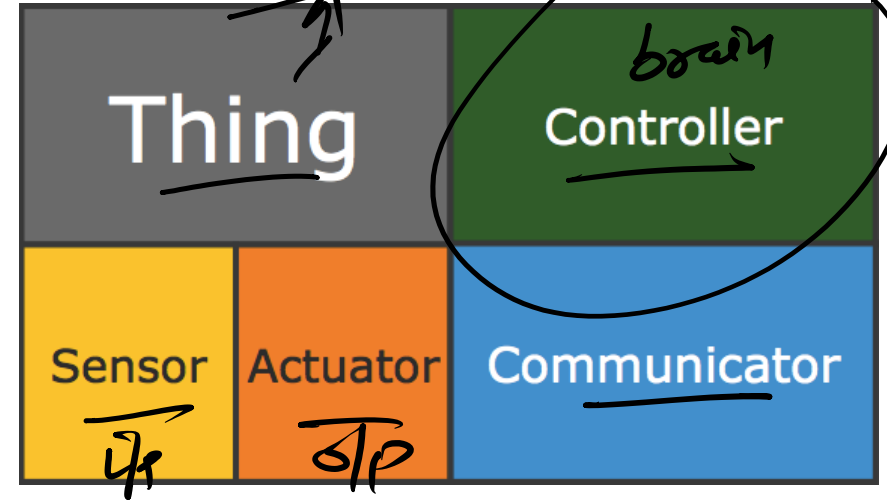


last lecture  
Application of  
IoT

# Components- Embedded Systems

Internet-of-Things

Lecture 5



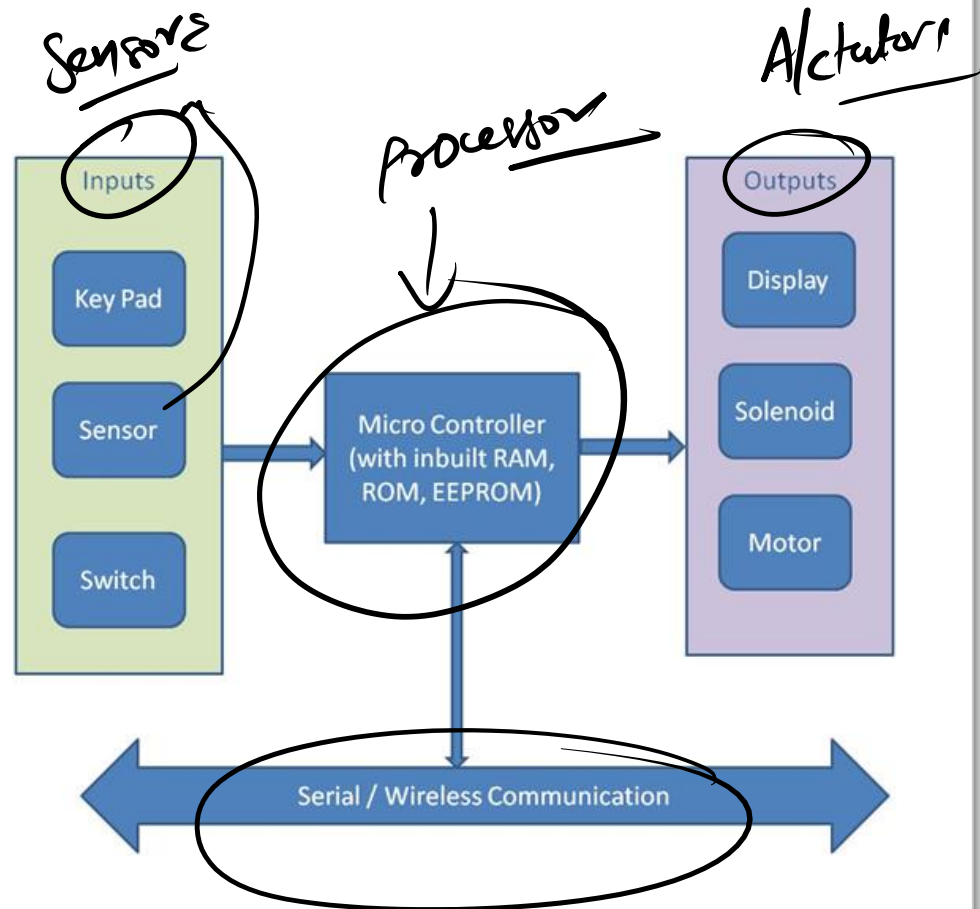
# Components of an IoT Device

# Embedded System/Computer

- “Any sort of device which includes a programmable computer but itself is not intended to be a general-purpose computer” - Wayne Wolf

