Real-time Software Design

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

- 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.
- 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.

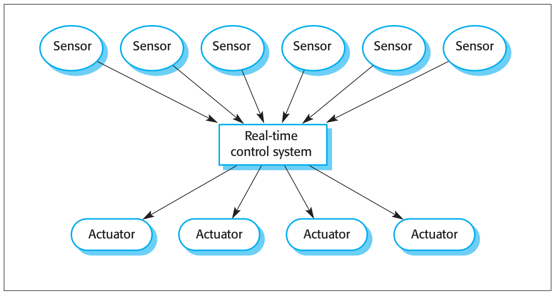
Stimulus/Response Systems

- Given a stimulus, the system must produce a response within a specified time.
- Periodic stimuli. Stimuli which occur at predictable time intervals
  - For example, a temperature sensor may be polled 10 times per second.
- Aperiodic stimuli. Stimuli which occur at unpredictable times
  - For example, a system power failure may trigger an interrupt which must be processed by the system.

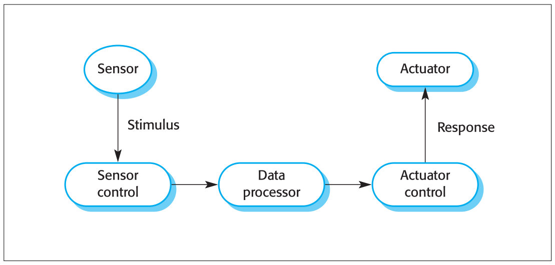
Architectural considerations

- 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 but real-time versions of Java are now available that address problems such as
  - Not possible to specify thread execution time;
  - Different timing in different virtual machines;
  - Uncontrollable garbage collection;
  - Not possible to discover queue sizes for shared resources;
  - Not possible to access system hardware;
  - Not possible to do space or timing analysis.

System design

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

R-T systems design process

- Identify the stimuli to be processed and the required responses to these stimuli.
- For each stimulus and response, identify the timing constraints.
- Aggregate the stimulus and response processing into concurrent processes. A process may be associated with each class of stimulus and response.

R-T systems design process

- Design algorithms to process each class of stimulus and response. These must meet the given timing requirements.
- Design a scheduling system which will ensure that processes are started in time to meet their deadlines.
- Integrate using a real-time operating system.

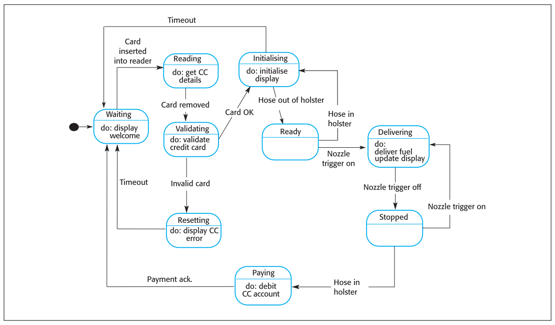
Timing constraints

- 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.
- May mean that low-level programming language features have to be used for performance reasons.

Real-time system modelling

- The effect of a stimulus in a real-time system may trigger a transition from one state to another.
- Finite state machines can be used for modelling real-time systems.
- However, FSM models lack structure. Even simple systems can have a complex model.
- The UML includes notations for defining state machine models
- See Chapter 8 for further examples of state machine models.

Petrol pump state model



Real-time operating systems

- Real-time operating systems are specialised operating systems which manage the processes in the RTS.
- Responsible for process management and resource (processor and memory) allocation.
- May be based on a standard kernel which is used unchanged or modified for a particular application.
- Do not normally include facilities such as file management.