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Context

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1 Executive summary

This workpackage WP 1.1 details the structure of the Advanced Industrial Informatics Specialization Modules (AIISM) and how to organize the AIISM methodology.

The AIISM courses use a Problem Based Learning (PBL) methodology [1, 2, 3] to instruct the design and implementation of industrial informatics systems to control industrial processes. The AIISM methodology is designed based on previous experiences of the EU universities on PBL and active learning techniques. The purpose is to create a working environment for the students similar to the real environment in companies, in particular:

- to guarantee fundamental knowledge of AIISM as basis for the development of further developments;
- to accustom students to work in teams when solving industrial problems;
- to encourage students to use practical skills to improve their problem solving abilities;
- to develop the ability to adapt to any new computer based systems, due to rapid advances in this area.

Likewise, other engineering transversal skills are gained during the course such as teamwork, technical competencies, oral presentation, budget management, report redaction, etc.

Section 2 presents an introduction to AIISM methodology and the module structure, section 3 describes the list of activities of one module, section 4 details the lecture session, section 5 presents the laboratory structure, section 6 shows the organization of the seminars, section 7 describes the mini-project and finally in section 8 are shown some references.

2 Introduction

The AIISM is structured into different tasks of progressive complexity to facilitate the teams to develop their projects along the course (see Figure 2.1-1). Each module will be organized in different activities: lectures, seminars, laboratories and mini-project implementation (see section 3).

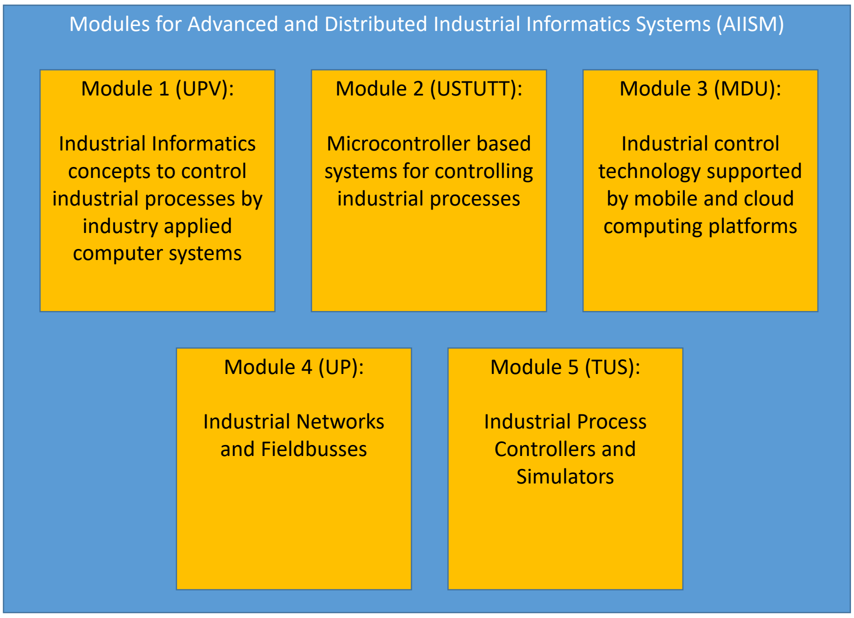

Figure 2.1-1 **Structure of AIISM**

The different activities are taught during 5 hours/day, one day of the week by a PBL methodology, using a combination of theoretical knowledge and a case study as an example relevant in practice. One example might be the control of a liquids tank, see Figure 2.1-2.

The control of the liquids tank or similar processes will be tackled by different automation platforms. UPV will solve the mini-project using an Industrial Computer. USTUTT will use microcontroller-based systems and MDU will apply mobile devices. UP will introduce Industrial networks and Fieldbuses to achieve the control of a combination of several interacting liquids tanks or similar processes. TUS will provide controllers and simulators to allow testing of the previously mentioned applications.