- General purpose
- Dedicated

specific to some application



# Embedded systems

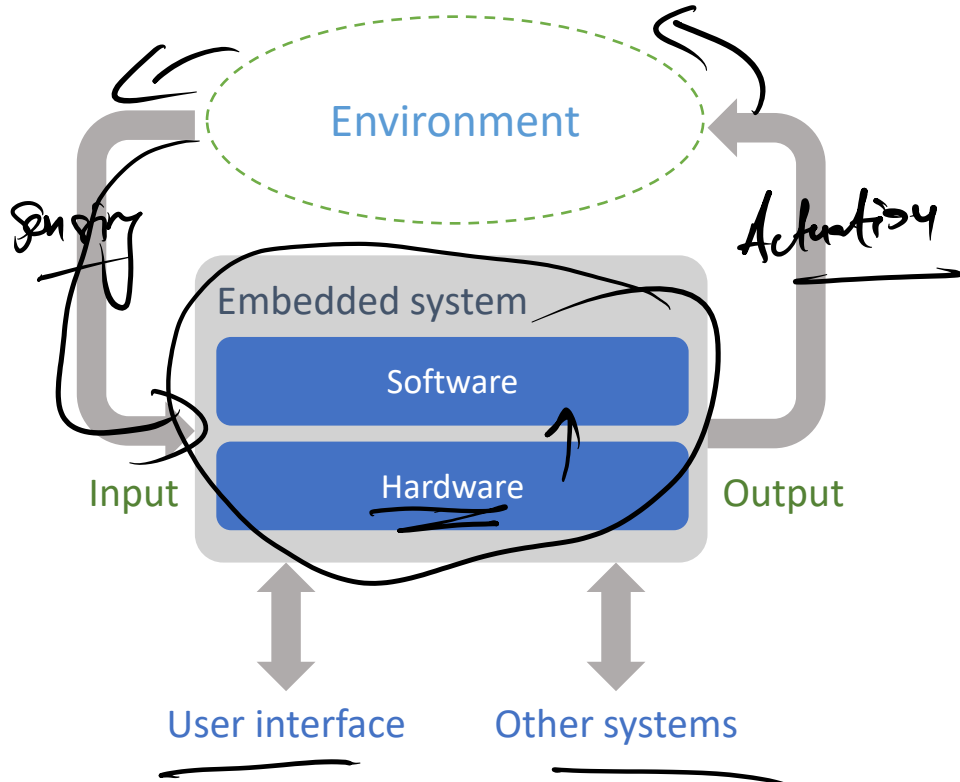
## Internet of Things (IoT)

- Application-specific computer system
- Built into a larger system
- Often with real-time computing constraints

## Adding embedded systems to larger systems

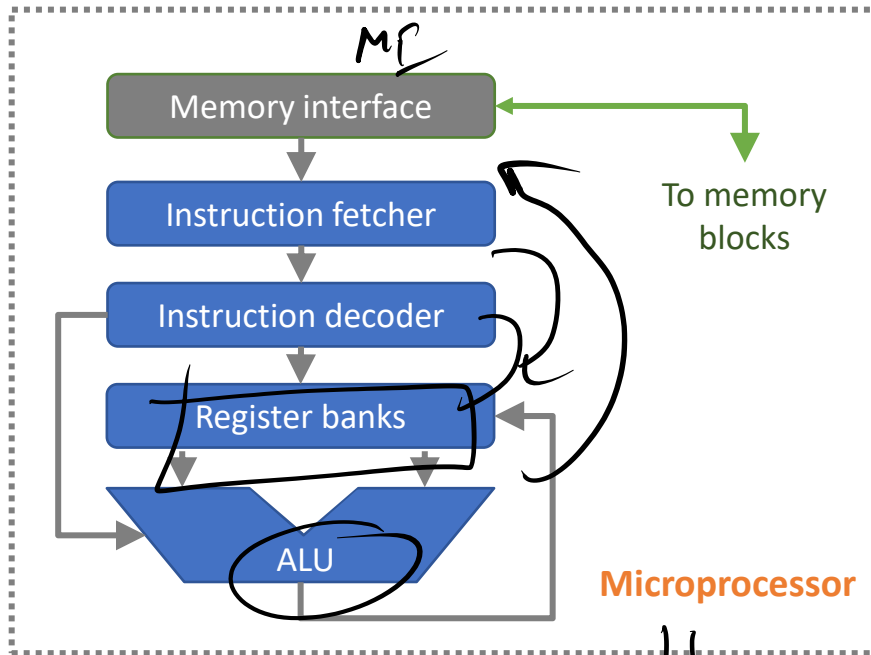
- ✓ Better performance
- ✓ More functions and features
- ✓ Lower cost, for e.g., through automation
- ✓ More dependability

**Examples:** smartphones, smart watches, printers, gaming consoles, wireless routers



# CPU → MCU → Embedded Systems

Microprocessor or Central Processing unit (CPU)



Defined typically as a single processor core that supports at least instruction fetching, decoding, and executing

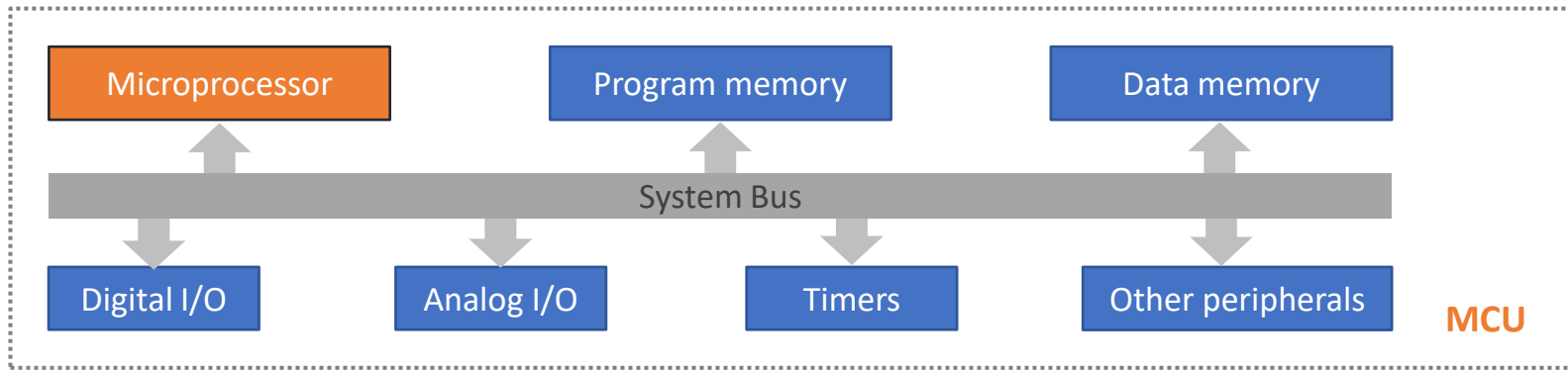


Used for general purpose computing, but needs to be supported with memory and Input/Output (I/O) interfaces

