EDUCATIONAL USES OF MICROMOUSE AND ROBOT PING-PONG IN THE TEACHING OF MECHATRONICS

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ABSTRACT

This paper considers the development of 'fun' robotics projects, such as Micromouse and Robot Ping-pong, and their use in teaching the fundamentals of mechatronics.

Micromouse integrates the basics of electronic and control engineering with mechanical and software engineering and is a perfect example of the integration of disciplines needed in the teaching of mechatronics.

Robot ping-pong is different, in that although integration of mechanical and electronic engineering is required, the emphasis in the software is more on digital signal processing.

The introduction of both these design projects into the final year project stream of the City Polytechnic of Hong Kong's diploma and honour's degree courses has not only raised the awareness of mechatronics within the department and also Hong Kong, but also inspired the students to work in a more coordinated and group mode than if more traditional projects had been used.

The fact that a number of students, up to 20, are working on these projects each year means that continuity is also established that helps the students within the department build up a methodology and experience that is handed along each year.

1. INTRODUCTION

Micromouse, as an exercise in the design and implementation of an integrated mechatronics application, has been around 1979. However it is only during the past six years that it has been taken seriously enough by the academic community, and considered as an ideal project for diploma and degree studenst.

There are a number of reasons for this. The experience of introducing robotics into the classroom suffered a number of setbacks in the early 80s that took some time to overcome. The experience in the UK, especially with turtle based designs using Logo, seemed to orientate robotics to the primary school. A number of attempts to overcome this, especially with Zero 2 from InterGalactic Robots (IGR) in 1983, met with some success, but like most of the companies involved in educational robotics, they met an untimely economoic demise just as Zero 2 was about to take off! This robot was turtle orientated, being programmed in Logo, but had the dimensions of a micromouse. In fact it was possible to write simple programs in Logo to make it move around a standard micromouse maze.

Other attempts, especially by John Billingsley at the London Computer Fairs from 1980 onwards, and Euromicro after that, took micromouse into the 'hobby' scene. One of the first groups to have any co-ordinated attempt at micromouse was based at the North London Hobby Computer Club at the Polytechnic of North London from 1979 onwards. In fact their first mouse, Quaestor, took part in a number of London contests, and the lessons from this were applied to Zero 2 later on.

During the mid eighties a number of papers were presented at conferences in the UK [1], [2], which attempted to raise the awareness of the use of robotics in engineering education, and a number of magazines, especially Practical Robotics and Practical Computing in the UK, continued to feature many articles on Micromouse. However it

was not until the Japanese entered the ring that the full potential of a coordinated approach to micromouse was appreciated [3].

A similar, but more low key, history applies to robot ping pong. A number of contests, especially in Europe, during the late 80s has brought the idea of robot ping pong to a wider audience. However, very few educational institutions seem to appreciate its educational uses. Robot ping pong is in a similar situation today as micromouse was in the early 80s - an interesting event but not considered much use!

2. MICROMOUSE IN EDUCATION

At the moment very few educational institutions around the world have anything that can be described as a coordinated programme of micromouse development. Perhaps the leading proponent of this is Ngee Ann Polytechnic in Singapore. [4]

The programme starts with the top 200-250 students being given a demonstration. Interested students then apply to join the Micromouse project stream, and the top 10% (18 to 20 students each year) are selected. A two week solid training programme follows (software, solving and search theory, hardware and sensor design etc). Every student builds everything from scratch, code is not reused; however students' software design efforts are transferred at the flowchart level. As in any successful student project programme, the top students have outstripped their supervisors. The supervisors keep close contact and follow the students work, but now the top students assist the lecturers with the detailed aspects of Micromouse! The best students have also created their development tools.

City Polytechnic of Hong Kong follows another approach, which follows the more 'free-wheeling' apects of Hong Kong society when compared to Singapore. In this programme, described in detail below, students are fairly free to follow their own ideas, but must work within departmentally set guidelines.

California State University at Long Beach, CSULB, in the United States also has a long running programme [5], [6]. They have around twelve students at any one time based in the Computer Science and Engineering Department. Although originally basing their designs around a Mappy kit [7] from Japan they have now moved on to locally designed hardware. Unlike other institutions, the interest in micromouse at CSULB was generated by the local IEEE student branch's purchase of the Mappy kit.

MIT in Boston, USA has always been at the forefront of micromouse design, especially because Dave Otten, a research engineer in the Laboratory for Electronic Engineering Systems (LEES) has won more international micromouse contest than anyone else! Their latest approach is to ask students on a robotics short course at MIT to build a micromouse using Lego parts. This approach is, in itself not new, with one of the first mice using Lego in 1980 [8]. In fact, some of the mice from this year's course were so successful that they ran in the 1992 APEC contest in Boston [9].

