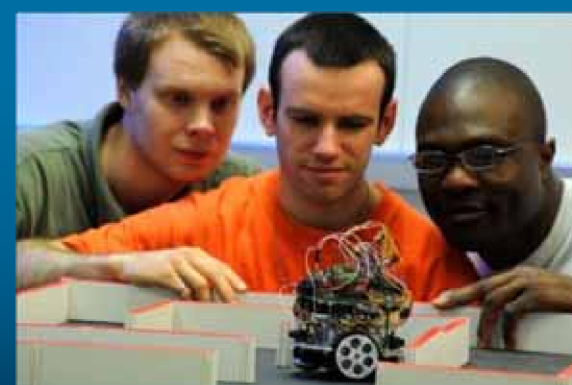
Micromouse Webinar

An overview to design and build a Micromouse

February 18, 2016



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Abstract

- A Micromouse is a small robot vehicle that is able to navigate its way through an unknown maze. It is autonomous, battery-operated and self-contained, encompassing computer technology, robotics and artificial intelligence. The main challenge for the Micromouse designers is to import the Micromouse with an adaptive intelligence which enables exploration of different maze configurations, and to work out the optimum route with the shortest run time from start to destination and back. In addition, the Micromouse must reliably negotiate the maze at a very high speed without crashing into the maze walls.

- The annual IEEE Region 1 Student Conference hosts the Micromouse Competition. The objective of the competition is to build a Micromouse that can negotiate a specified maze in the shortest time. This on-line webinar will introduce the design and development of the hardware and software of a Micromouse. The take away will be the fundamental knowledge with best practices and design strategies to build a Micromouse, and be really for the 2016 Region 1 Micromouse Competition.

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Webinar Outline:

- Introduction
  - What is Micromouse?
  - Video – An International Micromouse Competition
  - Soon's and others Micromice
  - Maze and Micromouse Specifications

- Micromouse Design Overview
  - Performance
  - Hardware Design (Senor, Motor Drive, Micro-Controller, Power Supply)
  - Software Design (Maze Solver Algorithm, Search Algorithm, Movement)
- Micromouse Competition
  - IEEE Region 1 Student Conference
  - APEC (Applied Power Electronics Conference)
- Micromouse Simulation Tool
- Questions and Sharing Design Ideas

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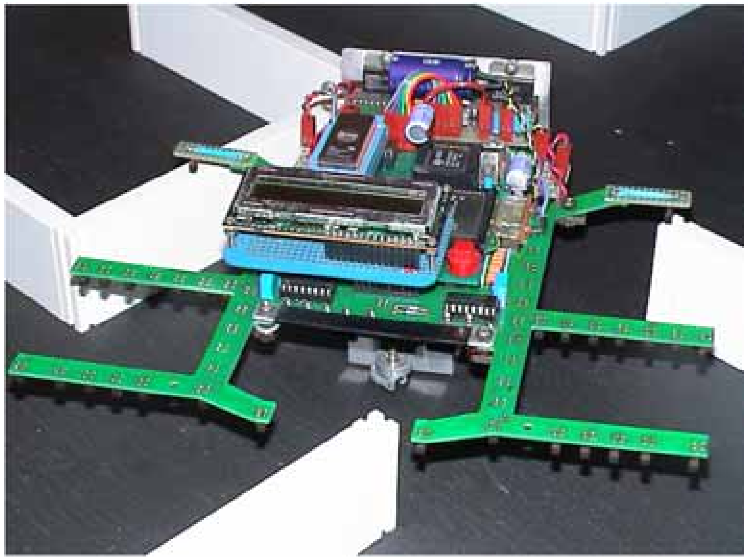
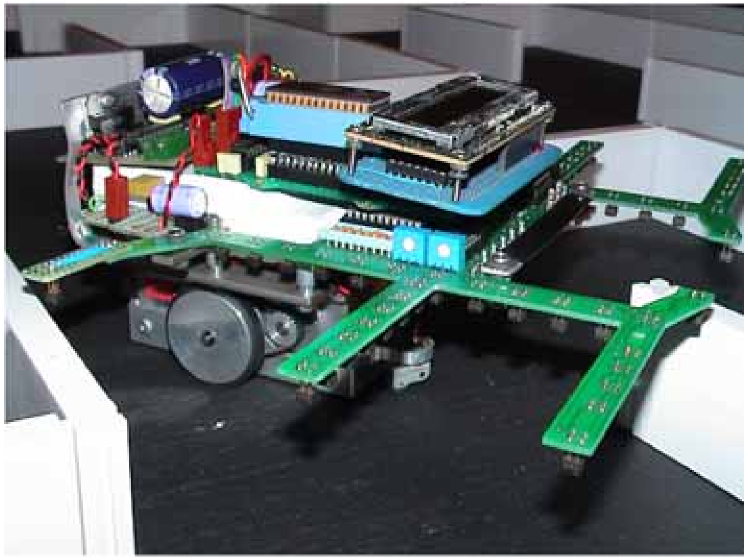
Introduction

What is Micromouse?

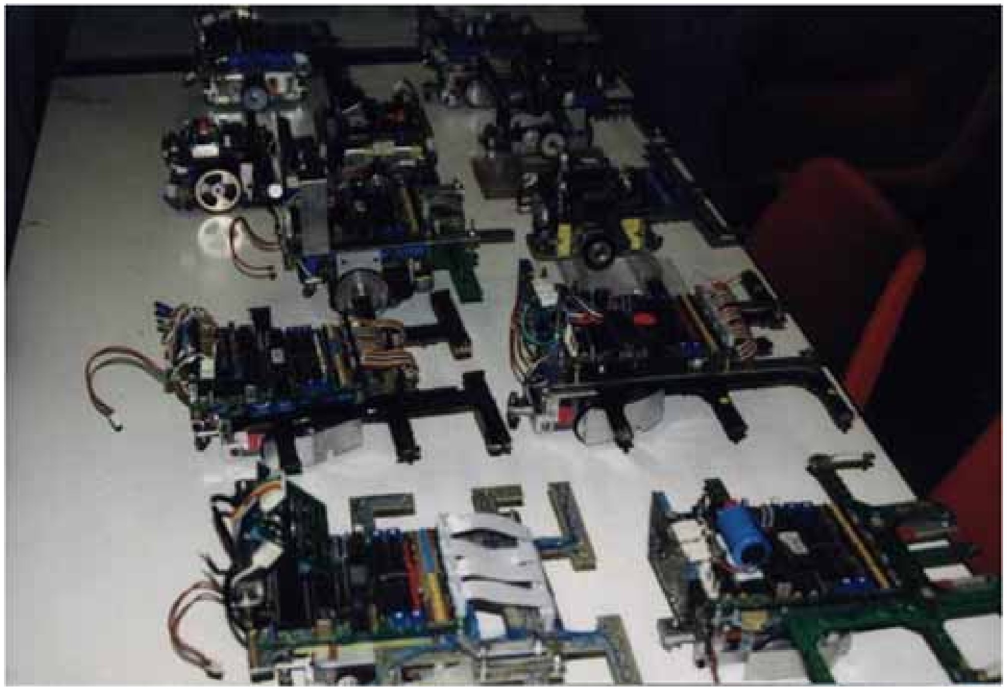
- A small microprocessor-controlled mobile robot which is capable to navigate its way in an unknown maze.
- Micromouse is autonomous, battery-operated and self-contained, encompassing computer technology, robotics and artificial intelligence.
- Main challenge is to import the Micromouse with an adaptive intelligence that enables exploration of different maze configurations. Then, to work out the optimum route with the shortest run time from start to destination and back.
- Micromouse must reliably negotiate the maze at a very high speed without crashing into the walls of that maze.

Soon’s Micromouse

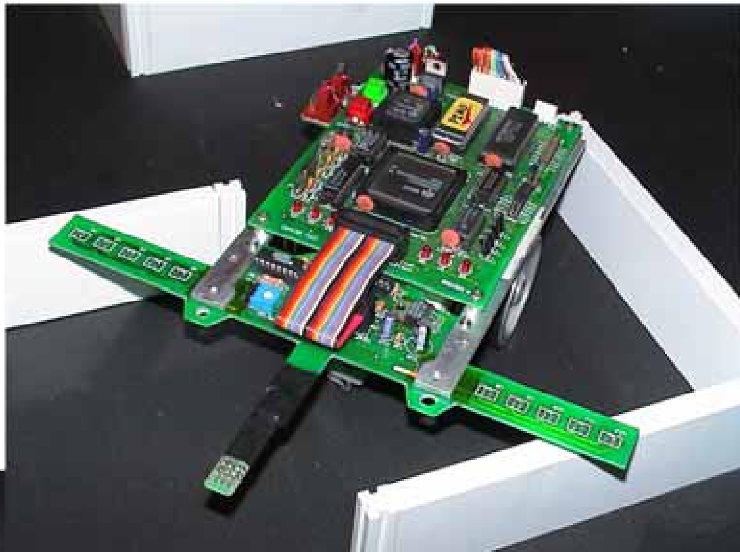




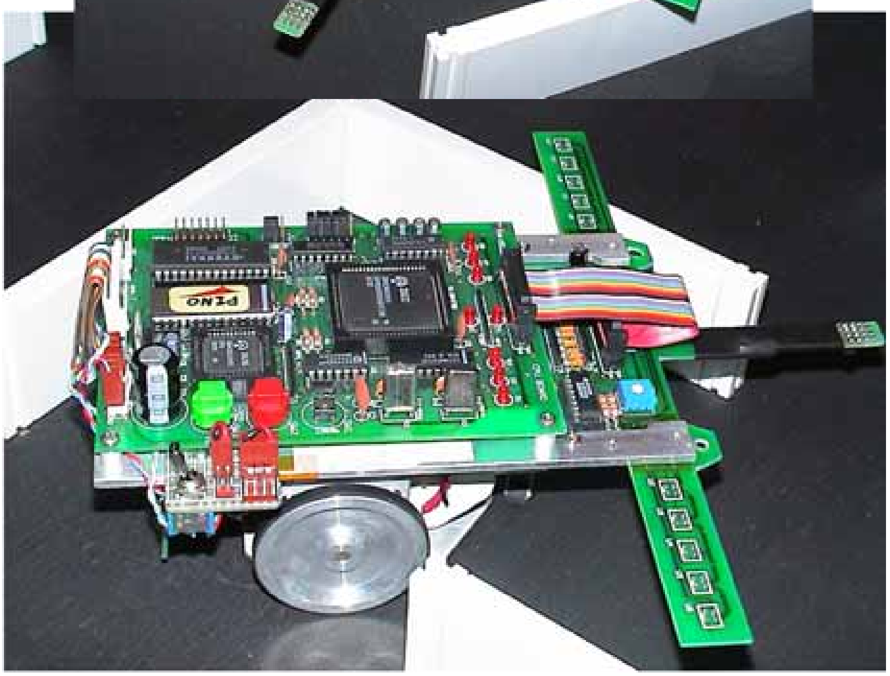
- Built when at High School
- Name: ZAP
- 1991 International Micromouse Competition Champion at Hong Kong



Soon's Micromouse



- Built when in 1996
- Name: Pinocchio
- 1997, 1998, 1999 IEEE Region 1 Micromouse Champion



Soon's Micromouse

- Built when at Vicor Corporation
- Name: VI-Mouse
- Most reliable micromouse at APEC 2001 International Micromouse Competition

Soon's Micromouse Activities

Origin of Micromouse

IEEE spectrum MAY VOLUME 14 NUMBER 5

spectral lines

Announcing the Amazing Micro-Mouse Maze Contest

It was through mere happenstance that *Spectrum*'s editors learned—by means of word propagated along the industry grapevine—of a so-called electronic mouse ("le mouse electronique" were the exact words that reached our ears). Upon assigning our top investigative reporters to the task of finding out the true facts, we quickly found that in January the magazine *Machine Design* had indeed called for designers and constructors of "electronique" mice to enter The Great Clock Climbing Contest. Contestants would be required to construct a mechanical mouse that could attempt to climb a vertical mesh screen ("le clock," one supposes). Our disappointment came when it was hinted the mice would merely be battery-powered and, probably, electric-motor driven. No electronics here, our purist minds concluded.

