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Context

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WPLeader	Universitat Politècnica deValència (UPV)
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1.1	2014/03/31	Seyfarth, M.; Neyrinck, A.	Final version
1.2	2014/03/31	UPV Team	Cover corrections

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1 Executive summary

This deliverable describes the learning activities proposed to implement the module “Microcontroller based systems for controlling industrial processes” for the Advanced Industrial Informatics Specialization Module (AIISM).

The AIISM is conveniently structured in different activities of progressive complexity to facilitate the teams to develop their projects along the course. The learning sessions are organized in these activities: lectures, seminars, laboratories, mini-project and tutorship.

In this deliverable, the structure, learning activities, prerequisites and schedule for “Microcontroller based systems for controlling industrial processes” module are provided.

2 Introduction

The developed methodology is mainly based on problem based learning (PBL) and other accepted active learning techniques with the intention of creating a realistic working environment which the student will experience in his future career. This model is based on the educational goals proposed by the Accreditation Board for Engineering and Technology (ABET) [1] and different experiences [2-5]. The general aims of the approach are:

- To guarantee that the student has a knowledge about the fundamentals of the specialization.
- To encourage the students to work as part of a team in solving industrial problems.
- To encourage students to apply practical skills in order to improve their problem solving abilities in the situations they will meet in their working environment.
- Due to the rapid advances in this area, to develop the capacity to adapt to any new computer based systems that may appear in the future.

Taking into account this methodology, all the learning activities are driven around a reference project. The example project for this module will be the control of a liquids tank.

The AIISM is conveniently structured in different activities, with progressive complexity to facilitate the development of projects along the course.

In order for the student to fully profit from the learning activities, a list of prerequisites is provided in the form of background knowledge and required skills that the student is expected to fulfil before beginning the activity.

3 Pre-requisites

These are the pre-requisites for this module:

- Basic C programming
- Basic digital electronics and algebra
- Basic analog electronics

4 The liquids tank model

The specification, design, implementation and validation of microcontroller based control systems are taught using a simplified continous process: a liquids tank. The size and complexity of this process is adequate to support the explanation of the essential concepts.

The process consists of a liquid tank that must be regulated at a reference temperature and to provide the fluid through a valve. A heater is responsible for heating the liquid and a pump to supply liquid to the tank. Level and temperature sensors allow knowing the current amount of liquid and temperature in the tank.

To sense physical magnitudes, the tank is equipped with the following sensors:

- An analog temperature sensor
- An analog level sensor
- A digital overflow sensor
- A digital overheat sensor

To actuate on the physics of the tank, and close the control loop, the following actuators are provided:

- A digital heater
- A digital valve
- An analog driver for the pump

Figure 1(a) shows a diagram of the different elements of the tank model.

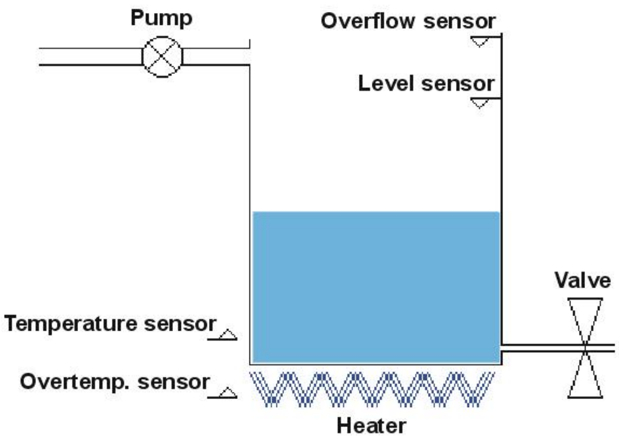

Figure 1-a Diagram of the scale model. 1-b Real tank developed model

The figure 1-b shows a real tank model that implements the characteristics of this proposal.

Sensors and actuators of the process are connected either directly to a microcontroller or by an electronic amplifier circuit and follow this description.

Signal	Direction	Type	Values/Range
Valve	Output	Digital	TTL, “0”->closed, “1”->open
Pump	Output	Analog	linear, 0V = 0%, 5V = 100% (pulse-width-

			modulated)
Heater	Output	Digital	TTL, “0” ->off, “1”->on
Overheat	Input	Digital	TTL, “0”->Overheat!
Overflow	Input	Digital	TTL, “0”->Overflow!
Liquid temperature	Analog	Input	Temperature Variable Resistor
Liquid level	Analog	Input	Variable Resistor

5 Module decomposition

Microcontroller based control systems are usually complex, but organized in a well defined structure. This structure is oriented to industrial control systems (Programmable Logic Controllers, PLC [6]) and state machines [7]. To develop a microcontroller based system with sufficient guarantees of success it’s important to follow a validated methodology. It is necessary to keep the complexity of the problem limited in each phase of the project: planning, design, development, validation, deployment and exploitation.

The experience of the software developers’ community over the past 50 years has identified important issues to be taken into account in industrial informatics projects. The recommendations can be transferred to those in embedded-systems, but enriched by particularities like real-time aspects.

Mainly, the basic and permanent recommendation consists of dividing the complicated problems in smaller or simpler pieces that can be addressed separately, based on the basics principles of the structured programming.

Since people are the key element in the project organization and their attention capacities are limited, it is necessary to make an abstraction process, keeping apart the irrelevant parts of a problem and focusing on the important things. This is also ideal for the students work.

The module proposes some basic design methods and programming techniques that allow this abstraction. The design and development recommendations proposed are based on concepts such as: top/down design approaches, modeling the problem before start coding, modular decomposition of the program, and minimizing interfaces between the modules.