↓  
desktop / computer

# CPUs → MCUs → Embedded Systems

## Microcontroller Unit (MCU)



Typically has a single processor core



Has memory blocks, digital I/Os, analog I/Os, and other basic peripherals



Used for basic control purposes, such as embedded applications

# CPU → MCU → Embedded Systems

## Embedded system



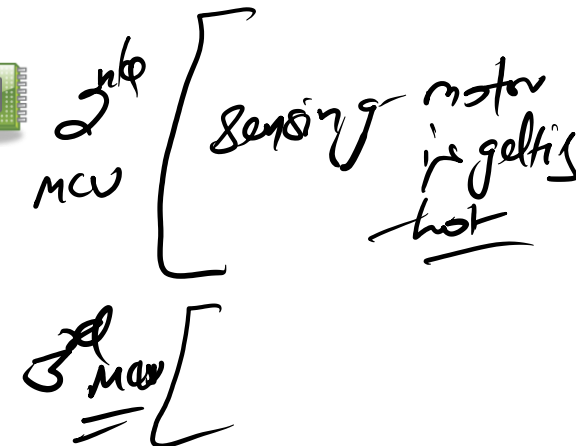
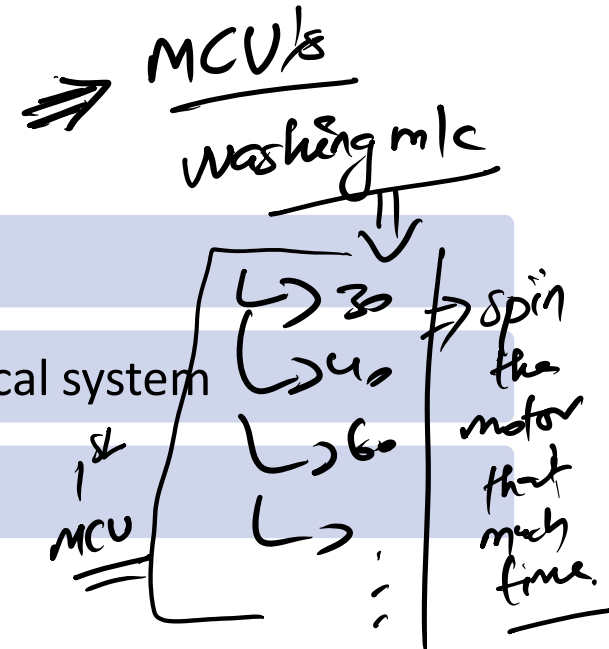
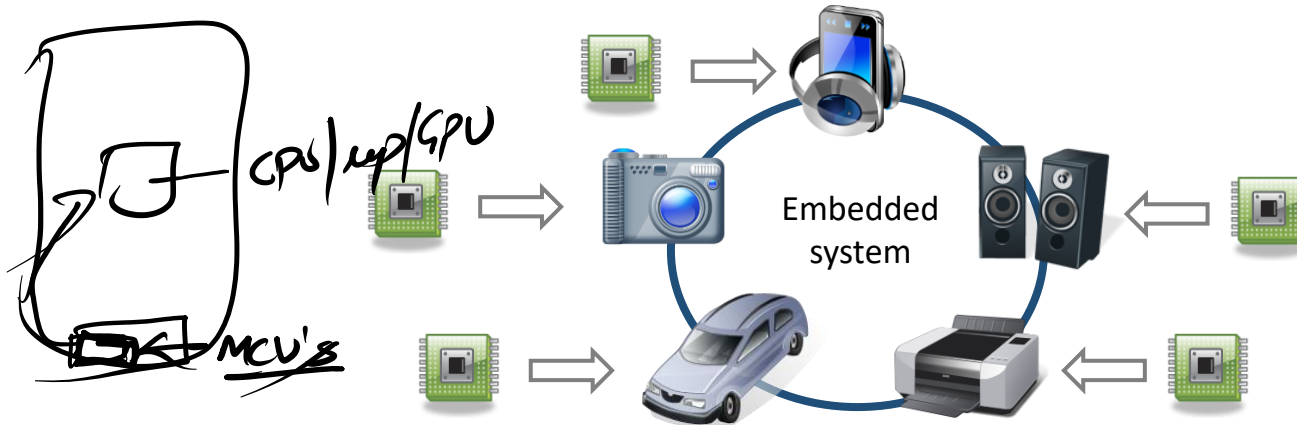
Typically implemented using MCUs



Often integrated into a larger mechanical or electrical system



Usually has real-time constraints



# Embedded system example: Bike computer

only  
one  
MCU

- Functions
  - Speed, cadence, distance, heart rate (HR) measurements
- Constraints
  - Size, weight, and cost; power and energy
- Inputs (Sensor)
  - Wheel rotation sensor and mode key
- Output
  - Liquid crystal display (LCD), BLE interface to smartphone
- Uses low performance microcontroller

Inputs:  
Wheel rotation  
Mode key



Outputs:  
Display/transmit  
speed, HR, etc.