Nevertheless, we found the project interesting enough to search further into its history. We discovered that, back in 1972, *Machine Design* sponsored Le Mouse 5000, a contest described by the magazine as having the objective of producing a vehicle powered only by the spring from a mousetrap. As MD reported it: "Prizes were awarded for the longest runs. A total of 94 entrants sent their spring-powered cars down the racetrack . . . while a capacity crowd viewed the proceedings, The first-place 'mousemobile' traveled 825.3 feet."

Then, last November, Stephen Jacobsen's design engineering class at the University of Utah built the first battery-powered climbing mice. As part of the class assignment, the students constructed vehicles using commonly available parts. Among the conclusions reached by the student researchers, who were required to send their mice up a 30-foot-long ⅛-inch mesh screen, was a general consensus that a standard 9-volt transistor radio battery was the best power source. Most of the test vehicles, it was reported, used a 900-r/min motor geared down to 400 r/min at its drive shaft. Professor Jacobsen, whose observations regarding the results of the classroom research project were reported in MD, noted that a number of the mechanical mice failed to keep a grip on the screen for a variety of reasons. Some had optimistically assumed perfection of the screen and could not cope with the flaws in the course. Some were too heavy, or had a center of gravity too far from the screen. Others simply ran off the sides of the 3-foot-wide screen. On still others, the complex drive train sapped too much of the motor's power.

Be that as it may, the Utah tests led to the idea of the Le Mouse II contest announced in January by *Machine Design*. (Sorry, the deadline for registration was March 1.) Beyond that, it set *Spectrum*'s engineer–editors to wondering why a true electronic mouse could not be built. We put our heads together and, after a few days of concentrated after-hours brainstorming, became convinced that the plan was feasible. In short, *Spectrum* would run its own real electronic mouse contest. The mice would be required to negotiate a maze (officially named the Mystery Mouse Maze because its configuration would be kept a closely guarded secret until race day). The contestants would each design and build his or her own mouse (officially termed a Micro-Mouse, because it would have to contain its own logic and memory—which only a microprocessor or its equivalent can provide).

Soon our editors were consulting with major manufacturers of microprocessors. Ideas were generated and discarded. A set of standard mouse-maze modules was proposed, criticized, and a new set proposed. Various cross sections of the maze course were considered and discarded. Finally, one was chosen. Would its walls be reflective so as to permit the use of optical sensors? The answer was decided: yes. What about the track surface? How about using 00 sandpaper? The answer: probably.

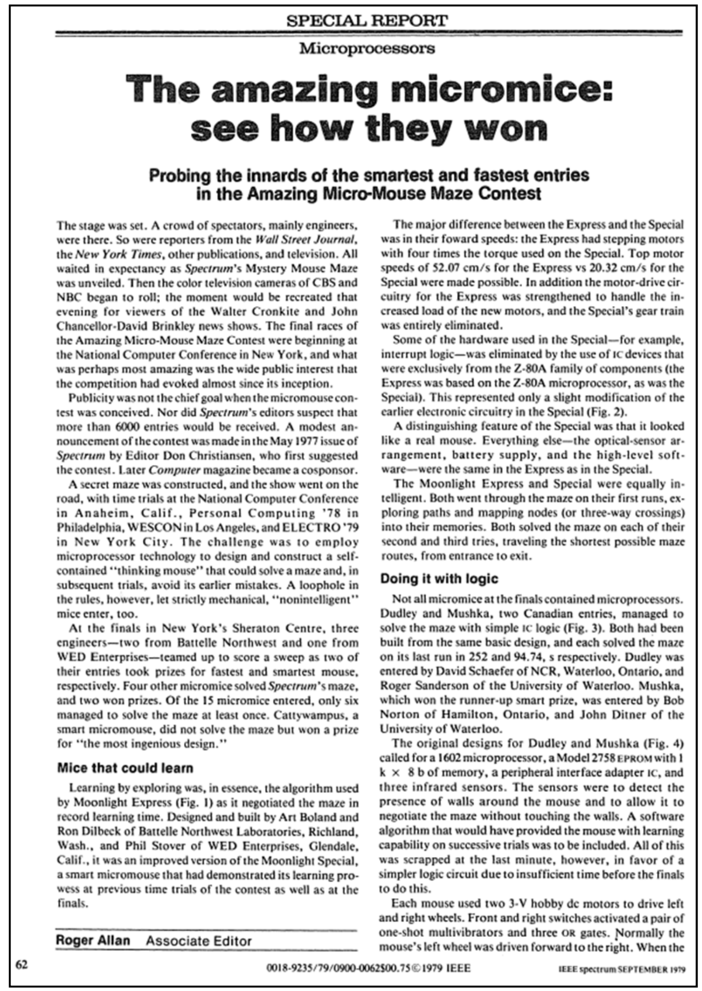
What about motive power? Any restrictions? Not really. Would a live mouse be permitted? Perhaps, but only if it were contained within a truly hermetically sealed package—to prevent unwitting alterations in the track's coefficient of friction.

Of course, certain restrictions on how contestants could be permitted to direct their mice will be necessary. For example, once released they could not be directed through either hard-wired or radio inputs. Thus, any mouse that looks suspiciously like an elephant, or, more particularly, like a giraffe, may be subject to internal examination.

Meanwhile, as *Spectrum*'s staff, with the aid of our microprocessor applications consultants, zeros in on the parameters of the Amazing Micro-Mouse Maze Contest, we'll keep potential contestants informed. In the interim, of course, if by chance you've entered *Machine Design*'s electromechanical mouse climb, we wish you luck. But for a more exciting challenge, stand by to enter *Spectrum*'s super contest. Drop us a note if you want to be mailed more details.

Donald Christiansen, Editor

IEEE Spectrum first introduced the amazing micromouse in 1977



SPECIAL REPORT

Microprocessors

The amazing micromice: see how they won

Probing the innards of the smartest and fastest entries in the Amazing Micro-Mouse Maze Contest

The stage was set. A crowd of spectators, mainly engineers, were there. So were reporters from the *Wall Street Journal*, the *New York Times*, other publications, and television. All waited in expectancy as *Spectrum*'s Mystery Mouse Maze was unveiled. Then the color television cameras of CBS and NBC began to roll; the moment would be recreated that evening for viewers of the Walter Cronkite and John Chancellor-David Brinkley news shows. The final races of the Amazing Micro-Mouse Maze Contest were beginning at the National Computer Conference in New York, and what was perhaps most amazing was the wide public interest that the competition had evoked almost since its inception.

Publicity was not the chief goal when the micromouse contest was conceived. Nor did *Spectrum*'s editors suspect that more than 6000 entries would be received. A modest announcement of the contest was made in the May 1977 issue of *Spectrum* by Editor Don Christiansen, who first suggested the contest. Later *Computer* magazine became a cosponsor.

A secret maze was constructed, and the show went on the road, with time trials at the National Computer Conference in Anaheim, Calif., Personal Computing '78 in Philadelphia, WESCON in Los Angeles, and ELECTRO '79 in New York City. The challenge was to employ microprocessor technology to design and construct a self-contained "thinking mouse" that could solve a maze and, in subsequent trials, avoid its earlier mistakes. A loophole in the rules, however, let strictly mechanical, "nonintelligent" mice enter, too.

At the finals in New York's Sheraton Centre, three engineers—two from Battelle Northwest and one from WED Enterprises—teamed up to score a sweep as two of their entries took prizes for fastest and smartest mouse, respectively. Four other micromice solved *Spectrum*'s maze, and two won prizes. Of the 15 micromice entered, only six managed to solve the maze at least once. Cattywampus, a smart micromouse, did not solve the maze but won a prize for "the most ingenious design."

Mice that could learn

Learning by exploring was, in essence, the algorithm used by Moonlight Express (Fig. 1) as it negotiated the maze in record learning time. Designed and built by Art Boland and Ron Dilbeck of Battelle Northwest Laboratories, Richland, Wash., and Phil Stover of WED Enterprises, Glendale, Calif., it was an improved version of the Moonlight Special, a smart micromouse that had demonstrated its learning prowess at previous time trials of the contest as well as at the finals.

Roger Allan Associate Editor

The major difference between the Express and the Special was in their foward speeds: the Express had stepping motors with four times the torque used on the Special. Top motor speeds of 52.07 cm/s for the Express vs 20.32 cm/s for the Special were made possible. In addition the motor-drive circuitry for the Express was strengthened to handle the increased load of the new motors, and the Special's gear train was entirely eliminated.

Some of the hardware used in the Special—for example, interrupt logic—was eliminated by the use of IC devices that were exclusively from the Z-80A family of components (the Express was based on the Z-80A microprocessor, as was the Special). This represented only a slight modification of the earlier electronic circuitry in the Special (Fig. 2).

A distinguishing feature of the Special was that it looked like a real mouse. Everything else—the optical-sensor arrangement, battery supply, and the high-level software—were the same in the Express as in the Special.

The Moonlight Express and Special were equally intelligent. Both went through the maze on their first runs, exploring paths and mapping nodes (or three-way crossings) into their memories. Both solved the maze on each of their second and third tries, traveling the shortest possible maze routes, from entrance to exit.

Doing it with logic

Not all micromice at the finals contained microprocessors. Dudley and Mushka, two Canadian entries, managed to solve the maze with simple IC logic (Fig. 3). Both had been built from the same basic design, and each solved the maze on its last run in 252 and 94.74, s respectively. Dudley was entered by David Schaefer of NCR, Waterloo, Ontario, and Roger Sanderson of the University of Waterloo. Mushka, which won the runner-up smart prize, was entered by Bob Norton of Hamilton, Ontario, and John Ditner of the University of Waterloo.

The original designs for Dudley and Mushka (Fig. 4) called for a 1602 microprocessor, a Model 2758 EPROM with 1 k × 8 b of memory, a peripheral interface adapter IC, and three infrared sensors. The sensors were to detect the presence of walls around the mouse and to allow it to negotiate the maze without touching the walls. A software algorithm that would have provided the mouse with learning capability on successive trials was to be included. All of this was scrapped at the last minute, however, in favor of a simpler logic circuit due to insufficient time before the finals to do this.

