INTRODUCTION TO REAL-TIME SOFTWARE SYSTEMS DEVELOPMENT

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### outline

Definition of real-time systems
Structure of typical real-time systems
Characteristics of Real-Time Systems
Examples of Real-Time Systems

## Introduction to Real-Time Systems

What is a Real-Time System?

Is defined as a system in which the time where the outputs are produced is significant (within specified bounds or deadlines)



Correctness depends on output values and the time at which the inputs are processed and the outputs are produced

### What are Real Time System?

#### Definition (Real time system)

A real time system is a system that must satisfy explicit (bounded) response-time constraints or risk severe consequences, including failure.

#### Definition (Real time system)

A real time system is one whose logical correctness is based on both the correctness of the outputs and their timeliness.

#### Definition (Real time system)

A real time system is any information processing activity or system which has to respond to externally generated input stimuli within a finite and specified period.

### Related Notions

reactive system continuous interaction with the environment (as opposed to information processing)

embedded system computer system encapsulated in its environment (device it controls), combination of computer hardware and software, dedicated to specific purpose

safety-critical system a failure may cause injury, loss of lives, significant financial loss

#### http://www.cnn.com/2012/03/01/us/toyota-memo-acceleration-concerns/index.html

Toyota "sudden acceleration problem"

- 2010 version:
  - sudden accelaration of cars
  - fault in electronic system?
  - related to our concepts real-time system, reactive system, embedded system, safety-critical system
- 2011 version:
  - "pedal misapplication" (accelerator, brake)

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### Introduction to Real-Time Systems

- Real-time systems often are comprised of a *controlling* system, *controlled* system and *environment*.
  - A Controlling system: acquires information about the environment using sensors and controls the environment with actuators.
- *Timing constraints* derived from *physical* impact of controlling systems activities. Hard and soft constraints.
  - Periodic Tasks: Time-driven recurring at regular intervals (e.g., sensors polling).
  - Aperiodic Tasks: event-driven (operator commands).

## Typical Real-Time System



### Structure of a Real-Time System

### Logical view



### Introduction to Real-Time Systems

- Timing constraints: constraints imposed on timing behavior of a job (also called deadlines): hard or soft
   Release Time: Instant of time job becomes available for execution. If all jobs are released when the
  - system begins execution, then there is said to be no release time
- Deadline: Instant of time a job's execution is required to be completed. If deadline is infinity, then job has no deadline. Absolute deadline is equal to release time plus relative deadline
- Response time: Length of time from release time to instant job completes.

### Introduction to Real Time systems



# Introduction to Real-Time Systems

- Real-Time Systems can be *Hard Real-Time systems* or *Soft Real-Time systems*
- In *Hard Real-Time* systems outputs must be produced within the specified deadlines or a system failure will occur (Examples include: Flight Control systems, Air Traffic Control systems, Robots, Automotive Control Systems,..)
- In Soft Real-Time Systems, deadlines can be occasionally missed (Examples include: communications systems using time out protocols, ATMs, Air line Reservation Systems, Process Control Systems designed to tolerate delays)

### Soft and Hard Real Time

deadline — a time within which the task should be completed
 hard RT system missing a deadline: failure of the system

 e.g., aircraft control, nuclear plant control,
 detection of critical conditions

 soft RT system missing a deadline: undesirable for

 performance reasons
 e.g., multimedia application, booking system,
 displaying status information

### Soft and Hard Real Time (cont.)

- most systems: combination of both hard and soft deadlines
- firm deadline: missing a deadline makes the task useless (similar to hard deadline), however the deadline may be missed occasionally (similar to soft deadline)
- generalization: cost function associated with missing each deadline

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# Characteristics of Real-Time Systems

• Real-Time systems are often *embedded systems* (i.e., contained within a larger system to provide monitoring, control, and computation functions)

• They often require concurrent processing of multiple inputs. Concurrent tasks must be created and managed in order to fulfill the functions of the system.

• Task scheduling is one of the important aspects of managing concurrency. Since tasks will compete for the same resources (such as the Processors)



# Characteristics of Real-Time Systems

- Real-Time systems need to respond to synchronous events (i.e., periodic events) as well as asynchronous events (or aperiodic events, those that could occur at any time)
- Real-Time systems often require high Reliability and Safety requirements.
- Real-Time systems often have special environmental, interfacing, and fault-tolerance requirements.
  - Environmental factors such as temperature (e.g., in space exploration applications systems must operate in a temperature range of -55 to 200 degree centigrade), shock and vibration, size limits, weight limits, usually have an impact on the system hardware and software requirements

# Characteristics of Real-Time Systems

- *Fault-tolerant* requirements and *Exception handling* have special consideration due to the high reliability and critical timing requirements. Fault-tolerance requirements greatly impact and usually complicate the design of software and hardware components of the system.
- Interfacing requirements. The devices which are typically interfaced to a RTS are many (Examples include sensors, actuators, switches, displays, communication links, D/A and A/D converters, and pulse-width-modulated controllers)

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### **Examples of Real-Time Systems**





Implementation with an infinite loop: An example of Periodic tasks:

initialize I/O ports, internal control variables; set timer to interrupt periodically with period T; at each timer interrupt, do obtain input; compute control output; send output to the plant; end do;

