INCLUDING BACHELOR STUDENTS IN RESEARCH ACTIVITIES IN REAL-TIME PROCESS CONTROL

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SAMMENDRAG

En særlig utfordring for regioner som ønsker å framskynde utviklingen av teknologibasert industri og nyetableringer, er å styrke båndene mellom regionens vitenskapsbase, representert ved universitetene, og industribedriftene. Ved Høgskolen i Ålesund (HIÅ) har det over flere år vært en kontinuerlig aktivitet på utvikling av innebygde sanntidssystemer i tett samarbeid med teknologimiljø i lokal industri. Mange av arbeidene er relatert til utvikling av systemer for styring og kameraovervåkning av prosesser og arbeidsoperasjoner i næringslivet, med hovedvekt på operasjoner om bord i skip. Hovedmålet er å øke sikkerheten og effektiviteten i krevende operasjoner på land og i skip. Utviklingen av dedikerte innebygde sanntidssystemer som integreres i et felles nettverk, har vist seg som en lovende framgangsmåte for å nå dette målet. Innenfor denne rammen har bachelorstudenter i Automasjon ved HIÅ vært involvert i mange forskjellige industriprosjekt. Dette har gitt dem en unik mulighet til å arbeide med utvikling av reelle industrioppgaver under ledelse av sine lærere og ingeniører ansatt i bedriftene. Oppgavene omfattet av dette arbeidet har inngått i et forsøk med et nytt utdanningsopplegg, hvor resultatene blir evaluert med tanke på hvilke oppgaver som har det største potensialet for videre innovasjon og forskning. De mest lovende oppgavene blir så fulgt opp videre gjennom bygging av prototyper og videre forskning. Denne kontinuerlige utviklingsprosessen krever betydelig innsats både fra studenter, lærere og de involverte bedriftene med hensyn til en grundig evaluering og videre tilrettelegging av arbeidene. Resultatene har imidlertid vært til fordel for alle parter dersom en dømmer ut i fra antall oppgaver som har resultert i videre innovasjon i bedriftene eller gitt uttelling i form av vitenskapelige publikasjoner. Da kvaliteten til en ingeniør først og fremst blir bedømt på grunnlag av hans evne til å gjennomføre prosjekter etter gitte spesifikasjoner og innenfor gitte kostnadsrammer, er resultatene av denne prosessen også en representativ kvalitetsindikator både på læreprogrammet og ingeniørstudentenes arbeider. I denne artikkelen presenteres prosessen og metodene som er brukt for å inkludere bachelorstudentene i denne type forskningsaktiviteter innenfor sanntids datateknikk. Først presenteres den pedagogiske og den tekniske basisen for opplegget. Deretter diskuteres betydningen av Commercial-Off-The-Shelf (COTS) produkter og utfordringene i tilknytning til systemintegrasjon. Til slutt presenteres resultatene av dette utdanningsopplegget med påfølgende konklusjoner.

ABSTRACT

A particular challenge for regions like Møre og Romsdal that are interested in facilitating the growth of technology-based industries and business start-ups is to promote the links between the regional science base, represented by the universities, and its industry base. At Aalesund University College (AAUC) there has been an ongoing activity for several years in the development of embedded real time systems in close cooperation with private technology developers from the local industry. Much of this work is related to the design and development of systems for process control and camera surveillance of industrial processes, with an emphasis on operations on-board ships. The main purpose is to maintain and improve safety and efficiency in demanding operations, both on land and in ships. A promising way to reach this goal consists of developing dedicated embedded real time systems integrated in a common ubiquitous network, each independently performing its special tasks. In this context, bachelor students at AAUC have been involved in several research projects that give them the possibility of working within an industrial prospective scenario under the supervision of both their professors and the company employed engineers. In this work, these activities have also been part of an innovative educational and research loop, in which the projects evaluated as having the greatest innovative potentials are followed up with new prototypes and research activities. This research approach is demanding and thus requires effort from the students, university staff and the companies involved, with regards both to the evaluation process and working conditions. The result, however, is beneficial for all parts, as seen by the number of projects that have been followed by real industry applications and in the production of scientific publications. As the quality of an engineer is mainly measured by his ability to perform the tasks given to him within the specifications and costs demanded, the result of this process is also a representative quality indicator of both the teaching program and the students' work. In this paper, an overview of the processes and methods of including bachelor students in research activities in the field of real-time process control are presented. The pedagogical and technological bases of this activity are first discussed, and afterwards the importance of Commercial-Off-The-Shelf (COTS) parts and the challenges related to system integration are analysed. Finally, the results and conclusions of this work are presented.

INTRODUCTION

During the past several years, Aalesund University College (AAUC) has worked with remote monitoring and autonomous embedded systems for process control and camera inspection purposes on-board ships (Rekdalsbakken and Osen, 2012). Some of these research projects turned out to be inspiring for new concepts concerning more efficient and secure work operations on-board ships and thus have been implemented into broader research programs in cooperation with the industry. Many of these projects were realised as embedded systems on different hardware platforms. In these activities, modern sensors together with vision technology and wireless communication systems were combined into self-contained systems independently performing important tasks in ship operations. Most of these systems had their beginnings in student projects in the "Real-Time Programming" course and in students' bachelor theses. A systematic evaluation and selection was done on these projects to pick out the most promising ideas and products that have the potential to be further explored. In this way, some concepts were followed with several projects and gradually improved over time until their results could be continued either as industry projects or as academic research programs. In this way, some of these activities resulted in the development of industry products or the publication of scientific papers. The main objective, however, was to include students in research projects and innovation activities in companies, thus increasing the quality and relevance of the teaching. Therefore, focus has been both on technology and pedagogy.

