ON EXPERIENCES WITH A SEMINAR FOR TEACHING ROBOTICS

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Abstract. The growing amount of new, additional topics to be handled without extention of the time students stay at the university and without an extension of the number of available lecturers poses a difficult problem for the teaching body. The paper presents experiences gained with a seminar as a possible solution in the area of robotics. After a discussion of the general scheme of education for electrical engineering at the Technische Hochschule Darmstadt, the structure of the seminar and experiences gained with it are described. The paper concludes with some remarks on another solution chosen with respect to introduce artificial intelligence approaches to control engineers.

Keywords. Education, Teaching, Robots, Artificial Intelligence.

I. INTRODUCTION

Educational schemes are fairly different in different countries even in an area with similar cultural background like Europe. In addition one has to take into account, that different branches like human sciences, natural sciences and engineering sciences are using different approaches to teach their body of knowledge due to tradition and/or requirements and inherent ways of arriving on general conclusions. Even in the same country and the same discipline certain smaller differences may exist, like in Western Germany, where due to its federal status and the relatively high autonomy of universities with respect to educational questions this is the case.

To describe unconventional solutions for certain problems arising at someones own university, one has to give therefore at first a general picture about the traditional approach and general layout of teaching the discipline to be discussed.

This paper is concerned with the problem of inclusion of education in the area of robotics and artificial intelligence into the study of control engineering at the Technische Hochschule Darmstadt - TH Darmstadt (= Technical University of Darmstadt) -. Control engineering is here a graduate study branch of electrical engineering and we shall discuss therefore in section II the general layout of electrical engineering education at Darmstadt. Section III deals then with the seminar approach used to make the students acquainted with this area, a solution relatively unconventional in electrical engineering, at least at our University. In section IV reactions of students, limitations to this approach and details on overall experiences will be taken up, since in the final outlook some remarks will be made on some further measure, to improve the situation regarding the subtopic artificial intelligence, which gets growing importance for advanced robotics, but can be handled only in a fairly superficial way in the seminar.

II. ELECTRICAL ENGINEERING EDUCATION AT THE TH DARMSTADT

The distinction between a bachelor degree and a masters degree is not known at German Universities. In technical disciplines the curriculae are ending always with the Dipl.-Ing., being equivalent to the masters degree. However, the studies are divided in two major sections, separated by an intermediate examination, the "Vorexamen". The first section of the studies, lying before this Vorexamen and needing a time-span of 2 years - 4 semesters (terms) - is mainly engaged in giving a general background for the discipline, since the second section, requiring at least furhter 2 1/2 years are tuned to give more specific information, to take into account special interests of the students and to allow them to make their first steps in the direction of independent work. Before and during the study time some practical work in industry is required as part of the studies. There are e. g. for electrical engineering 13 weeks in different prescribed shops requested - to be performed mainly before the first semester - and further 13 weeks on a more loosely prescribed basis during the second section of the studies.

There exists a certain coordination regarding topics and their detailization for the first and the second section with respect to engineering curriculae, which is mainly handled by the so-called "Fakultätentage", a cooperation of the respective faculties of German Universities - e. g. in our case of the faculties for electrical engineering - not installed by law, but practically as influential in their decisions as if there would be a legal background. This coordination allows for instance a fairly easy change between Universities after the "Vorexamen", since this examination is accepted by each other University as part of the overall engineering course for the Dipl.-Ing.

Table 1 gives some information about the general layout of the electrical studies to be completed before the "Vorexamen". After this examination a certain branching is possible. In Darmstadt we have eight respective branches as listed in table 2. An announcement by the student, which branch he has selected, has to be made, however, at the commence-

ment of his final examination, only, leaving a certain freedom for changes between the branches, since the study courses of them are partly overlapping. We are going to discuss the control engineering branch, solely. Information on the other branches may be found in /1/, details on the overall organization of electrical engineering at the TH Darmstadt and the existing laboratories for this discipline together with some historical information in /2/, /3/.

The control engineering education is divided in non-facultative basic courses, partly facultative specific courses on control engineering, some non-technical courses and a general engineering area, in which the students should either deepen their knowledge on one non-electrical technical process - due to the fact that the handling of such processes is the main area of work of control engineers in industry - or deepen their knowledge on electronic devices and/or software - due to the fact, that these topics are important areas of professional engagement for control engineers, too. Table 3 gives a more detailed description of the respective workload distribution and some course names. A further important part of the engineering education is study and/or thesis work. Electrical engineering at Darmstadt and by this also control engineering includes two separate student projects: The "Studienarbeit" takes 6 - 8 months and is in general some clearly separable sub-work from scientific research work in the laboratories, which the student tries to solve fairly independent, however, under the direction of one of the scientific assistants of the Professor heading the laboratory. Since in this work the time-limitation is not very strict, the final thesis work, the "Diplomarbeit" is strictly limited to three months, simulating the independent solution of some task under time and/or cost restrictions, as it is normally the case in industry. Again this work is a sub-task from some research project. Studienarbeit and Diplomarbeit may be chosen freely from any laboratory in electrical engineering and on request from some other university laboratory or even under certain circumstances from some industrial project, which leads to the wanted effect of a certain competition between laboratories regarding attractive topics. Information on actual research topics at the laboratory for control engineering (Institut für Regelungstechnik) at the TH Darmstadt can be found in /4/, /5/, regarding overall research topics at the THD in /6/.

