Real-time Software

Objectives

- To explain the concept of a real-time system and why these systems are usually implemented as concurrent processes
- To describe some design issues
- To introduce generic process architectures for monitoring and control and data acquisition systems

Topics covered

- Real-time systems
- Design issues
- Monitoring and control systems
- Data acquisition systems

Real-time systems

- Systems which monitor and control their environment.
- Inevitably associated with hardware devices
  - Sensors: Collect data from the system environment;
  - Actuators: Change (in some way) the system's environment;
- Time is critical. Real-time systems MUST respond within specified times.

Definition: real-time system

- A real-time system is a software system where the correct functioning of the system depends on:
  - the results produced by the system
  - and the time at which these results are produced.

Definition: Soft & Hard real-time systems

- A soft real-time system is a system whose operation is degraded if results are not produced according to the specified timing requirements.
- A hard real-time system is a system whose operation is incorrect if results are not produced according to the timing specification.

Stimulus/Response Systems

- Given a stimulus, the system must produce a response within a specified time.
- Two classes of stimuli:
  - Periodic stimuli
  - Aperiodic stimuli

Periodic stimuli

- Occur at predictable time intervals
- Provide info on the system's state and environment
- Example: a temperature sensor may be polled 10 times per second - The system takes action according to the sensor value (stimulus).

