Secondary School Robotics Competition

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Abstract

While several national and international robotics competitions have been established to cater for enthusiasts or experts from universities or research laboratories, few have been developed which operate successfully at the secondary school level. At a time when universities are keen to encourage secondary school students into science and engineering disciplines, and schools are looking to bolster their technology programs, such competitions provide a win-win scenario.

The major difficulties in establishing such a competition include (1) devising an inexpensive robot and associated task that challenges the student, (2) raising the skill level of teachers to a point where they are confident to run such an activity and (3) establishing a broad base of expertise to support large numbers of participants.

In this paper we detail the development, features and outcomes of the Robot Bilby Competition. The use of workshops and school visits to impart the necessary skills to teachers, and the process of competition expansion are also discussed.

From humble beginnings in 1995 to attracting a government grant in 1998, the Bilby has developed a solid base from which a national competition is emerging.

1 Introduction

The Micromouse contest has been running internationally for over seventeen years now. There are a number of powerful reasons for its continuing appeal. The objectives are very easy to understand and contestants can improve their performance, year by year, because the contest is ongoing. The mice are faced with the problem of a maze to solve and the need to find the fastest path to its centre. They must find the solution completely unaided by human handlers, while performing tasks of position and steering control, navigation, mapping and strategy.

The Robot Bilby Competition is similar in concept but utilizes a much simpler robot to race along a path. The Bilby path is based on the same size matrix as the Micromouse, but instead of alleyways it uses eighteen-centimetre squares cut from white-plastic coated board. The squares are laid edge to edge on a black surface to form a layout which looks a bit like a crossword puzzle. The Bilby robot is available in kit form, is simple to construct, relatively inexpensive and offers several options for computer control.

The Robot Bilby Competition was developed by Prof. John Billingsley, Mark Phythian and technical staff at the University of Southern Queensland, Toowoomba Australia, in 1995. The long association of Prof. Billingsley with Micromouse competitions led to the creation of the concept, out of a promotional exercise exhibiting a Micromouse to secondary students.

An essential feature of Micromouse is that the mice are totally self-contained, with all their processing power on board. This makes the pre-university entry level of expertise too high for all but a very few contestants. By allowing the rodent to be attached to a PC (or similar) computer, the computing and software problems become universally accessible.

There is of course no need to use a sixteen-by-sixteen maze. The 'starter' contest only requires the bilbies to race along a dozen squares or so, negotiating a few turns to reach the finish. Even this simple level requires sensing, exploring and steering control. Photoelectric sensors very similar to those of micromice are used to detect the edge of the track.

Once these first stages have been successfully accomplished, progress to the solution of a maze-like path can proceed. At the same time, the contestants will probably become dissatisfied with the performance of the simple stepper motor robots and will experiment with faster

motors and better sensors. The next challenge is to build the processing power into the Bilby.

Why call it Bilby? Well the notion of preserving the name of one of Australia's endangered species has much more appeal than edifying a another rodent. With perseverance, Bilbymania will soon be convincing secondary students that interfacing computers to problems in the real world is really not all that difficult - and that mechatronics is fun.

2 The Competition

The purpose of robot bilby project is to provide a challenging task on which participants can hone their mechatronic and programming skills. The objective of the competition is to build, program and race a robot that can complete an unknown path in the shortest time. The following subsections present the fundamental rules of the competition.

2.1 The Robot

The robot may be constructed of any available materials providing it is safe to handle and does not damage or mark the path. The maximum allowable dimensions of the robot are:

- Length = 25 cm
- Width = 25 cm
- Height = no restriction

The robot may be automatically controlled by a computer through either (1) an umbilical between the robot and the computer or (2) an on-board computer system. The robot may be powered from either (1) single 12 Volt DC power supply connected to the robot via a pair of wires or (2) an on-board battery supply system.

To encourage new participants into the competition, kit robots are made available by the host organization. See section 3.

