The Experience of using Micromouse and Robot Ping Pong for Teaching Mechatronics

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Abstract

Micromouse and robotic ping pong have been interesting mechatronic applications for the past decade or more. Recently a number of educational institutions around the world have started using these two 'fun' robotic ideas as a basis for a more structured approach to robotic engineering education. At City Polytechnic of Hong Kong regular project work using micromouse has been going on for a number of years. More recently robot ping pong has been introduced.

This paper also looks at the problems and opportunities involved in making micromouse a part of the curriculum. Finally, this paper addresses the specific needs of Hong Kong and southern Chinese industry and relates the learning experience of those students taking part in robotic projects to the needs of that industry.

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 students.

The experience of introducing robotics into the classroom suffered a number of setbacks in the early 80s. 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. 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 or BASIC 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 coordinated attempt at micromouse was based at the North London Hobby Computer Club at the Polytechnic of North London from 1979 onwards.

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 in in a similar situation today as micromouse was in the early 80s - an interesting event but not considered much use. The World Robot Ping Pong Championships held in Hong Kong in 1992 was dominated by research orientated entries, unlike the Micromouse World Championships held the year before, which was dominated by undergraduate entries.

2. The engineering challenge

Micromouse is essentially a totally autonomous robot that has to solve a very particular task, ie map an unknown maze and then find the quickest path to the centre of that maze. For the fastest mice this means controlling around 1kg mass moving at up to 3m/s with a positional accuracy of +/- 1mm in a 9 sq m area! The individual parts of the mice are inherently very simple and easy to assemble; however the integration of these parts into a unit that can solve the control problem above is not that easy - and this is the challenge to the students.

There are basically four parts to a micromouse. First the sensors; these can be infra-red, looking either down on the walls or at the sides of the walls, laser, ccd array (vision) or ultrasonic. Secondly, the motors can be brushed dc, brushless dc, servo or stepper. Thirdly, the processor can be anything available, form microcontrollers like the 80196 to simple 8 bit processors such as the Z80. Finally the software can be written in anything from C++ through assembler to Quick Basic. Normal algorithms can be used or even fuzzy logic or neural networks.

This great diversity means that every mouse is different! The potential combinations are nearly infinite - which is why micromouse is an ideal project to teach the integration of electronic, mechanics and control/software, ie mechatronics.

Robot ping pong, on the other hand, has rules which are less well defined. The only criteria is that the robot does not overhang the table - which is itself a cut down version of a normal table tennis table.

Any method is allowed for the vision system, as long as it does not interfere with the opposing robot. Thus stereo video cameras, rotating mirrors and even ultrasonics have been tried. At the same time the bat has been attached to a simple robot arm, vertical x-y plotter and, even, complicated metal and wood framework. Essentially the bat mechanism has about 1.5 s to respond to information from the vision system.

Robot ping pong seems to need a different approach that micromouse. Interestingly the Japanese have not taken to ping pong in a similar way to micromouse; maybe the engineering challenge is beyond the capabilities of their fairly rigid undergraduate education system.

3. Education's response

The leading proponent of a structured approach to micromouse is Ngee Ann Polytechnic in Singapore. Selected students initially follow a two week solid training programme involving 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. The supervisors keep close contact and follow the students work. The best students have also created their development tools.

City Polytechnic of Hong Kong follows another approach, which follows the more 'free-wheeling' aspects of Hong Kong society when compared to Singapore. In this programme, described in detail below, students are 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. 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 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. 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.

Finally, there is the Japanese approach. This originated with delegates from the New Technology Foundation, a government funded body set up to encourage the awareness 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. 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.

On the other hand, robot ping pong has been the preserve of post-graduate students. This is because the vision system has been considered too difficult to design and construct by undergraduates. Experience at City Polytechnic of Hong Kong has shown that this is not the case.

4. Hong Kong's experience

The Department of Electronic Engineering at the City Polytechnic of Hong Kong runs four main courses, three honours level bachelor degrees, and one MSc. Two Higher Diploma (senior technician) courses have recently been phased out. In total the department has over 1000 students, approximately 400 of which are studying part-time/ evening. The academic staff establishment is about 60.

Each year the department has to find around 350 projects for the final year students. Five 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 did their projects in pairs, the total number of students involved has been as high as sixteen.

Two years ago 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 space for such large equipment!

Up to six academic staff have been involved in micromouse on a regular basis, not all having 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. Table 1 shows the number of students per course.