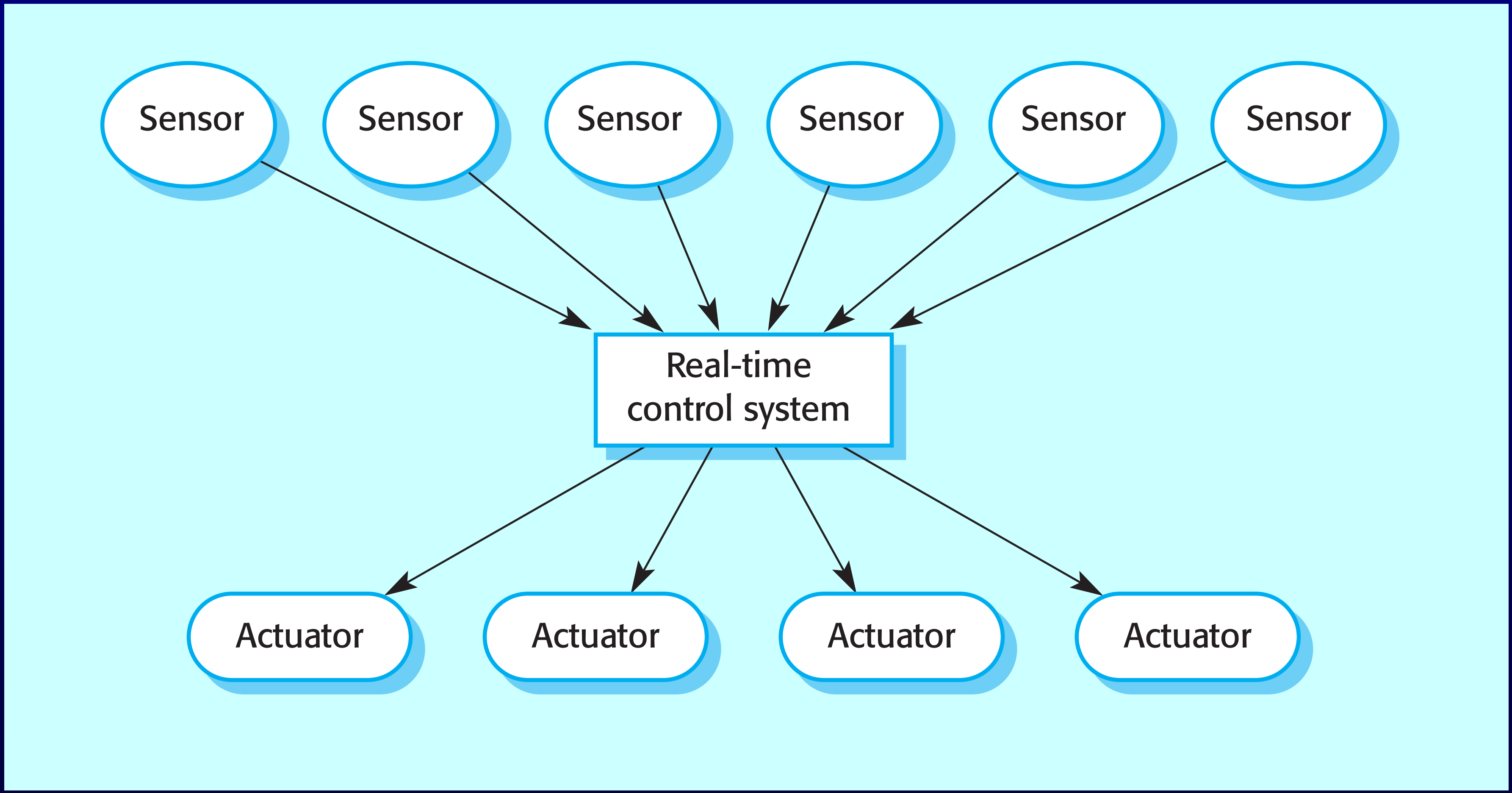
Aperiodic stimuli

- Occur at unpredictable times (irregular)
- Often indicate some exceptional conditions
- May be generated either by sensors or actuators.
- Example: a system power failure may trigger an interrupt which must be processed by the system.

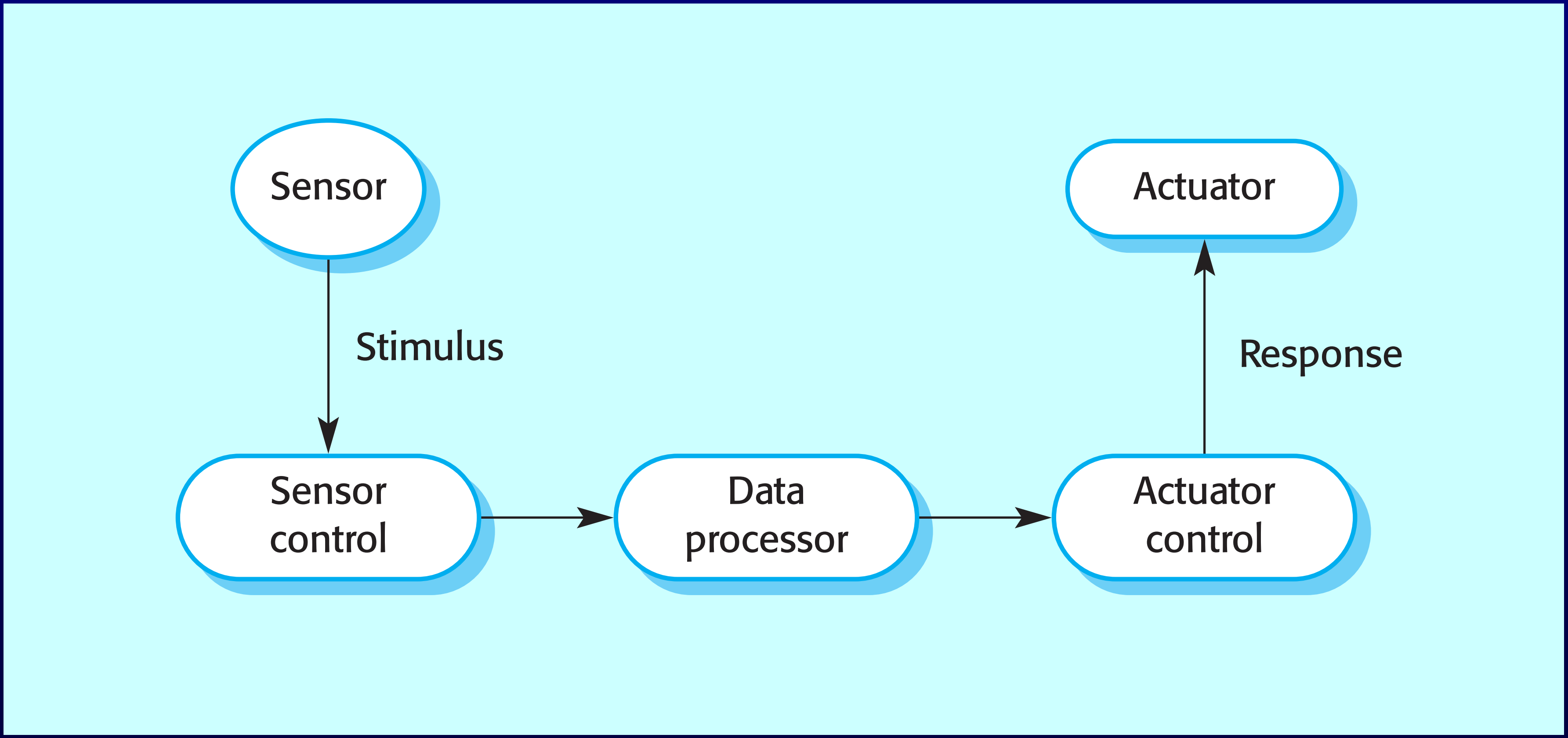
Architectural considerations

- Because of the need to respond to timing demands made by different stimuli/responses, the system architecture must allow for fast switching between stimulus handlers.
- Timing demands of different stimuli are different so a simple sequential loop is not usually adequate.
- Real-time systems are therefore usually designed as cooperating processes with a real-time executive controlling these processes.