PEDAGOGICAL BASIS

The purpose behind this research was to activate and motivate the students in the learning process. Several student groups were involved in the activities of defining, adapting and selecting the appropriate kind of projects. The procedure involved both the university staff and external partners. The students were encouraged to present their own ideas and proposals in order to include the newest technologies and program tools in the projects. In this way, the students were allowed to work with realistic problem settings using the most recent advances in technology and methods. The students were involved all the way. This idea originally comes from Piaget, focusing on operational learning. It is outlined in the book *Piaget in school* (Hundeide, 1985). The basis of this view lies in the concept of *implicit learning*, which represents a concept of knowledge based on experience. In this view, the emphasis is put on the significance of practical experience and close contact to working life and applied research. In such a view, the student laboratory will have a central and challenging position as a work place. Piaget's theories about learning emphasises that the knowledge must be gained personally through one's actions. By active processing of real situations, the knowledge has meaning. Piaget calls the result of this process *operational knowledge* in contrast to figurative knowledge, which is the representation by the senses of the external situation (Kleive et. al., 1994). This strategy can also be viewed as a kind of *Action Science* or *multimodal teaching and learning* (Kress et. al., 2001). We want to build new knowledge through acting and the reflection about acting. In such a situation, special demands will be placed on the teacher. He must act more as a stimulator than as an authority. He has to arrange for optimal active learning conditions. According to our experience at AAUC on project based learning, the role of the teacher should be more that of a catalyst and a counsellor. In such a situation it is important that the students are confident that the teachers have the necessary professional skills to define the correct problem settings and to give appropriate advice and corrections concerning the students' work.

Quality

Quality is central to this activity. At AAUC, the ISO (International Organization for Standardization) label process inspires the institutional policy of support to quality teaching. In our courses, all the teaching activities try to follow the ISO's systemic approach that could match the specificities of higher education. The university is putting is effort in drawing from ISO some meaningful lessons for designing an institutional policy on quality teaching. In this contest, the students are invited into a context of active learning in cooperation with both the university staff and industry partners. The engineering study programme in cybernetics aims to educate students and help to build a career as a professional engineer. This is a challenge with many aspects, of which only one is the theoretical part. The quality of an engineer is mainly measured by his ability to perform the tasks given to him within the specifications and costs demanded. The quality is therefore primarily measured by the usefulness and success of the products and services produced by the professional engineer. In the teaching situation described in this text the goal is to provide an environment for such developments and to measure the results. The students will work with real industry projects, and they will get the support needed to obtain results as expected. The quality of the educational program is measured by the ability to provide relevant industry innovations and research results. The quality of the students is measured by the originality of the solutions and the ability to perform in accordance with specifications. By presenting relevant and challenging projects to the students over years, and evaluating the outcome in industry developments and research results, this activity represents a method to measure the quality of both the students' work and the study program.

Student focus

This learning approach is very challenging for the students and involves the integration of sophisticated components in material handling, assembly, and production processes, offering the possibility of supervision and control. From a pedagogical point of view, the knowledge and skills required for these kinds of tasks are purely mechatronic and therefore multidisciplinary. In this setting, it is important that the university staff work in a context suitable for selecting the most beneficial project ideas for the students. To be of benefit to the students, the projects must be relevant to the students' field of work and it must be realistically possible to complete them in the given time. Furthermore, the technology and methods to be used must be among the most recent in the market. With the view of finding projects with a potential for future research and development activities it is important that the topics be business related and oriented towards the local industry. The students must be involved at an early stage in meetings with this industry and in discussions between their teachers and industrial partners. The objective of finding areas to follow up for longer periods of time is always in focus. Many students start with a project in real-time programming to explore some new concepts and end up choosing a bachelor thesis on this subject for further development. In this process they are given the necessary support to run a more comprehensive project through the introduction to project planning, and scientific writing and methods. In the evaluation of the final student products, including a scientific report and project presentation, the teachers are systematically looking for the scientific and innovative potential in the accomplished work. Work with such qualities will be considered to follow up in new projects. This way of implementing student projects into an educational situation represents an operational attitude towards learning and gives a continuous renewal of the teaching process.

TECHNOLOGICAL BASIS

The fields of consumer electronics and game development represent today's most rapidly changing technologies. They are pushing the fields of sensors and communication devices to the limit and have an increasing market. These technologies are also most relevant in this context, and are extensively used in the student projects described. This gives a demanding situation, but also a potential to realise new ideas and to develop new and cheap products. This background represented an important criterion when this educational strategy was defined. It requires that student projects include an extended use of novel and advanced components, regarding electronics, micro-controllers, sensors, cameras and data acquisition equipment. Since the problem settings are chosen from a realistic point of view, most projects are also related to the local maritime industry. In a coarse generalisation and from a theoretical point of view, we could say that the projects belong to one of three general categories. The first is stabilisation and control of motion platforms, the second is object recognition and surveillance by use of cameras, and the third is remote and autonomous control strategies for all sorts of robotic vehicles. These three categories are analysed in the following sections.

