EEE499 - Real-Time Embedded System Design

Real-Time Embedded (RTE) Applications

ROYAL MILITARY COLLEGE OF CANADA
ELECTRICAL & COMPUTER ENGINEERING

GÉNIE ÉLECTRIQUE ET GÉNIE INFORMATIQUE
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RMC CMR

Acknowledgement

The original material for this course was developed by Dr. Ron Smith Major (Retired)

Embedded Systems

Definition: a computer system with a dedicated function within a larger mechanical or electrical system. [5]

Embedded Systems

Most of them are real-time and cover some of the same applications.

Applications in:

- Automotive electronics: air bag control, ABS, engine control, etc.
- Avionics, Railways : flight control, anti-collision system, etc.
- Telecommunication: mobile phones, routers, switches
- Health care: pacemaker, hearing aids, etc.
- Etc.

Examples from [6]

Real-time System

"A real-time system is required to complete its work and deliver its service on a timely basis" [1]

Classic Applications

- Digital Control
- Higher Level Control
- Signal Processing
- Telecommunications Systems

Classic Applications

- **Digital Control**
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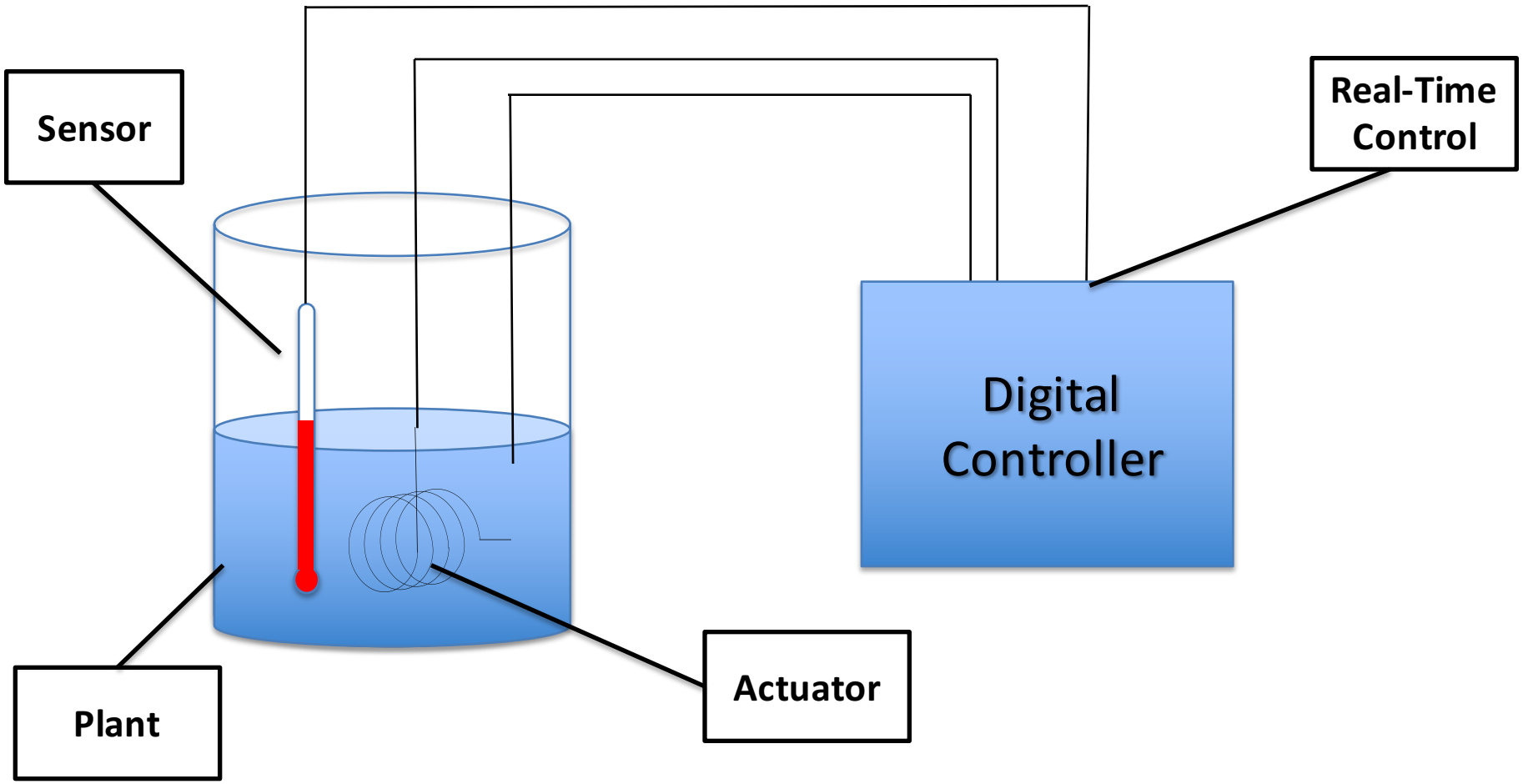
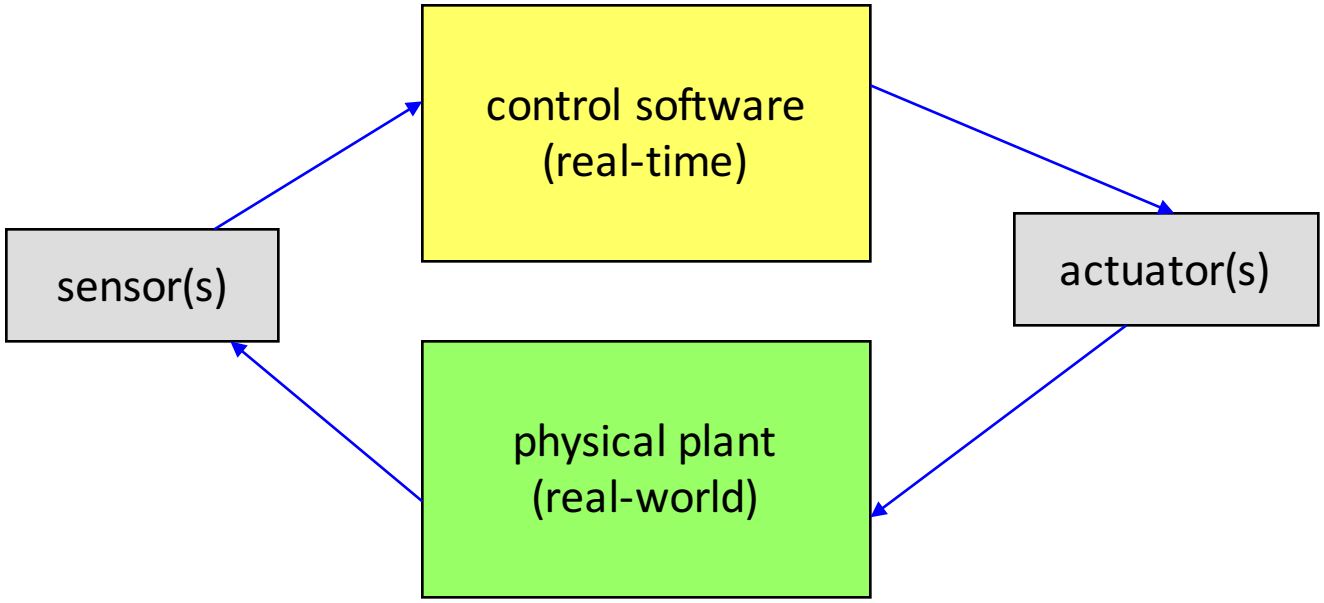
Digital Control