III. BACKGROUND AND ORGANIZATION OF "ROBOTIC AND AI"-SEMINAR

From 1980 on a number of scientific projects in the area of robotics started at the Control Systems Theory Group from the "Institut für Regelungstechnik". It became quite soon apparent that the necessary basic knowledge needed for inclusion of students by Diplom- or Studienarbeiten was nowhere taught at the university, making a relatively high familiarizing effort necessary for the students, diminishing by this the wanted effect of introduction into independent research work. At the same time the students were very eager to select their project and/or thesis work from this subject. Since in Germany the lecturing task is concentrated mainly onto the full professors, a lecturer level not being available, and since the already installed lectures on automatization and control seemed to be necessary furtheron, it was difficult to close this gap. So the solution of a students seminar was adopted, being a well-known tool in human and natural sciences, but not in engineering sciences. Although, there exist seminars also, their main aim is to allow students to report on their study and/or thesis work, building up the experience for presenting papers during the professional work later on. So only short summary talks of twenty minutes strict are the content of our control laboratory seminars.

For our yearly "Robotic and AI" seminar we choose the classical way of providing students with material on clearly defined subtopics leaving to them the preparation of a 2 - 3 hour talk by a group of two students. A prepared manuscript had to be distributed to all participants, which were limited to 28 students in accordance with one afternoon each week during the winter-term of 14 weeks. There was no rehearsal on the planned lecture and only a very limited critique by the responsible professor, H. Tolle, to avoid discouragement and lack of independence, especially since the other students were believed to utter a possible disappointment later on, anyhow. By this, the general effort was reduced to the selection of the material for the lectures by one of the scientific assistants, who are graduates, working on their Ph.D. thesis. A flexible strategy was adopted: Besides of some general introduction on robot layout, application, kinematics and dynamics, further topics were selected on the special research area of the responsible assistant who was changing each year. Due to the fact, that assembly tasks may be assisted heavily by knowledge based and vision systems, some introduction into artificial intelligences approaches and their languages LISP and PROLOG was included, too. Taking advantage of the limited number of students, the seminar was supplemented each year in November by a two-days excursion to industrial companies working on robot and AI-application and/or projects. A small get-together after the last seminar before Christmas - sponsored by the Professor, the preparation performed by the students on a voluntary basis - was a further help to bring up a certain group spirit and to make the seminar a continuous success.

IV. EXPERIENCES

The seminar was held in the winter-term 1987/88 for the fifth time. Table 4 is giving a list of topics, handled by the students in the five seminars alltogether, some being the same in all years, some being different in the different years. In general, the seminar proved to be of much better quality, than we had imagined. The high interest of the students let them use much more time for preparations than we had anticipated (our overall guidance to the students was a fortnight of work). Although we knew from our experience with Studienarbeiten, that students are longing for independent work and are willing to invest into such tasks very often some extraordinary determination, we were not aware, that the students felt furtheron, that in our traditional schemes we are not providing enough opportunities to present orally work done. Also, there was a high interest to get the fingers wet with programs and/or robot hardware. One group of students borrowed even a very expensive industrial vision system - the existence of which was known to them by the required work in industry, see section II - to give a practical demonstration to the seminar participants. The aim to give a much better background for study/thesis work was reached. The written lecture notes prepared by the students were partly superb improving over the time in the layout in accordance with the improvement of word processing tools for personal computers. Actually, each student owns by this at the end of the semester a fairly recent state-of-the-art handbook on robotics. One educational side-effect was, by the way, that these manuscripts turned out to be a good tool to teach adequate literature citation.

Naturally, some deficiencies were found to exist also. The first problem was the explanation of kinematic robot equations and dynamic robot modelling. This question was solved by changing the structure of the seminar for the first four weeks:

Instead of giving these topics to students, they were taken up by the responsible professor, supplemented by an extensive manuscript. The second problem was the high interest of students to include also some practical demonstrations into their lectures. Although the Control Systems Theory Group had the necessary robot equipment and appropriate programs available, there was a bottleneck in computing power, the computers at hand being already overloaded through project and thesis work. Regarding this question, the "Stiftung Volkswagenwerk" helped by supplying the money for a further computer in 1984 and since then always some demonstrations could be inserted into the seminar. A third problem was, that there were often more students interested in the seminar, than lectures could be given out to them. One year we tried to solve this question by making larger groups of three to four students to prepare one afternoon. This turned out to deteriorate the level of student lecturing. So we limited the number of participants to twenty recently (two for each lecture), taking into account the reduced number of available student seminars due to the kinematics/dynamics lectures in the beginning.