### **Examples of Real-Time Systems**



#### Sample Examples

### Navigation System

- aircraft navigation system
- inputs:
  - *x*, *y*, *z* accelerometer pulses (5ms rate)
  - roll, pitch, yaw angles (40ms rate)
  - temperature (1s rate)
- output:
  - compute actual velocity (40ms rate)
  - output velocity do display (1s rate)

processes are concurrent and have different rates

#### Sample Examples

### Airline Reservation System

- reservation of tickets for airlines
- distributed system, several agents may use the system concurrently
- turnaround time less than 15s
- no overbooking

#### Areas of Application

### Areas of Application I

#### vehicle control systems embedded systems in cars, space missions transport control systems railway switching networks, traffic control, air traffic control plant control production and manufacturing control, nuclear plants, chemical plants

Areas of Application

### Areas of Application II

databases booking systems, telephone switching, radar tracking

home appliances mobile phones, microwave ovens, washing machines, fridges

image processing multimedia, mobile phones, digital cameras, portable media players, personal digital assistants, high-definition television, virtual reality video surveillance systems, industrial inspection systems, medical imaging devices



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Cloud Computing and the Internet of Things (IoT)

# the Internet of Things IoT

 "IoT represents the most potentially disruptive technological revolution of our lifetime. With 50 to 100 billion things expected to be connected to the Internet by 2020" Guest Editors' Introduction, IEEE Computer, Jan 2013



# What is the Internet of Things IoT

• The term Internet of Things (IoT) describes several technologies and research disciplines that enable the Internet to reach out into the real world of physical objects"

 "Technologies such as RFID, short range wireless communications, real-time localization, and sensor networks are becoming increasingly pervasive, making the IoT a reality".

#### **The Internet of Things (IoT)**

#### Architecture



#### FIGURE 9.15

The architecture of an IoT consisting of sensing devices that are connected to various applications via mobile networks, the Internet, and processing clouds.

### A Cloud Service Architecture for IoT



## <u>OUTLINE</u>

What is Cloud Computing ? Services of Cloud Computing, What can we do with Cloud Computing? Challenges with Clouds and Cloud Types The Internet of Things (IoT) **Applications of IoT: Biomedical, Wearable Technology**, Smart Cities Conclusions

#### **Biomedical Applications**

#### **IoT in Telemedicine**



#### FIGURE 9.19

An example of how measured data can be transferred to doctors or medical professionals using a wireless sensor network.

#### Adopted from Ref 1, Ch 9

### **Biomedical Applications and IoT**

http://www.biomedical-engineering-online.com/content/11/1/95/abstract

The proposed technologies and methods would offer a low-cost and unobtrusive approach to trunk motor rehabilitation



#### Wearable Technology: The Smart Shirt

http://www.youtube.com/watch?feature=player\_embedded&v=q0GokKd2QRA First Responders at Site Smart Shirt: Soldiers on Battlefield Collects and Moves Data; Child Comfortable, Lightweight Washable, Durable Race Car Driver Smart Shirt Controller: Stores and/or Transmits Data Selects Best Transmission Method Data Transport Through Appropriate Communications Infrastructure Mountain Climber Off-Site Remote Monitoring and **Triage Station** Smart Shirt in the Field ...

# Wearable Technology:

http://waarablagamas.au/platform/

WOVEN is a piece of garment loaded with bend and heart-rate sensor as input, speakers, shake motors and a 12×12 pixel LED display
WOVEN links up with the virtual world via a Bluetooth wireless link to connect to the internet via smart-phones with it's apps or notebooks



#### http://www.talk2myshirt.com/blog/archives/5857

Wearable Technology:

## Google's Glass

## GL/ISS

high tech eyeglasses A user interface for important information from cell phones Includes Display, Camera, Audio, WiFi & Bluth, 16GB storage, Connects to MyGlass App. http://www.google.com/glass/start/





## Build Your Own Google Glass

- Rod Furlan "Build Your Own Google Glass: A wearable computer that displays information and records video", IEEE Spectrum January 2013.
  - Built with components bought on-line from a discontinued head-mounted display
  - Uses a fourth-generation iPod Touch processor
  - Extracted a micro-display and the optics required to focus the image properly
  - Mounted the components
     on a pair of plastic safety
     goggles.

Creating the software and hardware for Such a "brain prosthesis" is certainly within the realm of possibility for the next decade,



and I expect to see these features drive the mass adoption of the Google Glass technology. —Rod Furlan

## **Smart Cities**

http://www.libelium.com/top\_50\_iot\_sensor\_applications\_ranking/pdf

- Smart Grids Energy Consumption monitoring and managements
- Smart Environment Detection of air pollution, water pollution, forest fires, earthquakes, landslides
- Traffic Congestion Monitoring of vehicles and pedestrian levels to optimize driving and walking routes.
- Structural health Monitoring of vibrations and material condition in buildings, bridges and historical monuments.
- Noise Urban Maps Sound monitoring in special areas and centric zones in real time.
- Smart Parking Monitoring of parking spaces availability in the city.

## Smart Cities (Cont.)

http://www.libelium.com/top\_50\_iot\_sensor\_applications\_ranking/pdf

- **Smart Lightning** Intelligent and weather adaptive lighting in street lights.
- Waste Management

Detection of rubbish levels in containers to optimize the trash collection routes.

### Smart Roads

Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

• Eletromagnetic Field Levels Measurement of the energy radiated by cell stations and and WiFi routers.

#### Smart Cities, IoT, and Smart Grids



### IoT and Smart Grids





### IoT and Smart Homes

Check and control things at home," like temperature control as in changing the setting of the thermostat, security—
 making sure that doors are locked—or energy management like lighting control