2.2 The Path

The path is formed from squares of wood finished on the upper square surface with a white finish. Each square is of the following dimensions

- Side Length = 180mm
- Thickness = 12mm

Squares are to be held together by tape on the under side, or joined by a dowelling pin in the centre of adjacent edges. The squares should fit together when laid out on a flat surface, so as not to be disturbed by the robot itself. The path is laid out - white side up - on a flat, horizontal surface with a black non-reflective finish. The path configuration is flexible but will take the form of a single string of squares with only right angle turns as in Figure 1

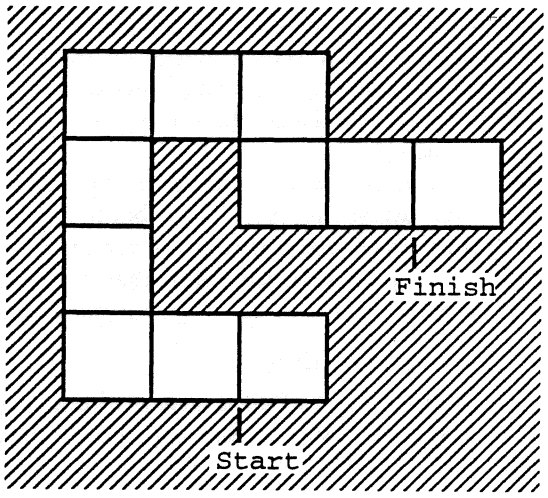

Figure 1: A typical Bilby path.

As a cost effective alternative, the path can be constructed using white paper on black card.

2.3 Robot Control

The control of the robot must be entirely programmed into the computer, that is - no human control is allowed during the race except to start, stop and restart the robot.

The configuration of the path is to be unknown to the controlling program, that is - the path configuration shall not be pre-programmed into the computer to aid in the solution. The program may however record the path configuration during any run for use in subsequent runs.

2.4 Competition Format

A practice session is held before the competition to test and adjust sensors, and allow teams to make final program changes etc. A typical path is laid out for practice, and all competitors are allocated time to test their robots on this path.

The competition is based on a collection of timed runs in a series of heats and a final. The *run time* is measured from the instant the Bilby crosses the join between the first and second squares, to the instant it crosses the join between the 2nd last and last square of the path.

In the heats each team is required to post a run time for their Bilby. The fastest run time for each team is recorded. The period allocated for each heat is set according to the number of participants, but would be typically 2 or three minutes.

A nominated number of teams recording the fastest run times are selected to participate in the final. Once these teams are selected their Bilby's will be 'caged'

ready for competition, and no further modifications will be allowed to either the robot or the control software.

The path configuration is changed for the final to ensure no advantage is gained from previous runs. Teams participate in the final according to run time order, from slowest to fastest.

Each team is allocated 3 minutes in the final in which to post their fastest run time. The robot to reach the end of the path in the shortest time is the winner. If no robot completes the path then the robot that moves furthest along the path within the time limit is the winner.

2.5 Robot Handling

Within the time limit of each heat or the final a Bilby handler may start, stop, pickup and restart their Bilby at any time. Control must be via single key strokes to the control program only.

Control / power cables to the Bilby must be supported by the handlers in such a manner that they neither impede nor aid the operation of the robot.

During the heats teams may adjust sensors and modify programs if so desired. During the finals teams may only adjust sensors.

3 The Bilby Kit

The fundamental design of the Bilby is a wheel chair configuration of two wheels directly driven by two stepper motors. The pitch of the robot is limited by two skids (front and rear) which are formed by the end of an adjustable bolt and nut assembly. A box shaped chassis supports the motors and skids, support rods for the sensors and the PCB. The PCB contains simple circuitry to drive the two 4-phase stepper motors from the 8-bit port of an IBM PC printer interface. Four inputs on the same interface are used to accept sensor input. Control via an umbilical may be replaced by an on-board microcontroller or other control circuitry. Figure 2 illustrates the standard configuration.

In addition to the robot a twenty page Users Guide, a twenty page Technology Workbook and sample Basic software are provided to ensure a quick start for the students.

3.1 Version 1.0

To establish the competition at minimum cost in its first year, and ensure that students had a working robot to begin with, a simple kit based robot was designed utilizing the following components:

- 2 stepper motors - from discarded 5.25" floppy disk drives
- an aluminium chasis and 2 plastic & rubber wheels
- a PCB containing an octal transistor array
- connections for 4 micro switch inputs as sensors

