FIELD ROBOT DESIGN CONTEST – A SHOWCASE IN AGRICULTURAL ENGINEERING EDUCATION

Joachim Müller[a], Steffen Walther[a], Stefan Böttinger[a], Arno Ruckelshausen[b] and Eldert J. van Henten[c]

[a] *University of Hohenheim (Stuttgart), Institute of Agricultural Engineering (GER)*
[b] *University of Applied Sciences Osnabrueck, Engineering and Computer Science (GER)*
[c] *Wageningen University, Farm Technology Group (NL)*

Abstract: Student numbers in Agricultural Engineering are stagnating in spite of a good job market. Agricultural robotics offer an excellent opportunity to attract more students. Therefore, objective was to stimulate the integration of robotic design projects in Agricultural Engineering education. An annual student design contest, the Field Robot Event, has been advertised. Since 2003, the number of participating teams increased steadily like the number of visitors and press representatives. Students are rewarded with study credits for the design project. The Field Robot Event triggered also professional technical development, leading to first agricultural applications like scouting and weeding.

Keywords: design, education, navigation, robots, vehicles, vision,

1. INTRODUCTION

In Western Europe and the U.S.A., student numbers in Agricultural Engineering are stagnating in spite of a good job market for graduates. High school students prefer studies associated with high-tech and information technology. However, they don't seem to be aware that both aspects are the backbone of modern Agricultural Engineering. Especially agricultural robotics could offer an excellent opportunity to attract more students. Therefore, objective was to stimulate the integration of robotic design projects in Agricultural Engineering education and to attract public attention to these activities.

2. MATERIALS AND METHODS

To make robotic design projects affordable for limited university budgets, Field Robots were introduced - a small-size version of autonomous off-road vehicles. Field Robots are sub-canopy robots that navigate within the alleys of row crops like maize (Müller, *et al.*, 2003). To stimulate activities at various locations, 'competition' as an essential element of game-based learning has been applied: a student design contest, called Field Robot Event (FRE), has been advertised. Agricultural Engineering groups have been invited worldwide by sending flyers and posters supported by a website (www.fieldrobot.com). In The Netherlands and in Germany also high schools have been invited.

The contest tasks, developed by an international scientific committee of 11 professors, varied slightly every year. Basic task in 2005 was as follows: make as many alleys (10 m long) as possible in a maize field (max 3 min), turn at the headland and count the number of plants at both sides. Beside the technical performance in terms of speed and counting, 45% of the scores were based on crop damage that is visually estimated by .the Jury. As in the FRE the choice of robot components is generally free to allow unlimited creativity, the Jury assesses the hardware costs of the robots according the bill of material. Low investment costs are rewarded with high scores. In FRE 2005 the share of the economy scores was 11% of the total scores. Trophy money, ranging from 500 to 1,000 € and being sponsored by a

manufacturer of agricultural machinery was offered to the three best teams.

3. RESULTS

3.1 Experiences at the University of Hohenheim, Germany

Since the first event in 2003, always a team from the University of Hohenheim participated at the event. In the first FRE the team made the first place with their robot ISAAC (Fig. 1).

Fig. 1. Field Robot ISAAC, winner of the FRE 2003.

The competition attracted especially older students that found it challenging to apply their acquired knowledge to a practical field. As they usually are at a finally stage of their studies, the team members changed almost totally from year to year and the 2003 success could not be repeated. The rapid change of team members, and partly also tutoring staff, is one of the main challenges to transfer know how concerning driving systems, sensors, and control strategies to the next team. Consequently more effort was taken to motivate team members form the former years to remain in the team, be it as tutors or as active members. In 2006 a team of three students, headed by a 2005 participant, made the third place with the robot ROBOKYB.

At the University of Hohenheim, participation at the FRE is voluntary for the students of Agricultural Engineering. There is so far no possibility to account any commitment of the students as a contribution to their studies. However, the Field Robot Event is promoted in several lectures. Especially students of the module 'Automation' (Electric, Electronics and Control Systems) are appropriate candidates, while there is also interest from students of 'Mechanical Engineering' and 'Technical Cybernetics' at the University of Stuttgart nearby.

Supervision of the teams by staff members of the Institute of Agricultural Engineering is also on a voluntary basis. Most of the required electrical and mechanical tools are available to the students in the laboratories. For mechanical works (e.g. metal sheet work) the mechanics of the institutes own workshop will help the students. Assistance by the specialists for electronic and control systems is available on request.

