Successful co-operation between industry and university

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1 Introduction

This paper will identify some of the key factors that make the co-operation between a university and an industrial partner successful. A few cases of such projects will illustrate the ideas.

Budget cuts force universities to search for additional funding in order to be able to continue their research programs. However, earning money is not the primary task of a university and on a longer term it may even endanger the existence of the university. The primary task of a (technical) university is to educate young engineers in a way that they are able to function well during a professional career of about 40 years.
This means that they should have a broad basic education and a critical mind, based on knowledge taught in courses on experience in research gained during an MSc. or PhD. thesis. The latter can be closely related to the design or development of an industrial product. But enough basic-research content and a critical attitude of the student are important for the quality of this training. This implies that each thesis project should allow enough freedom to stimulate creativity and should not be dominated by industrial time constraints. If so, there would be no reason to keep a student longer in the university. Pure industrial experience can be gained in the professional practice.
The university should train a critical attitude not only by searching for *a* solution, but also by asking more in depth questions. Is this the best solution? Can a similar or better result be obtained in a different way and is it really true what is obviously concluded? The university can afford asking such questions because students are ‘cheap labour’. But it would be wrong for industry to use students in co-operation projects, just because they are ‘cheap labour’. The critical and research oriented attitude that universities should teach their graduates, can only be realised in an environment that is sufficiently independent of sponsors and that has its own research goals. Therefore, it is important that university laboratories have their own long term vision and projects. Industry should support these activities, even if they do not pay off in a short period of time. Well-trained graduates will be the result, as well as innovative ideas that may be ready for commercialisation several years later.

2 Characteristics of good projects

From the introduction it can be concluded that increased co-operation between university and industry can be considered a good development, but only under certain constraints. The major characteristics of good co-operation projects will be summarised here and will be illustrated with a few cases in the remainder of this paper.

Good projects have the following characteristics:

- they deal with a problem that has *no obvious solution beforehand*
- it requires *knowledge gathered by the university during several years of research*, not yet ready for application without any further research

- it is *directed towards an industrial product* that is *really needed* by the industry, although it is *not so essential* that the industry could better develop the product itself, because of, for instance, time constraints
- *partners in the project should all be actively involved* during the duration of the project. Projects where the industry just pays and the university delivers the results, are less beneficial for both parties
- time allowed for the project should fit the *time scale of universit*y students. In the situation in the Netherlands this implies four years for a PhD. project and one year for (Mechatronic) Designer project.

The last point is important because only projects that run for at least one year, can have the research-related content that is essential for work done at the university. Of course shorter projects are possible, but this should be more an incident than common practice.

3 Cases

Two cases will illustrate the before-mentioned ideas. The examples treated will cover:

- a four year project dealing with the design of an advanced autopilot for ships
- a one year project dealing with the design of an accurate system for laser welding of surface mount devices (SMD's) on a printed circuit board (PCB)

3.1. *Design of an advanced autopilot for ships*

This case describes a project carried out some years ago while the author worked with the Control Laboratory of the EE Dept, of Delft University of Technology. It deals with the design of an autopilot for ships. Normally autopilots control the heading of a ship, using the rudder. In addition, fins with a separate control system should reduce the roll motions. It is well known that these two systems interact, but controllers that take this multivariable character of the system into account were non existent and are even today not very common. The project described here aimed at using this interaction in a positive way, by using the rudder simultaneously for course control and roll reduction.

3.1.1 CHARACTERISTICS

The project should require knowledge gathered by the university during several years of research, but that is not yet ready for application without any further research

Based on years of research on modelling of the manoeuvring behaviour of ships and on automatic steering of ships an adaptive autopilot had been developed (Van Amerongen and Udink ten Cate, 1975, Van Amerongen, 1982, 1984). In the last stage of the project some support from a company was given, resulting in a commercial product. The autopilot showed superior course changing performance as well as course keeping performance, providing a choice between economic and very accurate steering. Consequently, the background knowledge to start the project was available.

The project should be directed towards an industrial product that is really needed by the industry, although it is not of crucial importance

When the project concerning the development of adaptive autopilots was more or less completed and discussions where going on whether this project should continue or not, the university was approached by the company, Van Rietschoten & Houwens (R&H) in Rotterdam, the Netherlands. They were interested in the know how of the university in this area. At the same time, the Royal Netherlands Navy, already for a long time partner of the university in the autopilot project, was planning the construction of a new series of frigates. One of the options the Navy wanted to consider was the use of the rudder for stabilisation of the ship's roll motions, in addition to its normal use for course keeping. The new system should replace the conventional fin stabilisers, commonly used in naval ships and ferries. Advantages of such a system were expected to be a less expensive total system and –important for naval ships– less under water noise. Because R&H was heavily involved in many other deliveries for the frigates, they became even more interested in being involved in the design and realisation of an autopilot able to perform both tasks.

