Project Acronym: MEDIS

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Context

WP 1	Design of the AIISM-PBL methodology
WPLeader	Universidade do Porto (UP)
Task 1.1	Design AIISM - Structure of the AIISM courses
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1 Executive summary

This section of workpackage WP 1.1 details the structure of the Advanced Industrial Networks and Fieldbuses Modules (AINFM) and how to organize the AINFM methodology.

Similarly to other courses in this project, the AINFM course uses a mostly PBL (Problem Based Learning) methodology to teach the design, set-up and configuration of industrial communication networks used in automation systems. The AINFM methodology is designed based on the current course work offered at UP (University of Porto).

The main goals are to provide a context within which students may (1) become acquainted with the theoretical foundations of industrial communication networks, their architectures, and the common technologies currently in use, as well as (2) to become proficient in using that knowledge when asked to design, procure, set-up, and place into commission a data communication network in an industrial environment.

Secondary goals are to allow students to experience a context similar to an industrial working environment, therefore allowing them to (1) become confident in their capabilities to accomplish the tasks put to them, (2) to be able to identify their current limitations in knowledge and capabilities, (3) to acknowledge that the technologies used in the real world evolve quickly with the years, (4) to become proficient in seeking new knowledge by themselves, and being able to understand and apply that knowledge without external supervision. In other words, it is important in the context of ever evolving technology, that students become capable of learning by themselves.

Other non-engineering but still fundamental skills are also practiced, such as team-work, and expression of ideas either orally or in the written format in the form of a report.

The remainder of this document is organized as follows:

- Section 2 presents an introduction to AINFM methodology.
- Section 3 describes the list of activities of AINFM.
- Section 4 details the structure of the lectures
- Section 5 presents the structure of the Laboratory course work.
- Section 6 details the organization of the seminars.
- Section 7 describes the mini-project
- and conclusions are presented in Section 9.

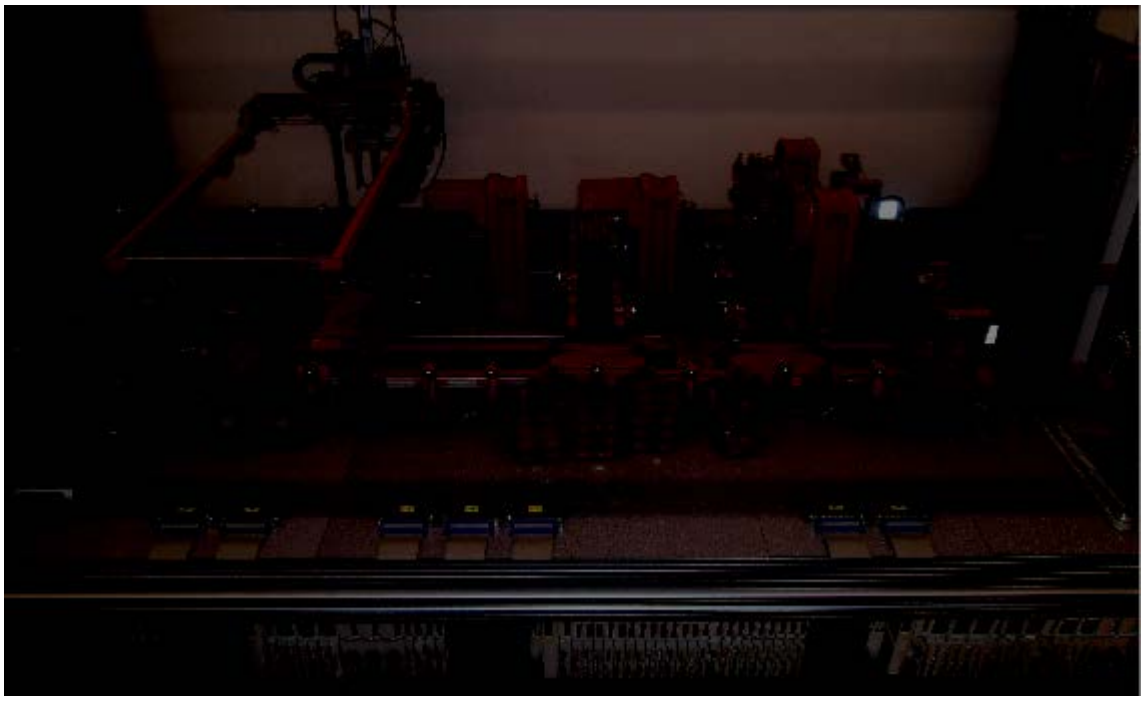
2 Introduction

The AINFM is structured with different types of activities, each with a distinct objective.