While possibilities to include Field Robot design into future lectures are investigated, the design and implementation of a technology platform as an outlook on how to approach the actual Field Robot, was assigned to one student as a research project prior to the work on the 2006 robot.

The technology platform is used as a demonstrator of robotic in-field action on a science fair funded and implemented by the Federal German Ministry of Science and Education (BMBF). The exhibition visits major German cities during a four months period from May through September and gives the Institute of Agricultural Engineering the unique chance to present its technological visions in a well recognized environment together with other renown universities and research institutions.

3.2 Experiences at the University of Applied Sciences Osnabrueck, Germany

Role of the FRE in education. At the University of Applied Sciences Osnabrueck, activities of agricultural, mechanical and electronic engineering as well as computer science are integrated, resulting in successful developments like sensor-based intra-row weed control (Ruckelshausen, *et al.,* 1999, 2004; In der Stroth, *et al.,* 2003). When the FRE came up, it was seen as a perfect link between those research activities and education in the various fields of engineering. Moreover, in the northwest of Germany, agriculture is of high importance and several companies with agricultural machinery are located with their headquarters in this area. As a consequence, most of the students have a practical background in agricultural engineering, independent of their actual study program.

Fig 2. Field Robot OPTOMAIZER during a test run in a maize field.

Different ways of implementing the FRE in the curriculum have been experienced since 2004 (Table 1). The basic idea was to reward design and application of the robot with ECTS (European Credit Point Transfer System; one semester workload totals 30 ECTS). In 2004, a team of 13

students worked on the Field Robot EYEMAIZE (Diekmann *et al.,* 2004), earning 5 ECTS each in the modules 'Optoelectronics' and 'Microsystems'. The students organized their work related to sensor and system technologies as well as to project management. Practical experiences with team work and a 'hard' deadline were reported by the students as being very helpful. Several meetings with the supervisors took place, where the results achieved so far have been discussed. A special input was given by the staff to use an innovative low-cost camera (CMUCam). Fundraising was integrated in the project from the beginning, thus all hardware costs have been covered by the support of companies in electronics and agricultural engineering industry. Since the FRE took place during the examination period, special agreements have been made with the faculty to allow the students to participate. The development of the Field Robot EYEMAIZE has been supported by the staff of the laboratory of micro- and optoelectronics and the interdisciplinary research centre Intelligent Sensor Systems (ISYS), thereby ensuring the continuity of the project for the next student generation.

Two members of the EYEMAIZE team were strongly interested to design a new robot for the next FRE in 2005. The two students designed the robot OPTOMAIZER (Klose *et al.,* 2005 a) as MSc-thesis in electrical engineering, which lasted 6 months, earning 30 ECTS (Fig. 2). Starting with the results of EYEMAIZE a new concept with a real time operating system has been developed. Information for row guidance, positioning for head land turns and counting plants is based on 21 sensors (8 different types) where the priority of algorithms is given to the low-cost camera CMUCam2. Beside bi-directional interfaces, a display and a WLAN have been implemented, which is a powerful tool for developing and testing the robot. Moreover, power electronics for speed and steering control of 2 engines were integrated. The main portion of the work, however, was the software development with more than 5000 lines of C code for OPTOMAIZER.

Table 1: Field Robots developed at the University of Applied Sciences Osnabrueck, Germany

Year	Field Robot	Students	Course	(ECTS)
2004	EYEMAIZE	13	Optoelectronics	(5)
			Microsystems	(5)
2005	OPTOMAIZER	2	MSc-Thesis	(30)
2006	MAIZERATI	9	Mechatronics	(5)

The success of the EYEMAIZE (3rd place in FRE 2004) and OPTOMAIZER (2nd place in FRE 2005) attracted attention of newspapers, radio and television. Moreover, the robots have been shown in several exhibitions including large industrial fairs like the Agritechnica 2005 and the Hannover Messe 2006. Thus, the motivation for students and supervising staff was very high to continue in FRE 2006. Consequently, a new Field Robot MAIZERATI was developed by students of the MSc-program 'Mechatronic Systems Engineering'. Nine students with knowledge in mechanical, electronic and computer engineering have chosen this topic as a project of the course 'Mechatronic Seminar'. The experience of OPTOMAIZER was integrated, moreover, mechanical simulations have been performed. Several new tasks for the FRE 2006 as compared to prior competitions were a challenge to the students, but finally MAIZERATI was winner of the FRE 2006 (Fig. 3).