A simple chemical experiment



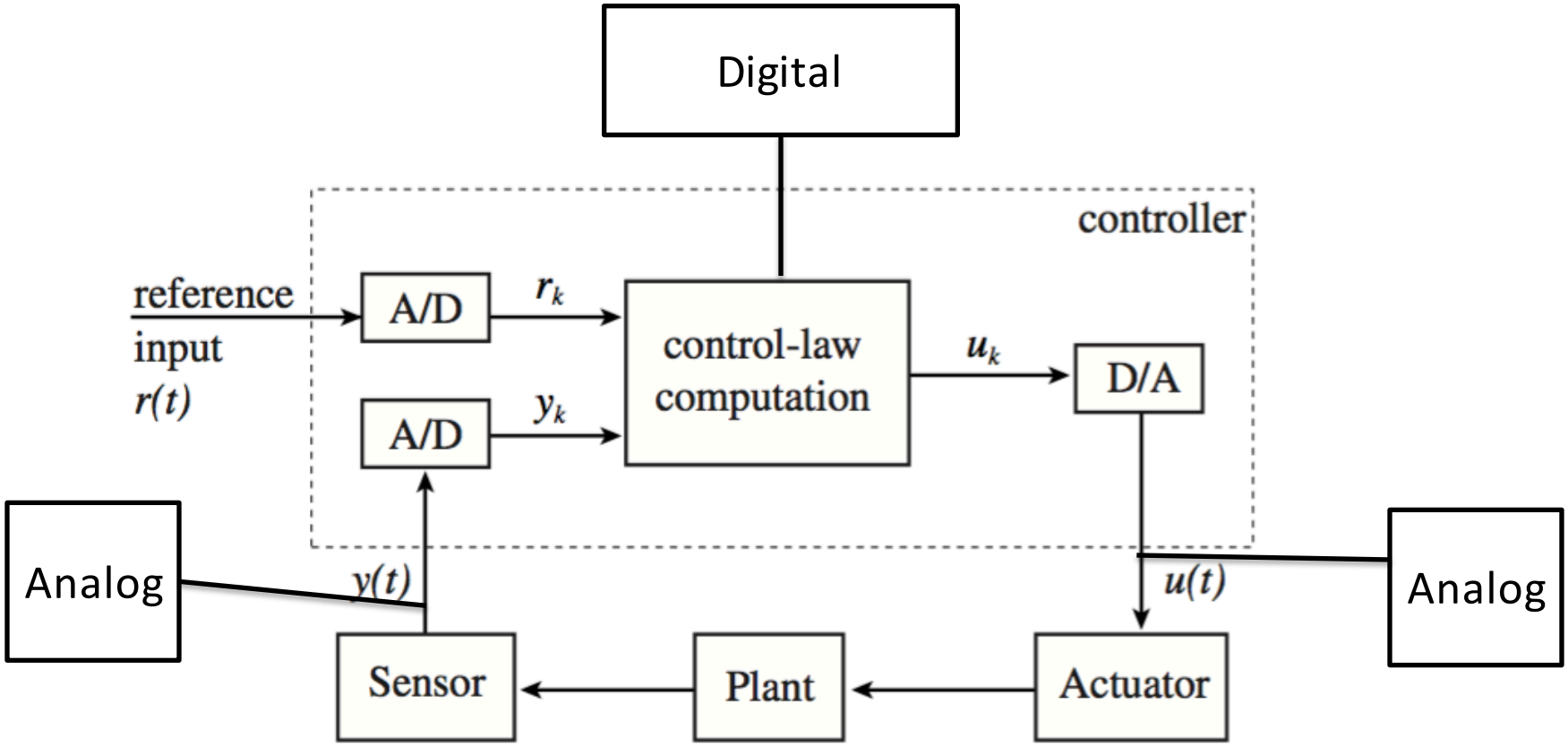
Digital Control

- Our general model:



