Control systems and Computer Networks

Embedded and Networked Systems

Dr Alun Moon

Lecture 1.2

► A Computer that is built into electronic devices to simplify the design or enhance performance.

- ► A Computer that is built into electronic devices to simplify the design or enhance performance.
- ▶ Often the user is unaware of the presence of the computer.

- ▶ A Computer that is built into electronic devices to simplify the design or enhance performance.
- ▶ Often the user is unaware of the presence of the computer.
- Interacts with the physical world.

- ▶ A Computer that is built into electronic devices to simplify the design or enhance performance.
- Often the user is unaware of the presence of the computer.
- Interacts with the physical world.
- ▶ Networked communicates with other devices and computers to co-ordinate actions and distribute the workload.

Reliability

- Reliability
 - Mission Critical

- Reliability
 - Mission Critical
 - life threatening

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs
 - Fast time to market required

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs
 - · Fast time to market required
 - No chance for future in service modifications

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs
 - Fast time to market required
 - No chance for future in service modifications
- Limited Interaction

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs
 - Fast time to market required
 - No chance for future in service modifications
- Limited Interaction
 - difficult to debug

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs
 - Fast time to market required
 - No chance for future in service modifications
- Limited Interaction
 - difficult to debug
 - · demanding technical and programming work

- Reliability
 - Mission Critical
 - life threatening
 - 24/7/365
 - Can't reboot
- Performance
 - Soft and Hard Real-Time requirements.
 - External events trigger actions.
 - Some degree of multi-tasking (interrupts/RTOS)
- Cost
 - Consumer market minimise manufacturing costs
 - Fast time to market required
 - No chance for future in service modifications
- Limited Interaction
 - · difficult to debug
 - demanding technical and programming work
- Challenging, demanding, fun, & very satisfying to work on

Jacqard Loom

Early industrial automation



- Punched Cards controlling loom
- ▶ 1804
- manufacturing textiles with such complex patterns as brocade, damask and matelassé

Embedded systems outnumber PC "Computers"

- ▶ Embedded systems outnumber PC "Computers"
 - \bullet \approx 100 : 1

- Embedded systems outnumber PC "Computers"
 - ≈ 100 : 1
- Many unseen

- Embedded systems outnumber PC "Computers"
 - ≈ 100 : 1
- Many unseen
 - 5 or more in the kitchen

- Embedded systems outnumber PC "Computers"
 - ≈ 100 : 1
- Many unseen
 - 5 or more in the kitchen
 - at least 2 on the outside of the PC

- Embedded systems outnumber PC "Computers"
 - ≈ 100 : 1
- Many unseen
 - 5 or more in the kitchen
 - at least 2 on the outside of the PC
 - several in this room

- Embedded systems outnumber PC "Computers"
 - ≈ 100 : 1
- Many unseen
 - 5 or more in the kitchen
 - at least 2 on the outside of the PC
 - several in this room
- ▶ A "Computer" is a collection of several micro-cotrollers/processors

- Embedded systems outnumber PC "Computers"
 - ≈ 100 : 1
- Many unseen
 - 5 or more in the kitchen
 - at least 2 on the outside of the PC
 - several in this room
- ▶ A "Computer" is a collection of several micro-cotrollers/processors

examples

- ▶ More than 86 billion ARM®-based chips shipped to date.
- Microchip PIC and AVR (ATmega in Arduino)

Apollo Guidance Computer

▶ First use of integrated circuits to build a computer.

- ▶ First use of integrated circuits to build a computer.
 - Kick started IC industry

- ▶ First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.

- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ► Early use of concurrency via extensive use of interrupts.

- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ► Early use of concurrency via extensive use of interrupts.
- ▶ One of the first significant avionics control systems

- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ▶ Early use of concurrency via extensive use of interrupts.
- One of the first significant avionics control systems
- High reliability.

- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ▶ Early use of concurrency via extensive use of interrupts.
- One of the first significant avionics control systems
- High reliability.
- Pioneered many embedded, safety-critical techniques.