Finally, there is the Japanese approach. This originated with delegates from the New Technology Foundation, a government funded body set up to encourage the awarenss of informatics in schools and colleges, doing the rounds of micromouse contests in the early 80s. Then they ran the first major world contest in Tsukuba in 1985, where the Japanese mice thrashed the competition [3]. Since then they have encouraged the growth of micromouse clubs around Japan, and these now number nearly 200. The annual Japanese contest regularly attracts over 100 entrants [11]. The Mappy kit was designed as a basic mouse for use in this programme.

3. MICROMOUSE AND ROBOT PING PONG AT CITY POLYTECHNIC OF HONG KONG

The Department of Electronic Engineering at the City Polytechnic of Hong Kong runs six main courses, two at Higher Diploma level (senior technician engineer), three

honours level bachelor degrees, and one MSc. The two HD courses are being phased out In total the department has over 1300 students, approximately 500 of which are studying part-time/evening. The academic staff establishment is about 70.

Each year the department has to find around 400 projects for the final year students. Three years ago it was decided that micromouse should be a 'running' project that would be offered across all courses, on a first-come, first-served basis. The total number of micromice would be restricted to ten, although due to the fact that HD students do their projects in pairs, the total number of students involved is about sixteen.

Last year it was decided to introduce robot ping-pong as another project that would run each year, although in this case the student numbers were restricted due to lack of resources, mainly the need for video cameras (since overcome).

There are four academic staff involved in micromouse on a permanent basis, all having some experience in robotics. Each of these staff has a different emphasis on how they supervise their project students - some insist on the use of a certain processor, another on a certain chassis design for example. The table below shows the number of students per course.

Year	90/91	91/92	92/93
HDEE	2(4)	2(4)	
HDCE		4(8)	
BEngEE	1(2)	4(4)	6(6)
BEngCE			1(1)
BScIT			
MScESD			1(1)

First number = number of mice
Number in () = number of students

TABLE 1: Number of EE students taking micromouse final year projects

It is interesting to note, that although offered across all courses, the take up from the Information Technology (BScIT) and Computer Engineering (BEngCE) students has been minimal. This is attributed to the perceived mechanical engineering component of micromouse.

The processors used range across the whole spectrum available. These have included Z80, 80C196KB, 8051, 80C39, 68HC1 and Z180. In some ways the choice of processor was predicated by the emulation facilities in the department, as well as reflecting supervisor or student choice.

Most students have used stepper motors to drive their mice. Clearly the ease of control compared to dc motors is more important than the power considerations. This is changing, however. As the department builds up its expertise it is interesting to note that at least half the coming year's students will be using dc motors. The recent acquisition of special stepper motors from Japan, specially designed for micromouse, means that much faster stepping speeds will be available in the future - up to 6000 pps. This will also tax the students' ingenuity in controlling up to 1kg travelling at up to 2m/sec.

The number and type of sensors is also evolving. In the first two years of the programme all used infra red snesors looking at the top of the walls, although one group did use a focused infra red beam from the front of the mouse to detect the distance to

an oncoming wall, as well as sensors on top.

In the coming year students will be investigating the use of low powered lasers to detect side walls as well as front and rear walls; ultrasonic detection for locating walls and for position control; and the use of a ccd camera to map the outline of the walls from the starting point so that maze solving can be done before the mouse moves!

The maze solving algorithms used range from the commonly used depth-first routine to some very esoteric ones designed by the students themselves! Although much background information is available for students to use in developing their software, supervisors do not encourage the simple copying of previously used software. For example, all previous project reports are available for novice students to study, as well as a very comprehensive library based upon copies of papers and magazine articles about micromouse published during the last 12 years.

From the end of this year the department will have a dedicated micromouse and robot ping pong laboratory. In the present building the maze is 'squatting' in the first year general teaching area; from November a purpose built laboratory will become available in a new building. This will have direct access from the outside so that students can use the laboratory over extended periods, outside normal laboratory opening hours. This new laboratory, of approximately 900 sq. m, will also contain a permanently set up robot ping pong table. There will also be easy access to the students' mechanical workshops.

Robot ping pong is a relatively new exercise for the Polytechnic. The first four students started during the 91/2 year. Two students were from the BEngCE course, and two from HDEE. In both cases it was necessary to group the students together such that one concentrated on the hardware aspects, and one on the 'vision' system. The two approaches taken were quite different, although the batting mechanism shared a common vertical x-y plotter configuration.

One project used two video cameras and much signal processing to follow the ball and predict its path. This proved very successful, although the students partner had problems with the batting mechanism.

The other project tried using a system of mirrors and infra red detectors. This has not proved a very productive route to follow.

However the lessons learnt by all concerned mean that the two groups of students next year, one from HDCE and the other from BScIT, may have an easier time!