Motion platforms

Motion stabilisation of equipment is a challenging problem in all sorts of ship activity. Because ships are always in motion when at sea, care must be taken in all kinds of operations to avoid dangerous situations and damage to materials. This is most important in all kinds of lifting and handling operations, especially when cargo is to be taken through the sea surface. Equipment such as cameras, search lights and precision instruments must also be screened from the ship movements. To correct for this unwanted motion, one can compensate by mounting the equipment on a stabilised basis or platform, which counterbalances these movements. In these cases the theory of kinematics and inverse kinematics is used. This involves the mathematical field of linear algebra with vector description and matrix transformations. Most common are physical systems of 3 to 6 independent axes, or degrees of freedom (DOF). At AAUC the work on motion platforms has been mostly directed toward the development of a full-scale physical high speed craft simulator, and the stabilisation of equipment on-board ships, such as cameras and search lights (Nogva et al., 2008), (Rekdalsbakken, 2005, 2006, 2007). A laboratory model of a 6DOF motion platform is shown in Figure 1. Based on a Cartesian coordinate system, the deck can be translated along three independent axes and can also be independently rotated about each of the same axes. For example, the transformation of a coordinate basis in 3 DOF from a given position to an arbitrary new one, is given by the transformation matrix below.

$$\mathbf{P}_{pr} =$$

$$\begin{bmatrix} \frac{L}{2}\cos\theta - \frac{\sqrt{3}L}{6}\sin\phi\sin\theta & -\frac{L}{2}\cos\theta - \frac{\sqrt{3}L}{6}\sin\phi\sin\theta & -\frac{\sqrt{3}L}{6}\sin\phi\sin\theta \\ \frac{\sqrt{3}L}{6}\cos\phi & \frac{\sqrt{3}L}{6}\cos\phi & -\frac{\sqrt{3}L}{3}\cos\phi \\ \frac{L}{2}\sin\theta + \frac{\sqrt{3}L}{6}\sin\phi\cos\theta & -\frac{L}{2}\sin\theta + \frac{\sqrt{3}L}{6}\sin\phi\cos\theta & -\frac{\sqrt{3}L}{3}\sin\phi\cos\theta \end{bmatrix}$$