No obvious solution is known beforehand

One of most important features of the earlier designed adaptive autopilot was that it minimised the rudder motions in order to reduce the drag, leading to a better fuel economy and considerable savings (Van Amerongen, 1984). As such the request for the design of an autopilot that would use large and frequent rudder motions seemed counterintuitive. At that stage only a few publications mentioned attempts to realise such a system. These attempts where either not very successful or had only a limited goal. Therefore it was a challenge to realise an autopilot that could perform rudder roll stabilisation while maintaining the good economic course keeping properties of the earlier designed adaptive autopilot.

The project should fit the time scale of university research

Because at the start of the project the frigates were still in an early stage of the design it would certainly take another four years before the final decision about the application of the Rudder Roll Stabilisation (RRS) system had to be taken. This allowed sufficient time for solving a number of fundamental problems, as well as for experiments.

3.1.2 REALISATION

After some negotiations it was agreed that three parties would start a co-operative research program to investigate the feasibility of the RRS-system. A four-year plan was made. All parties were involved throughout the project.

University

A recently graduated control engineer, who did his MSc. thesis on the applicability of RRS, would carry out the research at the university on a full time basis. In addition the university provided know how available from earlier studies on adaptive steering of ships. The university committed to let a number of MSc. students investigate smaller parts of the project. A technician and members of the scientific staff completed the research team. The university would do all measurements necessary to evaluate the results from theoretical investigations as well as from simulation studies.

Company

The company R&H paid the salary of the researcher by contracting him as an employee. The researcher was detached at the university, but stayed one day per week in the company. He formed the liaison between the university and the industry on a daily base. Especially at the end of the project he was responsible for a smooth transfer of knowledge from the university to the company. In addition, an annual fee was paid to the university to pay for the time of other university people and students, as well as for the necessary expenses related to the project, investments as well as non-durable goods.

Customer

The Royal Netherlands Navy as the future customer was a discussion partner, providing the specifications for the autopilot. The Navy provided, once or twice a year, facilities for experiments on board of several of their ships. The Navy also paid for a number of experiments together with MARIN, a Dutch institute for maritime research. These experiments involved trials with a nine-meter-long scale model of a frigate and experiments on the computers of MARIN with a detailed hydrodynamical model of the new frigate.

3.1.3 RESULTS

In an early stage of the project – after half a year– experiments were performed on a naval ship to demonstrate the potential of rudder roll reduction. Also experiments were done to obtain a good mathematical model. These experiments revealed that with a proper redesign of the rudder, rudder roll stabilisation was indeed an attractive option. Good results were obtained but the autopilot required still a lot of manual tuning making it not yet ready for normal use. These experiments indicated directions of research and solutions for the next theoretical phase of the project. This phase took almost one year and resulted in new algorithms that made tuning of the autopilot completely automatically. At that stage it was also decided that the project would be a good base for a PhD. thesis. The final product has certainly benefited from this decision. Several solutions got a much better theoretical base and were better understood because of the needs to account for them in the PhD. thesis. One of the inventions done at this stage resulted in a patent. After four years the project was completed with the following results:

- it was demonstrated during sea trials and with numerous simulations that RRS is able to give roll reductions similar to the conventional roll reduction systems
- the course keeping performance does not degrade when RRS is used
- a completely automatic tuning system was developed
- the steering machine hydraulics had to be made much faster. Specifications were delivered to the Navy
- a PhD. thesis was written (Van der Klugt, 1987), as well as a number of papers (e.g. Van Amerongen et.al 1990) and a patent was granted for one of the autopilot's algorithms. About 7 students did their MSc. work in this project.

The autopilot itself was developed further into a commercial product by the company and finally successfully installed and used on board of the new frigates. A non-military version was later on developed and successfully sold to merchant marine ships.

4.1 Accurate system for laser welding of SMD's on a PCB

This case describes a project done in the Mechatronic Designer program of the University of Twente. Students can follow this two-year program after completion of their Master's thesis. They get a moderate salary from the university. The program typically consists of one year of additional courses and a second year for a large design project. The course attracts mainly students with a background in mechanical or electrical engineering. The design project should be done in close co-operation with industry. If not carried out in industry, the project should be done on an industrial problem. The emphasis in this program is not on research, as in a PhD. project, but on design. This means that a design should be completed within the given financial and time constraints. Because of this, these projects *seem* more attractive for industry than the four-year PhD. projects. This holds especially for smaller companies, where four years is almost the same as infinity. But it is even more important for the university to guard the quality of the project by allowing enough freedom for creative solutions.

In addition, it is important to follow a good design approach, by considering alternative solutions instead of taking the problem as formulated for granted.
The case described here dealt with the design of a fast and accurate servo system for placing surface mount devices (SMD's) on a printed circuit board (PCB). Philips Electronics in Eindhoven, Netherlands manufactures assembly machines for placing components on PCB's. Until recently this was done by means of pneumatic systems, but these systems lack the flexibility and accuracy that can be obtained by an electric servo. The problem was to design and demonstrate an electric servo system that could simultaneously translate and rotate while achieving high speeds and positioning accuracy. Another idea was that the SMD's should not only be placed but also welded by means of a laser beam, rather than being soldered as usual. There are several advantages of laser welding above soldering. To name a few: the components will be less heated and there are environmental advantages. Philips requested the University of Twente to define a project where these two problems could be tackled. It was decided to do this project with three students in the Mechatronic Designer course under supervision of the Mechatronic Research Centre Twente, now transformed into the Cornelis J. Drebbel Research Institute for Systems Engineering (http://www.rt.el.utwente.nl/~drebbel).