Each mouse used two 3-V hobby dc motors to drive left and right wheels. Front and right switches activated a pair of one-shot multivibrators and three OR gates. Normally the mouse's left wheel was driven forward to the right. When the

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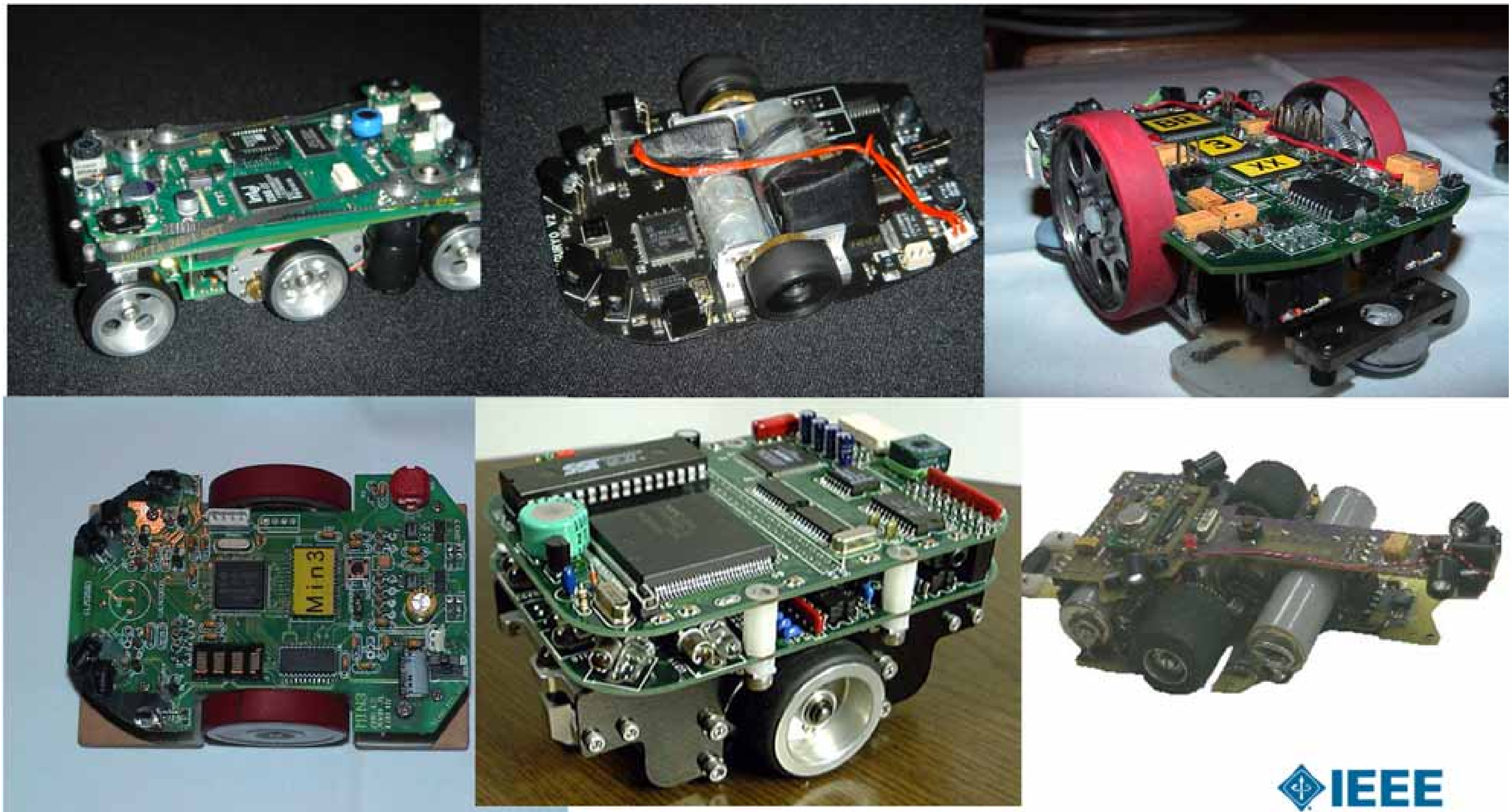
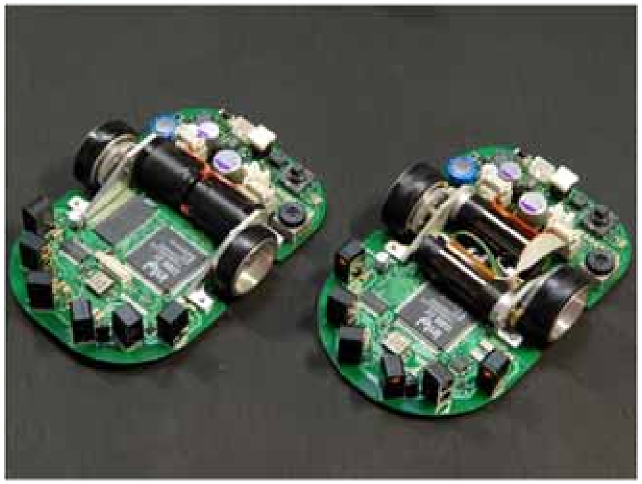
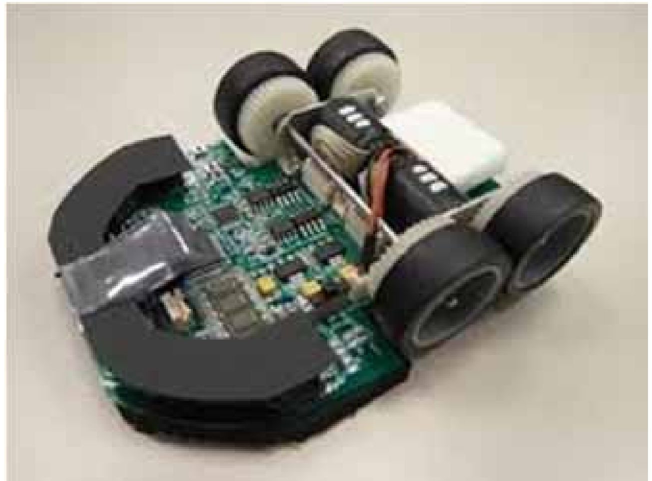
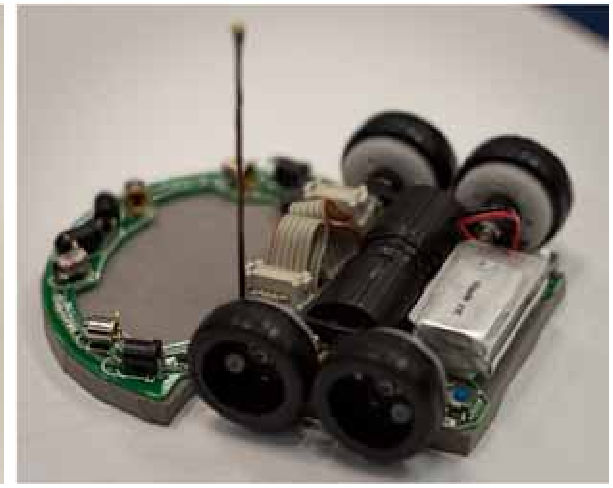
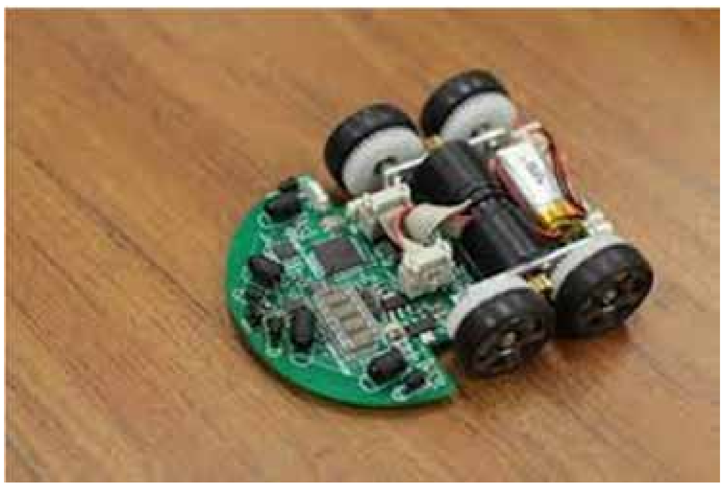
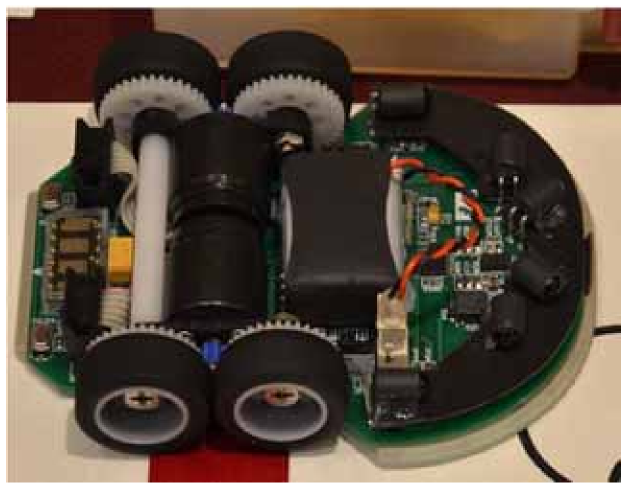
New Generation Micromice



Current Generation Micromice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Maze and Micromouse Specification