# Embedded system example: Gasoline engine control unit

- Functions

- Fuel injection ✓
- Air intake setting ✓
- Spark timing ✓
- Exhaust gas circulation ✓
- Electronic throttle control ✓
- Knock control ✓

- Constraints

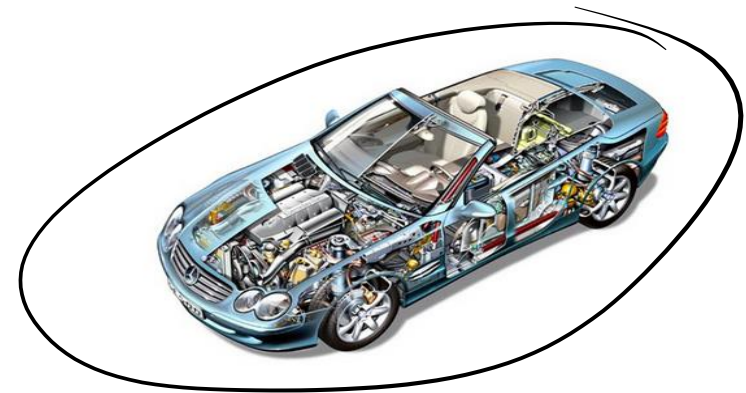
- Reliability in a harsh environment
- Cost
- Weight

- Many inputs and outputs

- Discrete sensors and actuators (MCU)
- Network interface to rest of the car (MCU)

- Uses high performance microcontroller

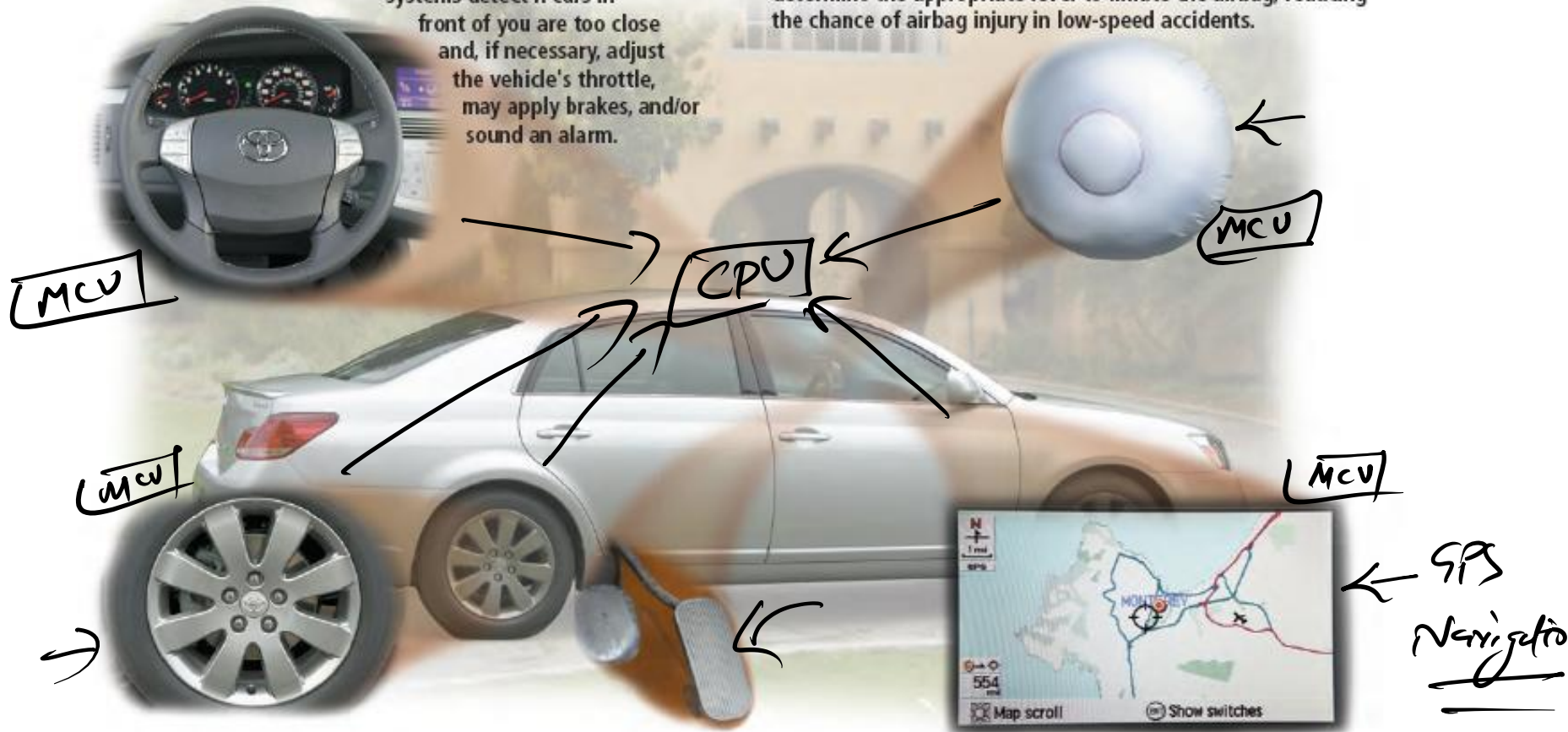
- E.g., 32-bit, 3MB flash memory, 150–300MHz



# Automotive Embedded Systems (Self drive car)

Adaptive cruise control systems detect if cars in front of you are too close and, if necessary, adjust the vehicle's throttle, may apply brakes, and/or sound an alarm.