A real-time system model



Sensor/actuator processes



System elements

- Sensor control processes
  - Collect information from sensors. May buffer information collected in response to a sensor stimulus.
- Data processor
  - Carries out processing of collected information and computes the system response.
- Actuator control processes
  - Generates control signals for the actuators.

Real-time programming

- Hard-real time systems may have to programmed in assembly language to ensure that deadlines are met.
- Languages such as C allow efficient programs to be written but do not have constructs to support concurrency or shared resource management.

Java as a real-time language

- Java supports lightweight concurrency (threads and synchronized methods) and can be used for some soft real-time systems.
- Java 2.0 is not suitable for hard RT programming

System design

- Partition functions to either hardware or software.
- Hardware delivers better performance but potentially longer development and less scope for change.
- Design decisions should be made on the basis on non-functional system requirements.

Timing constraints

- May require extensive simulation and experiment to ensure that these are met by the system.
- May mean that certain design strategies such as object-oriented design cannot be used because of the additional overhead involved (see comments).
- May mean that low-level programming language features have to be used for performance reasons.
- HW components have better performance than equivalent SW
- Use HW components for sys-processing bottlenecks

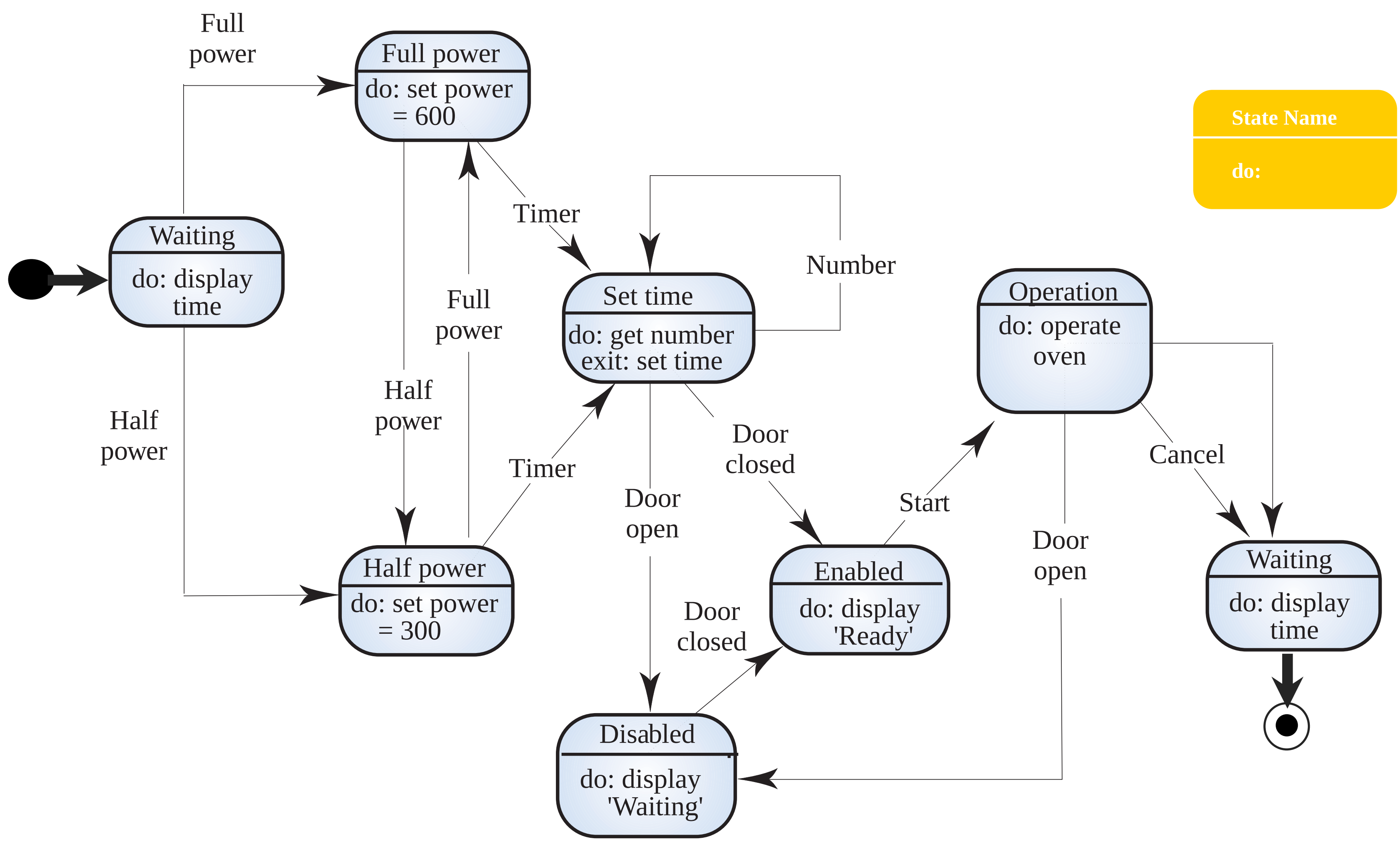
Comments on OO design & RT systems

- OO design is not suitable for RT systems
- OO involves
  - hiding data
  - Accessing attributes via operations defined with the object
- Performance loss because extra code is required to access attributes and handle calls to operations
- May be impossible to meet RTS deadlines.

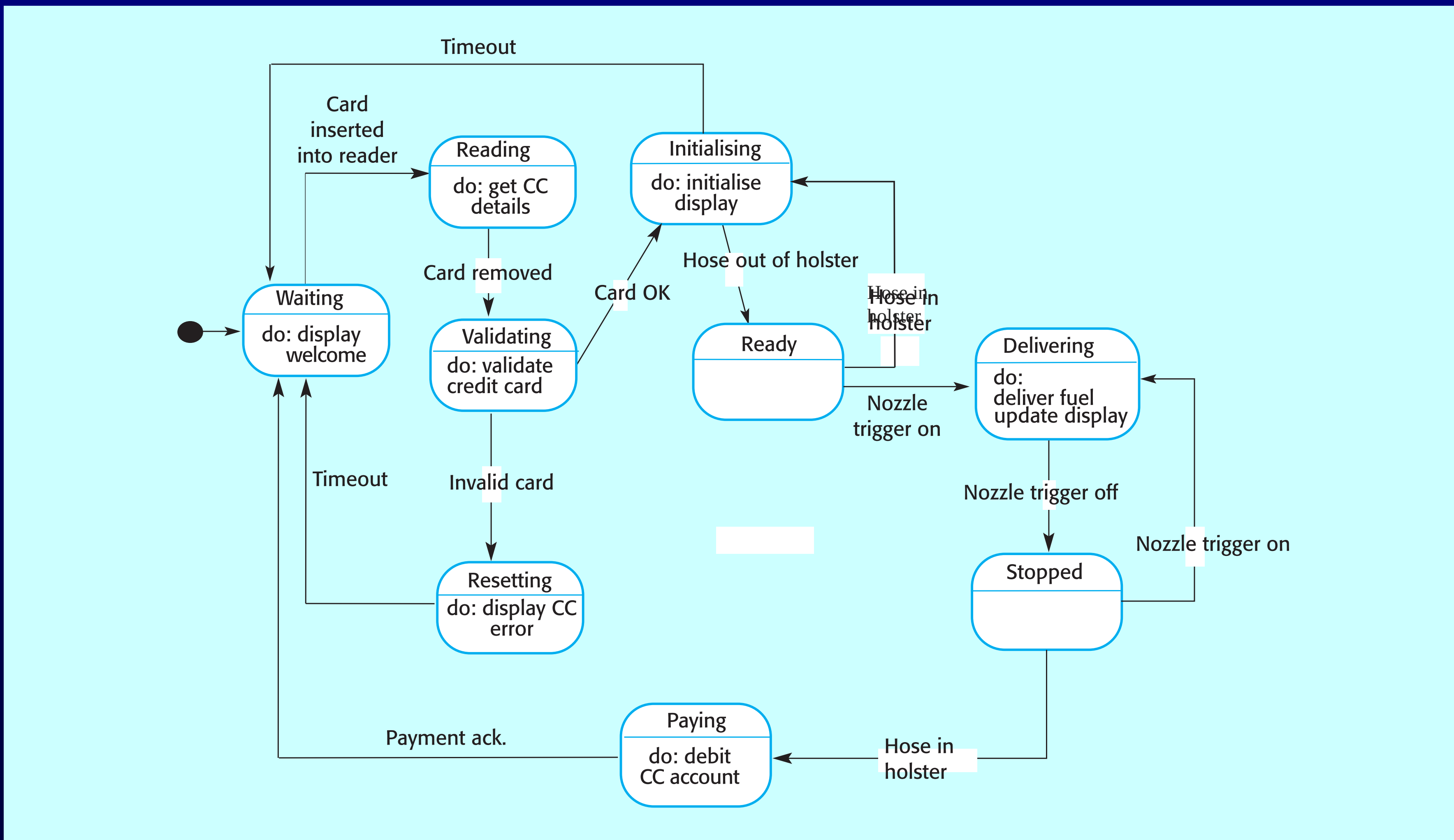
Real-time system modelling

- UML Finite state machines can be used for modelling real-time systems.