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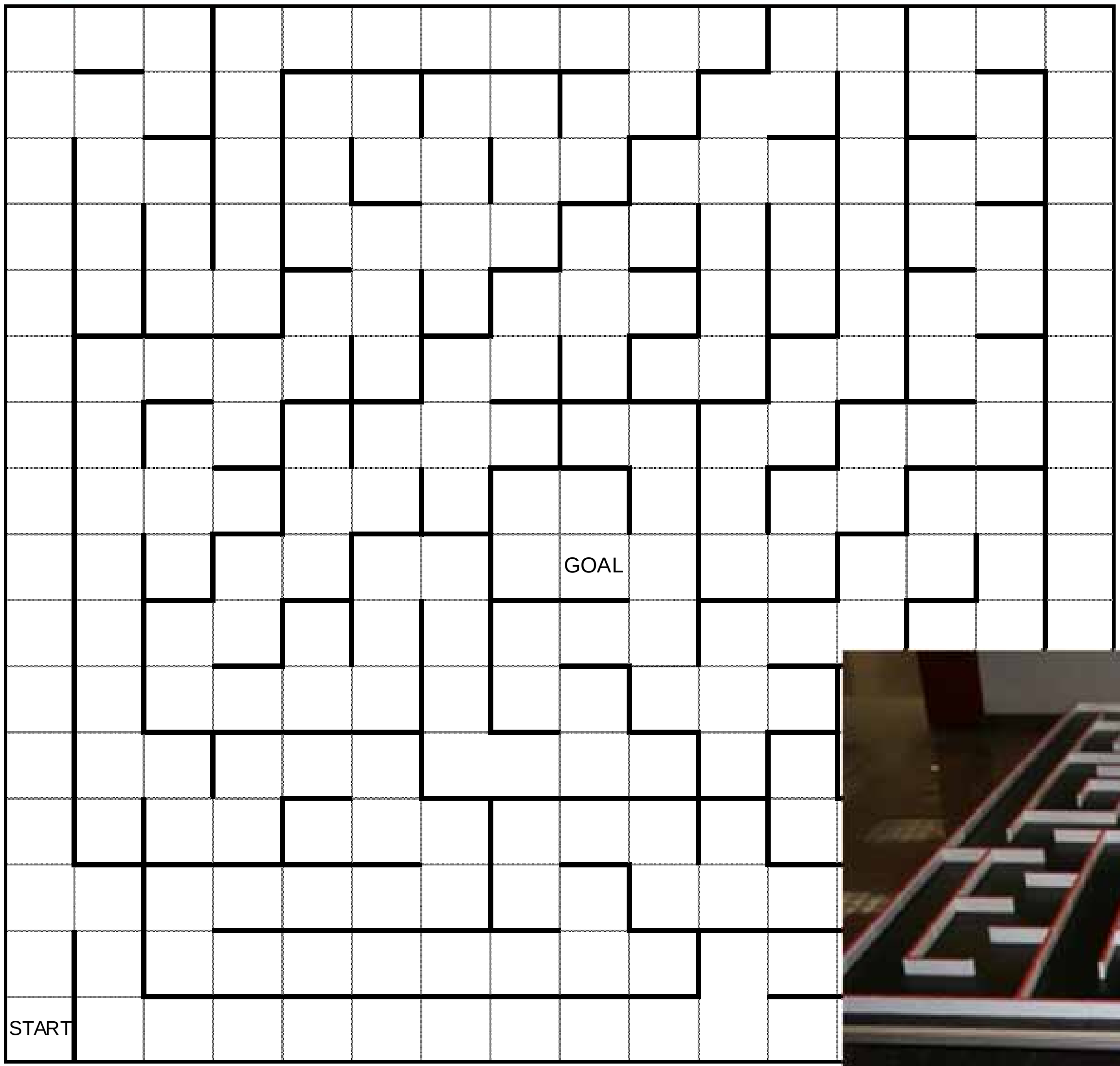
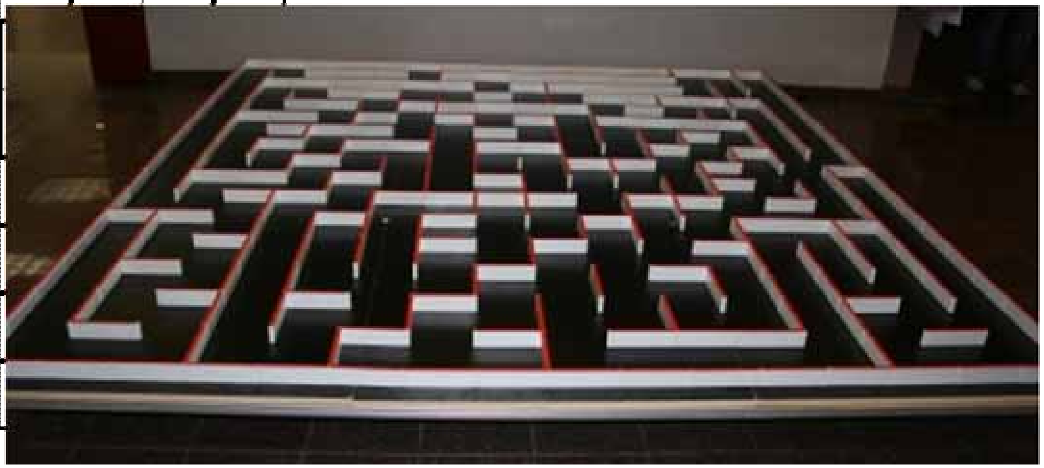
Maze Specifications

- Maze comprises 16 x 16 of 18cm x 18cm unit squares
- Walls are 5cm high and 1.2cm thick
- Side walls is white color, and the top shall be red or white color
- Outside walls enclose the entire maze
- Maze floor shall be made of wood and finished with a non-gloss paint
- Start square is at one of the 4 corners of the maze
- Destination is at the central square space (4 squares)
- There must be at least one wall touching each pole

Maze Specifications (continue)



- 16 x 16 squares
- 18cm x 18cm unit square
- Maze Wall
  - – 5cm High
  - – 1.2cm Thick



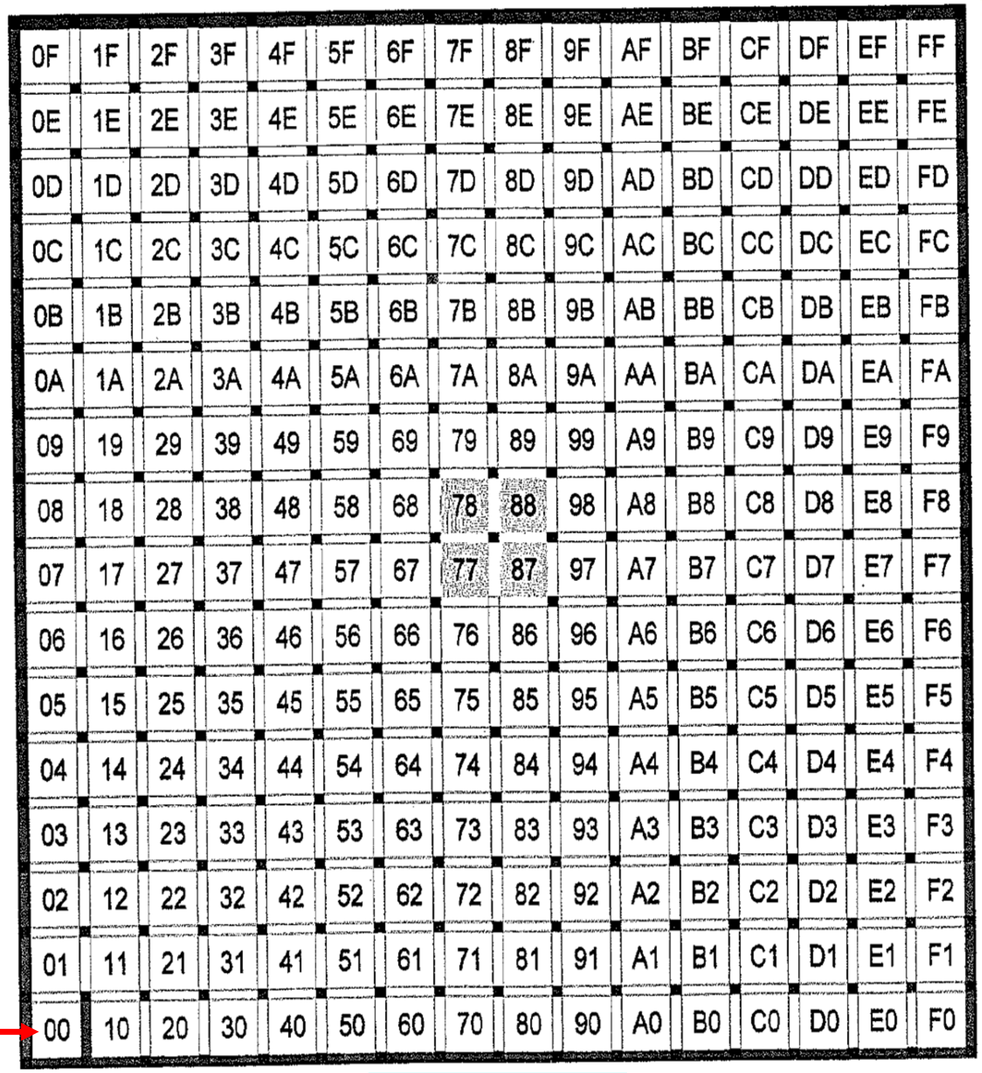
Maze Mapping

START = 0x00

GOAL1 = 0x77
GOAL2 = 0x78
GOAL3 = 0x87
GOAL4 = 0x88

NORTH

WEST



EAST

START

SOUTH

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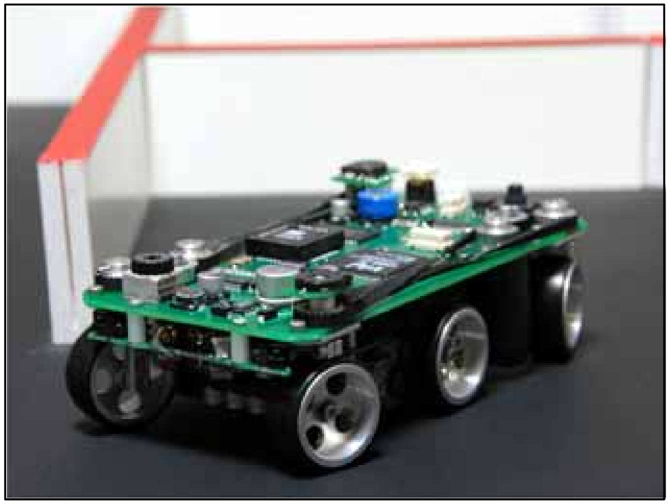
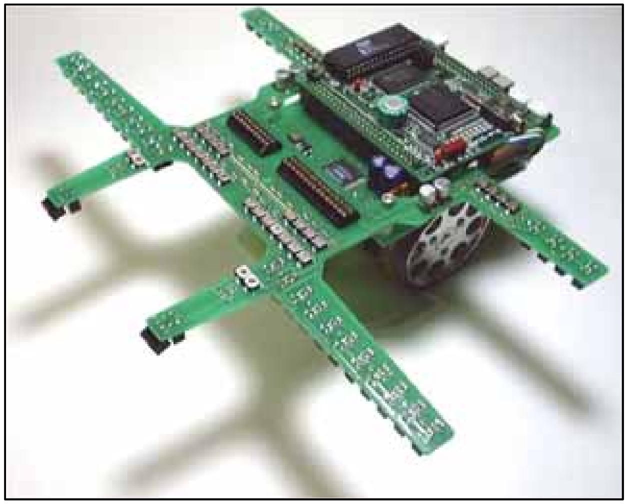
Micromouse Specifications

- A self-contained mobile robot
- Not leave anything behind while negotiating in the maze
- No combustion energy sources
- Must not step over, climb over, scratch, or damage the walls during exploring in a maze.
- Dimensions shall not greater than 25cm in length or width. But, there is no height limit.