V. OUTLOOK

Although it is necessary to include artificial intelligence topics into the Robotics and AI seminar, the available time for this subject is not big enough for a thorough understanding of this area as needed for making study and/or thesis work on related subjects. The informatics faculty provides naturally lectures on a number of special branches of AI. However, they are very specific and too time-consuming to be inserted into the free space of control engineering studies. Furtheron, they do not address the problem of real-time applications up to now. Since this is one of the research directions of our own work in this area and since we have taken up recently a growing number of such projects, we decided to fill this gap by an own AI lecture. Again capacity was a problem. The solution was to generate a two hours-per-week (2 + 0) lecture held by seven scientific assistants working on AI problems in the Control System Theory Group. So each one has to prepare two lectures only, however, at the same time a certain equalization of naming and problem handling is reached in the group and also lecturing experience can be gained by the assistants, which is otherwise concentrated on exercises only.

However, since this scheme has been used during the winter-term 1987/88 for the first time a final evaluation of possible advantages and disadvantages can be given at a later conference, only.

VI. ACKNOWLEDGEMENT

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VII. LITERATURE

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/5/ Institutsbericht 1988-TH Darmstadt, Institut für Regelungstechnik, Darmstadt 1988

/6/ Technische Hochschule Darmstadt - 8. Forschungsbericht 85/86, Darmstadt 1988

	1. Semester	2. Semester	3. Semester	4. Semester
Mathematics	6+3	4+2	4+2	2+1
Physics/Mechanics	3+1	3+1	2+2	2+2
El. Engin. Fundamentals	3+2	3+2	3+2	2+1
Specific Introduction on	materials 2+0	communic. 2+0	-	el.energy handl. 3+1
Informatics for Engineers	-	-	2+1	2+3
Techn. Design/ Drawings	1+2	2+2	-	-
Electr. Measurement	-	2+0	2+1	-
Laboratory work	-	-	physics 0+3	el.meas.0+3

Table 1: Electrical Engineering (TH Darmstadt) till "Vorexamen"; a+b = lectures + exercise courses; homework not included

General Electrical	Engineering	(Allgemeine Elektrotechnik)
Theoretical Electrical	Engineering	(Theoretische Elektrotechnik)
Electrical Energy	Engineering	(Elektrische Energietechnik)
Communications	Engineering	(Nachrichtentechnik)
Electro-Mechanical Design		(Elektromechanische Konstruktionen)
Control	Engineering	(Regelungstechnik)
Data Handling/Processing		(Datentechnik)
Solid State Electronics		(Festkörperelektronik)

Table 2: Selectable branches after "Vorexamen" (electr. engineering THD)

Obligatory Courses:	Control Engineering Fundamentals I/II	8+4
	Signal Processing	3+1
	Circuit Design Fundamentals and Applications	6+2
	Electronic High- and Low Voltage Devices	5+2
	Thermo- and Fluiddynamics	3+1
Obligatory lab. work:	Control/Communic./Electr. Engines/non-el. measurem.	1+5
Courses from:	Systems Theory/Automatisation/Process Dynamics	9+3
General Courses from:	Mechanical and/or Electrical Engineering	6+2
Economics/Human Sciences:		4+1

Project Work (Studienarbeit) 6-8 months/Thesis Work (Diplomarbeit) 3 months

Table 3: Control Engineering - Topic distribution, homework not included

Kinematic relations for robots/manipulators - (1)
Dynamic modelling for robots/manipulators - (1)
Industrial robot control in joint coordinates - (1)
Industrial robot control in cartesian coordinates - (1)
Comparison of centralized and decentralized robot control methods
Programming languages for industrial robots
State of the art and trends of robot development
Economic and social problems of robot employment
Assembly automation with industrial robots
Factory of the future: CAD/CIM/MAP/Assembly cells
Robot grippers
Force-torque sensors and their application with robots
Further sensors and their application with robots
Mobile robots-reviews on systems and state of the art
World-modelling path planning, obstacle avoidance for mobile robots
Multi-arm robots and their application
Collision avoidance for multiple robot systems
Modelling and control of elastic (flexible) manipulators

General layout and task distribution in vision systems
Binary value and grey level handling in vision systems
High level methods for pattern recognition and vision systems
Stereo vision methods

AI approach and methods of problem solving
Planning and search algorithms in AI
Expert systems
Learning control systems
AI programming languages LISP and PROLOG
AI assisted methods for assembly by robots

Table 4: Topics in the Robotic and AI seminars 1983/84 - 1987/88
- (1) now part of the introductory lectures