Advanced airbag systems have crash-severity sensors that determine the appropriate level to inflate the airbag, reducing the chance of airbag injury in low-speed accidents.

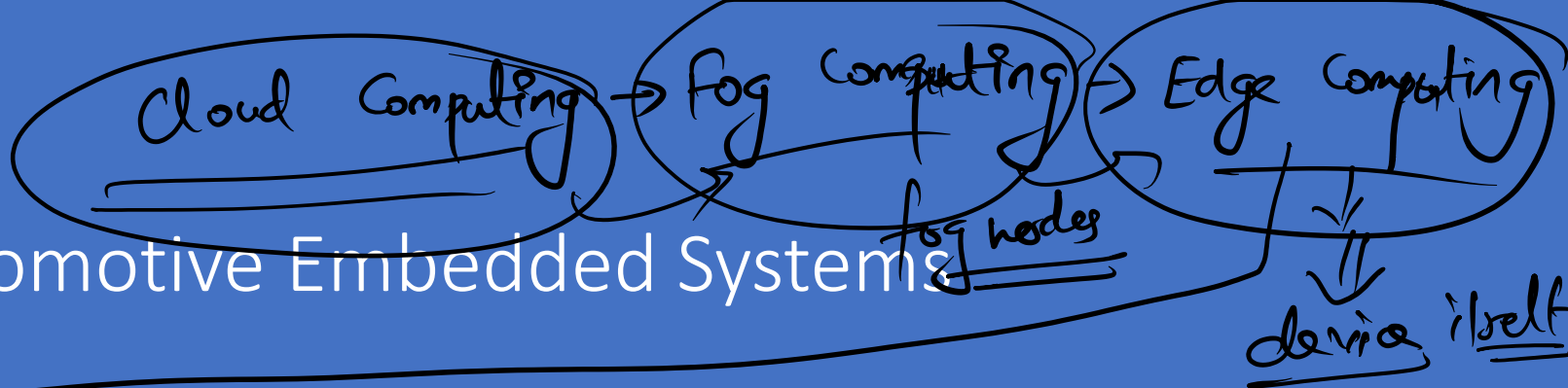


Tire pressure monitoring systems send warning signals if tire pressure is insufficient.

Drive-by-wire systems sense pressure on the gas pedal and communicate electronically to the engine how much and how fast to accelerate.

Cars equipped with wireless communications capabilities, called *telematics*, include such features as navigation systems, remote diagnosis and alerts, and Internet access.

# Automotive Embedded Systems



- Today's high-end automobile may have 100+ microprocessors:

Seat belt; dashboard devices; engine control; ABS; automatic stability control; navigation system; infotainment system; collision-avoidance system; tire pressure monitoring; lane warning; adaptive cruise control; climate control; airbag control unit; electric window and central locking; parking aid; automatic wiper control; alarm and immobilizer; power seat; electric power steering; electronic transmission; active suspension

Gen.  
Projects

pedestrian

Person

Street li.

Rail li.

Zebrg Cross

Other cars

side mirror

Left mirror

A/c

## Embedded Processor Market

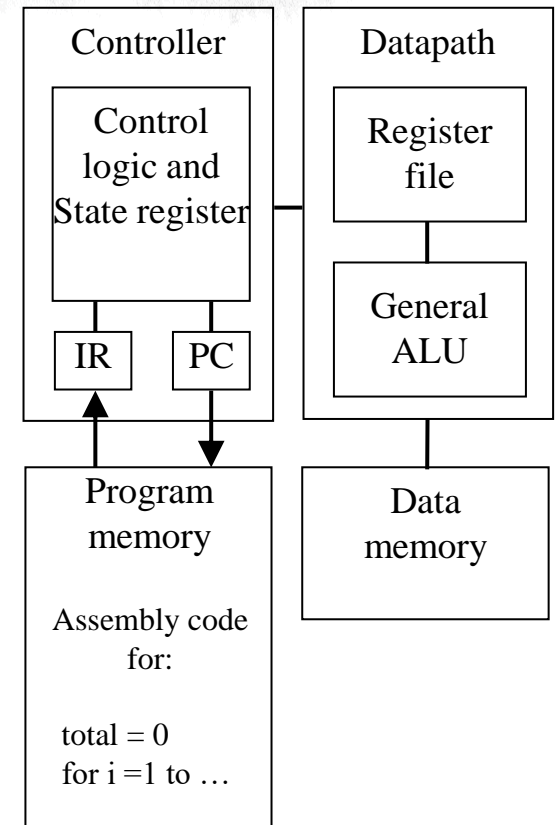
80 million PCs every year

3 billion embedded CPUs  
every year

Embedded systems  
market growing, while PC  
market mostly saturated

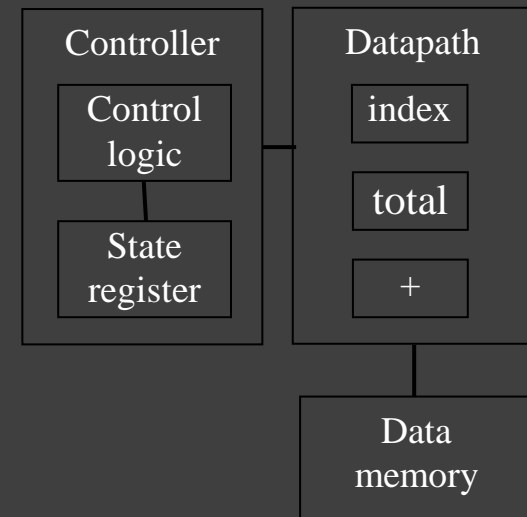
# General-Purpose Processor

- Programmable device, “microprocessor”
- Features
  - Program memory
  - General data path with large register file and general ALU
- User benefits
  - Low time-to-market and NRE costs
  - High flexibility
- Examples: Intel Core i7, AMD Ryzen 5, etc.