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Micromouse Design

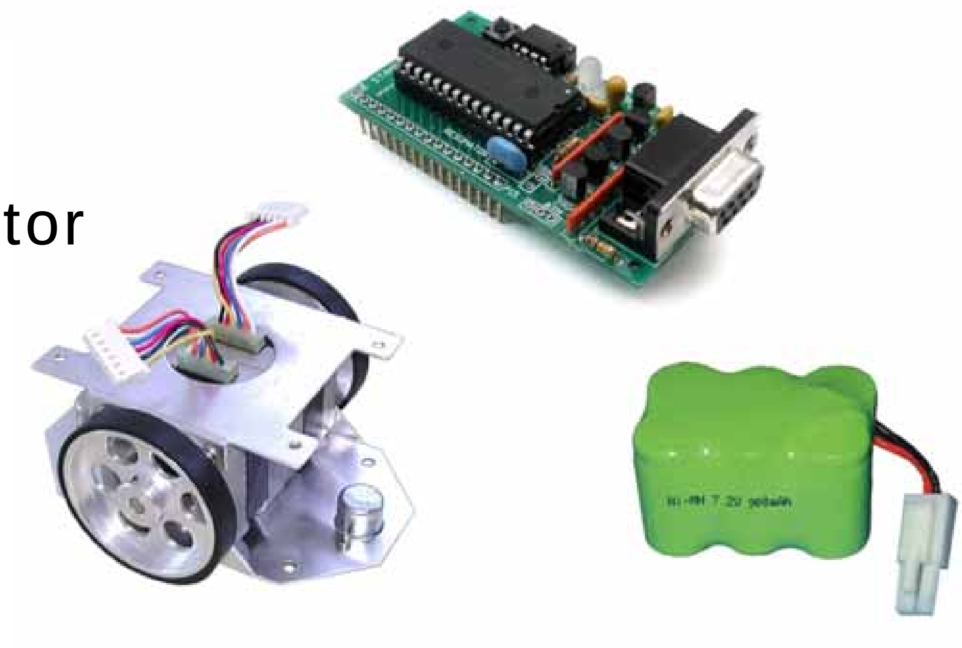
Micromouse Performance

- Performance can be measured by
  - Reliability
  - Speed
  - Intelligence

- Speed conflicts with reliability
  - High speed creates instability
- Proper motion control
  - Enable micromouse to run at higher speed without losing much on the reliability

Main Components

- Hardware
  - Micro-Controller
  - Motor Driver with Motor
  - Sensor
  - Battery Pack
  - Chassis, Wheels



- Software
  - IDE (Integrated Development Environment)
  - Acceleration Profile Generator
  - Simulator
  - Program Loader

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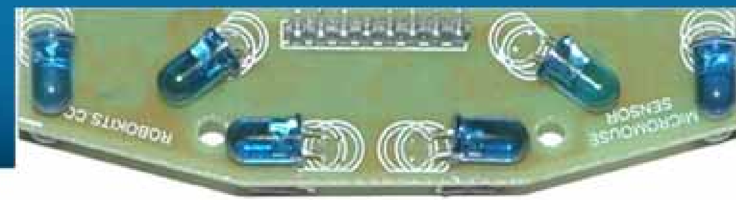
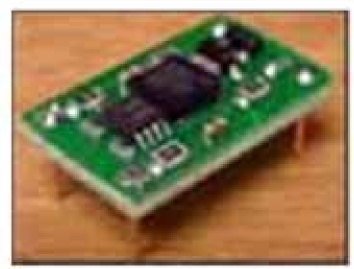
Micromouse Sensors



- Type of Sensors
  - Infra-Red Emitter/Detector
  - Digital Compass
  - Accelerometer
  - Bumper Switch
  - Rotary Encoder (wheel position)
  - Rangefinder
  - Sonar

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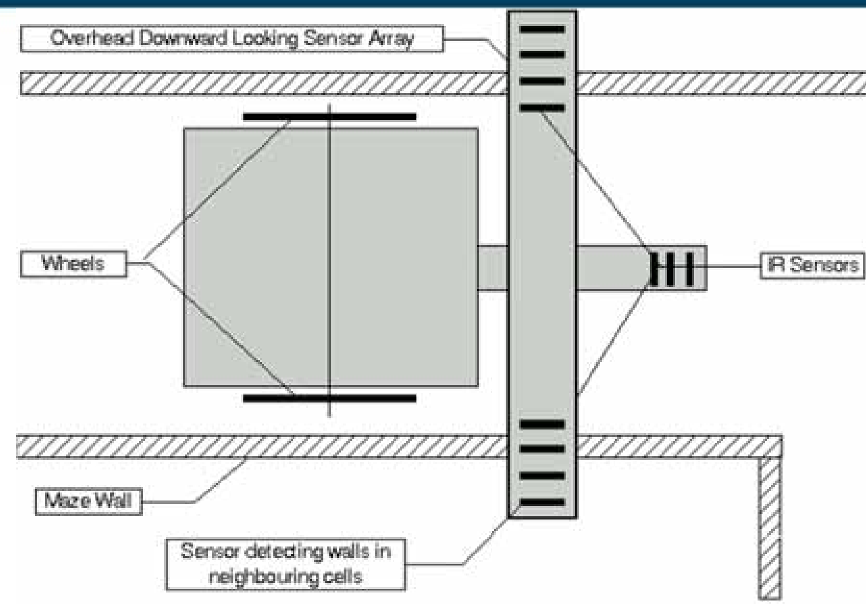
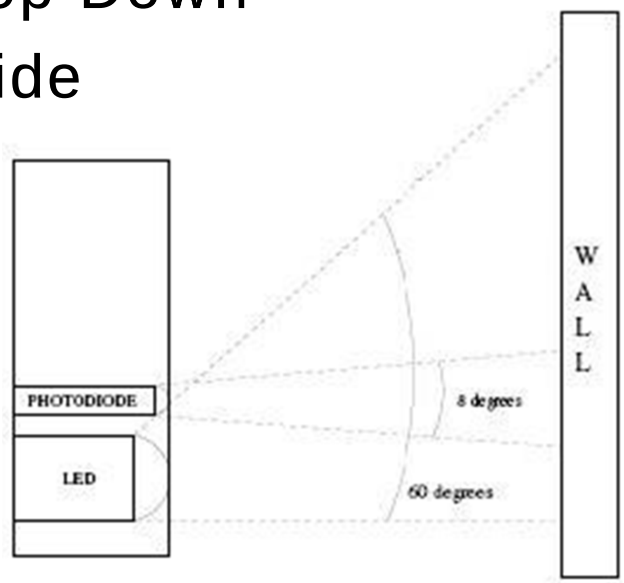
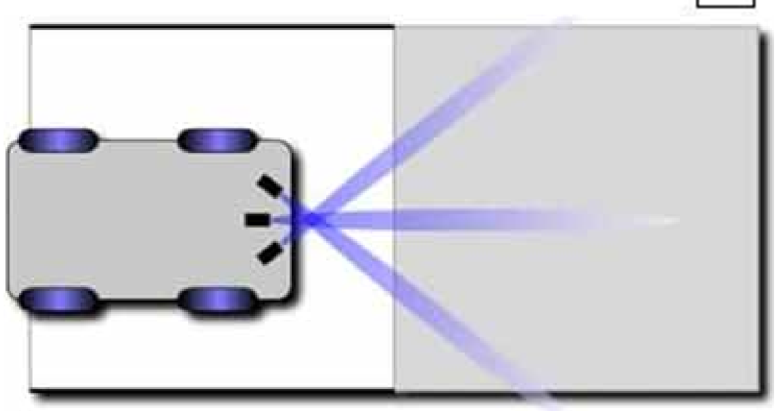
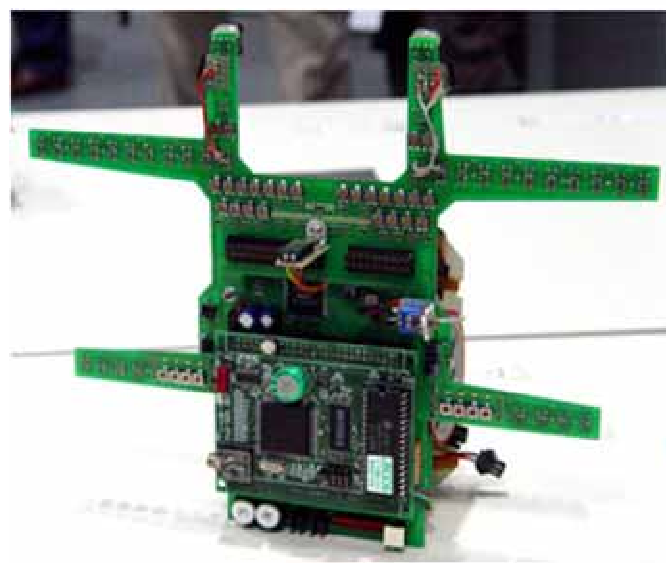
Micromouse Sensors