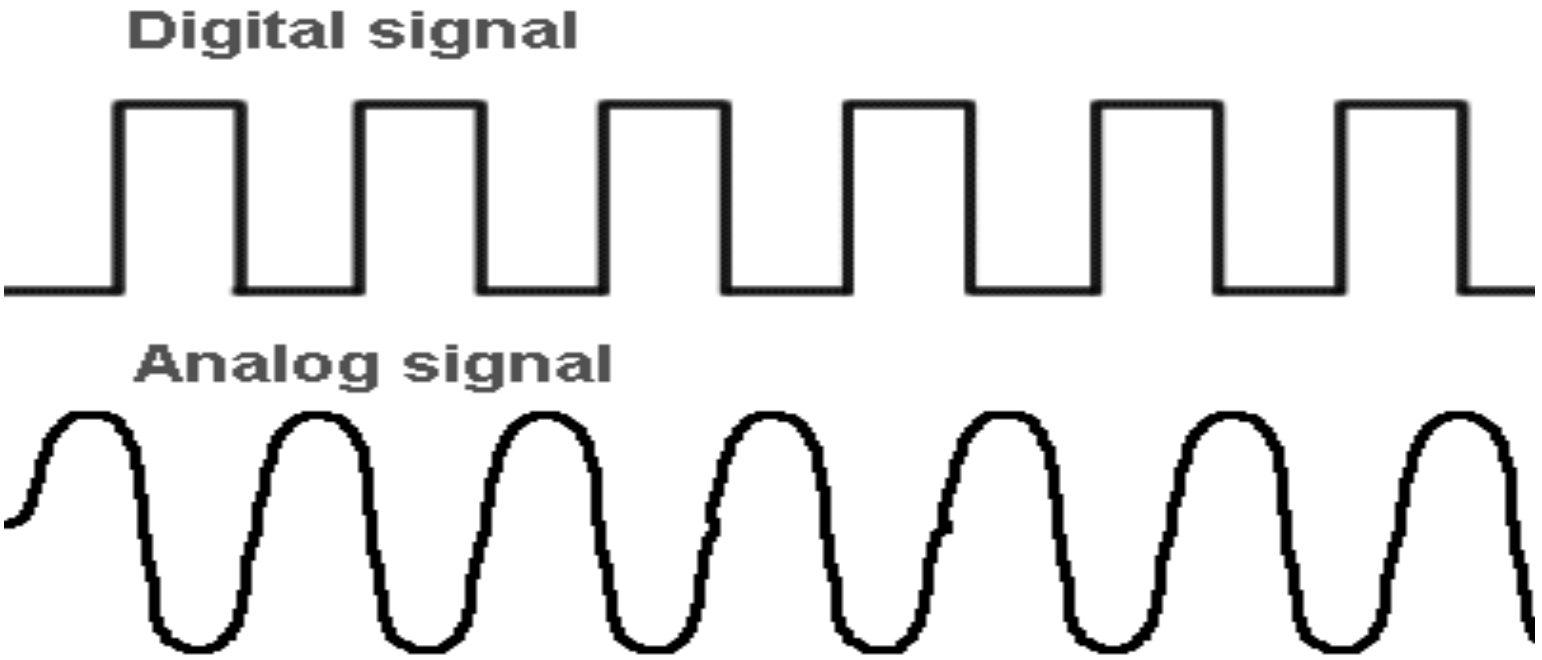
Other examples: Flight Control System, robotic arm, etc.

Digital Control Implementation



(Control loop feedback mechanism)

Digital vs Analog



Digital Control Implementation

- implementation using an infinite loop:

```
while (1) {
    read sensor
    compute control parameter
    control actuator
}
```

What are the implications of this algorithm?

