MEDIS: A Methodology for the Formation of Highly Qualified Engineers at Masters Level in the Design and Development of Advanced Industrial Informatics Systems

WP1.1: Design AIISM - Structure of the AIISM courses

Co-funded by the Tempus Programme of the European Union

544490-TEMPUS-1-2013-1-ES-TEMPUS-JPCR

Authors: Domínguez, C., Martínez, J.M., Hassan, H.

MEDIS: A Methodology for the Formation of Highly Qualified Engineers at Masters Level in the Design and Development of Advanced Industrial Informatics Systems

WP1.1: Design AIISM - Structure of the AIISM courses

Contract Number: 544490-TEMPUS-1-2013-1-ES-TEMPUS-JPCR

Starting date: 01/12/2013 Ending date: 30/11/2016

Deliverable Number: 1.1

Title of the Deliverable: Design AIISM - Structure of the AIISM courses

Task/WP related to the Deliverable: Design of the AIISM-PBL methodology – Structure of the AIISM courses

Type (Internal or Restricted or Public): Public

Author(s): Domínguez, C., Martínez, J.M., Hassan, H.

Partner(s) Contributing: UPV

Contractual Date of Delivery to the CEC: 31/03/2014

Actual Date of Delivery to the CEC: 28/02/2014

<u>Project Co-ordinator</u>

Company name :	Universitat Politecnica de Valencia (UPV)
Name of representative :	Houcine Hassan
Address :	Camino de Vera, s/n. 46022-Valencia (Spain)
Phone number :	+34 96 387 7578
Fax number :	+34 963877579
E-mail :	husein@upv.es
Project WEB site address :	https://www.medis-tempus.eu

Context

WP 1	Design of the AIISM-PBL methodology
WPLeader	Universitat Politècnica deValència (UPV)
Task 1.1	Design AIISM - Structure of the AIISM courses
Task Leader	UPV
Dependencies	USTUTT, TUSofia, MDU, UP

Author(s)	Domínguez, C., Martínez, J.M., Hassan, H.
Contributor(s)	Albaladejo, J., Capella, J.V., Perles, A

History

Version	Date	Author	Comments
0.90	31/01/2014	UPV Team	Initial draft
1.0	14/02/2014	UPV Team	Final version

Table of Contents

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 course uses a PBL (Problem Based Learning) methodology [1, 2, and 3] to instruct the design and implementation of II 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 objectives; To accustom students work in teams when solving industrial problems; To encourage students to use practical skills to improve their problem solving abilities; To develop the capacity 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 and such as teamwork, technical competencies, oral presentation, budget management, report redaction, etc.

Section 2 presents an introduction to AIISM methodology, section 3 describes the list of activities of AIISM, 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 9 some conclusions are sum-up.

2 Introduction

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

The activities are developed during 5 hours/day, one day of the week through a PBL methodology, using as a case study the example of the control of the liquids tank of the Figure 1.

The control of the liquids tank or similar processes will be tackled by different platforms. UPV will solve the mini-project using an Industrial Computer. Each of the EU partners has to tackle the control using the corresponding platform:

- USTUTT will use microcontroller-based systems.
- MDU will apply mobile devices,
- UP will provide the Industrial networks and Fieldbuses to achieve the control,
- TU - Sofia will design controllers and simulators.

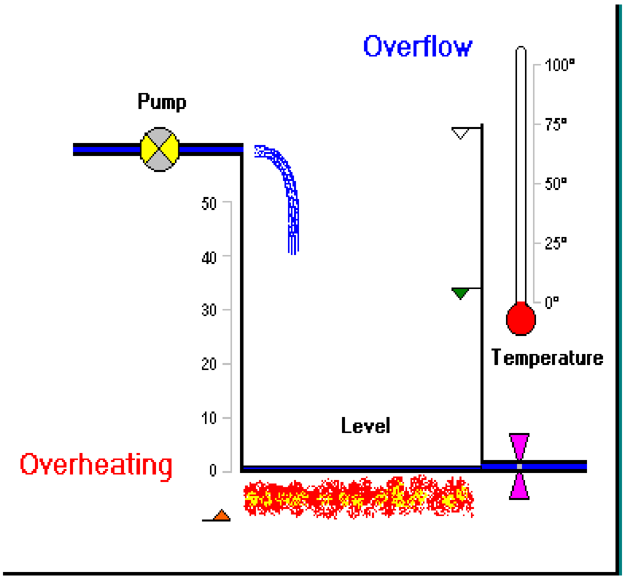

FIGURE -1 LIQUIDS TANK PROCESS

3 Learning activities description

In this section, the different activities are described with some guidelines about its practical implementation using the Industrial Computer.