- Way of Sensing Walls
  - Top Down
  - Side



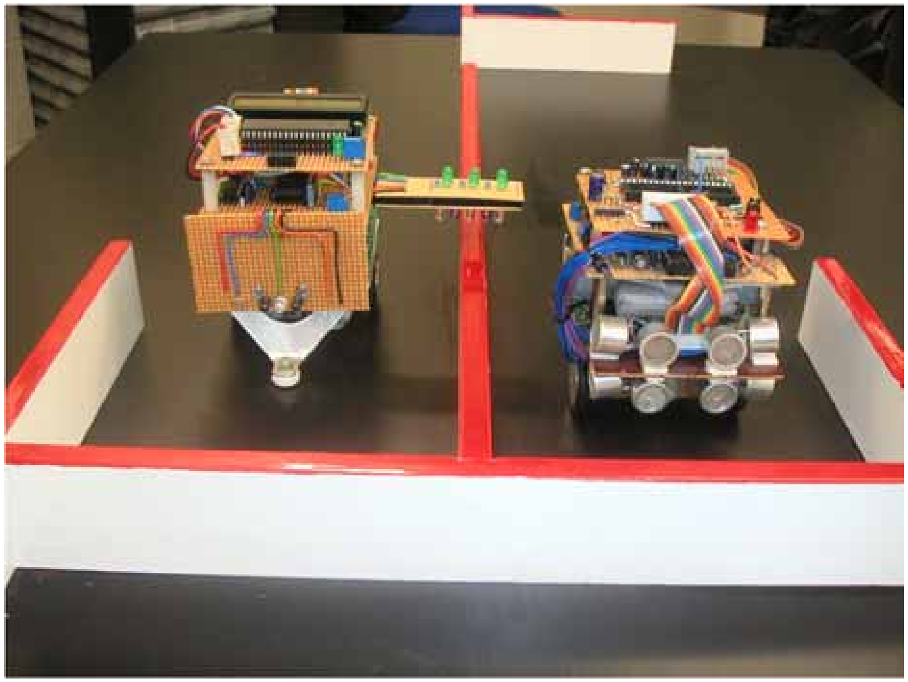






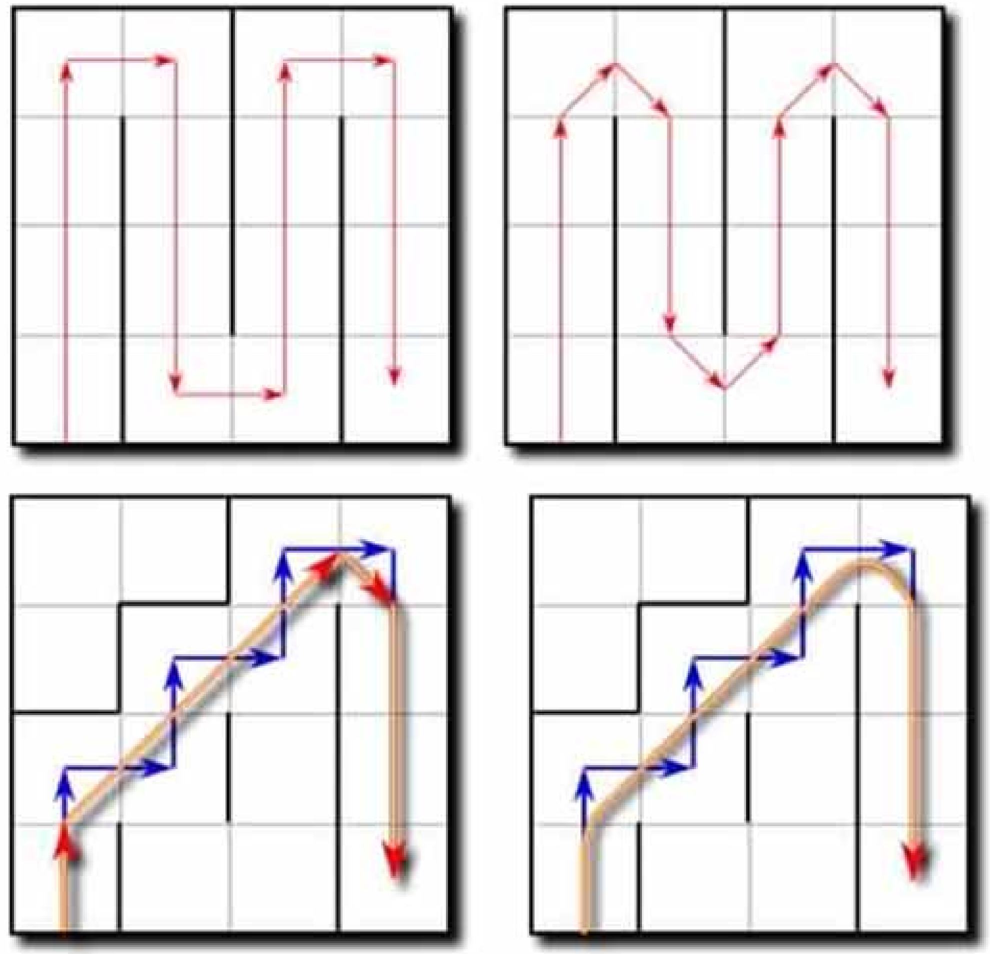
Micromouse Sensors

- Way of Sensing Walls

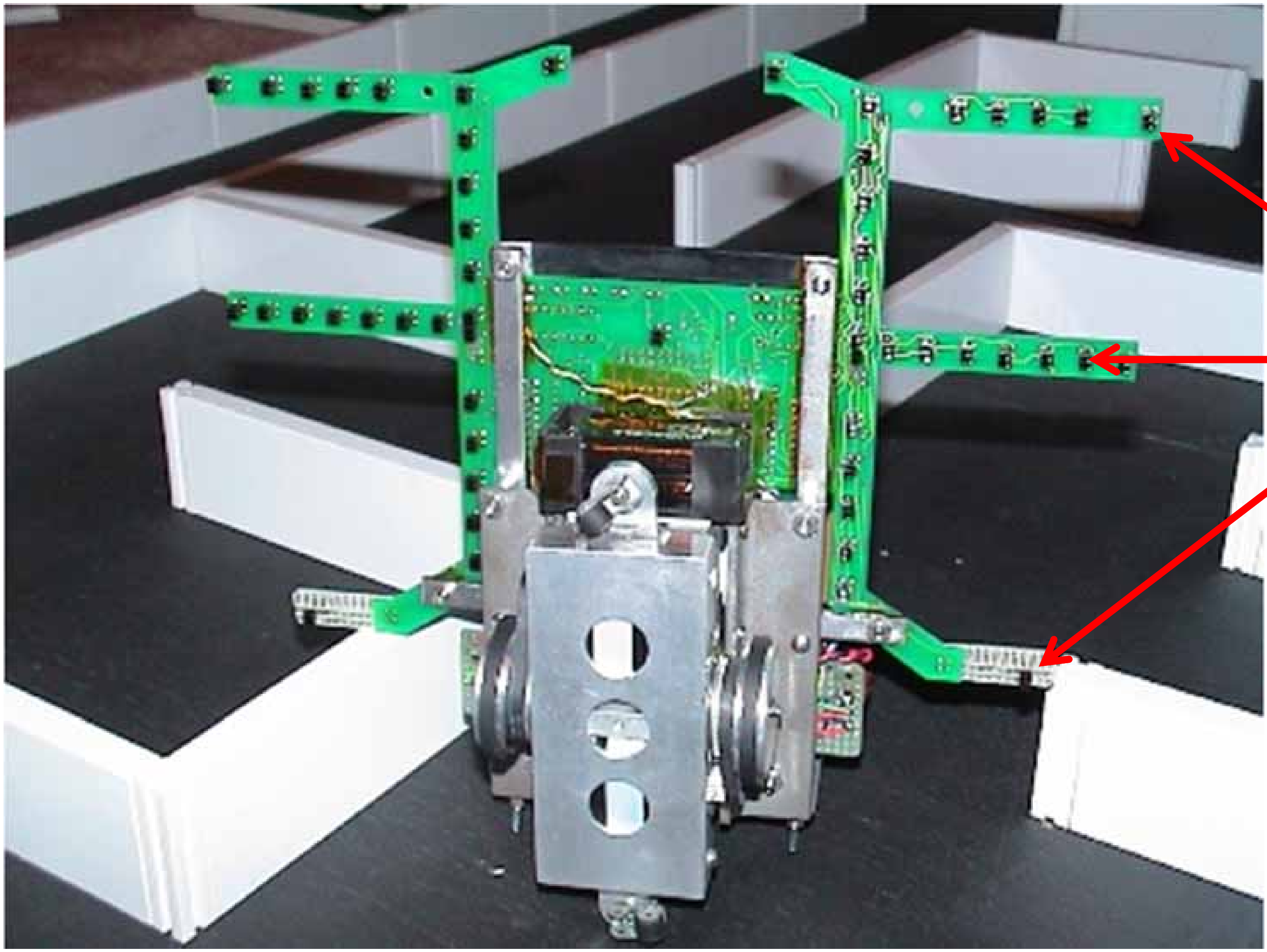


Micromouse Movements

- Basic Moves
  - Forward
  - Right Turn
  - Left Turn
  - U-Turn
  - Slow down and Stop
- Advance Moves
  - Diagonal Run
  - V-Turn
  - J-Turn
- Movements
  - Exploring, Fast run



Sensors Position for Movement



Infra-Red Sensors

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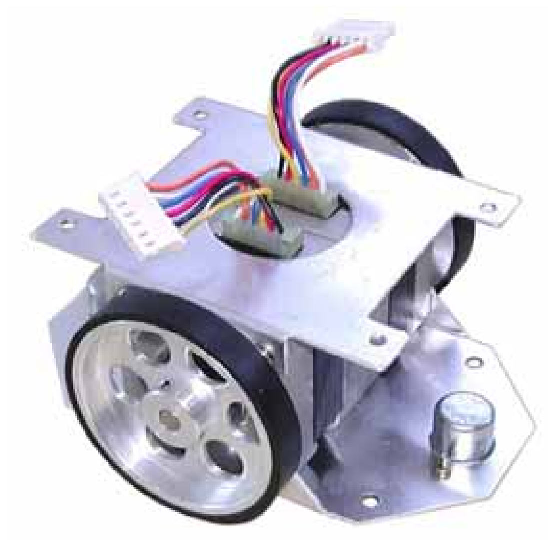
Micromouse Motors

- Type of Motors
  - Stepper Motor
  - DC Motor
  - Servo Motor
  - Brushless Motor

- Each micromouse should have at least 2 motors



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Software

- Navigation Algorithm
  - Micromouse must be able to keep track of its position.
  - Micromouse also need to remember all the junctions. At dead end or old path encountered, the mouse shall select a junction that will lead to a new path.
  - To make use of the exploring rules more effectively, a maze will be divided into several exploring sections. Each section uses different rule to explore.
  - When reached the destination, the micromouse will decide whether to come back for a fast run or just continue exploring.
  - A weight is used by the sorting program to determine whether the micromouse is more favorable to forward move or left and right turns.

Software (continue)

- Maze Solving
  - To search the shortest path from Start square to Goal for the fast run.
- Main Control
  - Micromouse to make decision on the next move in the maze.
  - Avoiding Crash
- Motor Control
  - Micromouse movements
- Sensor Control
  - Acquiring Walls information
  - Store data for maze sorting
  - Sensor sensitivity calibration

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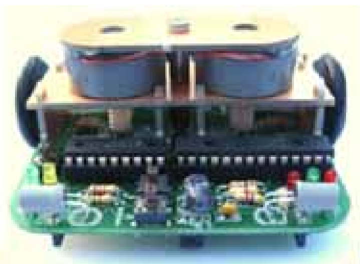
Available Micromouse Kits



http://www.rev-ed.co.uk/docs/KIT110.pdf
http://www.robotstorehk.com/micromouse/RS-AIRAT2.html

Micromouse Development Plan

- Hardware
  - CPU Board
    - Select Micro-Controller
    - Learn about the Micro-Controller
    - Design CPU circuit (PCB Layout)
    - Wiring and Soldering
    - Testing CPU
  - Sensor Board
    - Select Sensors
    - Determine Sensors Location
    - Design Sensor Circuit (PCB Layout)
    - Wiring and Soldering
    - Testing Sensor Board

Micromouse Development Plan

- Hardware
  - Motor Driver Board
    - Select Motor
    - Design Motor Driver circuit (PCB Layout)
    - Wiring and Soldering
    - Testing Motor Drive Board
  - Power Supply
    - Determine Power and Voltage requirements
    - Select Batteries
    - Testing Power Supply
  - Chassis
    - Mounting Motors and all PCBs with interconnection
    - Wheel and Gears

Micromouse Development Plan

- Software
  - Familiar with Micro-Controller Language (C Language)
  - Maze Solving Algorithm
  - Shortest Path Algorithm
  - Search Algorithm
  - Motor Control Coding
  - Sensor Control Coding
  - Test and Debugging

Region 1 Student Conference 2016

2016 IEEE Region 1 Student Conference

- **Conference Highlights**:
  Undergraduate Student Paper Contest , Student Ethics Competition, T-Shirt Design Competition, Micromouse Competition, Workshops, Award Ceremony and Dinner, Networking Opportunity, Meet IEEE Leaders and Industry Professionals

- **To register:**
  https://meetings.vtools.ieee.org/m/37907

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2015 Region 1 Student Conference - the highlights









IEEE Region 1 Micromouse Competition

- Micromouse Competition
  - The objective of the competition is to build a robot which can negotiate a specified maze in the shortest time.
  - First Place: $800, Second Place: $500, Third Place: $200

- Eligibility:
  - The entrant must be an undergraduate student at a school in the Region at which there is an IEEE Student Branch at the time of entry at the Branch contest.
  - A Student must complete and submit an application for membership in IEEE prior to entry in the contest.