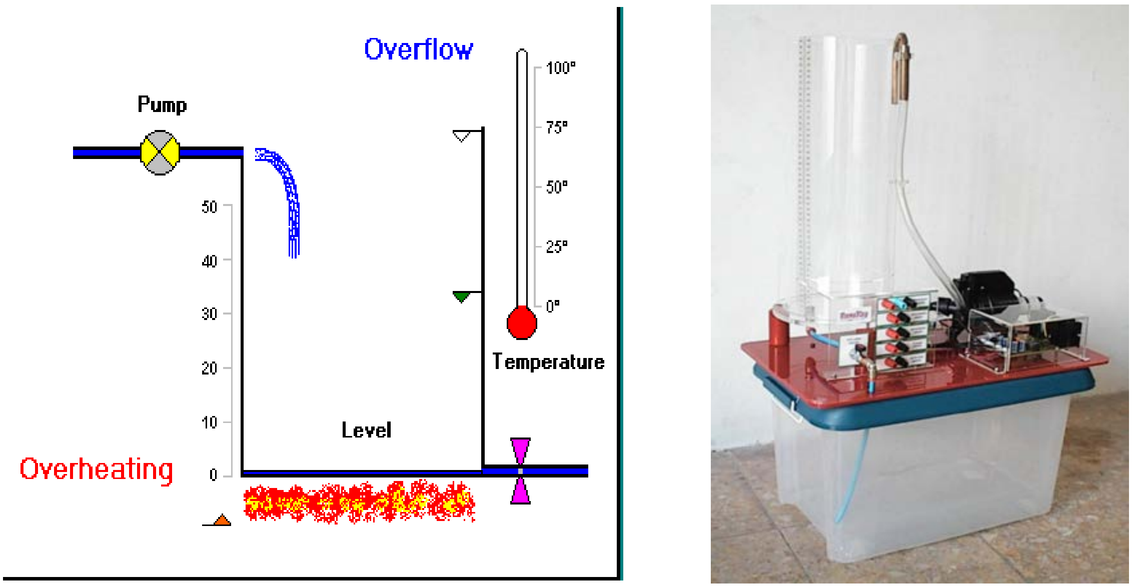

Figure 2.1-2 Liquids tank process

3 Description of Learning activities

This section describes the different activities in a module, with some guidelines about its practical implementation using Process Controllers and Simulators. As process controller will be used single-board computers and not PLC-like hardware. The single board controllers will be equipped with process periphery interface modules.

Each teaching module will consist of different activities: lectures, seminars, laboratories and mini-project implementation.

To reach the objectives of the course, students have to practically use the knowledge acquired from the lectures and the laboratory practices. The proposed learning activities include:

- Lectures: lecturer presents main ideas of lecture contents and proposes some application problems which student solve individually. This is mainly done by a presentation, interrupted by questionnaires and “whispering”-groups (e.g. 1.5 hrs).
- Laboratory session: Students solve a practical problem previously presented during lecture. Students work in teams of ideally 2 students. The lecturer gives some advices. This activity takes approximately 2 hours.

Final discussion: Each student team presents its methods, challenges and solutions of the laboratory session. The other student groups and the lecturer discuss these and give advices (e.g. 1 hr).

- Seminars: a panel discussion with student teams (4 students) lasting 30 minutes is proposed, consisting generally of solving a problem by means of PBL.
- Mini-project: dedicated to planning, design and development of the control system of the educational liquids tank or a similar process. The mini-project is performed by teams of 4 students. Weekly, the mini-project is advanced progressively. The students are forced to set up their own schedule and are responsible for finishing the project in time.

Each activity is described by a list of prerequisites, necessary background knowledge, required skills and the desired outcome.

4 Lectures

A lecture is the first step in the learning process for each of the topics in a module. The lecturer presents the main topics, basic knowledge and the structure of the contents. This includes some application examples.

4.1 Structure

During a lecture, the teacher:

- PREVIOUSLY: plans the lecture session based on his/her professional experience.
- Presents the learning objectives of the subject.
- Contextualizes the subject within the module, the course and the career, based on the problems to be solved and the resources that will be proposed to solve these problems.
- Motivates the subject based on the importance of the problems coped by the subject.
- Lists and discusses the bibliographic resources that support the concepts that will be presented during the lecture and that students may use to deepen in their study.
- Presents the key concepts related to the subject, providing the needed details to properly understand them, and specifying the extra available resources and the learning process that students should follow to complete the knowledge's acquisition. Follows a logical order for the argumentation, so that students can acquire the knowledge progressively and uses illustrative examples to clarify the presented concepts.
- Verifies that students correctly understand the presented concepts and adapts the speech if needed, allowing students to ask questions about the concepts that are not clear enough and observing the students' answers to the control questions.
- Interrupts his speech with small questionnaires and gives the students the chance to rest for a while.
- Informs about the skills related to the lecture that will be evaluated.