Lectures will allow students to become acquainted with the theoretical underpinnings of data communication networks. The laboratory sessions will allow students to put into practice this knowledge, and let them better understand the implications and real meaning of the theory previously mentioned, whereas the seminar sessions will foment the research activities of the student. The mini-projects will strengthen the student's confidence in their own capabilities, as well as foment their capabilities in researching, understanding, and using new technologies in this area.

The AINFM is structured so that the students will have a 4 hours per week contact with the course.

The activities are based around the PBL methodology, using two case studies. The first is an example of a discrete control system based on discrete conveyors, machine tools, warehouses and 3 axis manipulators (Figure 1), while the second, focused on the control of continuous processes, is the control of liquids in a tank (Figure 2).



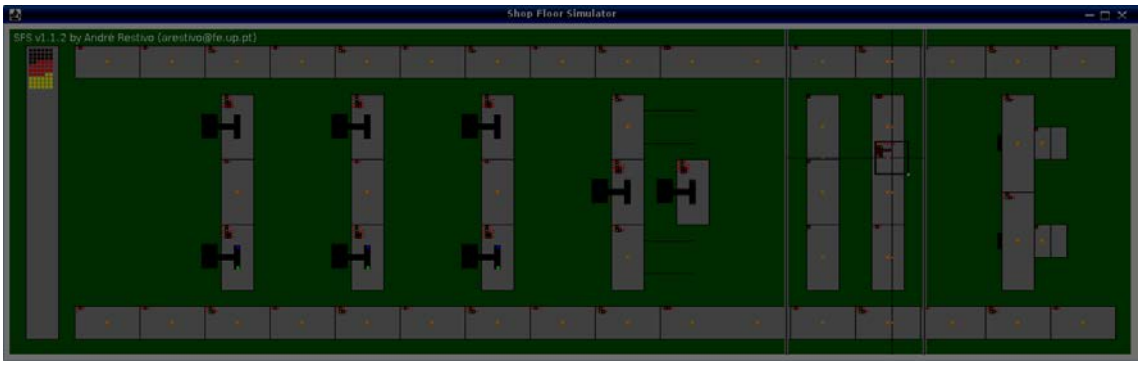


Figure 1 Processing Cell

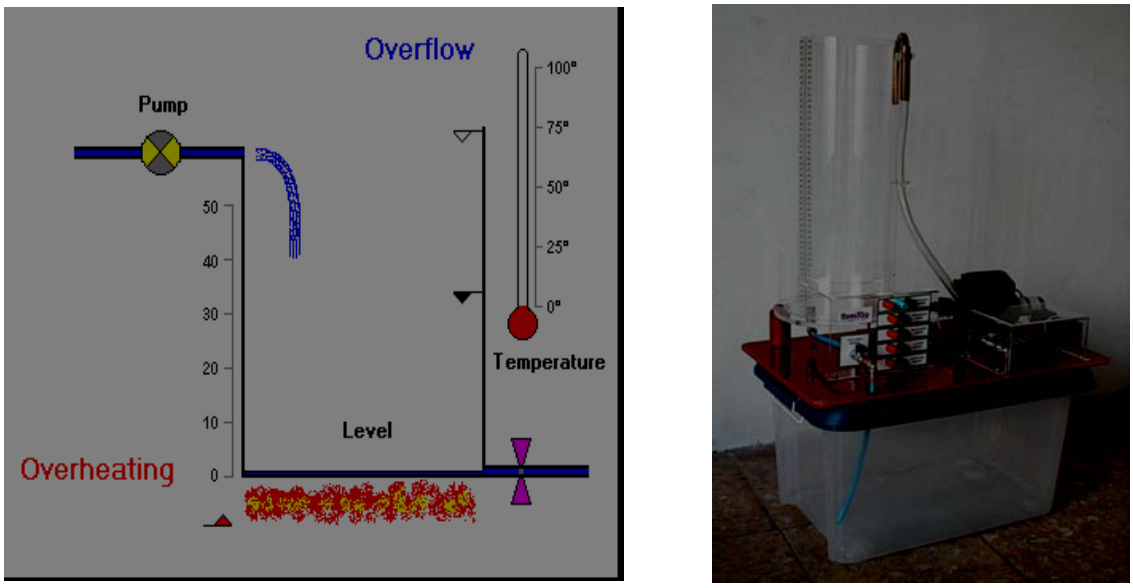


Figure 2 Liquids tank process

In this section, the different activities are described with some guidelines about its practical implementation using 2 distinct platforms, namely an Industrial Computer and a micro-controller.