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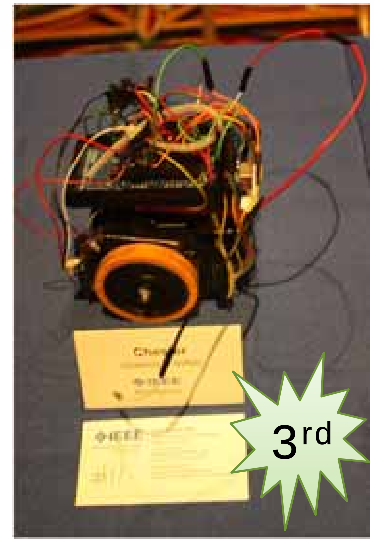
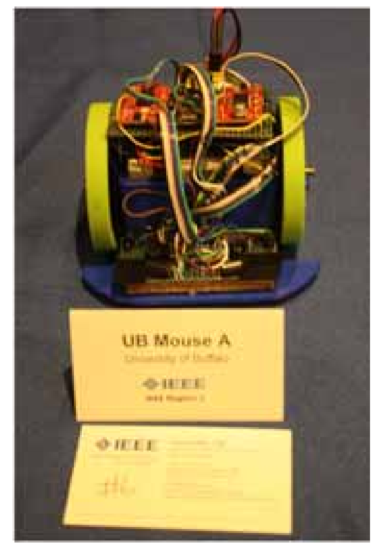
2015 Region 1 Micromouse Competition - student participants

2015 Region 1 Micromouse Competition - actions

2015 Region 1 Micromouse Competition - more actions

2015 Region 1 Micromouse Competition - Micromouse





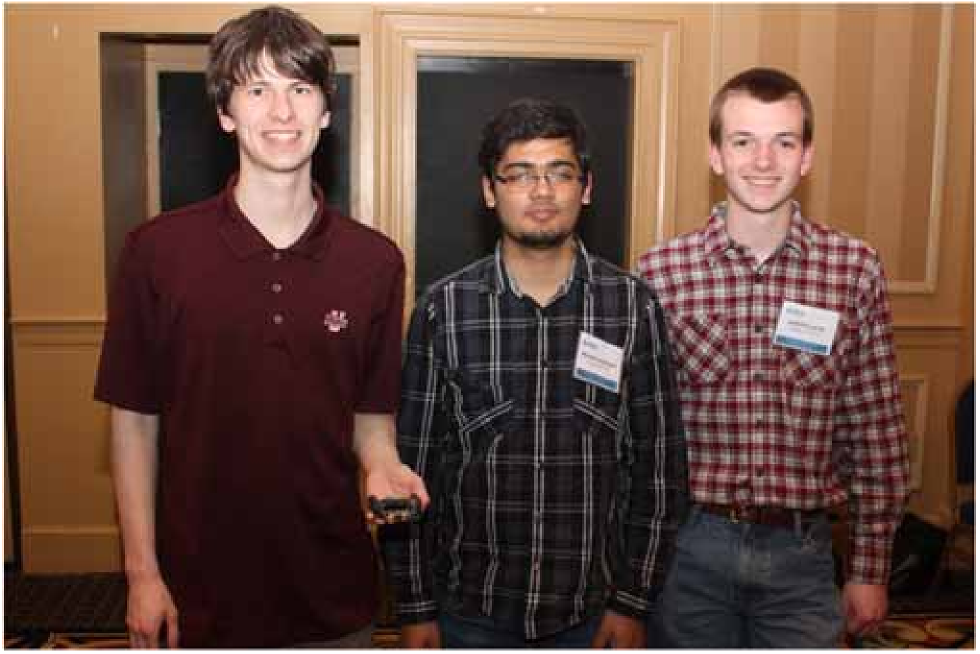
2015 Region 1 Micromouse Competition - more Micromouse

2015 Region 1 Micromouse Competition - winners

1st Place

(Run time to Goal = 14.97sec)

Mercury Micromouse



University of Massachusetts Amherst

- Justin Marple (Team Leader)
- Rohan Kapoor
- Aaron Lucia

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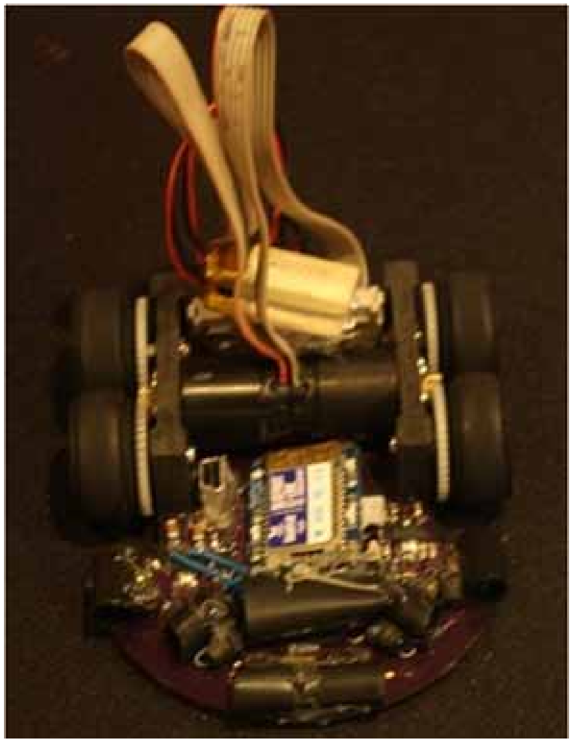
2015 Region 1 Micromouse Competition - winners

2nd Place

(Run time to Goal = 48.76sec)



MegaMouse Micromouse

University of Buffalo

- Kyle Thompson (Team Leader)
- Mack Ward
- Joe Materski
- Jimmy Mazur
- Tomasz Pietruszka

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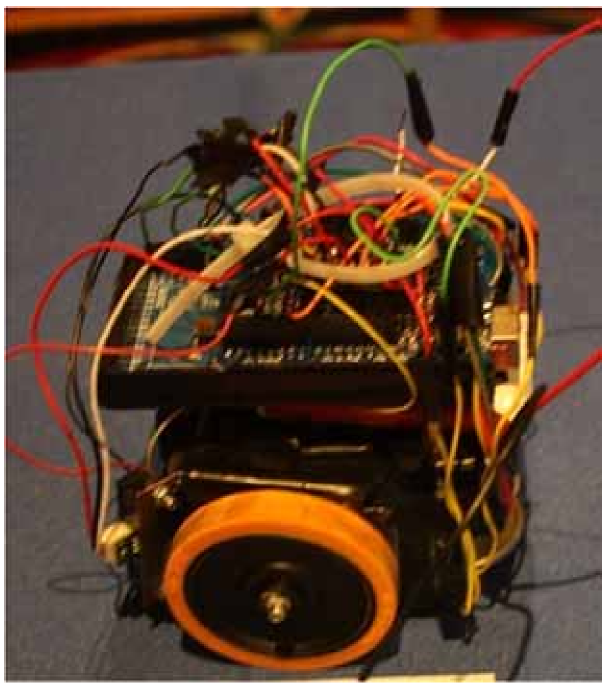
2015 Region 1 Micromouse Competition - winners

3rd Place

(1st Closest to the Goal)



Chester Micromouse

University of Buffalo

- Mike Szymkowski (Team Leader)
- Matt Spitzer
- Maxim Solomonyuk
- Nazia Hasan
- Carly Schulz
- Kevin McMahon

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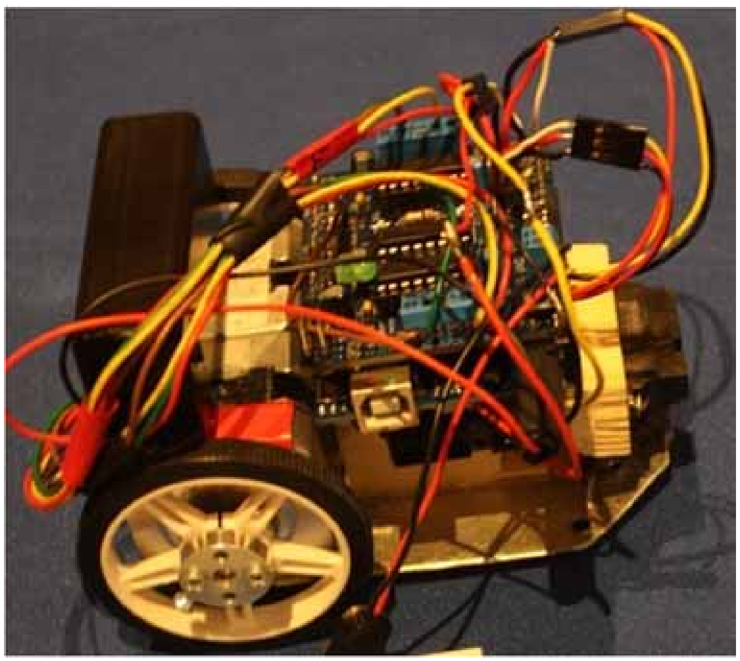
2015 Region 1 Micromouse Competition - winners

4th Place

(2nd Closest to the Goal)



Minute Micromouse

Suffolk University

- Frank Calderon (Team Leader)
- Michael Wall

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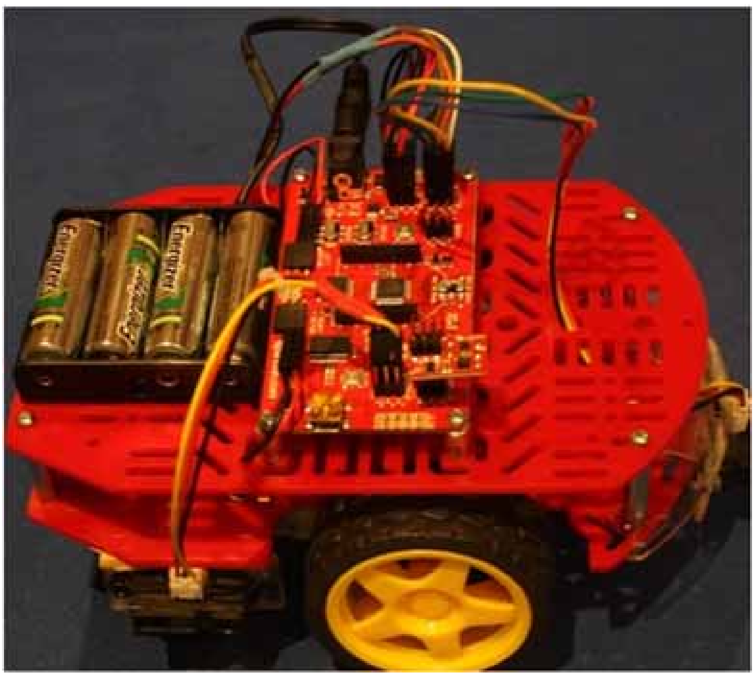
2015 Region 1 Micromouse Competition - winners

5th Place

(3rd Closest to the Goal)



Squeak Micromouse

Roger Williams University

- Ethan Daniels (Team Leader)
- Taylor Winnick, Nicole Marmo
- Nicholas Benoti, Kyle Lourens
- Kristi Perreault, Aidan Bradley
- Kelsey Cintorino