- Tells students about the practical application of the presented concepts that will be performed later during the seminars, laboratories and mini-project, and which are related to the lecture, encouraging students to study the issue with sufficient interest.
- After the lecture, keeps open communication channels with students, so they can make consultations before next lecture if necessary.
- LATER: should analyze the lecture session to improve his/her professional skills.

During a lecture, the student:

- PREVIOUSLY: has studied the recommended previous readings.
- Is receptive to the teacher's presentation and is proactive.
- Takes notes to conceptualize what is being exposed to facilitate its further study.
- Asks for concepts' clarification if necessary.
- Answers the questions the teacher addresses to the audience.
- LATER: should follow the learning method proposed by the teacher.

4.2 Goals

- After the lecture the students will know what is the problem and its importance, how the problem is described, which available alternatives would solve it and the criteria to select an appropriate solving alternative even though they will not have yet the skills to apply the proposed methods.
- They will have a studying plan that will be organized in the form of a set of labs, seminars and mini-project.

4.3 Prerequisites

- Previously to the lecture the student must be informed about the prerequisites to successfully follow the lecture.
- If the prerequisites are not satisfied, a plan should be supplied so that the student can acquire the necessary knowledge previously to the lecture.

4.4 Lecture Example

"Process Interface" Subject

This lecture discusses the communication between the program on the controller and the physical process to control. The context is focused on the multiprogram execution and multichannel control.

- *Goal*

To learn methods to observe the current state of the physical process under control and manipulate it, in order to make control decisions and apply them to influence the dynamic behavior of the process.

- *Contextualization*

The general concept of the process interface is specified for the specific characteristics of a controller applied. Hardware interfaces involved in the process control are presented. The architecture and electronic technology aspects of these interfaces and their programming aspects will be studied in this course. Special target is parallel and pseudoparallel access to multichannel process input and output and characteristics, their pros and cons and possible solutions for these situations.

- *Motivation*

The process interface is presented as an essential module in the control program.

The correct observation of the current state of the process is necessary to make accurate control decisions.

Students already know how to communicate with the microcontroller and know basic programming techniques; they have defined user interfaces in previous courses, where users were able to pass input data to the microcontroller and get the results using interfaces like keyboards and screens. The process interface they are going to develop in this course is an improving extension to that communication capability.

- *Bibliography*

- References to sensors and actuators.
- References to analog-to-digital and digital-to-analog converters.
- References to digital and analog ports on microcontrollers.

- *Concepts*

- The necessity of observation and manipulation of the physical process is presented.
- The concepts of sensors and actuators and their transfer functions are presented.
- The different types of signals: input and output, digital and analog, their codification and their interpretation as physical magnitudes are presented.
- The available methods of signal acquisition are presented and their programming aspects and the response time requirements are discussed.
- C/C++ programming concepts useful in the data acquisition programming are introduced: the use of bitwise operators and masks in the analysis of the I/O signals.

- *Examples*

- The signal from the sensor of the actual liquids-level in the tank is used as an example of an analog input signal.
- The alarm signal from the overflowing sensor is used as an example of a digital input signal.
- The signal to the heater in the tank is used as an example of a digital output signal.
- The signal to the liquids pump in the tank is used as an example of an analog output signal.

- *Control Questions and Recommended Further Reading*

Question Example:

Describe what possible technics and hardware solutions for multichannel analog sensor signals reading. References to data sheets of microcontrollers.

Do you know which type of digital input signals can be interpreted as pseudo-analog?

4.5 Recommendations

- During the lecture all the conversations in the classroom should be public, addressed to all of the members.
- The sequence of the lecture should be planned and predictable.
- The dynamics of the lecture should be attractive to the audience with short and direct explanations.
- The lecture shouldn't explain all the details of the concepts of the subject, it should give enough hints to let students autonomously complete the knowledge acquisition.
- The students must have the chance to formulate questions.
- Behavior rules must be defined to let the lecture to be productive and the corrective mechanisms should be effective and proportional.
- Potential distractors of the audience attention should be avoided or minimized.
- The lecture should be divided into subsequences for discussion the matter studied, interrupted by small questionnaires to give the students the chance to recapitulate the lecture so far.