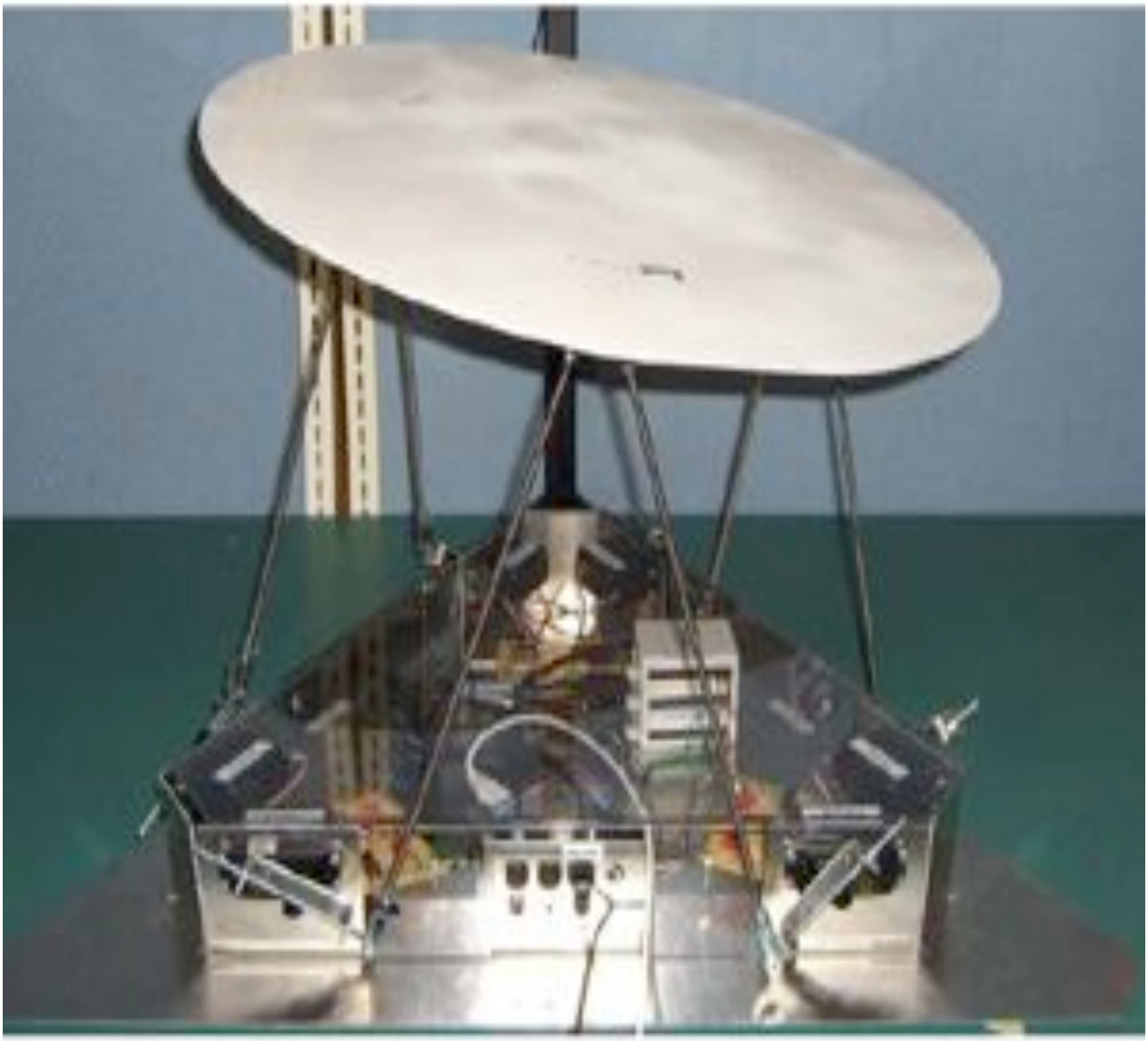

Figure 1: Picture of a 6DOF Motion Platform

This is the way to describe the kinematics of objects within a given coordinate system. Such matrix transformations naturally lead to the search for a general description of the relocation of object coordinates in a coordinate basis of any dimension. This is achieved by describing objects and their transformations as tensors. The tensor algebra defines general linear transformations in a way that is valid in all kinds of coordinate systems. This is because a tensor includes the transformations of both the object coordinates and the coordinate basis itself. This kind of mathematics is also very useful in the description of the kinematics of 3D graphical objects. To display a 3D object from all directions, an extra dimension is needed, i.e. a 4-dimensional coordinate system. The most general approach for obtaining this is to define a number system in the equivalent number of dimensions. The obvious benefit is that an object is now defined by a number, and the numbers follow the arithmetic rules of the number system. A 4-dimensional number system was discovered by the Irish mathematician and physicist William Rowan Hamilton in 1843 (Graves, 1882). It consists of one real and three imaginary axes. He called it "Quaternions". This number system is widely used today by scientists and engineers to describe the general motion of 3D objects.

Surveillance systems

In many situations of potentially dangerous or advanced operations, including those on-board ships, there is a need for close and continuous inspection of the working situation. In many of these cases modern camera technologies can be used to extend the natural sight of an operator to survey difficult and critical situations, for instance in rescue operations. With the aim of making such devices available at affordable prices in a competitive situation, the search for standard open source software and cheap hardware components is crucial to the future realisation of the products. Experience indicates that the frontier of these technological areas is pushed by developers of open source public domain software and a multitude of producers of small scale hardware systems. The challenge is actually knowing the technology market and how to integrate components and software in useful systems. The intention is to build general camera surveillance systems. Such systems usually consist of two independent parts that communicate over a network as a socket connection with a client-server protocol. The communication is based on a wireless LAN connection, but a wired connection may also be used. The server part of the system is built upon an embedded hardware platform for which the central equipment is a camera that can be controlled to acquire images from any direction in its sight of view (yaw ±180°, pitch ±90°). The system must be furnished with the necessary devices for fast image analysis in real time. In addition the system must have the devices necessary for network communication. The client system must be a computer with a network connection and software powerful enough for the communication and presentation of the stream of images in real time. To this end, a number of experiments have been performed at AAUC, with different kinds of software and components. Some of these systems are for applications on-board ships (Xu, 2011), and dynamical positioning of ships (DP) (Brandal et al., 2011). Other applications are for inspection on land, e.g. the search by mobile robots for pollution, dangerous materials and mines (Fjørtoft and Lund, 2010), (Håheim et al., 2010) or automatic product control (Gao et al., 2009). As these systems become more autonomous and self-sufficient there will be a growing need to combine them into more comprehensive networks in order to compare and group vital information from many sources. This will give a much better overview of complex situations.