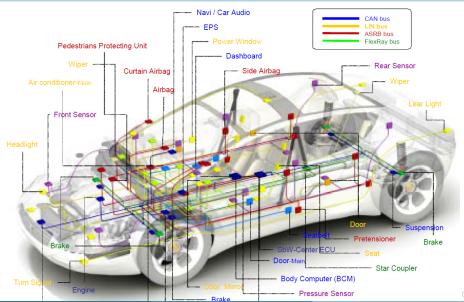
- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ► Early use of concurrency via extensive use of interrupts.
- One of the first significant avionics control systems
- High reliability.
- Pioneered many embedded, safety-critical techniques.
 - Margaret Hamilton, of the Massachusetts Institute of Technology, with her colleagues, she developed the building blocks for modern "software engineering," a term Hamilton coined.

- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ▶ Early use of concurrency via extensive use of interrupts.
- One of the first significant avionics control systems
- High reliability.
- Pioneered many embedded, safety-critical techniques.
 - Margaret Hamilton, of the Massachusetts Institute of Technology, with her colleagues, she developed the building blocks for modern "software engineering," a term Hamilton coined.
 - Apollo 11, 1201 and 1202 alarms

- First use of integrated circuits to build a computer.
 - Kick started IC industry
 - NASA/MIT brought millions of chips to improve reliability.
- ▶ Early use of concurrency via extensive use of interrupts.
- One of the first significant avionics control systems
- High reliability.
- Pioneered many embedded, safety-critical techniques.
 - Margaret Hamilton, of the Massachusetts Institute of Technology, with her colleagues, she developed the building blocks for modern "software engineering," a term Hamilton coined.
 - Apollo 11, 1201 and 1202 alarms
- May be the first "networked" embedded system



Modern Network of systems



► Deal with physical signals

- ► Deal with physical signals
- Physical Quantities

- Deal with physical signals
- ► Physical Quantities
- ► Sense environment

- Deal with physical signals
- Physical Quantities
- ► Sense environment
 - Voltages

- ► Deal with physical signals
- Physical Quantities
- Sense environment
 - Voltages
 - Temperatures

- ► Deal with physical signals
- Physical Quantities
- ► Sense environment
 - Voltages
 - Temperatures
 - Button Presses

- Deal with physical signals
- Physical Quantities
- ► Sense environment
 - Voltages
 - Temperatures
 - Button Presses
- Effect environment

- Deal with physical signals
- Physical Quantities
- Sense environment
 - Voltages
 - Temperatures
 - Button Presses
- ▶ Effect environment
 - Lights & Heating

- Deal with physical signals
- Physical Quantities
- Sense environment
 - Voltages
 - Temperatures
 - Button Presses
- Effect environment
 - Lights & Heating
 - Motors motion

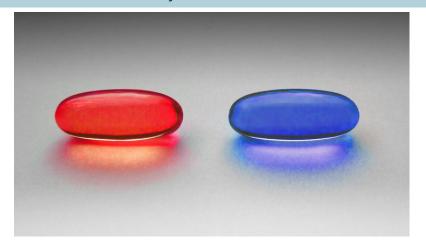
- Deal with physical signals
- Physical Quantities
- Sense environment
 - Voltages
 - Temperatures
 - Button Presses
- Effect environment
 - Lights & Heating
 - Motors motion
 - Change physical quantities

- Deal with physical signals
- Physical Quantities
- Sense environment
 - Voltages
 - Temperatures
 - Button Presses
- Effect environment
 - Lights & Heating
 - Motors motion
 - Change physical quantities
- Virtual Reality

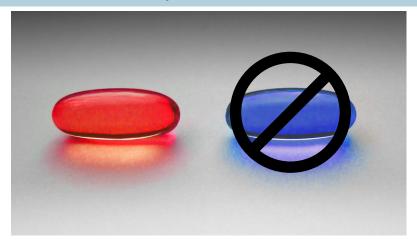


- Deal with physical signals
- Physical Quantities
- Sense environment
 - Voltages
 - Temperatures
 - Button Presses
- Effect environment
 - Lights & Heating
 - Motors motion
 - Change physical quantities
- ► Virtual Reality

We Deal with Reality



We Deal with Reality



You take the red pill – you stay in Wonderland, and I show you how deep the rabbit hole goes.

Morpheus, The Matrix