EEE499 - Real-Time Embedded System Design

Real-Time Embedded (RTE) Applications

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]
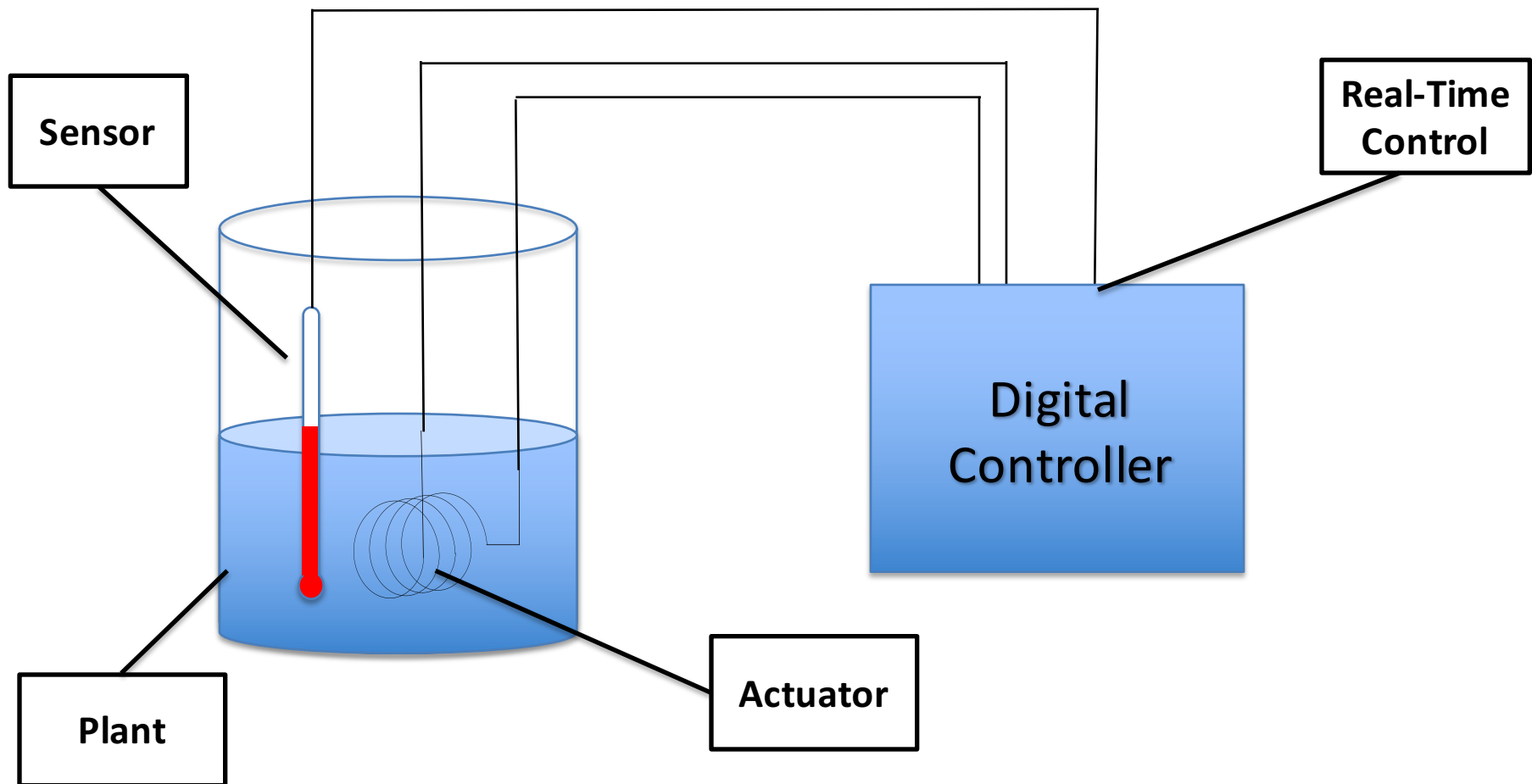
Classic Applications