Vehicle control

The third main area of interest at AAUC is the development of remotely controlled and autonomous vehicles. Such mobile robots are used for numerous purposes and have a broad and increasingly important position in many kinds of operations. Very often such vehicles combine several advanced technologies into an integrated system. For instance, a robot intended for object search and recognition must have a sophisticated image acquisition and analysis system, inertial sensors for the registration of angles and acceleration, and a wireless radio or WiFi system. In addition, a robust control system is also necessary. In this way, all of the technologies described here are integrated. The most famous such vehicle is the Mars rover, but the majority of them have much less sophisticated duties, e.g. the search for mines in post-war locations. At AAUC, several control systems for such vehicles have been designed. To speed up the prototyping process and save time on the mechanical design, the simplest way is to buy a model assembly kit with steering and speed control and build up the control system for the robot. In particular, these model assembly kits can be taken apart, modified and expanded into more functional and suitable systems. Vehicle communication usually takes place over a radio communication link or a WiFi network, typically controlled from a cell phone or a game controller. The most widely use of such vehicles is in search and surveillance operations. Examples are an iPhone-controlled RC vehicle by use of the Apple remote control program OSCemote (Giske et al., 2009), and servo control of a wireless vehicle by use of a Wii Remote controller (Myskja et al., 2009). Over the last few years, our research group at AAUC, together with our international partners, has also put some effort on proposing new prototypes of mobile robots. For instance, the mobility of several newly designed modular robots has been investigated. In particular, the configuration of a five-limbed modular robot was introduced (Liu et al., 2012). A specialised locomotion gait was designed to allow for omni-directional mobility as shown in Figure 2. Due to the large diversity resulting from various gait sequences, a criterion for selecting the best gaits based on their stability characteristics was proposed. A series of simulations were then performed to evaluate the various gaits in different walking directions. A gait arrangement scheme toward omnidirectional locomotion was finally derived.

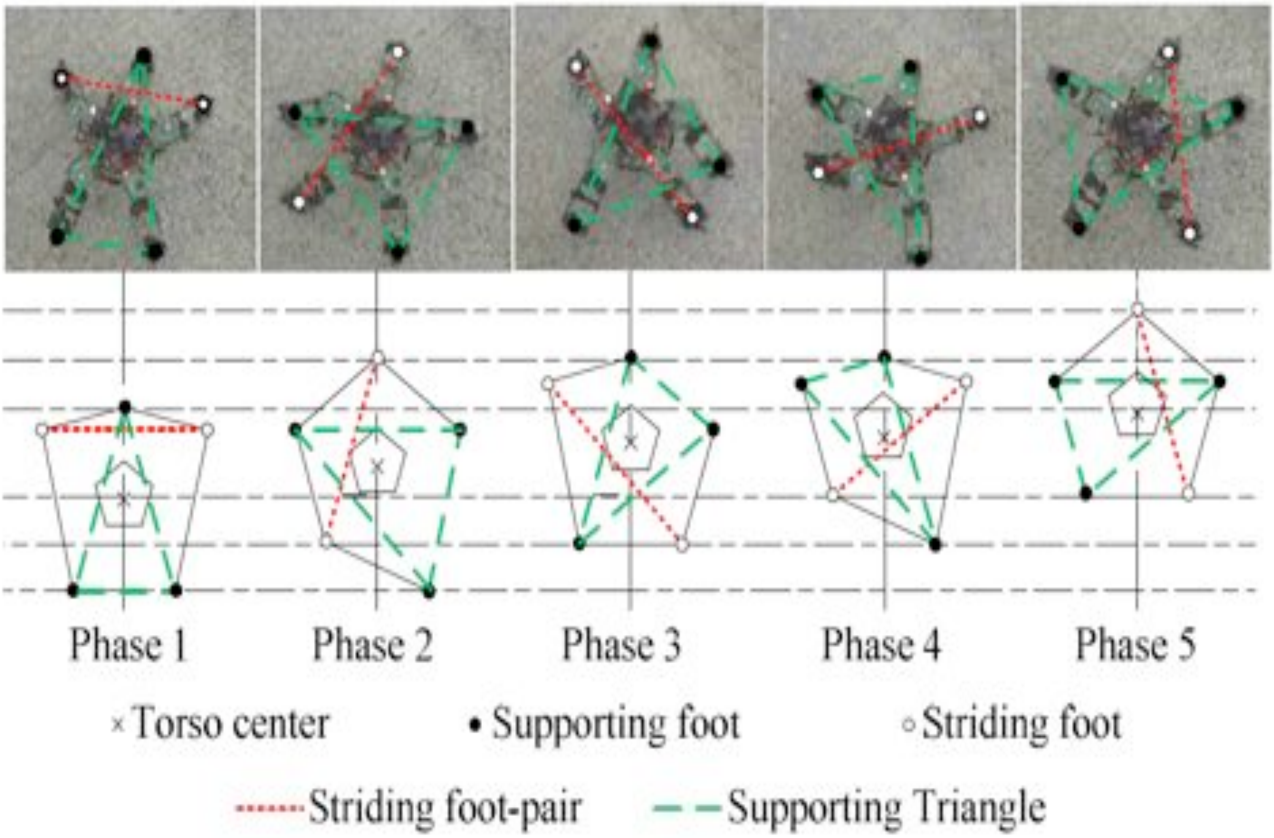

Figure 2: The pentapedal robot succeeds in walking in a stable manner.