3 Learning activities

The course is organized in such a way that students will apply the knowledge acquired from the lectures in both the laboratory sessions and while completing the mini-projects. The proposed learning activities are the following:

- Lecture and problems: lecturer presents the main ideas of lecture contents and proposes some application problems which student solves individually (e. g., 1-2 h).
- Laboratory session: the students, in teams of two, follow a laboratory session guide that will help them in implementing a solution to a practical problem previously presented during lecture (2h - 3h).
- Seminars: a panel discussion by teams of 4 students, lasting 30 minutes, followed by a question & answers session between all students. The subject of the seminar is provided two weeks in advance, and may consist of a problem to which the students must propose a solution.
- Mini-project: will consist in designing, development, and evaluation of a distributed control application, using industrial communication protocols to connect the distributed nodes. The mini-project is performed by teams of 4 students, and will start once the students have acquired sufficient knowledge to be able to accomplish the required tasks. In the first weeks of the course, no time will be alloted to the mini-project, whereas towards the end of the course, most or all of the time will be used up to develop this project.

4 Lectures

The 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.

5 Structure

During the 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.

6 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.

7 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.

8 Lecture Example

“Serial Communication Protocols”

In this lecture serial communication protocols are discussed, and actual implementations of this method of data transfer are presented (RS232, RS485, ...).

- *Goal*

To allow the student to be able to understand how data communication is achieved using serial communication protocols. Focus will be made on the properties of the individual implementations and their configuration parameters, in order to allow the student to be able to decide whether this specific technology for linking equipment at the physical layer is appropriate for a specific control application, while taking into account the specific requirements imposed by the control application and the environment in which it will be deployed. The student will be capable of configuring the protocol's parameters, and to write programs that access these communication interfaces using an industrial computer and a micro-controller..

- *Contextualization*

The general concept of serial communication protocols is presented, and technologies for achieving this interconnection are discussed. This is particularized for both the PC (personal computer), as well as for microprocessor based platforms.

- *Motivation*

Serial communications are presented as an essential layer in the communication network. Without a means of exchanging signals, no communication is possible.

Students have probably already used communication networks (e.g. Ethernet, Internet), but have never thought about how the data is in fact transferred from one computer to the next. This lecture will allow them to realize that several alternatives exist, each with their own advantages and drawbacks. In the realm of industrial communication networks, where many networks are still currently in use, it becomes necessary to be able to understand and choose the most appropriate network for the problem at hand.

- *Bibliography*

- References to documentation regarding serial communication technologies.
- References to physical layer standards: RS232, , RS485.
- References to micro-controllers with communication interfaces.
- References to APIs to directly access physical layer (e.g. RS232) from a PC.

- *Concepts*

- Broadband vs. baseband transmission
- Serial vs. parallel data transfer.
- Synchronous vs. asynchronous communication.
- Multi-point vs. point-to-point topologies
- Balanced vs unbalanced transmission of signals.

- *Examples*

- The communication between a PC and a micro-controller is used as an example of a RS232 based connection.
- The communication between a sensor and a microprocessors in an industrial context is used as an example of a RS485 based network.

- *Control Questions and Recommended Further Reading*

Question Example:

Do you know the advantages of balanced transmission vs unbalanced transmission? References to RS323 and RS485.

Do you know how many signals and wires are used in an RS232 data link?

9 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.

10 Labs

The laboratory is the first opportunity that the students have to put into practice the skills that were explained in the lecture. The exercises in the labs solve specific and well-defined problems; they are guided, fully documented, and have a progressively increasing complexity.

11 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.

12 Goal

After the lab the student should be able to establish and configure an RS232 data communication channel between two PCs and between a PC and a micro-controller. They should also be able to write programs to transfer data over this communication channel. These skills will be useful in the next related seminars and mini-project exercises, where a higher layer protocol (Modbus) will be implemented using these physical layer protocols.

13 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.