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

Classic Applications

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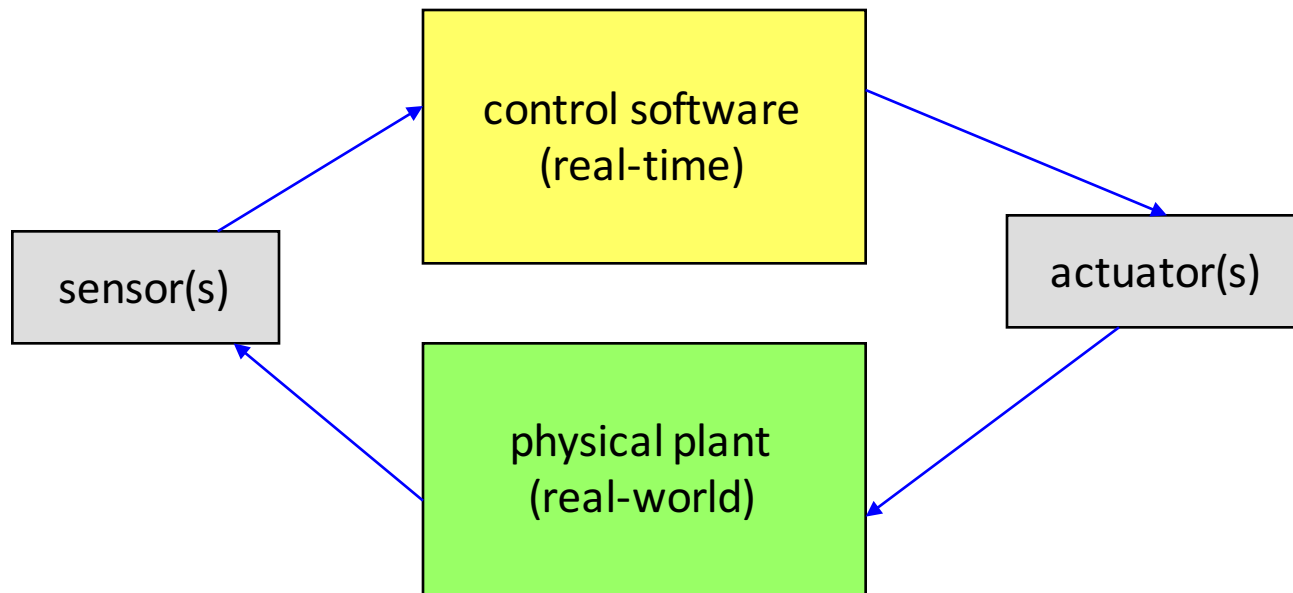- Signal Processing
- Telecommunications Systems