Year	90/91	91/92	92/93	93/94	94/95
HDEE	2(4)	2(4)		2(4)	*
HDCE		4(8)		*	
BEngEE	2(2)	4(4)	6(6)	5(5)	2(2)
BEngCE			1(1)		1(1)
BScIT			1(1)		
MScEE			1(1)	1(1)	

First number = number of projects ie mice
Number in () = number of students
* Course discontinued at CPHK

Table 1: Number of students taking micromouse projects by course

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, 8OC39, 68HCl1 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.

The number of students doing micromouse in the Department of Electronic Engineering is dropping off for a number of reasons. First, the HD courses have been transferred to the local Vocational Training Council College. However, this college will now institute micromouse as a compulsory second year mini-project for all EE students.

Secondly, the establishment of a Mechatronics degree course in the Department of Manufacturing Engineering (ME) at the Polytechnic means that students are now available with a background in mechanical engineering as well as electronic and computer engineering. Some final year project students from ME have redesigned the standard chassis originally developed by the author [4]. This is now a very efficient base on which students can build. It has been adopted by a number of schools and colleges in Hong Kong.

The implications of these two expansions of interest in micromouse, especially for the Hong Kong economy are addressed below.

The majority of 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 of this 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 lkg travelling at up to 2m/s !

The number and type of sensors is also evolving. In the first two years of the programme all used infra red sensors 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. Recently, students have been encouraged to experiment with other sensors. These include 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. The latter project has been very successful, with the vision system able to map the whole maze from just four observation points [5].

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 an a very comprehensive library based upon copies of papers and magazine articles about micromouse published during the last 12 years.

Robot ping pong is a relatively new exercise for the Polytechnic, starting during 1991/92. Table 2 gives the course involvement.

Year	91/92	92/93	93/94	94/95
HDEE	2(1)	2(1)		*
HDCE				*
BEngEE				1(1)
BEngCE	2(2)		1(1)	
BScIT	1(1)	1(1)		
MPhil			1(1)	1(1)

First number = number of projects ie mice
Number in () = number of students
* Course discontinued at CPHK

Table 2: Number of students taking robot ping pong projects by course

The methods used by the students have ranged from the sublime to the ridiculous! One project used two video cameras and much signal processing to follow the ball and predict its path. This proved very successful, and was used as the basis of the robot that came third in the 1992 World Championships.

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

Recently the Department bought the robot that came second in the 1992 World Championships, Charlie V. This has been used as the base for some further development work. Charlie V uses rotating mirror to build up a record of the angle subtended by the trajectory of the ball. A second camera has been added to make each record more unique [6].

Collaboration with ME students means that robot ping pong has now become multidisciplinary. Just as with micromouse, a number of students from ME have also participated in the mechanical design of robot ping pong. In 1993/4 two groups of HDME students were redesigning the framework of Charlie V. Further development of the structure is expected in the coming year.

5.The pedagogic argument

Micromouse and robot ping pong impinge upon the students' training in many areas. The obvious one in 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$1000. These extra disciplines mirror in some way the precosses involved in an industrial/commercial envirorment.

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, as well as useful in teaching mechatronics.

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 Laboratory carries a stock of dc and stepper motors, gears etc, the students have to validate their purchases, and, in most cases, measure the specification, as data in not usually available. This gives the students good practice in areas of electronic and electrical engineering that they may have glossed over in their other academic work.

At the same time, 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. Finally, the contests that are held locally, regionally and internationally each year provide an added incentive in the way of travel and prizes.

Each year Hong Kong has a local contest, usually attended by around a dozen teams. As the VTC, and other institutions introduce micromouse into their curriculum these numbers will increase.

The winner from Hong Kong has, in recent years, also attended contests in UK, Australia, New Zealand and Singapore. This added cross-fertilisation of ideas has meant that some technologies not considered in Hong Kong have been adopted, with interesting results.

In October 1992, the Department of Manufacturing Engineering (ME) started an Honours level Bachelor's Degree in Mechatronic Engineering. The Department of Electronic Engineering (EE) is involved with about 30% of the teaching. As mentioned above, some joint project work between EE and ME students has already resulted. This should help the EE students overcome their reluctance to get involved with mechanical design and construction.

The Polytechnic's involvement in the organising of the annual Hong Kong Micromouse contest, now in its fifth 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. This year, for the first time, another institution will be hosting the Contest.

Each year the Polytechnic arranges short workshops on Micromouse for schools and colleges. This is usually attended by teachers and lecturers from a whole range of institutions. The adoption of a simple chassis means that it is relatively easy for school students to concentrate on the electronic and software design, and not on the mechanics which seems to frighten them!