State Machine model of a Microwave



State Machine model of a Petrol (gas) pump



Process priority

- Interrupt level priority. Highest priority which is allocated to processes requiring a very fast response.
- Clock level priority. Allocated to periodic processes.

Interrupt servicing

- Control is transferred automatically to a pre-determined memory location.

- This location contains an instruction to jump to an interrupt service routine.

Periodic process servicing

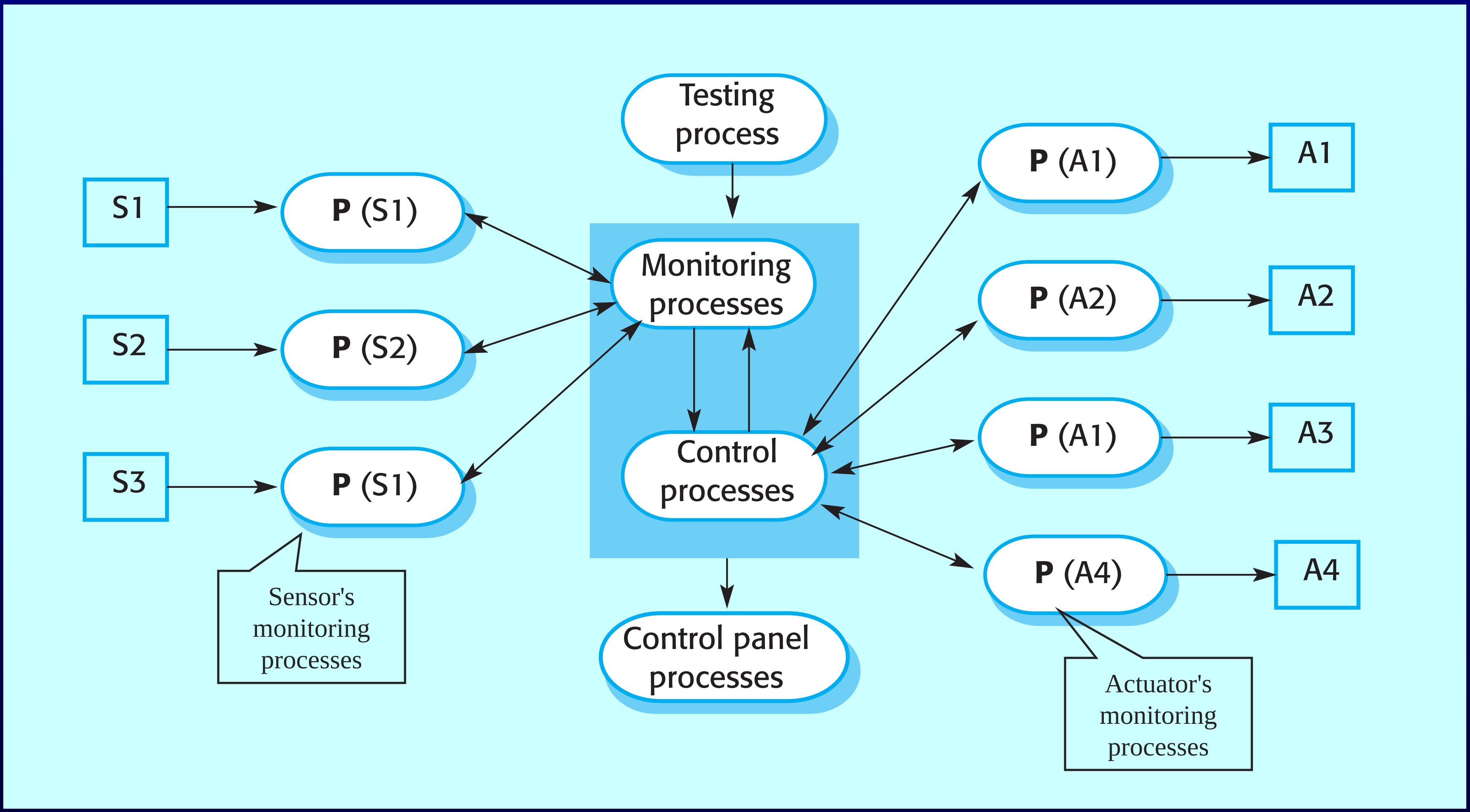
- Periodic processes are executed at specified time intervals (Examples: data acquisition & actuator control).

- The process manager selects a process which is ready for execution.