THE IMPORTANCE OF COTS AND SYSTEM INTEGRATION

The most important side of this academy-industry cooperation is that these projects represent a way of testing the possible future realisation of new concepts and prototypes, both with regard to technology and economy. Having many groups of students working with similar problem settings on different hardware and software platforms gives an insight into which solutions may be useful as research projects. For implementation as a real industrial system, e.g. on a ship, there must first be an obvious need for the product. Second, the reliability of the technology must be documented and its components must be easily available in the future. Furthermore software solutions must be openly available and easy to improve and maintain. These kinds of systems must be part of a complete solution for the ship's operation. To manage the realisation of such systems, the most important thing is to have a broad knowledge of the electronic COTS market, especially the consumer and game products. The frontier of new electronic systems lies here and this market segment represents the most vital dynamics. As emphasised above, the most important technology fields in this development are the following: wireless communication, camera systems and modern sensor technology. All these technologies have undergone and continue to undergo enormous development through the mobile phone market and game industry. In particular gyro and accelerometer components of high quality and small size, and cameras of extreme image quality and usability have been developed in the last few years and can be bought at very low costs. Together with freely available software tools and driver libraries, this situation opens up a new world of exciting challenges to the engineer who develops complex embedded systems for all kinds of applications. The possibilities for innovation and product development are huge for those who have the courage and aptitude to grasp them.

Equipment and Assembly

In all our experiments the computer hardware and all necessary equipment are available at ordinary customer retailers and net shops. A typical example is one of our student projects for building a search vehicle, which represents quite a complex system. The search operation is realised by the building of a small scale autonomous model vehicle equipped with a web camera on a stabilised motion platform. The vehicle is furnished with an Arduino Duemilanove micro-controller board, featuring an ATmega328 micro-controller from Atmel. Because of the substantial computational load of the image analysis the video stream from the camera is transferred as a sequence of still images over a WiFi connection to a stationary PC. The PC receives the images through another ATmega328 micro-controller connected to the PC, and it performs the image analysis and recognises the object. When the position of the object is found, its location relative to the vehicle is calculated, i.e. the distance and angle of direction. In particular, the target object is located by utilising two still images or frames taken from different points of view by the robot in such a way that a stereoscopic image of the target can be obtained. The location of the object is sent to the micro-controller on the vehicle and used to calculate the reference signals to control the vehicle and the camera. The internal vehicle software applications are designed to do all local control and data acquisition, such as stabilising and positioning of the camera, controlling the vehicle motion, and capturing and transmitting the camera images. Everything is built and developed by use of cheap and openly available hardware and software. Illustrations are shown in Figure 3 and Figure 4 below.