5 Laboratory Session

The laboratory session (lab) is the first practical exercise that students take to acquire a basic set of skills related to the topic presented in the lecture. The exercises in the lab solve specific and well-defined problems; they are guided, fully documented, and of progressively increasing complexity. The lab provides students with a set of tools and skills that can be used to solve more open problems during the seminars.

5.1 Structure

During the laboratory session, the teacher:

- PREVIOUSLY: plans the lab session based on his/her professional experience.
- Presents the learning goals of the lab.
- Contextualizes the lab within the subject.
- Motivates the practical exercise to be performed during the lab based on the importance of the problem it addresses.
- Lists and comments the equipment, the material and documentation resources needed to perform the lab.
- Describes the correct utilization of the lab equipment and warns about potential material and personal damage due to inappropriate use.
- Answers of the students questions during the practical exercise.
- LATER: should analyze the lab session to improve his/her professional skills.

During the laboratory session, the student:

- PREVIOUSLY: has studied the lab documentation, and has attended the related lectures.

- Is receptive to the teacher's indications and is proactive.
- Takes notes to remember the indications.
- Asks for concepts' clarification if necessary.
- Works in teams of two students on the practical exercises of the lab.
- Answers the questions of the teacher related to the exercise.
- LATER: should review and document the results of the practical exercises and eventually performs the extra optional exercises.

During laboratory session, the technical assistant:

- PREVIOUSLY: Prepares the necessary equipment for the lab in each of the workbenches based on the teacher's requests and his/her professional experience.
- Helps solving problems that could arise related to the equipment, power supply, communications and software; makes diagnosis about the safety and correct operation of the equipment and replaces damaged components.
- LATER: should analyze the lab to improve his/her professional skills.

5.2 Goal

After the laboratory session the student should have acquired the skills to develop a controller based control and data acquisition system. Next they will know how to make a simulation using desktop or server-based simulation software. Finally students should have knowledge how to build and connect to the controller object simulator, based on a single-board controller hardware and environment. These skills will be useful in the related seminars and mini-project exercises.

5.3 Prerequisites

- The student should have attended the related lecture and have read the recommended further lectures and the lab guide.
- Teams of two students should have been defined.

5.4 Laboratory Session Example

“Process Interface” Subject - “Pseudo-Analog Input: Rotary Pulse Encoders” Lab

In this lab analog input signals are acquired using a multiple rotary pulse encoders for motion tracking and pulse-counting inputs of the controller. The current angle of turning and rotation speed is observed.

- *Goal*

To learn how to acquire pulse encoders' input signals, preprocess and store them using controllers.

- *Contextualization*

The general concept of the process interface is specified for the specific characteristics of a microcontroller platform studied in this module of the course.

Hardware interfaces involved in the process control are presented. The architecture and electronic technology aspects of these interfaces and their programming aspects will be studied in this course.

- *Motivation*

The importance of the motion tracking (pulse encoder output) signals in the control of physical processes is presented.

- *Contents*

The lab documentation starts with and introduction, the general problem specification, the necessary hardware equipment – controller, motors and pulse encoders, a description of the electrical function of the sensors and an introduction to the use of the counter input ports, followed by a number of exercises.

List of exercises:

1. Introductory phase - basic and completely guided exercise
   - The process to access counter ports of a microcontroller to acquire the signal of the pulse encoders is fully described. This will be presented to the students.
2. Reinforcement phase
   - The student is requested to acquire different pulse encoded signals (two phase signals, two phase + zero signal, speed and direction signals), coming it from a different sensor types, and to process and interpret these new signals with a different transfer function. The student must develop the exercise without the previous guide. The physical signals are simulated using a signal generator in this case and different type of signal transformations.
3. Advanced phase
   - The student is requested to combine the code that was developed in the previous exercises with the developed code in a previous lab. The goal is to acquire and plot the ration speed and turning angle on the computer screen of the classroom and interpret two digital input signals as limit alarm signals.
4. Optional phase
   - The student is requested to analyze the effects on the observed signal depending on the frequency of the input signal, which is simulated with the generator, and the frequency of the signal acquisition loop.

5.5 Recommendations

- The laboratory session should be fully documented.
- The lab guide should start with an introduction that remarks to the concepts of the lecture that are going to be applied in the practical exercise, the goals definition and a list of the material and documental resources that will be needed.
- The guide should continue with a definition of the practical activities in the following phases of progressive and increasing complexity: introductory, reinforcement, advanced and optional.
- The first exercise in the introductory phase should be described step by step.