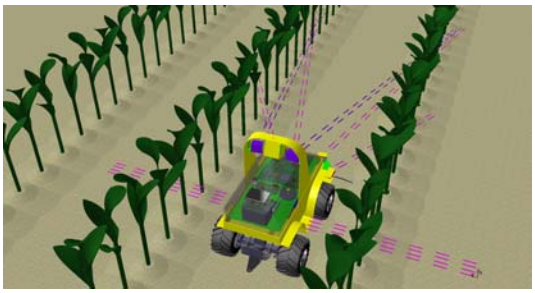

Fig. 3. MAIZERATI: Mechanical design and simulation in CATIA software.

Impact of the FRE on research. Despite the fact that the activities in Osnabrueck have been started less than 3 years ago, the impact the FRE to research is already of high relevance. The aspects range from basic research up to prototypes of products. There are 3 major fields:

Implementation of new technologies: Many different technologies have been integrated in the Field Robots. Since investment costs are an essential scoring criterion of the FRE, the implementation of new low-cost sensors – like gyroscopes or acceleration sensors – has been of high importance, which corresponds to boundary conditions for industrial design solution. Thus, new technologies such as low-cost row-guidance are evaluated with respect to application in other products, in cooperation with companies (Klose, *et al.,* 2005 b).

Information technology in agriculture: The strongly increasing application of new technologies in agricultural equipment, e.g. in precision farming, requires fast and efficient process data acquisition and communication. Thus the complex robotic system OPTOMAIZER has been extended as a platform for testing remote control and data exchange. Meantime, OPTOMAIZER is serving as a robotic platform for teleservice and electronic documentation in agricultural applications (Klose, *et al.,* 2006).

Field Robots for agricultural applications: Based on the experience gained in FRE activities, a professional Field Robot WEEDY has been developed as a fully autonomous vehicle for weed control in row crops (Ruckelshausen, *et al.,* 2006). Several technologies of the student Field Robots have been directly implemented in the new robot, moreover the experiences of field testing and user interfaces had a strong impact in the development.

3.3 Experiences at Wageningen University and Research Centre, The Netherlands

Role of the FRE in education. At Wageningen University, participation in the FRE is offered as a 'free course' to Agrotechnology students in their third study year. In 2006, a group of 6 students built the robot FIELDMEISTER. Each student was required to invest 8 weeks of 40 hours into this project, so FIELDMEISTER was built in approximately 2000 hours. In return, each student earned 12 ECTS for participation in this course. The students operated as a self organising team. A project leader was appointed and tasks were divided amongst the individual members. Main task blocks identified were: (1) electronic and mechanical hardware and (2) software. Three team members worked on each of these tasks. The FIELDMEISTER was not built from scratch. The 2006 team modified the Field Robot frame of the student entry in FRE 2005. The 2006 team felt active steering wheel to be an advantage over skid steering used the year before, and modified the platform accordingly (Fig. 4). Sensors and control hardware remained the same. Control software was fully implemented in LabVIEW®.

Fig. 4. Active, single steering wheel used on the FIELDMEISTER in 2006.

The team was coached on an occasional basis by a faculty member of the Farm Technology group of Wageningen University. Meetings with this coach were held 5 times during the period. Because of lack of knowledge in computer vision, the student team was offered a short introductory course. The team also had the opportunity to use available knowledge of the 2005 student team, as well as the expertise of the members of the Farm Technology group and Systems and Control group of Wageningen University, but staff members did not participate actively in the design and development process.

Afterwards, the students identified two main learning objectives, including first of all technical skills directly related to building a robot, more specifically, electronics, mechanics, sensor technology, data acquisition, and data processing, machine vision and LabVIEW® programming. Building a Field Robot is seen as a chance to put theory into practice. Secondly, students experienced building a Field Robot for this event to be a true team effort and developed and used team skills to achieve a common goal.