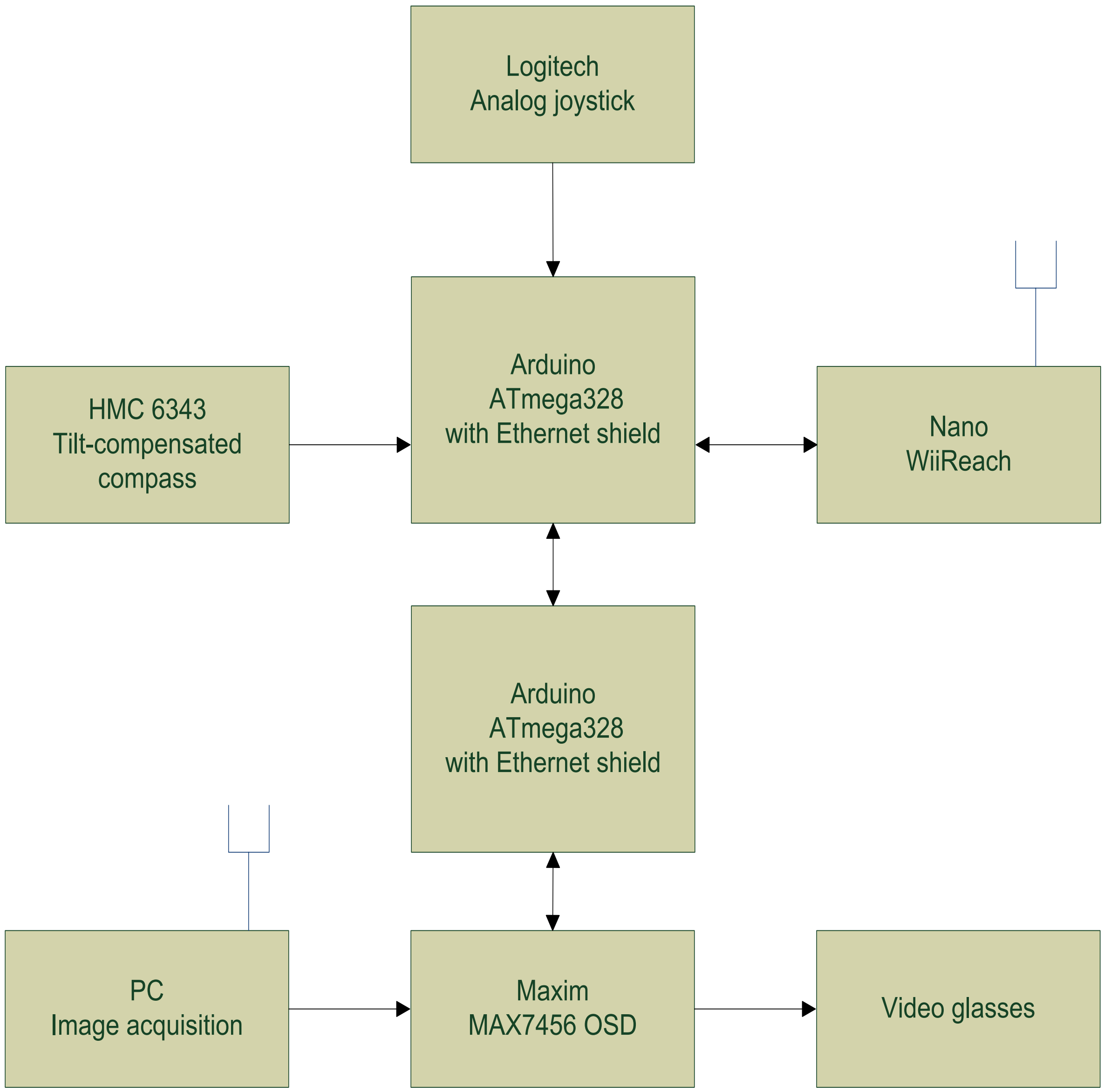

Figure 3: Control Station Diagram

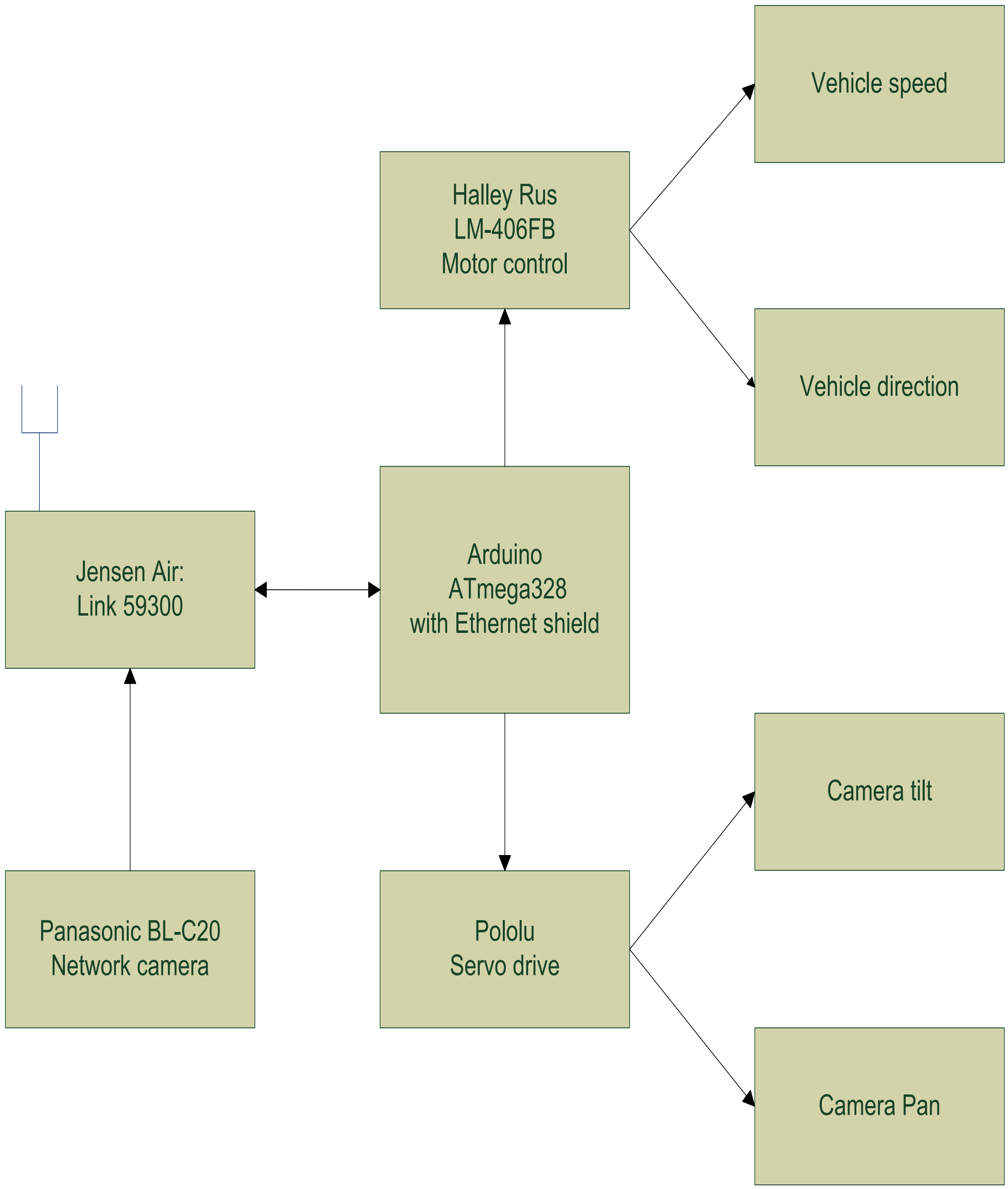

Figure 4: Vehicle Connection Diagram

SOFTWARE AND COMMUNICATION

The application programs for these kinds of systems are quite extensive and will represent the most intensive work and potentially most expensive part of the project. Thus, it is important to choose a software base and development tools that are easy to work with, easy to update and cheap to purchase. These are good arguments to look for public domain software. In particular, Java was chosen as the programming language for the software development of these projects, with NetBeans as the principal development environment. For each micro-controller and a given operating system, a runtime system will always follow, with a software development kit to use. In addition to standard Java, most often some auxiliary program libraries and software tools must be purchased.