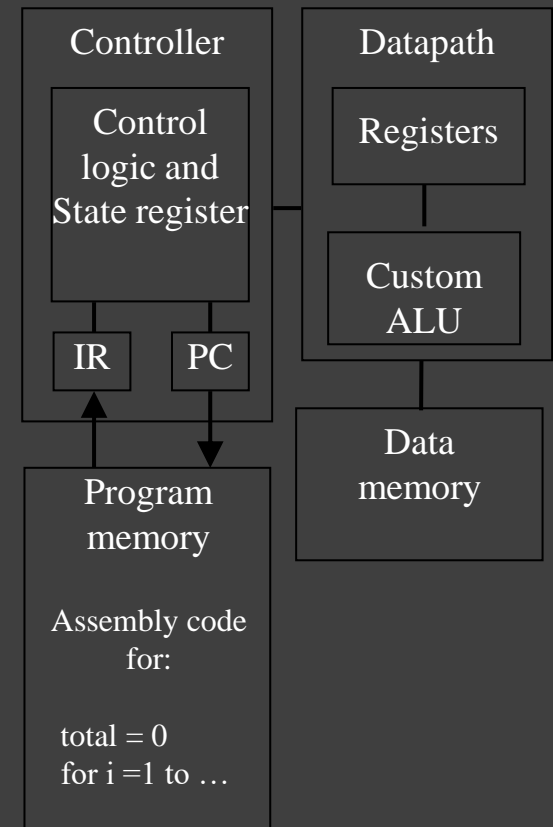
# Dedicated Processor

- Digital circuit designed specifically for one purpose
- Features
  - Contains only the components needed to execute a single program
  - No program memory
- Benefits
  - Fast
  - Low power
  - Small size



# Application-Specific Processor (ASIC)

- Programmable processor optimized for a particular class of applications that have common characteristics.
- Features
  - Program memory
  - Optimized data path
  - Special functional units
- Benefits
  - Some flexibility, good performance, size, and power, “reusable”



# Characteristics of Embedded Systems

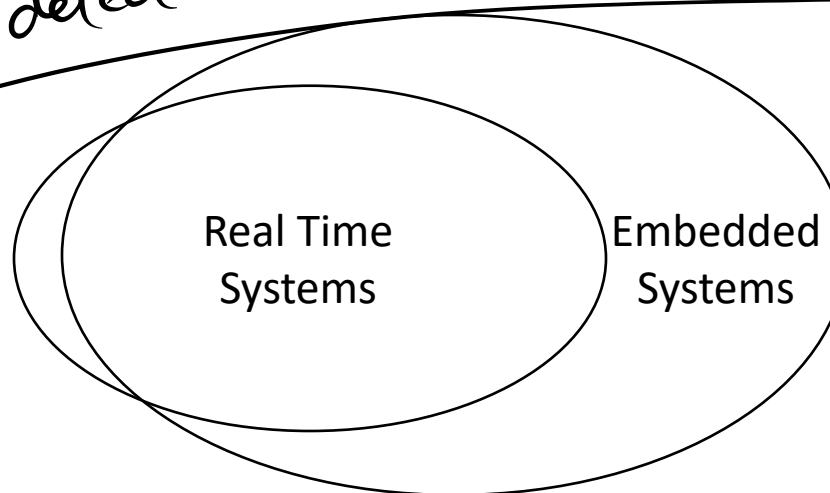
- Dedicated functionality ✓
- Real-time operation ✓
- Small size and low weight ✓
- Low power ✓
- Harsh environments ✓
- Safety-critical operation ✓
- Cost sensitive ✓



# Embedded vs. Real Time Systems

- Embedded system: is a computer system that performs a limited set of specific functions; it often interacts with its environment
- RTS: Correctness of the system depends not only on the logical results, but also on the **time** in which the results are produced

Time pressure pedestrian detection - in self drive car - RTS



Examples?

# Examples

- Real Time Embedded: ✓
  - Nuclear reactor control ✓
  - Flight control ✓
  - Basically, any safety critical system ✓
  - GPS ✓
  - MP3 player ✓
  - Mobile phone ✓
- Real Time, but not Embedded:
  - Stock trading system
  - Skype
  - Pandora, Netflix

} software
- Embedded, but not Real Time:
  - Home temperature control ⇒
  - Sprinkler system
  - Washing machine, refrigerator, etc.

# Benefits of embedded systems



## Greater performance and efficiency

More sophisticated control through software



## Lower cost

Cheaper components  
Reduced manufacturing costs  
Reduced operating and maintenance costs



## More features

Many not possible or impractical using other approaches



## Better dependability

Adaptive systems that can compensate for failures  
Better diagnostics to improve repair time

# Constraints specific to embedded devices



## Cost

Competitive markets penalize products that do not deliver adequate value for money



## Size and weight limits

Mobile (aviation, automotive) and portable (e.g., handheld, wearable) systems



## Power and energy limits

Battery capacity, cooling limits



## Environment

Temperatures may range from -40 degrees C to 125 degrees C, or even more.