14 Lab Example

"Physical Layer" Subject - "Serial communications: RS232" Lab

In this laboratory session, two computers are interconnected using an RS232 interface, and a computer is connected to a micro-controller, also using RS232. A data cable is built, the interface is configured, and data is first transferred using existing communication programs (e.g. terminal emulator). Next, a small program is developed to transfer data over the same channel, using an appropriate API (Application Programming Interface).

- Goal

To learn how to set up an RS232 based data channel, to configure it, and to access it from a student written program.

- Contextualization

The general concept of serial communications is particularized for the RS232 standard and the PC platform. The electrical signals involved in the data transmission are presented, and the required configuration options are explained.

- Motivation

The importance of communication between devices used by the control application is presented.

- *Contents*

The lab documentation starts with an introduction, the general problem specification, the necessary hardware equipment (PC, serial cable, micro-controller), a description of the RS232 standard, and the library API's. A set of exercises follow.

List of exercises:

1. Introductory phase - basic and completely guided exercise

- Connect two computers, configure RS232, and test connection using terminal emulator program on each computer. Write a program to send and receive data, and test against a terminal emulator.

1. Reinforcement phase

- Write a program to send and receive data over RS232 on the micro-controler. Test data transfer with the computer.

1. Advanced phase

- The student is requested to combine the code that was developed in the previous labs (e.g. reading of physical input) with the developed code. The goal is to acquire a signal on one computer, and to transfer this information to another computer. Care must be taken with encoding of data wider than 8 bits.

1. Optional phase

- The student is requested to analyze the effects of distinct transmission speeds, and data corruption on the data channel.

15 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 document 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.

16 Seminars

During the seminar the students must present the their proposal of how to solve a specific distributed control problem. The solution should be based on the theoretical foundations explained in the lectures, and the practical experience obtained in the laboratory sessions.

The students are expected to propose an architecture of their solution, and to defend this architecture based on models and calculations that prove that their architecture is sound, and will meet functional and timing requirements of the control problem.

The distributed control problem to be analysed during the seminar will consist of a complete closed loop control with an industrial context. The students will work as system integrators, and with their experience of the partial solutions to these problems previously explored during the laboratory sessions, will choose which communication protocols and inter-connection architectures are best suited for the problem. The activity will also involve the search for further information from several resources, and calculations.

Students work in groups of 4, and share the result of their research with the whole course during the seminar presentation.

17 Structure

- The teacher will propose the problem to be analysed 2 weeks in advance.
- The seminar will begin with the teacher highlighting the aspects of the problem that for which solutions are sought.
- Each group will have a set time to present their solution.
- A debate between the students, with the teacher as moderator, will then proceed. During the debate the relative merits and demerits of the proposed solution will be discussed.
- The seminar ends with the teacher making a summary of the solutions, and a comparison of the approaches taken by each group.

18 Goals

- To practice the concepts presented in the related lectures and laboratories, and to 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.

19 Prerequisites

- The student should have attended the previous lectures and laboratory classes, 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.

20 Seminar Example

- *Problem:*

A beer brewery needs to expand by building two new mashers and coppers, with associated heat exchangers, pumps, mixers, etc. The control of this equipment will be based on distributed control platforms, as well as distributed sensors and actuators. A SCADA system will also be required for supervision and control of recipe execution, as well as interfacing with the plant's MES (Manufacturing Execution System).

- Sub-problems:

- Research and study the typical timing requirements imposed by the industrial process being analysed.
- Research and study the environmental conditions (humidity, temperatures, acceleration, distances between equipment, electromagnetic interference, etc.) typical of the industrial process being analysed.
- Research and study other field-buses not mentioned in the course.
- Research and study other communication protocols to higher layers of plant control.
- Analyse all the requirements, and propose a solution that will meet them.

21 Mini-project

During the mini-project students apply the knowledge and skills that they have acquired in the lectures, labs, seminars, as well as other courses in the AIISM, to develop a distributed control application. The resulting application will typically integrate some of the software and configurations done in the laboratories.

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 may be 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.

22 Goals

- After the mini-project, the students should be able to propose solutions for the inter-connection of devices in a distributed control application.
- They should also be able to place the proposed solution into working order.
- They should be able to document and present the mini-project process and outcome.

23 Prerequisites

The students should have attended all the lectures and completed all the laboratory exercises.

24 Mini-project Example

To develop a distributed controller for a factory floor composed by discrete conveyors and machine tools, integrating the following application modules:

- Communication protocol between supervisory control (SCADA) and automation controllers.
- Communication protocol between automation controllers and remote Input/Output.
- Discrete control module
- Process interface module