Concurrent Java

Java is the preferred software development system, mainly because of its extensive and easily available real time qualities. Java has integrated the thread mechanism and a broad range of thread management methods. It also has implemented extended timer functions and an effective system for handling software interruptions, made possible by event handlers. In addition, standard Java is an open source system, free for anyone to download and use.

Linux OS and driver software

It is important to choose a simple and flexible operating system. Linux exists in many variations from independent developers, and all of them are openly available and free to use. When designing embedded systems, the possibility of finding suitable driver software for the kinds of connected equipment is crucial. Developing driver software is a time-consuming task. Linux has a great potential for driver software, and usually one will find the desired software on the Internet.

Software Libraries

In spite of the extensive application programming interface of Java (API) there will always be a need for special software methods. Especially when working with systems comprising extensive external equipment one will need specialised software. Examples of such systems are image acquisition and analysis from cameras, communication protocols for the networks and software for controlling different kinds of motors and actuators. Software methods governing such dedicated areas are often collected into complete software libraries. Many of these libraries can be found free to use on the Internet. A broad insight into the existence of such tools is a very useful quality and can save oneself from many hours of work. In consideration of the numerous software tools available on the free software market, the ability to chose and adapt the most useful system programs is vital.

RESULTS

The results of this pedagogical and research system with continuous selection and improvement of student projects over the period from 2003 until now must be said to have been in accordance with the aims of the plan, both with regard to students and teachers, and also for local industry partners. A lot of project ideas were tested and the relationships between the university and local industry companies are now stronger as a result. A total of approximately 150 projects were involved during the past ten years. Altogether, 15 scientific publications have been presented on international conferences and in well-reputed journals. A substantial part of the projects were carried out in cooperation with local industry; for the bachelor thesis this amounts to 80%. The result is that all students at the cybernetic study program now have the possibility to take part in research projects and to participate in industry innovation programs. This has strengthened the scientific profile of the engineering faculty at Aalesund University College. As a rewarding bonus on top of this, AAUC was asked by the European Council on Modelling and Simulation (ECMS) to host the 27th European Conference on Modelling and Simulation, ECMS2013. This comes as a result of the substantial contributions to this conference from AAUC over many years. The conference was held at AAUC from May 27 – May 30 2013.

DISCUSSION

This report presents a systematic way to include bachelor students enrolled in engineering programs in research activities. The students belong to the study program in Cybernetics, and the focus has been on the Real-Time programming course and the students' bachelor theses. The primary goal of this activity is to raise and maintain the quality of the Cybernetic bachelor program. The students were included in an implicit learning context through working with relevant industrial projects. Through close contact with industry partners and critical selection of projects by the academic staff, the students were challenged to work with the most promising product ideas. The thorough evaluation and follow up of project results also allowed for the continuity of the best projects. In this way, quality was gradually improved. The main issue of this work has been to investigate new trends in sensor and vision systems for possible integration of such technologies in new products and operations, especially on-board future ships. As the tasks of modern products become increasingly more complex and demanding, there is a growing need for system integration from many fields and insight regarding consumers and COTS. Here, the focus has been to explore the rich market of consumer electronics, which is driven mainly by the cell phone and game industry. These components can be used in the development of advanced and low-cost customer specified products. Experiments with selected equipment of this type have been performed on small scale physical models, mainly by building remotely controlled and autonomously operating ground vehicles. However, the aim is to integrate these new technologies into new products for the future. The vehicles only represent an easy approach to testing the equipment and methods in an adequate way for real operations. The approach of building small scale models as test equipment has shown to be very fruitful in the testing of new devices and concepts. The aim is to test and document which of these devices function well in the designed context and perform their tasks in accordance with plans. By following this scheme, the activities most valuable in the pursuit of further projects are selected. This is like an interactive trial and error process where components and methods are systematically selected for further refinement and development. In the end some of these projects could be realised as industry projects or scientific publications. With this process, all students gain an insight into scientific methods and scientific writing.

CONCLUSION

The underlying aim of this work is to investigate some new products in the consumer technology market for possible future employment of such technologies in the development of new solutions mainly for operations on-board ships. Practical testing of vision and sensor systems on small scale models has shown to represent a fertile way to reveal the potential for adapting such technologies into the modern ship. The surplus of new devices within wireless communication, vision systems and MEMS components available in the consumer market, driven by the cell phone and game industry, represent fantastic new possibilities in the integration an adaptation of advanced technology into more traditional fields, both in the production process and in the products. The experiments performed in this work have revealed that it is necessary for young engineers and applied scientists to have a thorough insight into this market. The results of the experiments also encourage further work toward implementation and use of such technologies in product development. The way of conducting these projects, with careful selection of new ideas, and systematic follow-up of selected projects in close cooperation with industry companies, has also been very fruitful. The industry partners get a tool to select and test new product ideas; the students get a chance to make good contacts with local industry companies and hands-on training in scientific and innovative work. Finally, the teachers have a way to keep themselves technologically updated and have a system for research and production of scientific publications.

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