Impact of the FRE on research. Beside the student activities, the Field Robot CROPSCOUT was developed by a team of senior researchers of Wageningen University and Research Centre (Fig. 5). CROPSCOUT is a small-scale experimental platform for research on precision agriculture in applications such as detection of weed or diseases. Also, it serves as a test bed for autonomous robot control algorithms using sensor fusion techniques and artificial intelligence to deal with the variability and uncertainty in the working environment robots are confronted with when applied in agriculture and horticulture (Fig. 6).

Fig. 5. Cropscout, winner of the Field Robot Event 2004 in Wageningen, The Netherlands.

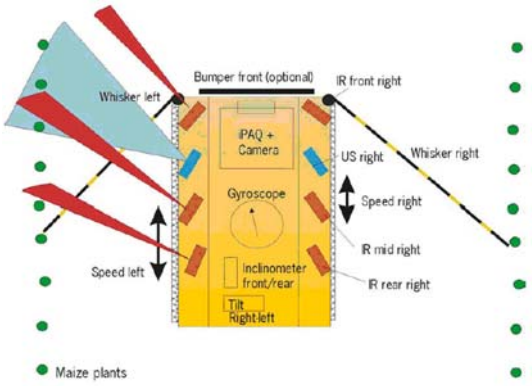

Fig. 6. Sensor system of CROPSCOUT.

The development of CROPSCOUT fits into a long term strategy of Wageningen University and Research Centre, aiming at a sustainable high-tech agriculture and horticulture. Robotics is one of the instruments to pursue that goal. Examples of earlier research on agricultural robots are CUPID, a cucumber harvesting robot (Van Henten *et al.,* 2002), BELEAF, a de-leafing robot for cucumbers (Van Henten *et al.,* 2004) and an autonomous vehicle for mechanical weeding (Bakker *et al.*, 2005). Besides two scientific papers (Van Henten *et al.*, 2004, Van Henten *et al.*, 2005), the victory of CROPSCOUT in 2004 yielded many entries in newspapers and magazines, as well as exposure on

radio and television. Additionally, CROPSCOUT was used as an attraction during various technical fairs like the annual Horti Fair in Amsterdam, thus contributing to the exposure of Wageningen University and Research Center as a center of expertise in the field of agricultural engineering.

4. CONCLUSIONS

Due to the quickly growing knowledge in navigation and machine vision, various groups of scientists are working on the development of autonomous vehicles for precision agriculture. Most of these activities are based on research projects that are not yet linked on an international level. Opening the competition of Field Robots also for professionals is a welcome occasion for the researchers to get together in a sportsmanlike atmosphere for personal exchange of knowledge and a unique opportunity for the audience to see a variety of autonomous vehicles at work (Fig. 7).

Fig. 7. Participants with their Field Robots at the 4th Field Robot Event 2006 at the University of Hohenheim, Germany.

In the past 4 years, a total of 48 Field Robots participated in the Field Robot Event (Table 2). As the tasks change from year to year, and the teams gain experience, robots are usually either new in contest, or, in the case of platforms, have to be modified in depths. Participants from universities as far abroad as Japan, Chile, and Malaysia reflect the growing recognition and true scientific demand in the approach.

Table 2: Field Robots and countries

	Field Robots			
	2003	2004	2005	2006
The Netherlands	7	9	7	5
Germany	1	2	4	4
Poland		1		
Denmark	1	1		
Ireland		1		
Finland			1	1
USA		1		
Japan			1	
Chile				1
Malaysia				1

The enthusiastic contribution of the student teams to the past Field Robot Events triggered a fresh impulse of creativity in Agricultural Engineering. Hands-on learning by designing own Field Robots is a strong motivation for students, also addressing off-curriculum skills like communication, leadership, teamwork and fundraising. The publicity effect of such contests attracts the interest of high school students to get involved into the subject. Meantime the Wageningen Field Robot Event developed to a annual event. To keep ideas fresh, it was decided that the event will change location within Europe, returning home to Wageningen University every odd year. Universities can apply to host the Field Robot Event, the decision will be made by the Scientific Committee.

The interest in the Field Robot Event can be divided into three main groups. Group number one are mainly students and perspective students. These students are interested in technology and can be seen as the main target group. The second group includes companies with various backgrounds – mainly agricultural engineering companies, software companies, and the automotive industry – and is very engaged regarding funding issues. The media, and hence the public, form the third group and are closing the circle. With increasing performance of the robots the FRE will remain in the edge of recognition and attract students and funding.

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