Digital Control

A simple chemical experiment

Sensor

Real-Time Control

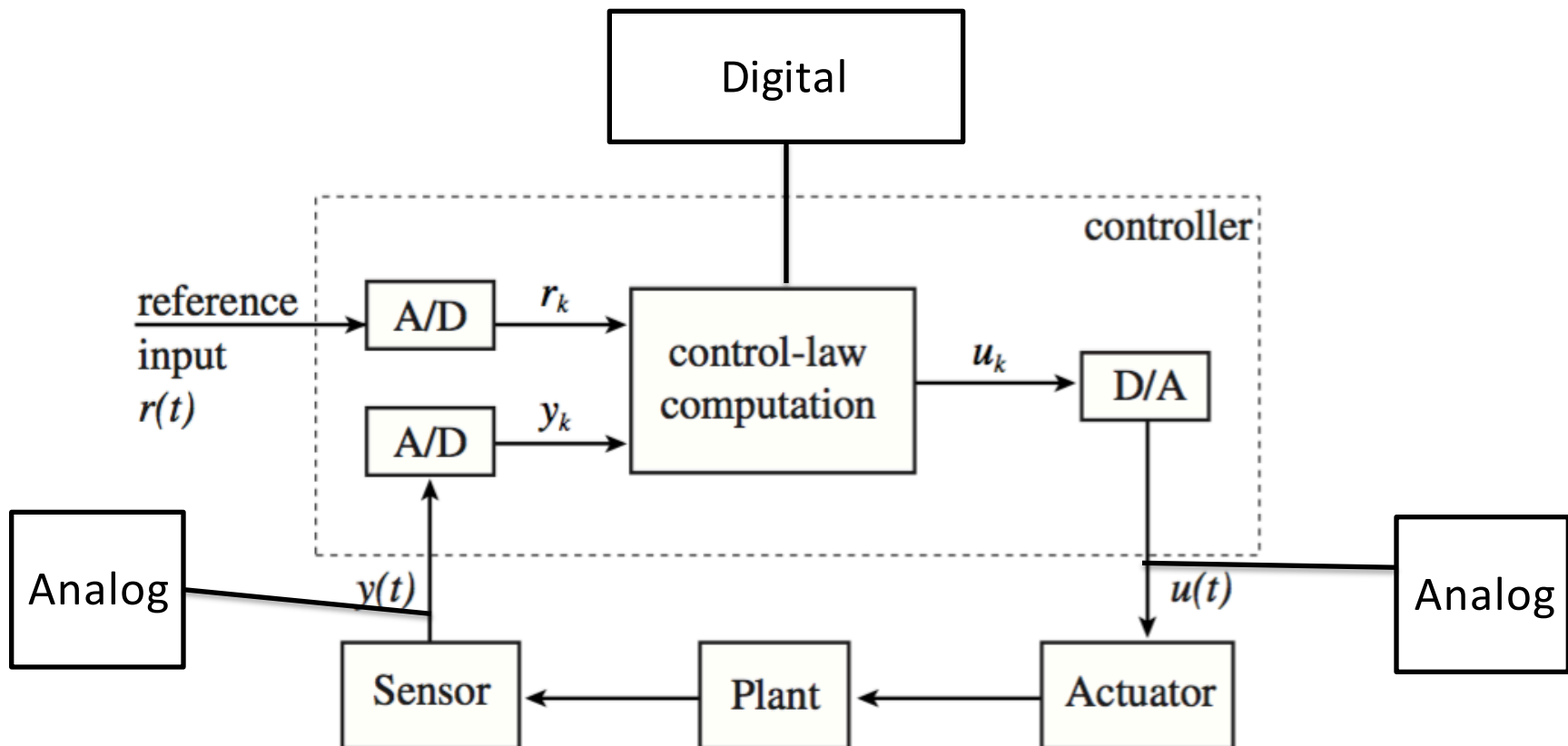**Digital Controller**

Plant

Actuator

Digital Control

- Our general model:

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

Digital Control Implementation

(Control loop feedback mechanism)