Monitoring and control systems

- Represents an important class of real-time systems.
- Continuously check sensors and take actions depending on sensor values.
- Monitoring systems examine sensors and report their results.
- Control systems take sensor values and control hardware actuators.

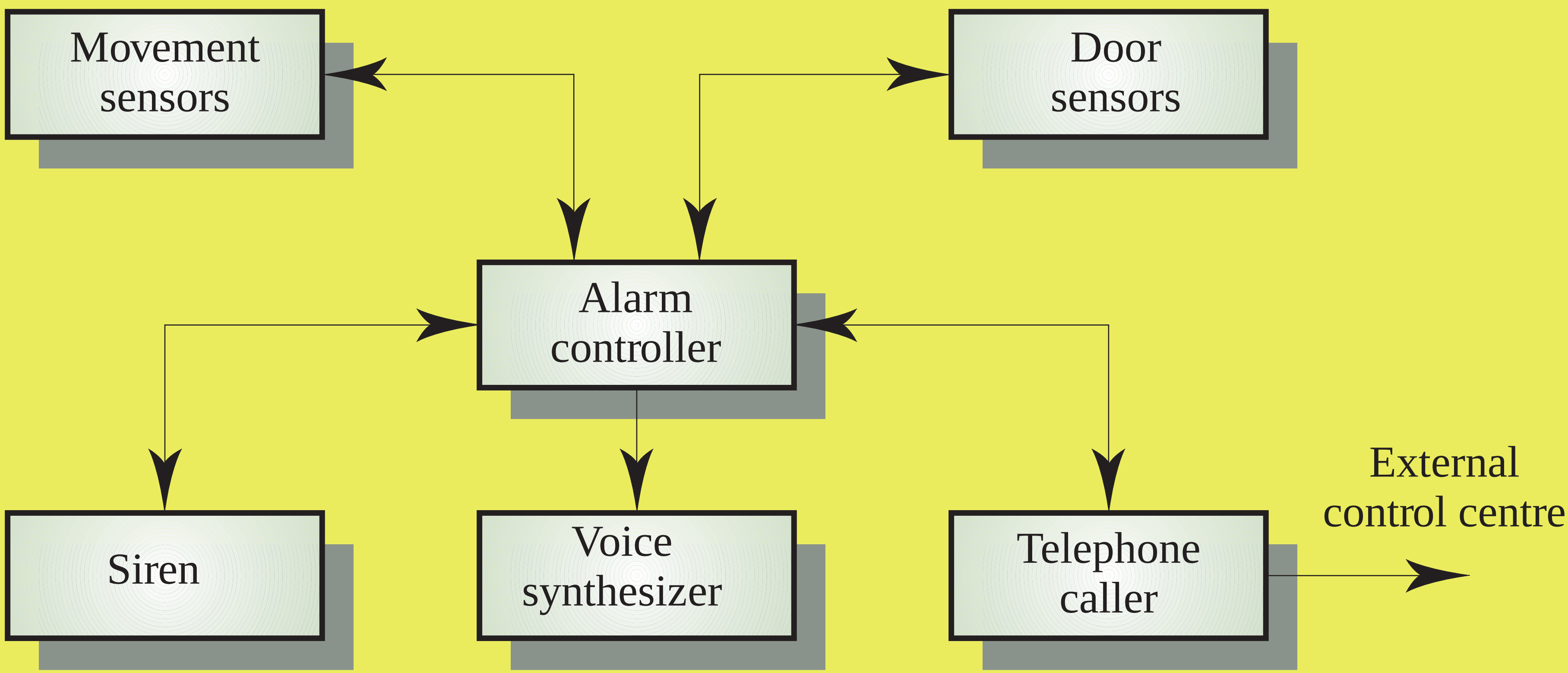
Monitoring and control systems: Generic architecture



Burglar alarm system

- A system is required to monitor sensors on doors and windows to detect the presence of intruders in a building.
- When a sensor indicates a break-in, the system switches on lights around the area and calls police automatically.
- The system should include provision for operation without a mains power supply.

Burglar alarm “Intruder Alarm” System Block Diagram



Burglar alarm system

- Sensors
  - Movement detectors, window sensors, door sensors;
  - 50 window sensors, 30 door sensors and 200 movement detectors;
  - Voltage drop sensor.
- Actions
  - When an intruder is detected, police are called automatically;
  - Lights are switched on in rooms with active sensors;
  - An audible alarm is switched on;
  - The system switches automatically to backup power when a voltage drop is detected.

The R-T system design process

- Identify stimuli and associated responses.
- Define the timing constraints associated with each stimulus and response.
- Allocate system functions to concurrent processes.
- Design algorithms for stimulus processing and response generation.
- Design a scheduling system which ensures that processes will always be scheduled to meet their deadlines.