- The second exercise in the reinforcement should practice the same concepts and method than before but on a different set of problem data and without the help of the guide in this case.
- The third exercise in the advanced phase should practice the application of the previously acquired tools, protocols and skills to solve a small sized and small complexity application problem.
- A fourth exercise should be defined in an optional final phase to let advanced students to consider further technical questions related to the topic of the lab.
- The teacher should supervise the practical exercises of the students, answering their questions, guiding them and providing enough hints to let the students find solutions by themselves.
- Recurring errors and problems, and interesting student's designs during the lab should be shared with the whole group. Remote desktop sessions of the workbench computer screen could be presented on the slide projector.

6 Seminars

During the seminars the students must solve problems on the topic of the lecture. They have already collected experiences on related topics and procedures in the previous laboratories.

The type of the activities in the seminar deals with the application of software tools and procedures to design solutions to specific problems. These problems are manageable parts of more complex problems. The activities include information extraction by the Internet, calculations and presentation.

Students work in groups of 4 people, but they must explain and share their experiences with the whole group during the seminar meetings.

In the seminars different problems and sub-problems related to the design and programming of single-board-based controllers of physical processes are analyzed from the perspective of the controller platform studied in this modules.

6.1 Structure

- The seminar starts with an introduction of the teacher recapitulating the key concepts presented during the lecture, and the presentation of several related design problems.
- The problems are decomposed in smaller parts, and the connections between the different sub-problems are discussed.
- Some of the problems are proposed to the whole group to start a debate, meanwhile other problems are proposed to be selected and solved by the different working teams during the seminar.
- After the analysis and design activities developed by each of the working teams the speaker of each team shares the obtained conclusions with the whole group and a second debate starts.
- The seminar ends with a resume by the teacher and the homework definition for each of the working teams that will prepare the next seminar session.

Note: Seminars can be split in several sessions if required cause of the complexity of the problems.

6.2 Goals

- To practice the concepts presented in the related lectures and verify that these concepts have been assimilated correctly.
- To relate the previous concepts with other technical concepts that usually is studied in different subjects, in a contextualized way.
- Acquire team-working skills.
- Acquire documentation and presentation skills.
- Acquire skills concerning the critical search of information.

6.3 Prerequisites

- The student should have attended the related lecture and have read the further recommended readings.
- Working teams of four people should have been defined. A balanced team is recommended with a similar level of initial knowledge for each of its members. One of the team members will act as their speaker.

6.4 Seminar Example

- *Problem:*

Integration of the following mini-project modules (written in C-Language or configured by program generator) for the implementation of the liquids tank level and temperature simulator: Process Interface Module, Common Variables Module and Control Module. Uses knowledge for the same problem form the other course.

- *Sub-problems:*

- Simulation of the physical problem's dynamics (level and temperature of the liquid in the tank) to generate the simulator's model.
- Implementation of the simulator of the physical process under control with included possibility to inject perturbations (aperture of the output valve, change of the ambient temperature and change of the input liquid temperature).
    - Simulations of the continuous signals (level and temperature).
    - Acquiring actuators signals (simulate liquid pump and heater).
    - Design of the state graph (operating modes and operating phases in the liquid service).
    - Programming of the state graph.
    - Validation of the simulator.

7 Mini-project

During the mini-project students use the knowledge and skills that they have acquired in the lectures, laboratory sessions and seminars to develop the controller for a physical process in an integral way. The problem of the mini-project is the highest complexity problem in the course. The working teams in the mini-project are the same as in the seminars. The designs developed by the teams during the seminars are used as components of the mini-project's problem's solution. The teams can combine seminar designs of different other teams to solve their mini-project.

7.1 Goals

- After the mini-project, the students should be able to integrate the tools and protocols practiced during the course to develop simple complexity and medium sized applications to control physical process.
- They should be able to document and present the mini-project process and outcome.

7.2 Prerequisites

The students should have attended the lectures and completed the practical exercises of the laboratory sessions and seminars that are related to the module of the mini-project that is going to be developed.

7.3 Mini-project Example

Development of a complete controller for a set of multiple liquids tank, integrating the following application modules:

- Common Variables Module.
- User Interface Module.
- Process Interface Module.
- Tasks Module.
- Control Module.
- Communication and Synchronization Module

8 References

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