Digital vs Analog

Digital signal

Analog signal

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
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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 msec do {            // 200 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 5 sec {         // 0.2 Hz
        conduct built-in test (BIT)
    }
    wait for next cycle
}
```

Digital Control Examples

- Airplane Navigation System
  - Computing the true velocity, position, acceleration

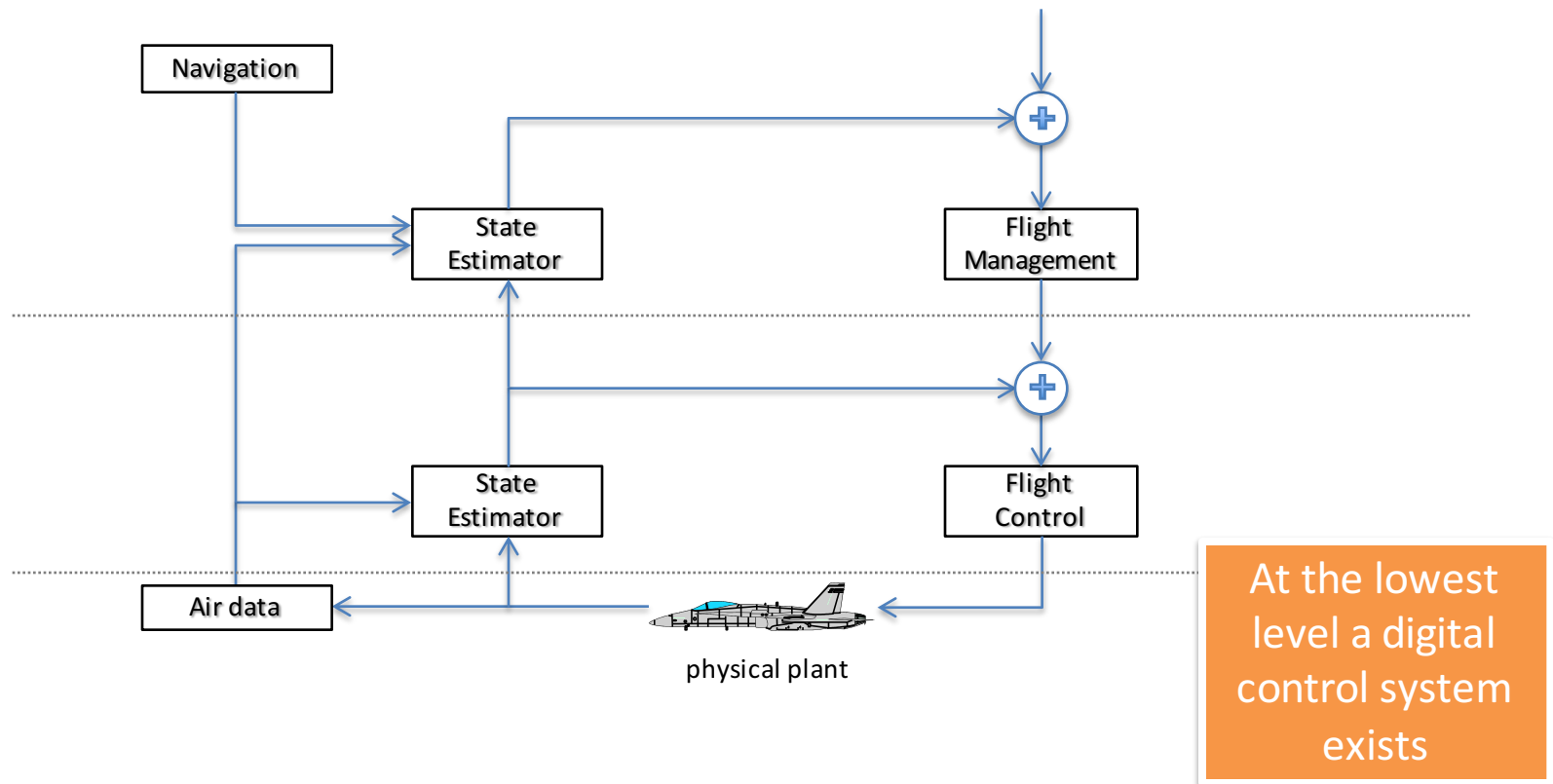- Nuclear Power Plant Monitoring

- Street lights

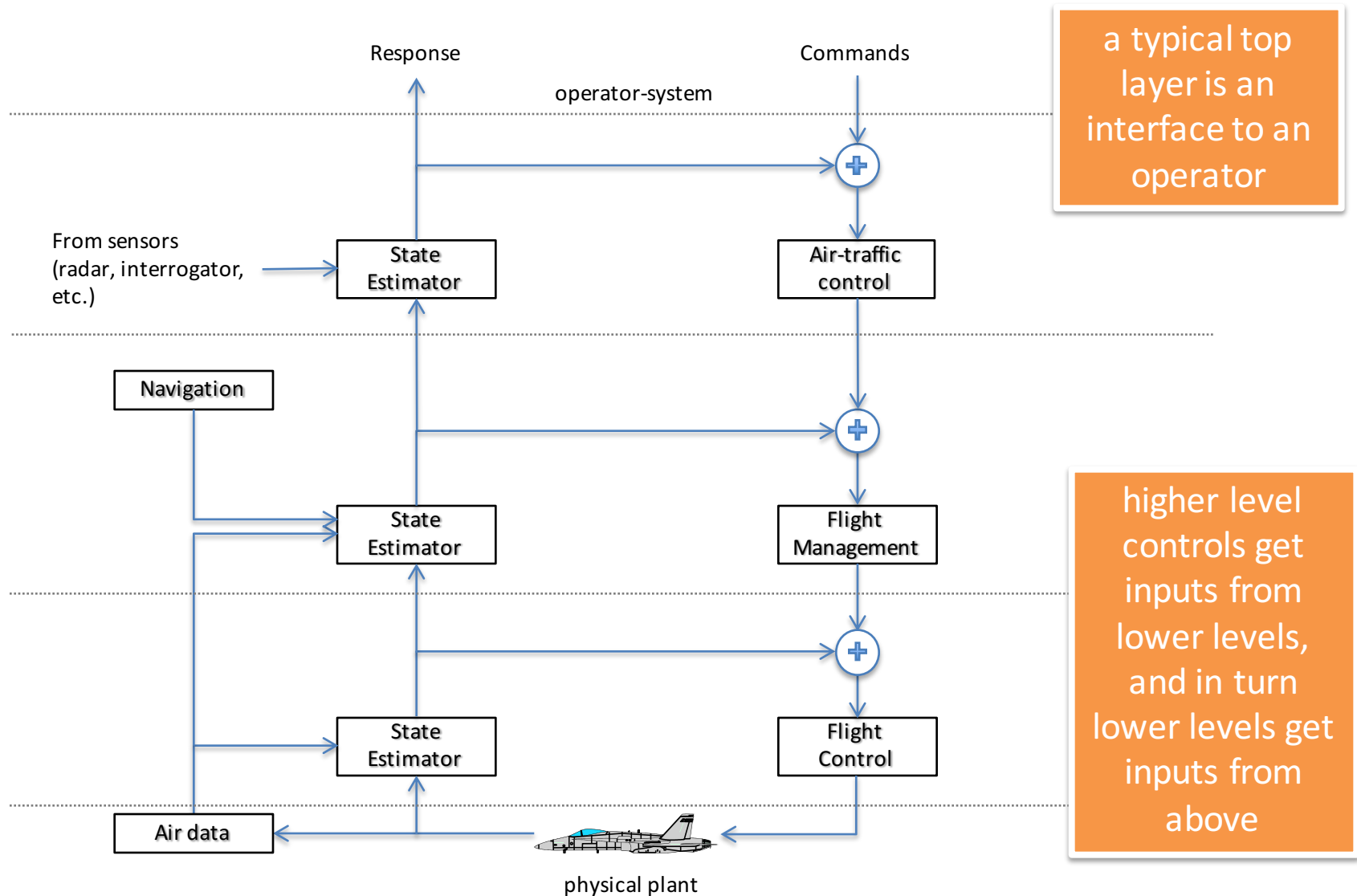Examples from [4]

Classic Applications

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

High-Level (Hierarchical) Control

- more complex monitor and control systems are typically hierarchical

physical plant

At the lowest level a digital control system exists

High-Level (Hierarchical) Control

Response   Commands

operator-system

a typical top
layer is an
interface to an
operator

From sensors
(radar, interrogator,
etc.)