Digital Control (Implementation Criteria)

- **periodicity (sampling rate)**
- latency
- oscillations
- multi-rate systems
  - harmonic
  - non-harmonic

Digital Control

- periodicity (sampling rate)
- **latency**
- oscillations
- multi-rate systems
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Digital Control

- periodicity (sampling rate)
- latency
- **oscillations**
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Digital Control

- periodicity (sampling rate)
- latency
- oscillations
- **multi-rate systems**
  - harmonic
  - non-harmonic

Digital Control

- Multi-rate system example

```
every 5 sec do {          // 0.2 Hz
   collect sensor data
   every 50 msec do {     // 20 Hz
      compute controlled output
      control actuator
   }
   every 100 msec {       // 10 Hz
      check for keyboard input
   }
   every 15 sec {      // 0.06 Hz
      conduct built-in test (BIT)
   }
   wait for next cycle
}
```

Digital Control Examples

- Airplane Navigation System
  - Computing the true velocity, position, acceleration
- Nuclear Power Plant Monitoring
- Street lights

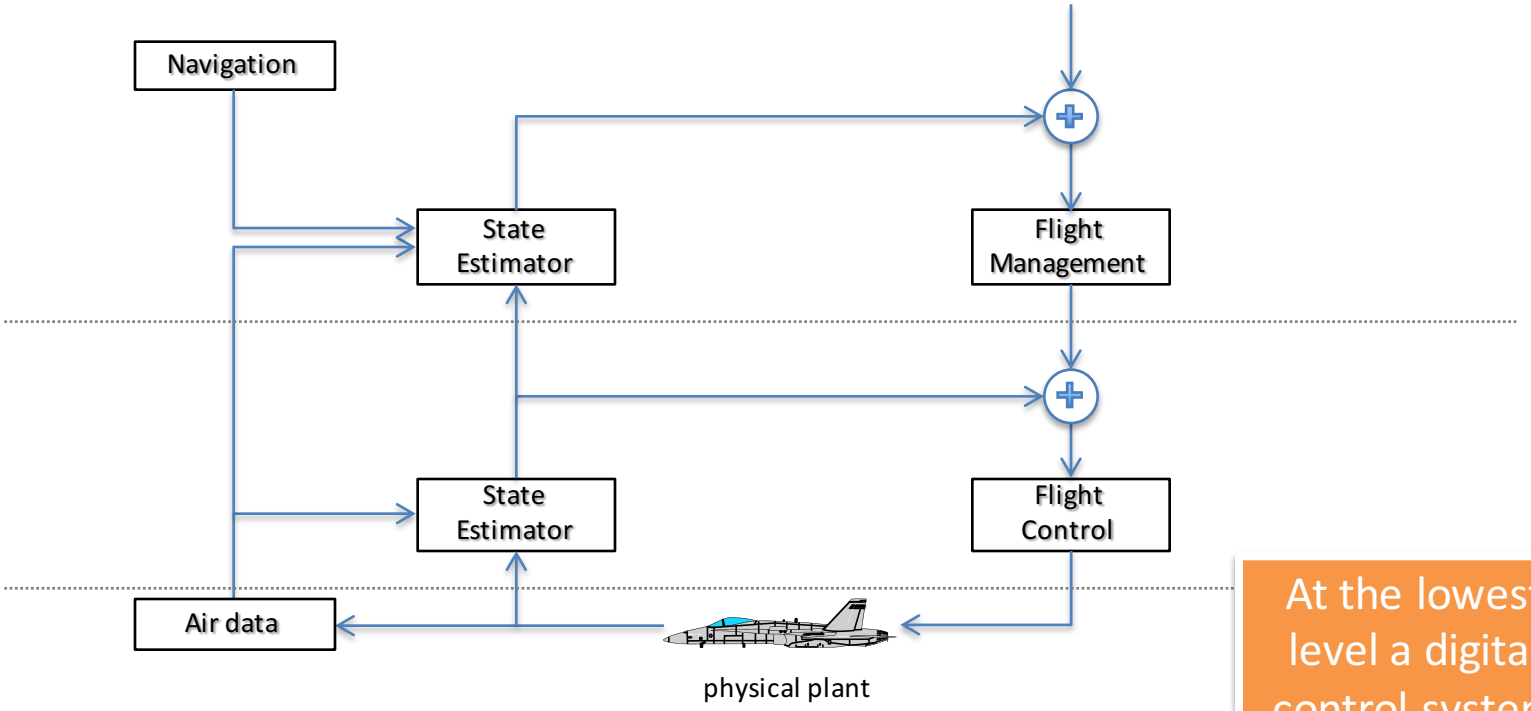
Examples from [4]