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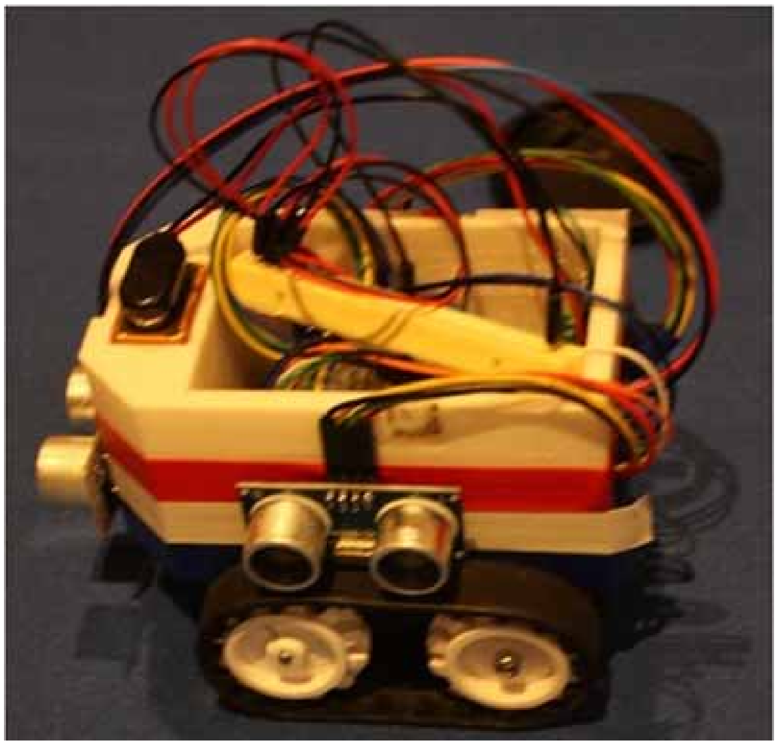
2015 Region 1 Micromouse Competition - special award

Funny Award



Grody Micromouse

Monmouth University

- James Blessing (Team Leader)
- Abdul Muhsin Al-Kandari
- Nico Flora
- Alex Kristensen
- Veronica Granite

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2015 Region 1 Micromouse Competition - the judges

Alvin Joseph, Green Mountain Section
Bala Prasanna, Region 1 Treasurer $$$
Bob Pellegrino, Region 1 Southern Area Chair
Anthony Wan, Future IEEE Member
Dave Harame, Green Mountain Section
Rob Vice, Region 1 Young Professionals Coordinator

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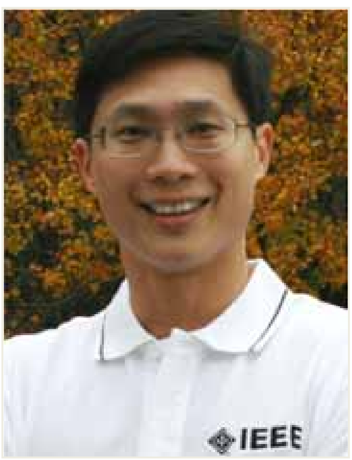
Thank you



Soon Wan

2015 Region 1 Student Conference Micromouse Competition Chair

gimsoon@ieee.org

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IEEE Region 1

Micromouse Design
Open Discussion

2012 Region 1 Student Conference at Hartford CT

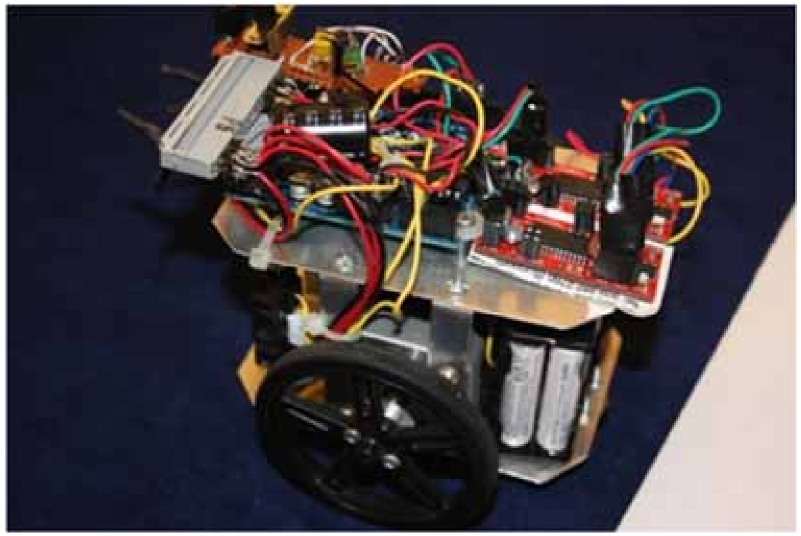




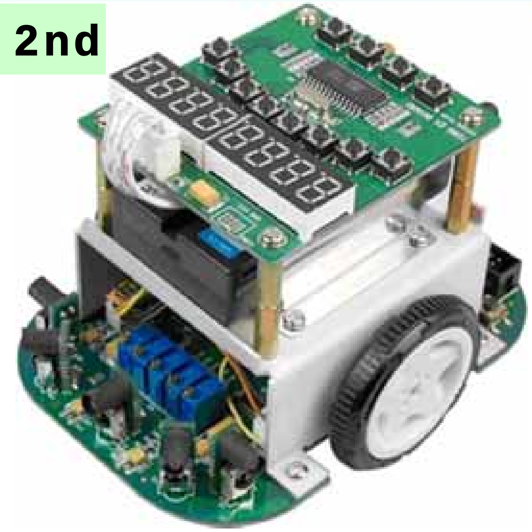


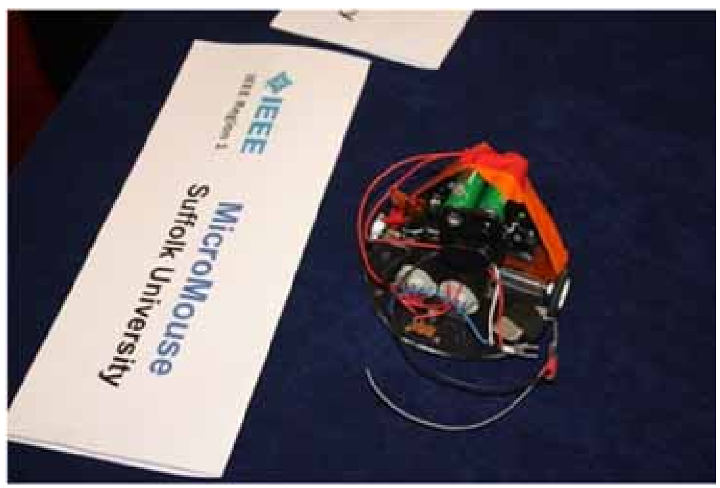


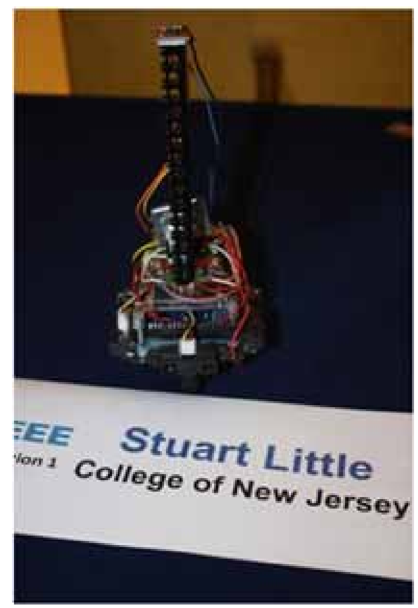
2012 Region 1 Micromouse Competition at Hartford CT



2nd





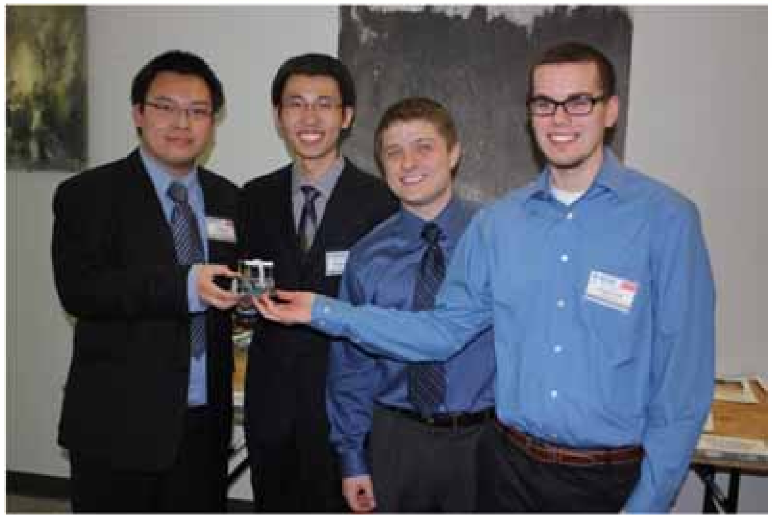


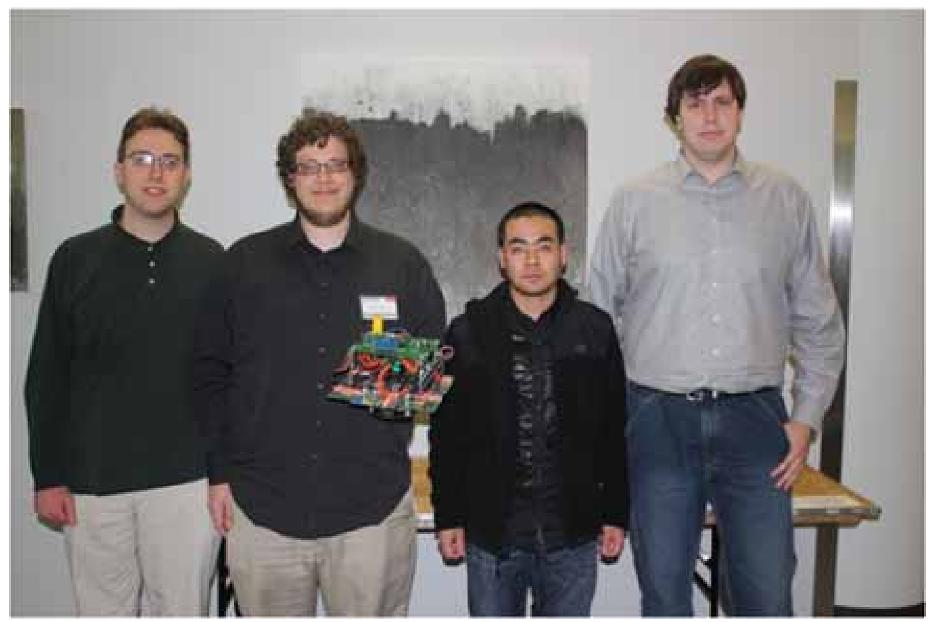
http://www.youtube.com/watch?v=DuG-WF9yT5c

2012 Region 1 Micromouse Competition at Hartford CT

2011 Region 1 Micromouse Competition at Boston University

2011 Region 1 Micromouse Competition at Boston University





2011 Region 1 Micromouse Competition at Boston University

2006 Region 1 Micromouse Competition at University of Maine

1st: The College of New Jersey

2nd & 3rd: Suffolk University

4th: Fairleigh Dickinson University

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Region 1 Micromouse Competition