State Estimator   **Air-traffic control**

Navigation

State Estimator   **Flight Management**

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

State Estimator   **Flight Control**

Air data

physical plant

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
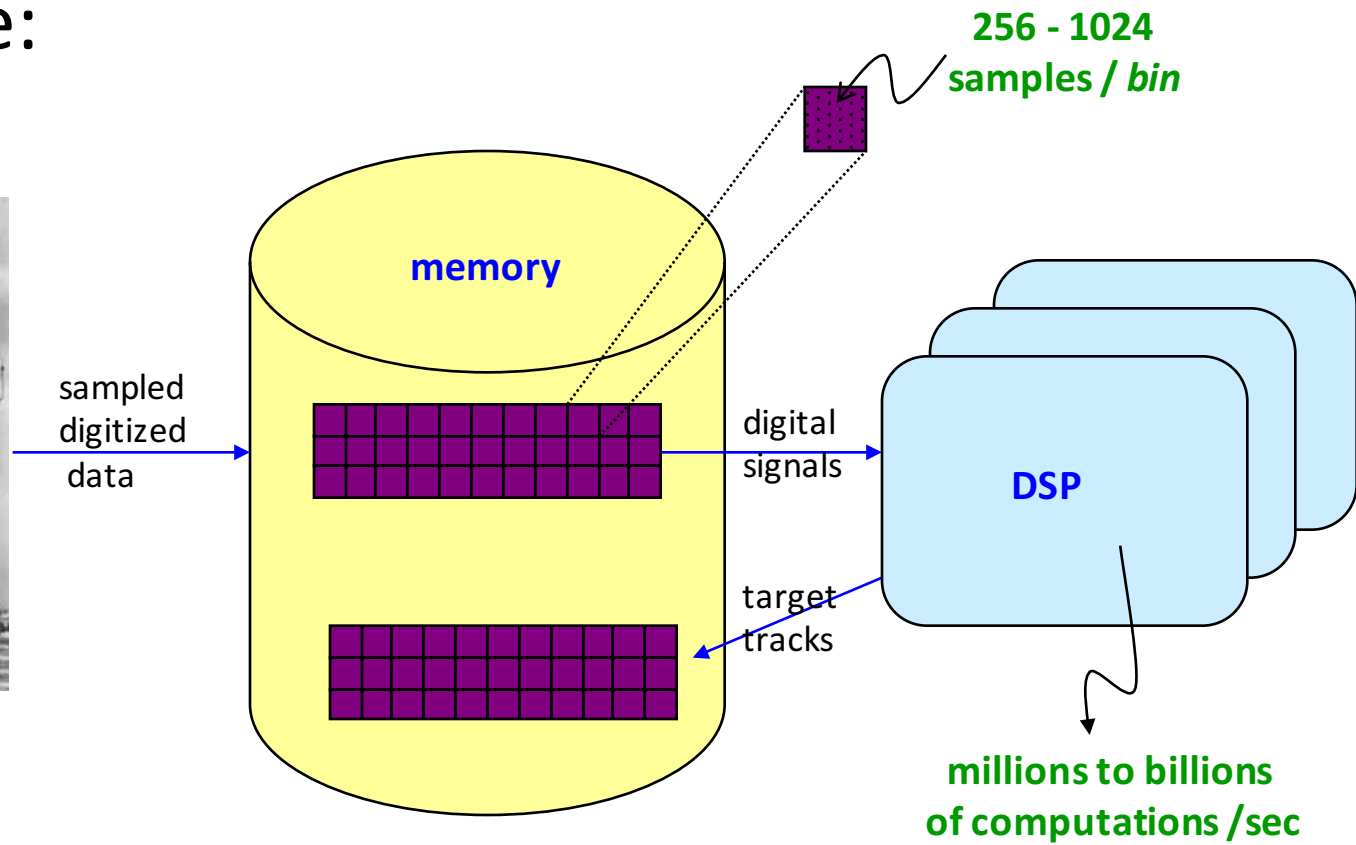
Classic Applications

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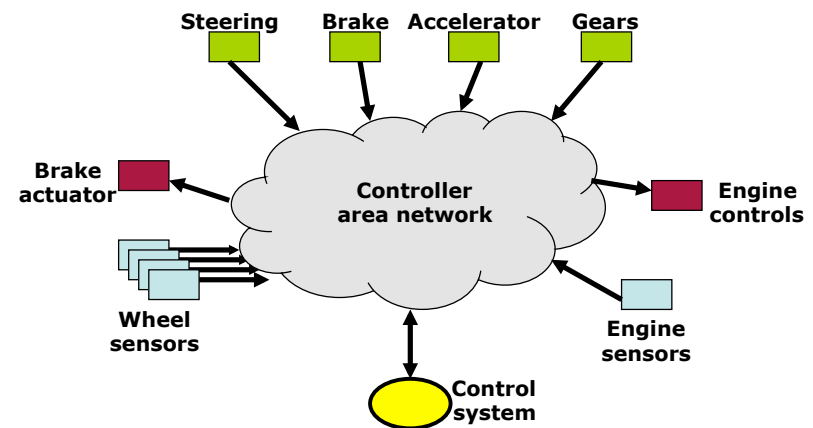
Source: Dr. Colin Perkins' Real-Time and Embedded Systems Course

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.