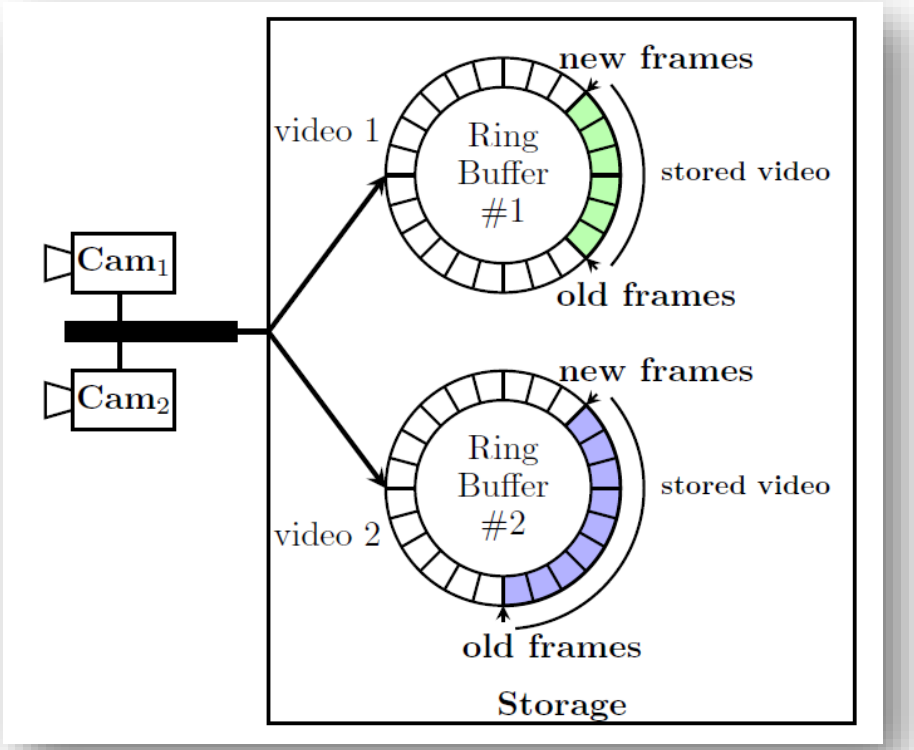
Current work

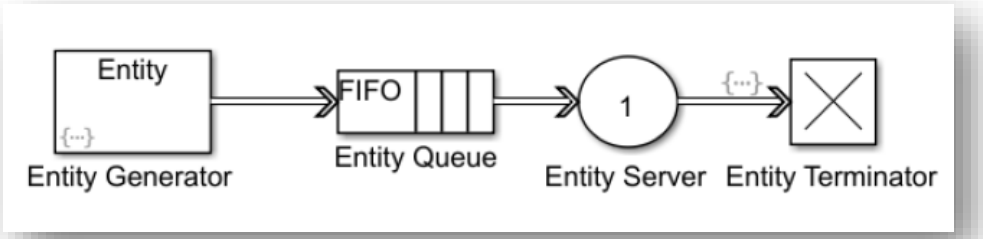
Two tracks:

- Continuation of the control-based approach to resource management for the camera scenario
- Auction-based resource management

Teaser

- Additional control signals
  - Camera compression
  - Frame rate
- Additional shared resources
  - Reservation-based network
  - Depend on each other
  - Simulink SimEvents
- Additional control objectives and modes
  - Stored video duration and latency
  - Stored mode and live mode





Teaser

- Midrange control
  - Valve position control
- Paper in preparation for ACC 2021