# Functions of embedded systems

## Closed-loop control system



Monitor a process, adjust an output to maintain the desired set point of operation (temperature, speed, direction, etc.)

## Sequencing



Step through different stages based on environment and system conditions

## Signal processing

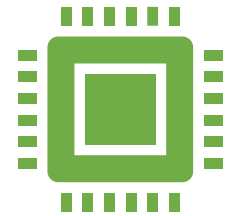


Remove noise, select desired signal features

## Communications and networking

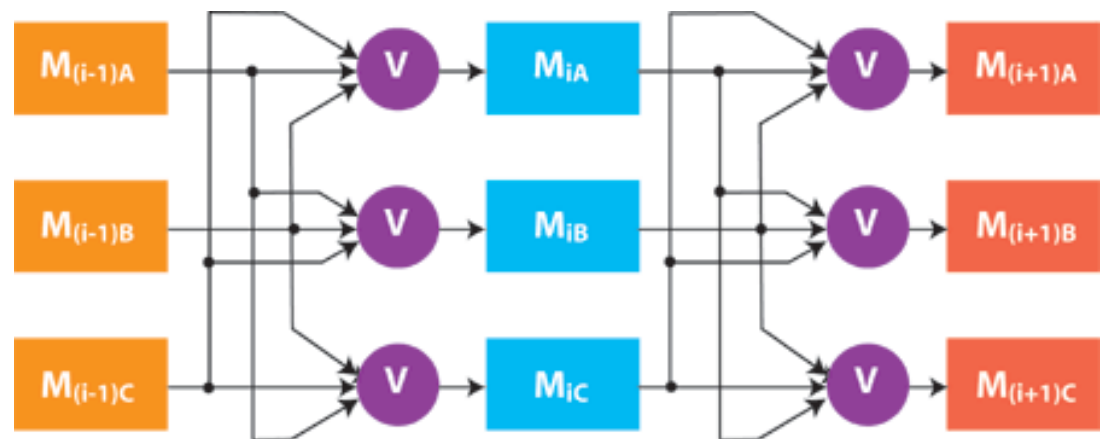


Exchange information reliably and quickly

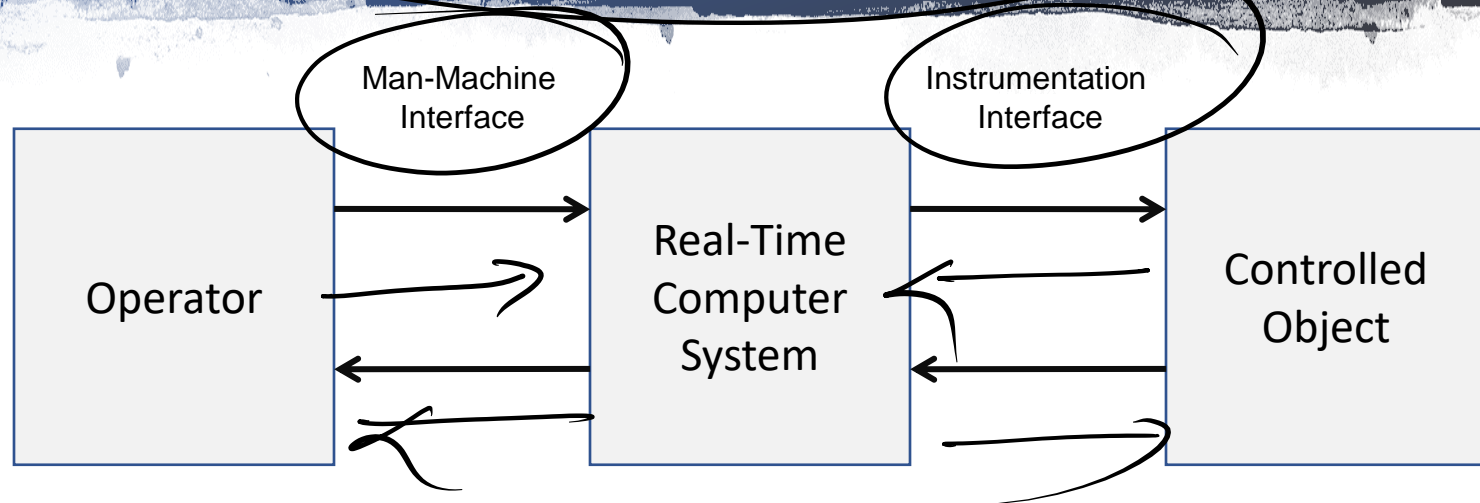


## Characteristics of RTS

- Event-driven (reactive) vs. time-driven
- Reliability/fault-tolerance requirements (example: triple modular redundancy)
- Predictability
- Priorities in multi-programmed systems