Classic Applications

- Digital Control
- **Higher Level Control**
- Signal Processing
- Telecommunications Systems

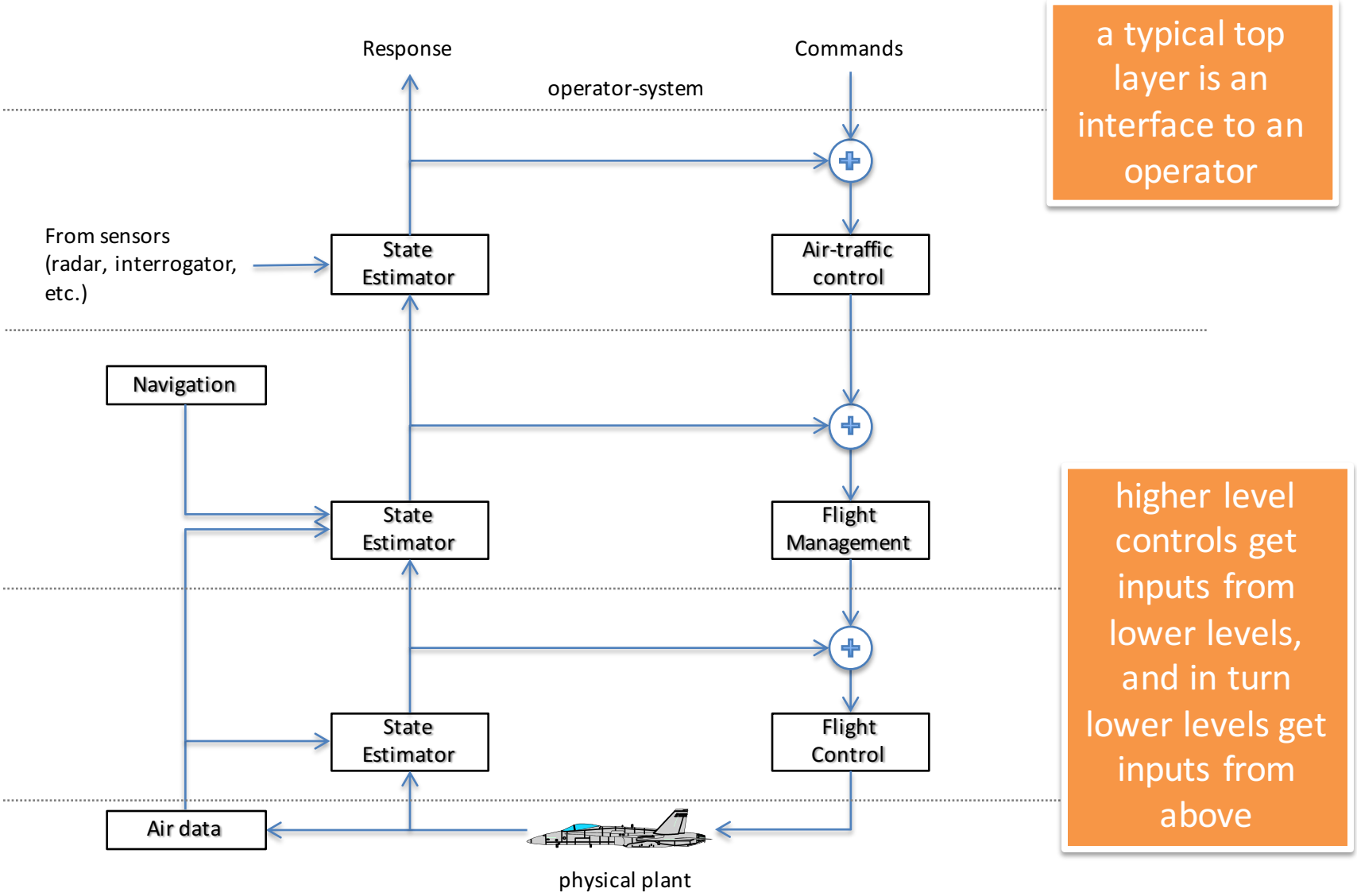
High-Level (Hierarchical) Control

- more complex monitor and control systems are typically hierarchical



At the lowest level a digital control system exists

High-Level (Hierarchical) Control



a typical top layer is an interface to an operator

higher level controls get inputs from lower levels, and in turn lower levels get inputs from above