The AIISM is conveniently structured with different activities, with progressive complexity to facilitate the working teams to develop their projects along the course.

To develop the course, students have to apply the knowledge acquired from the lectures and the laboratory practices. The proposed learning activities are the following:

- Lecture and problems: lecturer presents main ideas of lecture contents and proposes some application problems which student solves individually (e. g., 1 h).
- Laboratory session: To implement (1 h 15’’) a practical problem previously presented during lecture. Students work by teams of two students.
- Seminars: a panel discussion with student teams (4 students) lasting 45 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. The mini-project is performed by teams of 4 students during 2 hours. Weekly, the mini-project is advanced progressively.

It is necessary to establish for each activity a prerequisites list in order to provide the background and required skills in order to take profit of the activity.

4 Lectures

Lecture is the first step in the learning process for each of the topics in each course's module. The lecturer presents the main topics of the theme contents. It includes some application examples.

4.1 Structure

During lecture, the teacher:

- PREVIOUSLY: plans the lecture session based on their 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.
- 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 analize the lecture session to improve their professional skills.

During 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 aren't satisfied a previous to the lecture formation plan should be supplied.

4.4 Lecture Example

"Process Interface" Subject

In this lecture the communication between the control program and the physical process to control is discussed.

- *Goal*

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

- *Contextualization*

The general concept of the process interface is particularized for the specific characteristics of the personal computer control platform. Hardware devices involved in the process interface are presented. The architecture and electronic technology aspects of these devices will be studied in other courses, their programming aspects will be studied in this course though.

- *Motivation*

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

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

Students already know how to communicate their computer programs with the real world; they have defined user interfaces in previous courses, where users were able to pass input data to the program 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 transducer devices: sensors and motors.
- References to analog-to-digital and digital-to-analog converters.
- References to data acquisition cards.
- References to APIs of data acquisition libraries.

- *Concepts*

- The necessity of observation and manipulation of the physical process is presented.
- The concepts of sensor and actuator 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: the use of bitwise operators and masks in the interpretation of the I/O lectures.

- *Examples*

- The signal from the sensor of the current liquids level in the tank is used as an example of analog input signal.
- The alarm signal from the overflowing sensor is used as an example of digital input signal.
- The signal to the heater in the tank, which is manipulated on an ON/OFF basis, is used as an example of digital output signal.
- The signal to the liquids input pump in the tank is used as an example of analog output signal.

- *Control Questions and Recommended Further Reading*

Question Example:

Do you know which external representations for integral numbers are allowed in C/C++ language? References to octal, decimal and hexadecimal representations in C/C++.

Do you know how a literal integral number in a C/C++ expression is internally represented in memory? References to internal data representations in C/C++.

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.

5 Labs

The 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 labs solve specific and well-defined problems; they are guided, fully documented, and in progressively increasing complexity. The labs provide students with a set of tools and skills that can be used to solve more open problems during the seminars.

5.1 Structure

During lab, 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 students questions during the practical exercise.
- LATER: should analyze the lab session to improve their professional skills.

During lab, 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 lab, the technical assistant:

- PREVIOUSLY: Sets 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, making diagnosis about the safeness and correctness operation of the equipment and replacing damaged components.
- LATER: should analyze the lab session to improve their professional skills.

5.2 Goal

After the lab the student should have acquired the skills to develop a basic data acquisition system. These skills will be useful in the next 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.
- Working teams of two people should have been set.

5.4 Lab Example

"Process Interface" Subject - *"Analog Input: Temperature Sensor" Lab*

In this lab analog input signals are acquired using a Data Acquisition Card by National Instruments. The current temperature is observed.

- *Goal*

To learn how to acquire analog input signals using API libraries of commercial DACs.

- *Contextualization*

The general concept of the process interface is particularized for the specific characteristics of the personal computer control platform studied in this module of the course.

Hardware devices involved in the process interface are presented. The architecture and electronic technology aspects of these devices will be studied in other courses, their programming aspects will be studied in this course though.

- *Motivation*

The importance of the analog 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 – DAC and temperature sensor, a description of the transfer function of the sensor and an introduction to the DAC's library API's. It follows with a set of exercises.