It is interesting to note that some of the students choosing robot ping pong come from those courses that have not been too enthusiastic about micromouse. It can only be assumed that they perceive that robot ping pong is more software based tham micromouse, although the problems with designing the batting mechanism do not seem obvious at the initial stages!

4. THE USEFULNESS OF MICROMOUSE AND ROBOT PING PONG

Micromouse and robot ping pong impinge upon the students' training in many areas. The obvious one is the use of a simulated real life situation or problem. This allows them to come into contact with the sort of engineering problems faced in the 'real world' instead of the more theoretical simulation employed much too frequently at this level.

Micromouse and robot ping pong also give the students real problems to solve; and they have to be solved within a set time - around 40 weeks in City Polytechnic's case, and within real budgets - around HK$1500. These extra disciplines mirror in some way

the processes involved in an industrial/commercial environment.

The integration of software, electronics and mechanical design along with the problem solving techniques involved in maze searching and solving algorithms, makes these type of projects unique, which is why they are so popular.

However, within the Hong Kong context, other aspects arise. Most of the students buy the parts for their projects from one of three street markets that specialise in selling used, or 'stock lot', electronic products. Thus, although the Micromouse and Robot Ping Pong Development Group carries a stock of dc and stepper motors, the students have to validate their purchases, and, in most cases, measure the specification, as data is not usually available at the prices they pay! This gives the students good practice in areas of electronic and electrical engineering that they may have glossed over in their other academic work.

Finally, the fact that they are members of a team, with regular discussion between 'competing' groups, also gives an added dimension to development work that can be missed in a more traditional approach. Also, there are not many final year projects that hold the promise of cash prizes for the winners of local, regional and international contests!

5. THE FUTURE

Beginning October 1992, the Department of Manufacturing Engineering (ME) at City Polytechnic of Hong Kong will start a Mechatronics Honours Degree course. The Department of Electronic Engineering (EE) will be involved with the teaching. It is planned that micromouse and robot ping pong will be an integral part of the project work on this new course, maybe as a mini project in the second year. There will definitely be joint project work between EE and ME students for their final year. This should help the EE students overcome their reluctance to get involved with mechanical design and construction. At the same time it will mean that the number of students involved in these areas will increase rapidly.

At the same time, the Polytechnic's involvement in the organising of the annual Hong Kong Micromouse contest, now in its third year, as well as the Micromouse World Chapmionships in 1991 and the Robot Ping Pong World Championships in 1992, has meant that both micromouse and robot ping pong have developed a very high profile in the territory. So much so that other institutions, from universities and polytechnics, to schools and technical institutes, have now asked for help in starting projects of their own.

Each year City Polytechnic arranges a short workshop on Micromouse, usually run by Prof. John Billingsley. This year this will be a whole day session, and students from all instituions interested will be invited. There will also be a one day workshop on robot ping pong.

The University of Hong Kong, for example, has approached the department to help design a basic chassis that can be used as a basis for a 12 week mini-project for all 2nd year computer science students.

Work on this design is well advanced and a prototype has been running under pc control. The kit is designed to use very cheap stepper motors, as used in daisy whell printers. These cost around HK$6 each! Although the step angle is large, 3.6^{o}, and the motors heavy and not too powerful, it means that the overall cost of the chassis is about HK$1000. The controller used is a Motorola 68HC11 evaluation board, which mounts on the top of the chassis. No sensors are on the basic unit, nor is software, other than that provided by Motorola with the evaluation board, given to the students. They have to work that part out themselves!

One project student next year will write a number of software sub routines, as well as develop simple sensor and motor driving circuits so that a properly structured handbook can be produced for those institutions not having the facilities or expertise to develop these themselves.

With this basic low cost kit available to anyone in Hong Kong that is interested in building a micromouse, it is expected that interest will grow rapidly.

6. CONCLUSIONS

During the two years that micromouse has been used for final year project work at City Polytechnic of Hong Kong thirteen mice have been built by twenty two students. About six of these have successfully reached the centre of the maze. In last year's World Championships, Polytechnic students came 11th and 12th. The integration of electronics, mechanics and software, allied with the time and cost constraints, has made each micromouse project one of the best simulations of a real life design problem.

The added bonus of working as part of a team, and also the competitive nature of the contests, has also given the students a foretaste of the commercial environment. This is not usually possible with most final year projects, and would certainly not be true if only one or two mice were built each year.

Robot ping pong, on the other hand, provides the student with a different stimulus. In this case they must consider a complicated situation and then simplify it to such an extent that a minimal solution is possible within their understanding, as well as budegtary and time constraints. So far, with only two groups of students working on robot ping pong, it is too early to see any benefits beyond the obvious. However, one micromouse graduate is now engaged in a robot ping pong masters project that involves fuzzy logic, as well as advanced signal processing. It is possible that techniques learned within the department on robot ping pong will be used in research projects dealing with robot vision systems.

7. REFERENCES

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