High-Level (Hierarchical) Control

- straight digital control systems are concerned primarily with external hardware control

- high-level control systems tend to involve
  - planning
  - guidance
  - synthesis …

generally there's an optimization requirement

Classic Applications

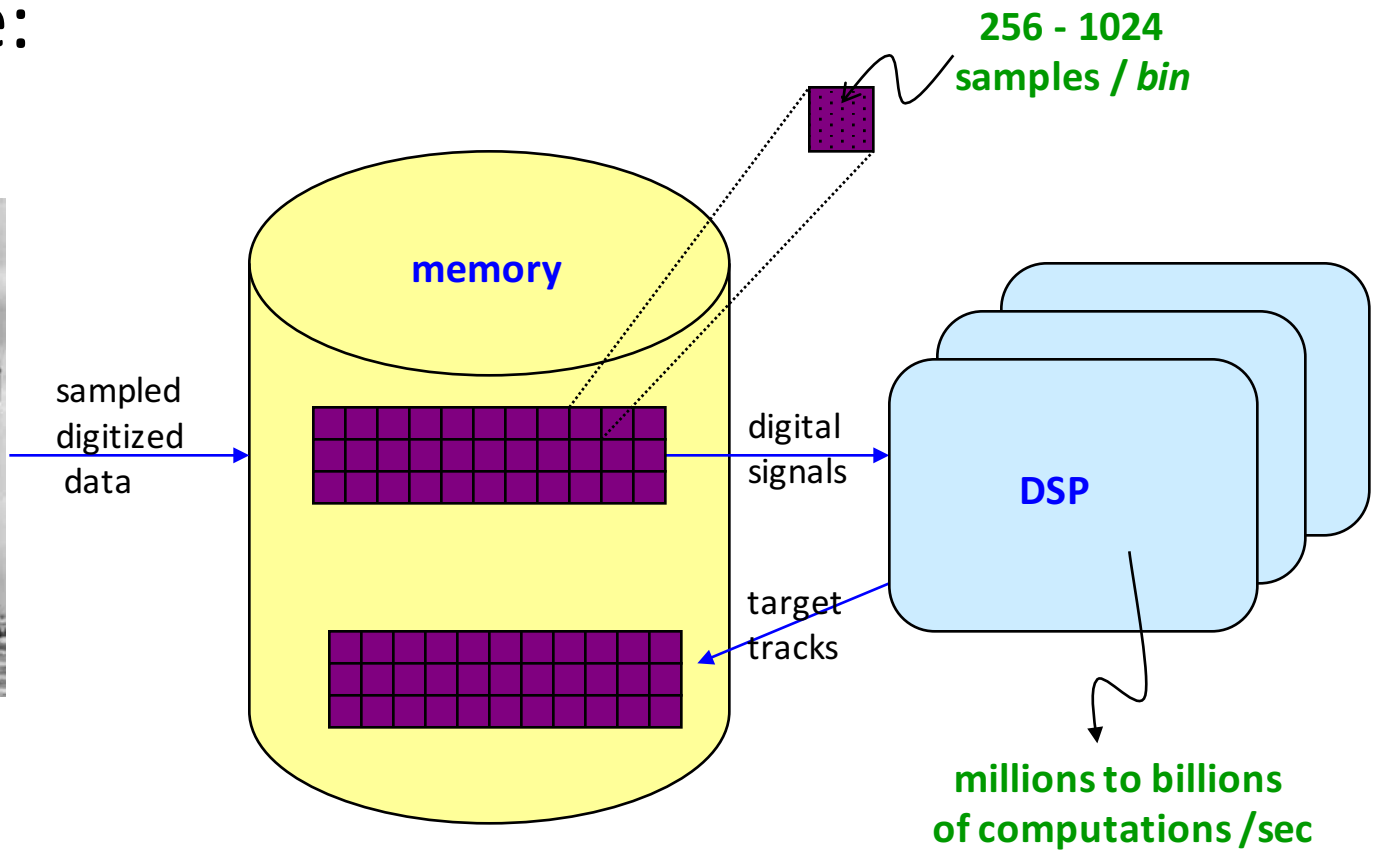
- Digital Control
- Higher Level Control
- **Signal Processing**
- Telecommunications Systems