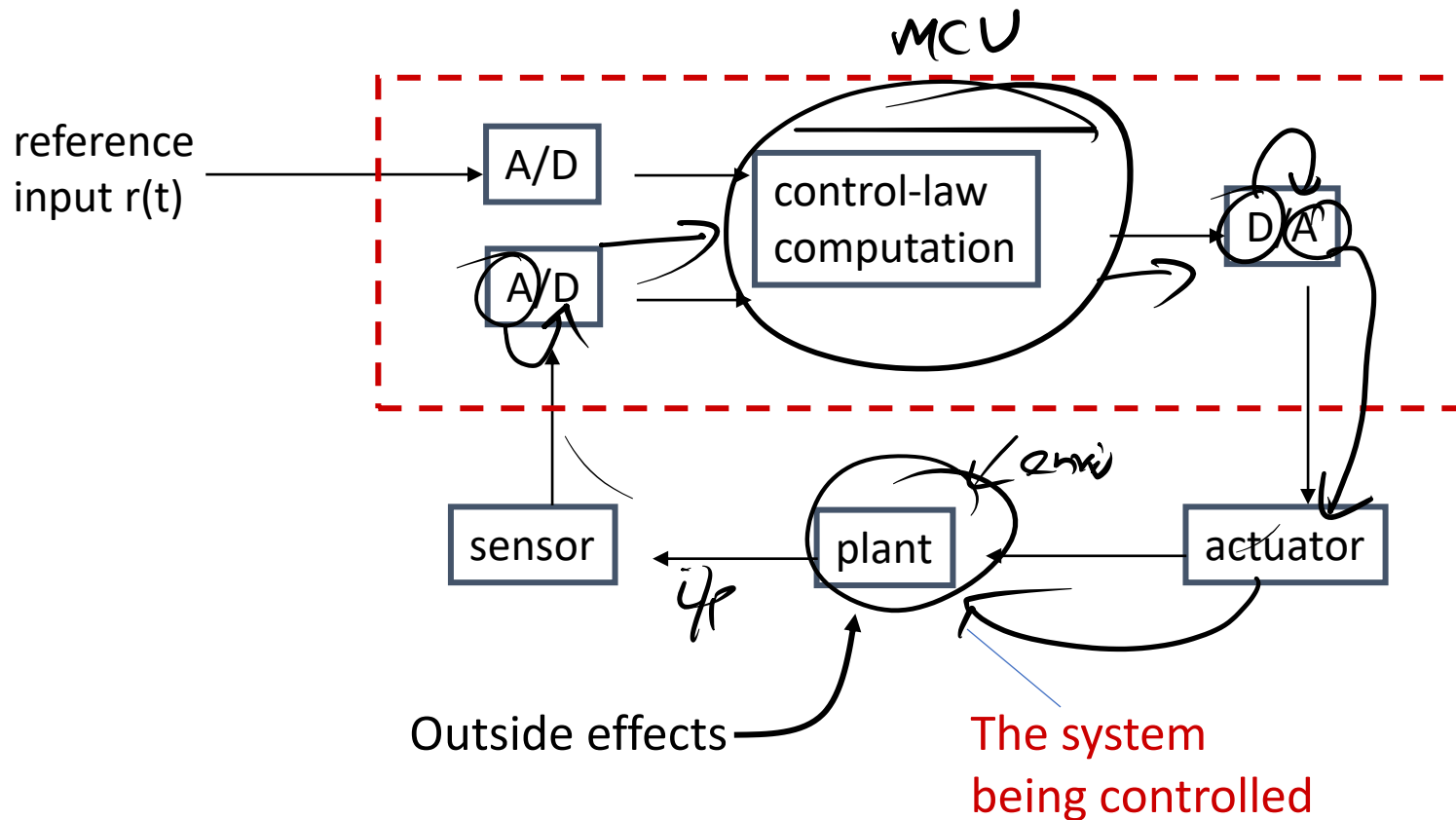
# Control Systems



- **Man-machine interface:** input devices, e.g., keyboard and output devices, e.g., display
- **Instrumentation interface:** sensors and actuators that transform between physical signals and digital data.

# Control System Example

**Example:** A simple one-sensor, one-actuator control system.





# Control Systems Cont'd.

## Pseudo-code for this system:

```
set timer to interrupt periodically with period  $T$ ;  
at each timer interrupt do  
    do analog-to-digital conversion to get  $y$ ;  
    compute control output  $u$ ;  
    output  $u$  and do digital-to-analog conversion;  
end do
```

process it  
decode it.

$T$  is called the sampling period.  $T$  is a key design choice. Typical range for  $T$ : seconds to milliseconds.

# Sensors and Actuators

## Sensors:

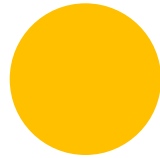
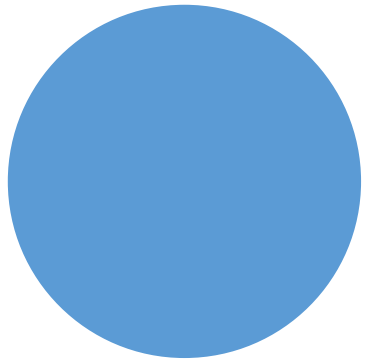
- They are mainly input components
- They sense and collect surrounding information

## Actuators:

- They are mainly output components
- They alter the surrounding

# Communications

- Connects devices with each other & the cloud
- Communication type:
  - Wireline (e.g., copper wires, optical fibers)
  - Wireless (e.g., RF, IR); RF-based communication is the most popular choice
- Popular RF-based communication solutions:
  - IEEE 802.15.4 (LR-WPANs) (Zigbee, 6LoWPAN) *LoRa*
  - IEEE 802.11 (or Wifi) ✓
  - Bluetooth (BLE)
  - Near Field Communication (NFC), e.g., RFID



Thank You!!

Next Session:

**Human  
Computer  
Interaction**

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