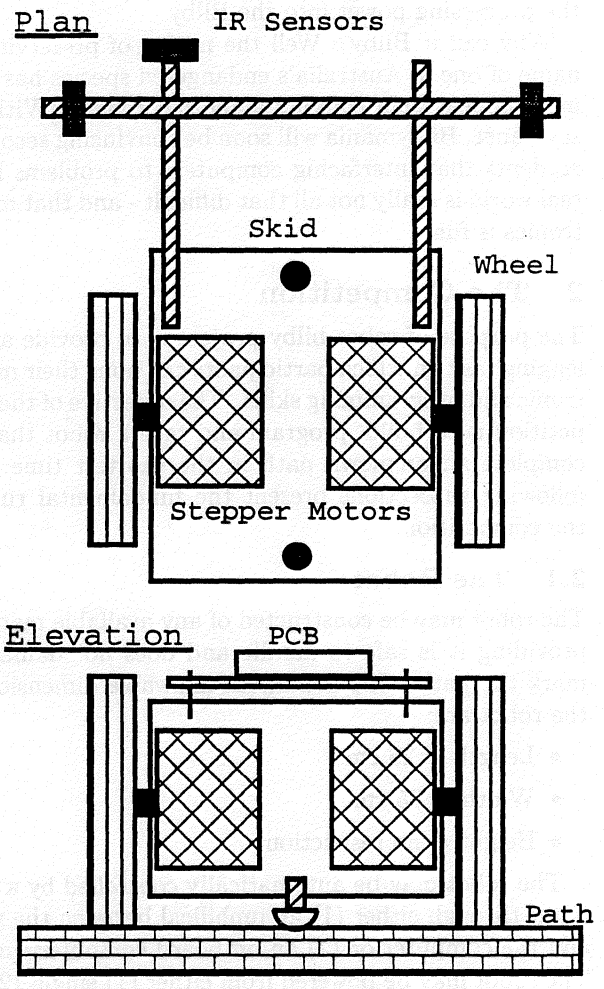

Figure 2: Bilby Robot configuration.

While this solution met the initial criteria of minimum cost, and was well received by schools, several groups failed to participate due to a lack of skills, perceived or otherwise, by the teaching staff.

3.2 Version 1.1

In the subsequent year four reflective infra-red sensors (OPB704) were introduced into the kit along with plastic rods for their support. Sensitivity adjustment and transistor switch circuitry were added to the interface by the provision of a second PCB which plugged onto the sensor connector strips on the original PCB. A sensor adjustment procedure and test card were also provided.

3.3 Version 2.0

To streamline production of kit components several modifications were incorporated into version 2.

- The folded aluminium chassis was replaced which an NC drilled, 120mm section of PVC downpipe.
- The wheel mounting was simplified by using a small sleeve to press fit the larger hub to the motor shaft.
- A single PCB was produced incorporating all interface circuitry.
- new motors were sourced to eliminate problems encountered using and scavenging second hand motors.

In short production runs of 10 to thirty units the cost of the version 2 kit, excluding assembly, is approximately A$150.

3.4 Kit Variations

It was anticipated that as the competition matured participants would seek to include on-board controllers in their bilbies. Indeed the use of connected PC's complicates the running of the competition itself.

A variation already adopted by one host organisation [Supernova, 1999] utilizes a PIC processor, the Basic Stamp 1 from Parallax running a Basic interpreter. While this option requires some additional training for the teachers and students, this variation of the Bilby greatly appeals to the participants due to its autonomy. In 1999 an on-board controller based on either the BS2-IC or the MC68HC811E2 is to be introduced as an option to the original Bilby kit.

One benefit that is lost in progressing to on-board control is the reduction in choice of programming language. While the kit comes complete with sample Basic software some participants have chosen to apply Delfi and Pascal to control their robots.

4 Introduction of Bilby into Schools

In establishing the competition it was hard to estimate what the initial response would be. Several teachers involved in teaching Information Processing and Technology curricula in secondary schools in the Toowoomba region were invited to view a prototype Bilby and listen to a proposal on the competition.

After an enthusiastic response version 1.0 kits were produced and distributed at no charge to eight schools. Each kit was delivered by staff members of the host organization, and presented along with a thirty minute introduction to the robot's function and the competition.

Several other visits were also organized to offer direct assistance to students where teaching staff were struggling with some aspects of the task. Through these requests for assistance it became evident that training for teachers was essential.

4.1 Promotion and Scheduling

Notification of the competition is made directly to the school principals early in the school year, along with posters and an invitation for the school to participate. At the same time science and technology teachers are invited to attend a free Technology Workshop run by the host organization. Scheduling the workshops from 2pm to 5pm on a weekday resulted in the best attendance. Content of the workshop is outlined in section 4.2.

Associated with the workshop is an introduction to the Bilby robot and the competition, from which teachers are encouraged to promote the competition to their students through a supply of posters and invitations to participate.