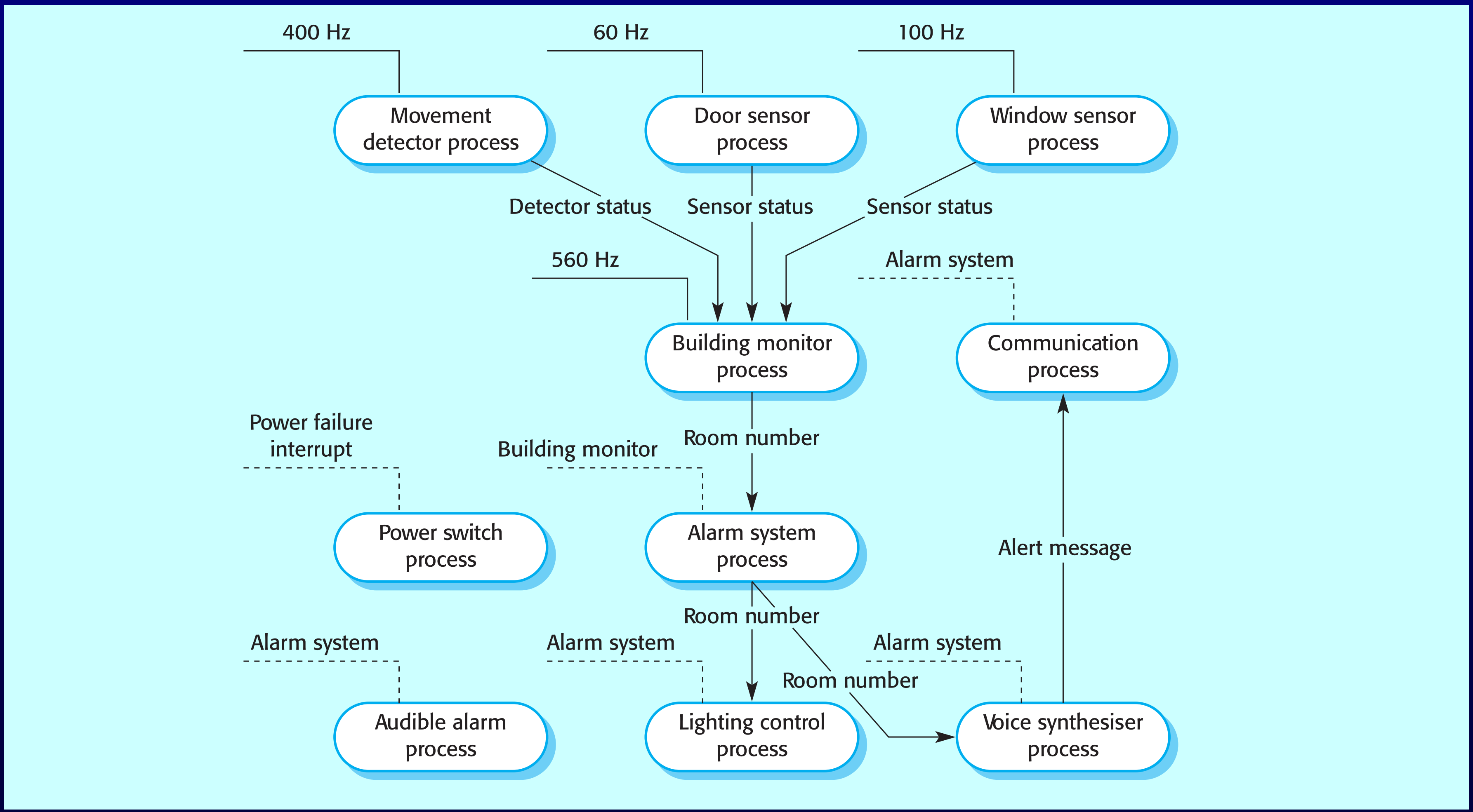
Stimuli to be processed

- Power failure
  - Generated aperiodically by a circuit monitor. When received, the system must switch to backup power within 50 ms.
- Intruder alarm
  - Stimulus generated by system sensors. Response is to call the police, switch on building lights and the audible alarm.

Timing requirements

Stimulus/Response	Timing requirements
Power fail interrupt	The switch to backup power must be completed within a deadline of 50 ms.
Door alarm	Each door alarm should be polled twice per second.
Window alarm	Each window alarm should be polled twice per second.
Movement detector	Each movement detector should be polled twice per second.
Audible alarm	The audible alarm should be switched on within 1/2 second of an alarm being raised by a sensor.
Lights switch	The lights should be switched on within 1/2 second of an alarm being raised by a sensor.
Communications	The call to the police should be started within 2 seconds of an alarm being raised by a sensor.
Voice synthesiser	A synthesised message should be available within 4 seconds of an alarm being raised by a sensor.