As mentioned above, the Vocational Training Council College at Tsing Yi has adopted micromouse as a compulsory mini-project for its second year students, starting from Autumn Term 1994. It is expected that about 30 groups of students will take part in this work.

The simple chassis design uses cheap stepper motors, costing about HK$12 each. These are limited in power and speed but provide enough of both to move the mouse at an acceptable rate. Initially it was hoped that the MC68HC11 Evaluation Board from Motorola would be used as the controller part. However, it was found that the i/o was not as flexible as needed. Consequently no processor board has been adopted. We are, though, moving in the direction of designing a simple controller board based on the 80C196, which has good hardware and software support in Hong Kong.

During the past few years a library of software subroutines, as well as simulation programs, have been accumulated. It is hoped that these can be well documented and made available for others to use.

The situation with robot ping pong is more complex. The perceived difficulty of the project has still to be overcome. Therefore we have decided to use this as a project to investigate collaboration between EE, ME and Mechatronics (MTE) students. Although in its early days, it is clear that this syntheseis of approaches and disciplines offers a unique simulation of industry.

6. Implications for industry

Any education programme that aims to be useful to the local industry that supports it has to have a balance between academic and practical work. In an Asian environment, especially one based essentially on Chinese culture, emphasis is usually given to the rote learning of bookbased knowledge.

One of the objectives of tertiary engineering education is to overcome years of pre-conditioning, and to get the students to think together and to work together. At the same time, introducing experimental work into the curriculum that will be useful training for industry is also important.

The changing face on Hong Kong industry during the past decade has meant that this experience is not now part of everyday life. In the 60s, 70s and 80s, Hong Kong's main employment came from light, low tech, manufacturing. In the 90s this has mostly moved to southern China.

Hong Kong is moving towards a management, financial and skills centre for the Pearl River delta. This means that engineering education has to be more aware of these roles.

Group based projects, such as micromouse, coupled with inter-disciplinary ones such as robot ping pong, are one method of meeting these challenges.

The fact that vocational colleges and schools are also participating in mechatronics-based project work will enhance the appreciation of evolving and integrating technologies.

The only other country to take micromouse seriously, Japan, did so because its government saw exactly the same opportunity and need. Unlike Japan, however, Hong Kong has no centrally imposed curriculum or financial or technical support for setting up micromouse clubs. It is only the interest of members of staff at these institutions that allows such activities to flourish.

As southern China moves into higher technology manufacturing, it is clear that the same needs will arise there as arose in Hong Kong in the 80s, ie a technically advanced engineering profession conversent with up to date technologies. Micromouse and robot ping pong provide low cost, and exciting, ways of getting students interested in mechatronics.

7. Conclusions

During the five years that micromouse has been used for final year project work at City Polytechnic of Hong Kong thirty two mice have been built by forty three students. About twenty of these have successfully reached the centre of the maze. In 1991 World Championships, CPHK students came Ilth and 12th. In the 1993 World Finals in London the Hong Kong Champion came 2nd in the Student Class. Clearly great strides have been made.

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 budgetary and time constraints. The close working relationships expected with teams of students from ME and MTE courses gives the EE students experience in working with people from other, related, disciplines.

Finally, the rapid expansion of micromouse projects amongst the secondary schools, colleges and universities of Hong Kong is providing a means for students to meet 'real' engineering challenges. As Hong Kong loses its production base to southern China, this ability to solve problems in a close simulation of an industrial environment may be the only experience of project planning and management that our students meet in the local context.

8. References

[1] Bradbeer, R. T., "Using robotics to teach computer applications", Proceedings, Second Educational Computing Conference, London, 1983

[2] Bradbeer, R. T. , "Using Logo to teach robotics", British Logo Users Group Annual Conference, Cheltenham, UK, 1984

[3] Billingsley, J., "Micromice at Expo 185 Tsukuba", Electronic System News, Spring 1986, pp32-33

[4] Bradbeer, R. T., "Educational Uses of Micromouse and Robot Ping Pong in the Teaching of Mechatronics", Proceedings The 29th Annual National Electronics Conference - NELCON '92, pp 75-80, August 1992, Wellington, New Zealand

[5] Bradbeer, R. T., "Advances in Mechatronic Education using Micromouse as a Teaching Tool", Proceedings, International Conference on Mechatronics and Machine Vision in Practice, M^2VIP, September 1994, Queensland, Australia

[6] Bradbeer, R. T. and Knight, J., "Charlie V; A Robot Ping Pong PLayer using a Novel Vision System", Proceedings, International Conference on Mechatronics and Machine Vision in Practice, M^2VIP, September 1994, Queensland, Australia