Follow up letters serve as reminders, as do media releases which also attract other schools into the competition. A number of participants are introduced by teachers already involved in the competition. The average response rate for participation from schools first contacted in a region is between 30 and forty percent.

Depending on the number of teams participating, practice heats and finals can be held on one day or over a series of shorter events. The best attendance of competitors and spectators was achieved when the competition final was held in conjunction with the university's open day on a Sunday in August. Holding the competition much after this date tends to clash with senior examination preparation.

4.2 Technology Workshops

By far the greatest hurdle in establishing the competition was to overcome the reservations held by teaching staff to successfully supervise such an activity. The offering a few three hour workshops early in the competition season greatly increased the participation and retention rates.

The topics covered in the workshops include:

- fundamental electrical theory
- AC and DC power sources
- analog and digital signals
- interfacing to the IBM PC and safe practices
- simple input/output circuitry
- software for input/output
- transistor switches
- stepper motors
- an introduction to the Bilby robot

At these workshops teachers are provided with a copy of the Technology Workbook which accompanies the Bilby kit, a small prototyping interface board for the IBM PC printer port and some simple devices such as LEDs, resistors and switches.

Teachers are led through the material in the booklet from which they discover how to connect input and output devices to the PC, and how to write a Basic program to utilize that interface. These workshops are very well received and teachers often comment on how they intend to utilize the knowledge they gain in other school projects. Teachers are also encouraged to use the technology booklets in the classroom.

The competency level of the students varies from no real programming skills to fairly proficient. With enough participation, different skill levels can be accommodated by introducing competition divisions based on age, experience or slightly different competition requirements.

4.3 Bilby Web Pages

What technology based venture would be without its own web page? The Robot Bilby Home Page commenced operation in 1997, and in 1999 will include:

- background information on the competition
- documention including the Users Guide and the Technology Workbook
- technical details on robot construction
- hints and tips
- event calendar
- photographs of robots and competitions
- contact details for host organisations

The Robot Bilby Home page is hosted by the Univerity of Southern Queensland at [USQ, 1999]. The second host organization for the Bilby competition, the Supernovia Newcastle Regional Museum, also hosts a web site at [Supernova, 1999].

5 Competition Expansion

In 1998 the Bilby Project Group at USQ successfully bid for a small government grant from the Science and Technology Awareness Program to develop the competition Australia wide over a three year period. In 1999 universities and other technology groups from around Australia are being invited to catch Bilbymania.

Prospective host organizations are provided with - sample documentation and procedures for establishing a local chapter of the competition in their region, details of support offered by the co-ordinating body and an outline of the organization of the National Competition.

It is expected that new host organizations will wish to incorporate the Robot Bilby Competition into their own promotional activities, thus relevant permissions can be arranged to utilize logos, artwork and trade names in production of materials. Within the guidelines of the competition host organizations are permitted to develop alternate robot designs and training courses, and co-ordinate regional competitions.

Co-ordination of the National Competition is through the USQ Robot Bilby Project Group, in co-operation with the regional host organizations.

6 Outcomes

Over the 4 years in which the competition has run organizers have seen a steady increase in participants, to a point where over thirty schools have robot bilby kits in the Toowoomba Region and around ten in the Newcastle region. Unfortunately not all schools have participated each year. Other host organizations around Australia are now beginning to show a keen interest in adopting the competition.

Performance wise the standard bilby kit robot is capable of speeds up to around 0.4m/s. Timed over a course of around 1.8m with four turns, teams have dropped their times from around 30 seconds in the 1995 to around 8 seconds in 1998. With each team typically comprised of 3 or four students and a supervising teacher, competition day gets to be fairly busy.

A strong core of interested teachers has ensured a steady development of Bilby programs and robot configurations. This means that new teams joining the competition find it tough to compete against the more established teams. To encourage new participants and to expand the scope of the competition, it is likely that two divisions will be created - one retaining the standard path problem, and another set a simple maze type problem.

In coming years organizers are planning to make the competition much more visible to the public. This not only improves the atmosphere, but encourages participation, makes the competition more attractive to prospective sponsors and gains wider media attention.

7 Conclusion

The Robot Bilby Competition has captivated students, teachers and the general public in the same style as the Micromouse still does. The concept is clear, the robots relatively inexpensive to build and just what many secondary school technology teachers have been looking for. The promotional opportunities for the host organizations are great. The type of exposure and hands on experience The Robot Bilby Competition creates has already attracted students to study computer science and engineering courses.

References

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