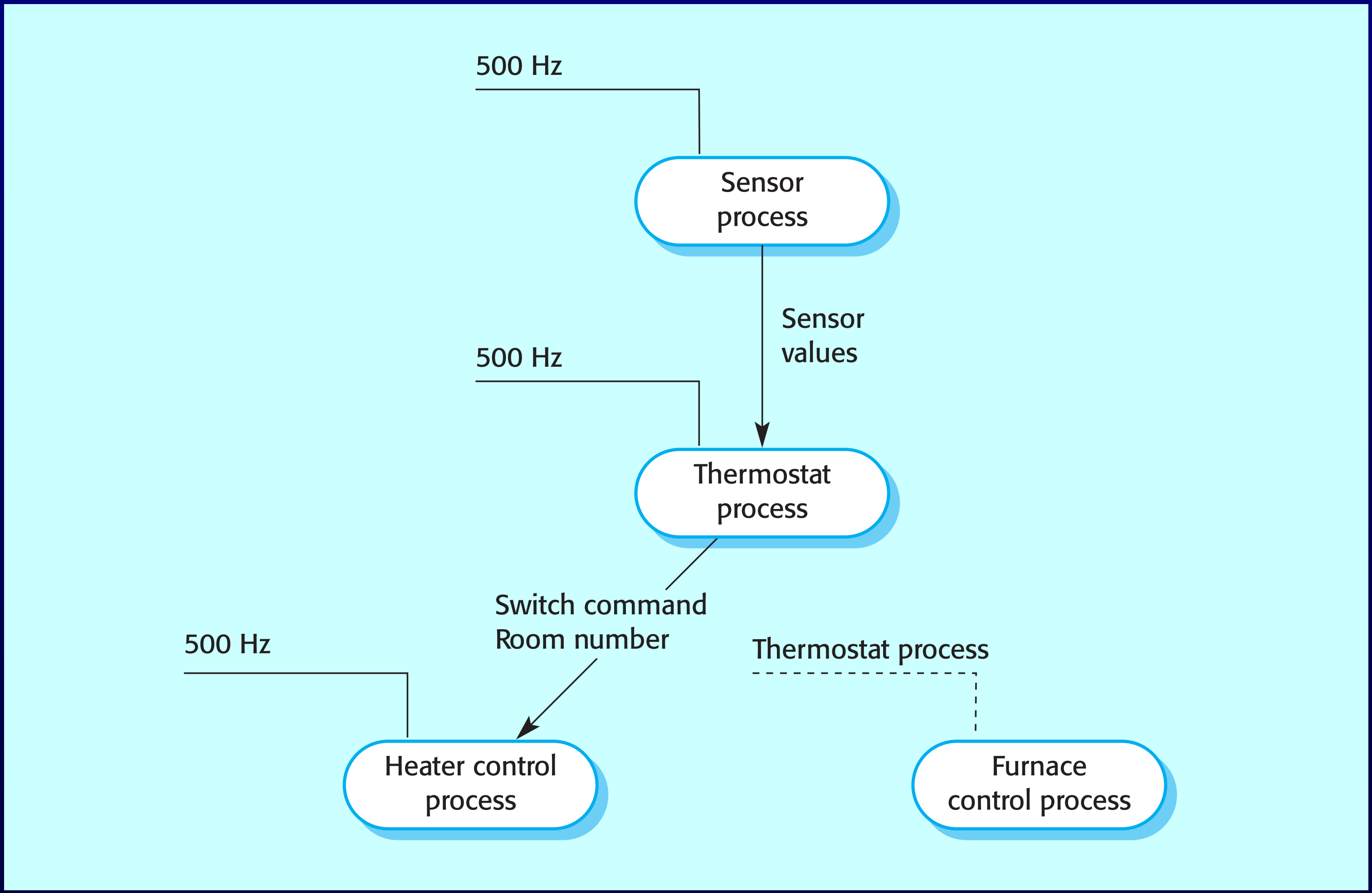
Burglar alarm system processes



Control systems

- A burglar alarm system is primarily a monitoring system. It collects data from sensors but no real-time actuator control.
- Control systems are similar but, in response to sensor values, the system sends control signals to actuators.
- An example of a monitoring and control system is a system that monitors temperature and switches heaters on and off.

A temperature control system



Data acquisition systems

- Collect data from sensors for subsequent processing and analysis.
- Data collection processes and processing processes may have different periods and deadlines.
- Data collection may be faster than processing e.g. collecting information about an explosion.
- Circular or ring buffers are a mechanism for smoothing speed differences.