These are proposals of interest to ensure the success of the project:

- To mix different design approaches has advantages if tailored specifically to each part of the project. For example, top-down approach is recommended in the design of the tasks. The main control task can be decomposed in a set of more specific collaborating tasks: “observe the actual situation”, “desire a new situation”, “decide the action”, “act” and “report to user”. The bottom-up approach is recommended however for developing some of the basic utilities and services, such as the input / output operations to sense and manipulates the external process, or the reading / writing operations on the blackboard system.
- Formal modeling during the design phase has advantages, because it allows a systematic codification from the model and then it is also easy to verify the program using the model. For example to formally design a state machine and then to easily code it using a “switch” instruction in C language.
- The modular decomposition based on divide and conquer algorithms has advantages too, because it allows address a complex problem into simpler parts by abstraction and concealment. You can delegate the development of each part to different team

members, and it accelerates the edit-compile cycle cause of the smaller translation units.

- The minimization of interfaces between the modules, through the “common data module”, has advantages, because it improves the consistency of information, avoiding duplication of variables, and simplifies the use of the variables by using a common interface. Additionally a centralized policy management and protection of the variables can be developed with the use of the blackboard access functions.

6 Learning activities

The learning activities are based on a PBL approach. This section provides a first approach of chapters, based on groups of different topics for the microcontroller based module. The timelime and detailed contents of the learning activities will be fine tuned in the following workpackage 2, according to pilot experencies and the curricula of the partner country universities (WP 3).

The following chapters are proposed for the microcontroller module:

1 Introduction to microcontrollers and process control
2 Project management and project planning
3 Input-/Output system of microcontrollers
4 Timer and interrupt functions on microcontroller systems
5 Graphic systems for microcontrollers
6 Communication systems on microcontrollers
7 Implementation of Control methods on microcontrollers
8 Integration and validation

Chapter 1 introduces basics about the microcontroller, its architecture, its usage and programming possibilities.

One important element of the learning activities is a mini-project. The students must work on a project similar to their later job. The knowledge of correct management and documentation of a project is a basic of an engineer. So chapter 2 deals with basic methods of project management and project planning. This is also a horizontal content of the module, so it is spread along the course and in a position where student understands its implications.

Microcontrollers deal in a special way with input- and output signals. It’s very close to hardware and electronics. So chapter 3 develops skills on handling the I/O-system of a microcontroller.

Chapter 4 introduces special functions of microcontroller that are closely related to their hardware. Especially timers and interrupts are handled.

Chapters 5 and 6 deal with ways of communication with a microcontrollers. On one hand it’s the communication with a user via a graphics systems, on the other hand it’s the communication between two or more microcontrollers.

To handle advanced automation applications, chapter 7 introduces the basics of closed loop controllers and their implementation on microcontroller based systems.

Finally chapter 8 shows how the subfunctions are integrated to a full project and how testing of each piece of the entire system is done.

As it has been stated above, this is a provisional proposal that will be developed in subsequent WPs.

7 Scheduling

This section provides a proposed scheduling distribution of the chapters in weeks. The course has been scheduled assuming a duration of 15 weeks, with 4 hours of direct teacher student interaction per week.

Chapter	Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	INTRODUCTION																
1	Lecture	Introduction to microcontrollers; architecture of microcontrollers	x														
1	Lab	Development environment; connection of microcontroller to PC	x														
1	Lecture	Introduction to Process Control and mini project		x													
1	Seminar	C programming basics		x													
2	PROJECTMANAGEMENT																
2	Project	Formal specification of the mini-project		x													
2	Project	Analysis of project specification			x												
2	Seminar	Project managment			x												
2	Project	Project planning, management and timetable of mini-project				x											
2	Project	Design of mini-project					x										
2	Seminar	Discussing mini-project status										x					
2	Lab	Tools for project documentation														x	
2	Seminar	Project documentation strategies														x	
3	I/O-SYSTEM of microcontrollers																
3	Lecture	Digital I/Os of microcontrollers			x												
3	Lab	Digital I/O			x												
3	Lecture	Analog I/Os of microcontrollers				x											
3	Lab	Analog I/O				x											
3	Lecture	Amplifier circuits for actuators and sensors					x										
3	Lab	Build up a basic amplifier circuit					x										
3	Seminar	Libraries					x										
3	Lecture	State machines, scheduling						x									
3	Seminar	Software tools for modeling of state machines						x									
3	Project	Using libraries in the mini-project						x									
4	TIMER AND INTERRUPT HANDLING																
4	Lecture	Timer Handling							x								
4	Lab	Basic timer functions							x								
4	Project	Implementing digital I/O							x								
4	Lecture	Interrupt handling								x							
4	Lab	Basis interrupt functions								x							
4	Project	Implementing analog I/O								x							
5	GRAPHIC SYSTEM																
5	Lecture	Displays and graphic routines									x	x					
5	Lab	Basic Display functions									x						
5	Project	Implementing state machine and controller									x						
5	Lab	Advanced display functions										x					
5	Project	Implementing display										x					
5	Project	Implementing user interface											x				
6	COMMUNICATION between microcontrollers																
6	Lecture	Communication between different microcontrollers												x	x		
6	Lab	Basic communication methods (Serial)												x			
6	Project	Communication to other liquid tanks												x	x		
6	Lab	Advanced Communication Methods													x		
6	Lecture	Communication between different microcontrollers														x	
7	CONTROL METHODS																
7	Lecture	Closed Loop Controller: modeling and algorithms											x				
7	Lab	Programming closed loop controllers											x				
8	INTEGRATION AND VALIDATION																
8	Project	Module integration and documentation of the mini-project.														x	
8	Lecture	Testing microcontroller projects															x
8	Seminar	Test and validation strategies															x
8	Project	Test and validation of the project; documentation of the mini-project															x

8 References

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