List of exercises:

1. Introductory phase - basic and completely guided exercise
    - The process to program the DAC to acquire the signal of the temperature sensor and show the current temperature of the laboratory room on the computer screen is fully described.
2. Reinforcement phase
    - The student is requested to acquire a different analog signal, coming it from a different analog input port, and to interpret this new signal with a different transfer function. The student must develop the exercise without the previous guide. The physical signal is simulated using a signal generator in this case. The frequency of the signal acquisition is set constant.
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 on the computer screen the temperature of the room and interpret a digital input signal as an overheating alarm sensor.
4. Optional phase
    - The student is requested to analyze the effects on the observed signal depending on the frequency of the input signal, which simulated with the generator, and the frequency of the signal acquisition loop.

5.5 Recommendations

- The lab 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 of 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 them shelf.
- Recurrent 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 exercised on related tools and procedures in the previous laboratories.

The type of the activities in the seminar has to do with the application of those tools and procedures to design solutions to specific problems. These problems are manageable parts of more complex problems. The activities involve information searching over the Internet, designs and calculations.

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 of the course different problems and sub-problems related to the design and programmings of physical processes controllers are analyzed from the perspective of the personal computer control platform studied in these modules.

6.1 Structure

- The seminar starts with a teacher speech remembering about the key concepts presented during the lecture, and the proposition 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 investigation and design activities developed by each of the working teams the spokespeople share 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 are studied in different subjects, in a contextualized way.
- Acquire team-working skills.
- Acquire documentation and presentation skills.
- Acquire critical searching of information skills.

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 set. A balanced team is recommended with a similar level of initial knowledge for each of its members. One of the members' team will act as spokesperson.

6.4 Seminar Example

- Problem:

Integration of the following C++ mini-project modules for the implementation of the liquids tank level and temperature regulators: Process Interface Module, Common Variables Module and Control Module.

- Sub-problems:

- Simulation of the physical problem's dynamics (level and temperature of the liquid in the tank) to validate the controller.

- Simulation of the behavior of the physical process under control due to expected perturbations (aperture of the output valve, change of the ambient temperature and change of the input liquid temperature).
- Observations of the continuous signals (level and temperature).
- Alarm handling (overflowing and overheating digital sensors).
- Acting (input liquid pump and heater).
- Design of the automata (operating modes and operating phases in the liquid service).
- Design of the regulators (level and temperature control).
- Programming of the automata.
- Programming of the regulators.
- Coupling issues between controlled variables (level and temperature).
- Validation of the controller.

7 Mini-project

During the mini-project students apply the knowledge and skills that they have acquired in the lectures, labs and seminars to develop in an integral way the controller of a physical process. 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 use in their own mini-projects, seminar designs that other teams have shared.

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 labs and seminars that are related to the module of the mini-project that is going to be developed.

7.3 Mini-project Example

To develop of a complete controller of a liquids tank, integrating the following application modules:

- Common Variables Module.
- User Interface Module.
- Process Interface Module.
- Tasks Module.
- Control Module.

8 References

[1] H. Hassan, J. Martínez, C. Domínguez, A. Perles, J. Albaladejo " Innovative Methodology to Improve the Quality of Electronic Engineering Formation through Teaching Industrial Computer Engineering". IEEE Transactions on Education Vol: 47, No 4, pp: 446-452, 2004.

[2] Hernando, M.; Galan, R.; Navarro, I.; Rodriguez-Losada, D.; , "Ten Years of Cybertech: The Educational Benefits of Bullfighting Robotics," IEEE Transactions on Education, vol.54, no.4, pp.569-575, Nov. 2011.

[3] J. R. Savery and T. M. Duffy, "Problem Based Learning: An Instructional Model and its Constructivist Framework," in Constructivist Learning Environments: Case Studies in Instructional Design, B. Wilson, Ed. Englewood Cliffs, NJ: Educational Technology Publications, 1996.

[4] H. Hassan, C. Dominguez, J.-M. Martinez, A. Perles, and J. Albaladejo, "Remote laboratory architecture for the validation of industrial control applications," IEEE Trans. Ind. Electron., vol. 54, no. 6, pp. 3094–3102, Dec. 2007.

[5] H. Hassan, J. Martínez, C. Domínguez, A. Perles, J. Albaladejo, JV. Capella. Integrated Multicourse Project Based Learning in Electronic Engineering, International Journal of Engineering Education, Vol. 24, Nº 3, pp: 581-591, 2008.

[6] Houcine Hassan, Juan-Miguel Martinez-Rubio, Angel Perles, Juan Vicente Capella, Carlos Domínguez, José Albaladejo: Smartphone-Based Industrial Informatics Projects and Laboratories. IEEE Trans. Industrial Informatics 9(1): 557-566 (2013).