4.1.1 CHARACTERISTICS

The project requires knowledge gathered by the university during several years of research

The partners in the Mechatronic Research Centre Twente had a research background in the design of linear induction motors and in the control of servo systems as well as in the use of lasers for manufacturing purposes.

The project should be directed towards an industrial product that is really needed by the industry, although it is not of crucial importance

Both parts of the project were not immediately needed, but were considered for a next generation of assembly machines. Similar developments were started within the company, based on DC-motors. A solution with an induction motor was considered an attractive alternative but probably not the most obvious one, because of a number of unsolved problems.

No obvious solution is known beforehand

The problems involved here consisted of finding solutions for accurate (contact-less) position measurements for a device that simultaneously translates and rotates. Also the efficiency of the rather small induction motor in a servo application was a point of concern. With respect to laser welding the process parameters, such as the angle of incidence of the laser beam and the intensity and duration of the beam were the main points of research

The project should fit the time scale of university research

Because the project should be completed on a relatively short term, it was not suited for a PhD. project. It was decided to assign three students of the Mechatronic Designer Course to the project, one for the laser welding, one for the constructional aspects of the motor and one for the control system. In addition about four MSc. students were involved with parts of the projects.

4.1.2 REALISATION

Within Philips facilities for carrying out the project were not available at the time. It was decided to carry out the project in the university. The three Mechatronic Designers worked as a team, according to a mechatronic design philosophy. Two of them had a background in mechanical engineering and one in electrical engineering. The first year of the Mechatronic Designer Course brought them on a level that they could easily communicate, understanding each other's language, and could create interdisciplinary solutions.

University

The university provided the experimental and computer facilities needed for the project. Scientific staff members from the faculties of electrical and mechanical engineering supervised the students. Technicians provided the necessary technical support.

Company

The students themselves had contact with the company about every one or two weeks. Every month a meeting of the complete team, including the supervisors was held. The company paid for the salary of the Mechatronic Designer 'students' as well as for the supervision and provided facilities. In addition they introduced the students to designers in the company and did part of the supervision. Especially in the laser-welding project, close interaction with specialists of Philips was needed to get the proper information and test pieces.

4.1.3 RESULTS

The main objective of the design was the replacement of the presently used pneumatic manipulator by a well controllable electrical servo system, able to perform translational and rotational motions, while placing an SMD on a PCB. Compared with the pneumatic devices the new device should have a higher position accuracy and should be able to control:

– impact velocity (and force)
– press on force
– orientation of each manipulator separately
– *z*–position, allowing limitation of the applied stroke.

In addition, the manipulator should have:

– a vacuum nozzle at the end of the translator
– long lifetime
– little maintenance
– independent operation of φ– and *z*–motions.

Design

A high accuracy and bandwidth require that the moving parts are as light as possible and that friction is minimised. It was decided to develop an induction motor able to rotate and translate simultaneously. Together with appropriate power electronics, this induction motor should behave as a DC–motor. A new patented linearizing feedback was designed that combined minimum dissipation with good control properties. The main advantage is that when no force or torque is required, the motor current is zero.

Sensors

To maintain the nice properties of the contact-less translator, contact-less sensors are required as well. As a proper sensor for the *z*–motion was not commercially available, it was developed in the project. It consists of a single coil in which a magnetic core is moved. The design of a contact-less rotational sensor is more complex, because of the translations. No commercially available solutions were found. A new patented sensor was developed. Focussed light from (in principle) three LED's is projected at three photo diodes. LED's and photo diodes are mounted at the stator. A sheet of polarised material connected to the translator tube changes the polarisation of the light sources when the translator rotates. A small sheet of polarised material is placed in front of each photo diode as well. The directions of polarisation of the latter differ exactly 120°. This enables the angle to be measured. In order to improve the accuracy and reduce the sensitivity for noise, the applied light is sinusoidally modulated. By means of a standard resolver–to–digital converter, the signals from the photo diodes can be directly converted into a digital signal with 14 bits of resolution. Therefore, the sensor has been called an optical resolver.

Results

The result of the project was a prototype of the manipulator that met most of the design specifications. Because there is no contact at all between the 'translator' and the outside world, it can rotate over an arbitrary angle. The maximum force as well as the maximum moment was larger than requested. The attained accuracy was 25 μm for the translation and 0.09 mrad for the rotation. In the experiments, the bandwidths of the controlled system were limited to 40 Hz for the rotational motion and 50 Hz for the translational motion. By using a second order path generator in the controller a linear motion of 70 mm could be made in 50 ms, without overshoot. The laser welding system performed according to specifications as well. At final stage of this project the system was able to realise 30 high quality welds per second. After completion of the project this speed has been further increased.

5 Conclusions

In two case studies it has been demonstrated how the formulated characteristics for good co-operation between university and industry were realised. Both projects were successfully completed. Additional examples could be given and of course also examples of projects that were less successful because one or more of these requirements were not fulfilled.

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