LIÈGE université

Embedded systems

Exercise session 4

Software Architectures

Deadline 1 for projects reminder

Objective

Concise but complete reminder of your project objectives.

Hardware

- Clear and complete block schematic of your electronic circuit
- Explanation on some important choices (e.g. components choice, the reasons for the need for a given circuit part, etc.)

Software architecture

Clear and complete description on how you plan to implement your software. This includes (but is not restricted to) :

- Clear justification of your motivations for your architecture choice
- Clear and complete block diagram/explanation of the different tasks to be performed aboard the microcontroller
- Explain how those tasks will be organized inside of your architecture

Real time constraints

- **Soft** real-time constraints

→ Timings **should** be verified. If they are not verified, performances are lowered.

Example: LCD display

- **Hard** real-time constraints

→ Timings **must** be verified! If they are not verified, fatal failure.

Example: airbags in car

- We want to obtain the greatest amount of control over the system response time

→ Select the simplest architecture that will meet the response requirements

⇒Main choice criterion : Latency of the architecture followed by the complexity of the architecture

Software architecture comparison

	Priority	Max response time	Robustness against modifications	Complexity
Round-robin	None	Sum of tasks execution time	Bad	Very simple
Round-robin with interrupts	Interrupts	Interrupts + sum of tasks execution time	Good for interrupts, bad for tasks	Concurrent access
Function queue scheduling	Interrupts & tasks	Interrupts + longest tasks execution time	Quite good	Concurrent access; function queue
Real-time operating system	Interrupts & tasks	Interrupts	Very good	Very complex but within OS

January 2017 exam exercise

A quadcopter contains a microcontroller for controlling its four motors. This microcontroller is responsible for stabilizing the spatial position and orientation of the aircraft during flight, and for processing the orders sent by the pilot via a remote control. In order to do this, it has to perform the following tasks:

- Reading, processing and filtering data received from various sensors such as accelerometers and gyroscopes. This task has to be performed at a rate of 200 Hz, and takes 2 ms.
- Implementing a control loop. This task has to be performed at a rate of 100 Hz, and takes 1 ms.
- Communicating with the remote control. This task has to be performed at a rate of 50 Hz, and takes 0.2 ms.
- Writing a flight log in flash memory. This task has to be performed at a rate of 10 Hz, and takes 15 ms. The operations carried out by the task essentially amount to waiting for the flash memory component to trigger an interrupt signalling the
- end of the write operation.

a) List the tasks that have to be performed by this system. Give their respective period and/or execution time if they have one.
b) Are interrupts required to implement this system? If yes, what interrupt sources would you use? Carefully justify your answer. (Short answer: Yes, they are)
c) What is the best software architecture for this system? Carefully justify your answer. (Short answer: Round-robin with interrupts)
d) Using pseudo-code, give the generic skeleton for this architecture.
e) Using pseudo-code, adapt this skeleton to give the global structure of the embedded software corresponding to the system described in the statement.

August 2017 exam exercise

A nanosatellite in charge of taking pictures of the earth is controlled by an embedded system. This system is equipped with a radio transceiver that receives telecommand data packets from a ground station. Upon receiving a data packet, the radio transceiver sends an interrupt request to the onboard microcontroller. Such requests are always separated by a delay of at least one second.

The microcontroller has to perform the following tasks:

- $\tau 1$ fetches and processes the data packets communicated by the radio transceiver;
- $\tau 2$ performs computations for estimating the position of the satellite, every 10 ms;
- $\tau 3$ regulates a DC/DC power converter, every 2 ms;
- $\tau 4$ acquires an image from a camera, after telecommand data requesting to perform this operation has been received from the ground station. It then performs image processing operations.

Tasks $\tau 1$ and $\tau 3$ execute in less than 0.1 ms; task $\tau 2$ needs 1 ms. The execution of task $\tau 4$ may require up to 500 ms of CPU time, depending on the image processing operations that must be carried out.

a) List the tasks that have to be performed by this system. Give their respective period and/or execution time if they have one.

b) Are interrupts required to implement this system? If yes, what interrupt sources would you use? Carefully justify your answer. (Short answer: Yes, they are)

c) What is the best software architecture for this system? Carefully justify your answer. (Short answer: RtOS)

d) Using pseudo-code, give the generic skeleton for this architecture.

e) Using pseudo-code, adapt this skeleton to give the global structure of the embedded software corresponding to the system described in the statement.

January 2018 exam exercise

A 3D printer is equipped with a microcontroller that takes care of the printing process. Printing instructions are contained in a precomputed queue data structure, that enumerates the successive sets of coordinates by which the printing head must pass. The printing process consists in first popping a set of coordinates from the queue and processing it, which takes 0.2ms. Then, the motors are driven in order to move the printing head to those coordinates. This requires to command the motors every millisecond, which takes (each time) 0.1ms. When the printing head has reached the target coordinates, the controller pops the next instruction from the queue and repeats the same process, until the queue is eventually empty.

Additionnally, the microcontroller has to perform the following tasks:

- A task $\tau 1$ monitoring the temperature of the printing head heater every 10ms. This task requires 0.5ms to execute.
- A task $\tau 2$ updating a LCD display with the current status of the printing process every 20ms. This task requires 5ms to complete, but can be freely paused and resumed at any time in order to perform other operations.

a) List the tasks that have to be performed by this system. Give their respective period and/or execution time if they have one.

b) Are interrupts required to implement this system? If yes, what interrupt sources would you use? Carefully justify your answer. (Short answer: Yes, they are)

c) What is the best software architecture for this system? Carefully justify your answer. (Short answer: RtOS by default, RRwI also possible but only if pause() and resume() functions are used to pause and resume $\tau 2$)

d) Using pseudo-code, give the generic skeleton for this architecture.

e) Using pseudo-code, adapt this skeleton to give the global structure of the embedded software corresponding to the system described in the statement.

Conclusion for today

Main choice criterion : Latency + Complexity of the architecture

Next session

- Task scheduling exercises