Signal Processing

- Often has to be real-time as it is involved in the collection/processing of a continuous analog signal
  - voice,
  - image,
  - RF,
  - etc.
- These systems tend to be sampling rate sensitive
- Usually very to extremely computationally intensive
- Often uses specially designed hardware (DSPs)

Signal Processing

- Example:
  - Radar

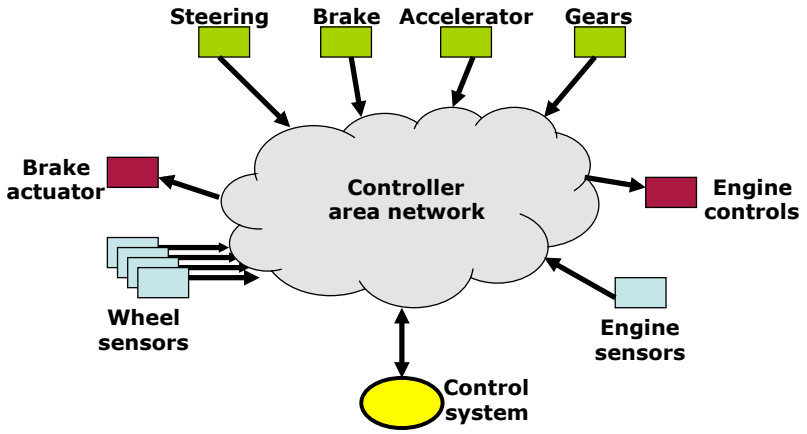


Classic Applications

- Digital Control
- Higher Level Control
- Signal Processing
- **Telecommunications Systems**

Telecommunication Systems

- Multimedia
  - processes, stores, transmits & displays video streams, audio streams, images, graphics and/or text
  - these "raw" media require extreme bandwidth and memory
  - therefore **compression** is central in Multimedia apps
  - example: VoIP, digital video camera, etc.
- Real-time communications
  - Systems are often distributed
  - Communication step involved



Source: Dr. Colin Perkins' Real-Time and Embedded Systems Course

RTE
Software Architectures

- Cyclic executives
- Event-driven systems with both periodic and aperiodic activities
- Pipelined systems
- Client-server systems
- State machine systems

References

[1] Liu, J. W. S. Real-Time Systems. Prentice Hall, 2000.

[2] Smith, R. SOFT426: Real-Time Systems Course. Queen's University, 2004.

[3] Perkins, C. Real-Time and Embedded Systems Course, University of Glasgow, 2007.

[4] Laplante, P. A. Real-Time Systems Design and Analysis, 3rd edition. IEEE Press, 2004.

[5] Wikipedia contributors. Embedded system. Wikipedia, The Free Encyclopedia. January 2, 2018, 03:34 UTC. Available at: https://en.wikipedia.org/w/index.php?title=Embedded_system&oldid=818189332. Accessed January 5, 2018.

[6] Marwedel, P. Embedded System Design, 2nd edition. Springer, 2011.