Robot Competitions in the Curriculum

Andrew Jennings
RMIT, Melbourne, Australia
ajennings@rmit.edu.au

***Abstract**: Robot competitions are growing in popularity as elements of both school and University curriculum This paper describes the development of a simulator and course for team robotics. Challenges of balancing workload and challenges are discussed in the context of further development of this approach.*

***Keywords**: autonomous robots, competition, simulators*

Introduction

The spectacular growth of robot competitions (robots.net 2003) since 1995 is at one level simply a phenomenon of growth of robot culture, especially in Japan. The dramatic drop in cost of the electronics for constructing robots has brought them within the reach of every high school enthusiast. The technology itself has matured dramatically: we can think of the size and cost of simple digital camera that is useful for robot vision. Although many companies were slow to realise the potential of robotics in educational settings, Lego were active pioneers in this direction, and the release of Lego Mindstorms (Lego 2003) propelled robotics into the higher school curriculum. Other companies (eg. Parker 2002) have followed with further development of the technology. In Australia, this has been evidenced in the spectacular growth of Robocup Junior with a presence in a very large number of high schools throughout the country. Verner (1999) describes the Israeli experience in detail: competitions act as a catalyst to attract students to systems approach to technology. He reports a very strong favourable response by students, with an indication that the competition is very influential in attracting them to technology courses.

But of course it is not just the availability of the technology that has fed the growth. In format they are closer to a sporting competition than a technology fair, making them very accessible to the general public. This is especially valuable in engineering, where although exciting to its followers, it is difficult to convey the joys of engineering to a broad audience.

As a participant in the robocup (Robocup 2003) robot soccer competitions, I would often say that "soccer is a more universal language than English". This is certainly the case: it is hard to find a corner of the world where soccer is not understood. The competitions are highly accessible, and serve as a first point of inspiration for many future technologists and engineers. Robocup has a number of leagues where teams of robots compete in a setting that is inspired by the human game of soccer. This provides for an event with a public audience, with intense competition between teams of technologists.

Researchers often have difficulty with the sporting aspects: a game is certainly not a scientific experiment. The real value of competitions here is that it serves to benchmark one against another in a standardised setting. Many approaches to robotics look promising in experiments but fail in the standard setting of a robot soccer game.

When we created the robocup concept, we took it as a natural successor to the "computer chess" competitions, which eventually resulted in the victory of a computer chess program over the world human champion. The computer chess challenges served to challenge our imagination of what is possible with a computer. Regardless of the merits of computer chess intelligence, it serves as an amazing landmark in the development of computer technology. The long journey from the public ridicule of chess playing computers in the 1970’s and 1980’s stands as an appealing narrative for technologists.

There is no doubt that as a point of inspiration for junior technologists, and a focus for the public these competitions are very powerful. It was natural to consider whether this setting could be useful in a University curriculum (Meeden 1998, Murphy 2001). But of course the demands of a University subject are quite different from the goals of a technology challenge. This paper describes a course incorporating many aspects of the robocup concept designed for fourth year and postgraduate engineers. The lessons of this process may be useful to wider adoption of robot competitions in the University curriculum.

Core concepts

The core curriculum demands of a university level subject have some elements in common with the robot competitions, but there are important differences. My main interest in robot competitions was as an exploration of the research issues of robot teams. The soccer environment is highly dynamic, and provides an ideal testbed for research prototypes. I started with the core concepts for team robotics.

Educationally there are significant challenges. Robotics integrates a broad range of concepts together into a single vehicle. The robot itself will not function unless all aspects are working, and the demands of the mechanics and construction can easily overwhelm the class time. I was searching for a way to concentrate on systems issues but to give some realism to the learning environment.

Figure 1 illustrates the core concepts of team robotics. There are some notable exclusions in this set: apart from simple motion equations, consideration of robot *mechanisms* is not considered. Similarly I exclude energy consumption and electronics for robots. These are incredibly challenging subjects that are worthy of entire courses in their own right. The course was designed to focus on the computer systems aspects of team robotics.

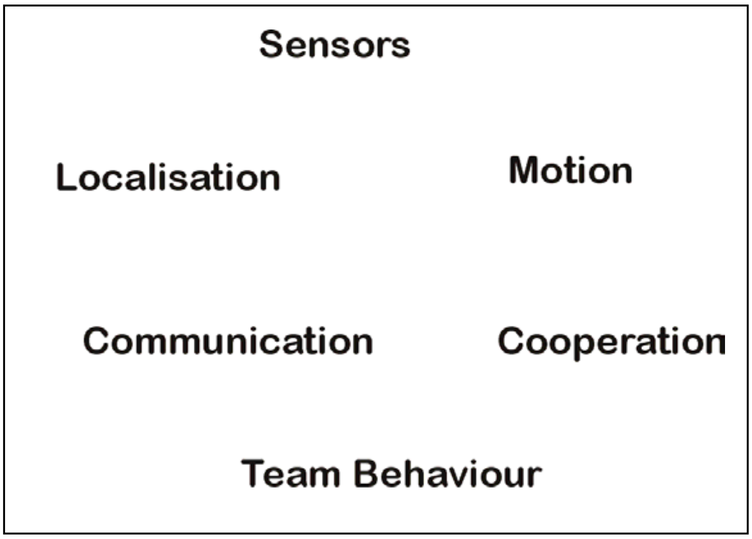

Figure 1: Core concepts for a team robotics subject

Sensors

Team robotics uses small, cheap sensors that do not consume much power. Typically these include ultrasonic beacons and receivers, small radio frequency transponders, bump sensors and similar. The accuracy of these sensors is well known, so performance can readily be simulated. However it is difficult to model complex aspects of the sensors: for example in ultrasonic sensors we only attempt to model the first reflection.

Localisation

Given a set of sensor readings, the robot must determine its location. Localisation is an enormously challenging problem: in the absence of direct beacon readings (eg. GPS) only unreliable sensors such as wheel encoders and ultrasonic reflections can be used. The simulator described here incorporates the localisation problem.

Communication

Robots can only communicate using simple protocols that are economical in their use of energy. A robot team must maintain common knowledge and coordination using very simple means of message exchange. Typically it is not possible to have a lengthy exchange of messages to work out what to do next.

Behaviour Modelling

Robots must behave appropriately in a wide variety of circumstances. To approach the design of this behaviour requires some method of description. Choices range from simple state machines, the specific structure of the subsumption architecture (Brooks) or many other possible choices. A core design activity is developing these descriptions for each robot.

Team Behaviour

The robot team must coordinate to both defend and attack. It is not possible to adopt a highly communicative approach, so coordination strategies are very important.

The educational challenges here are perhaps best summarised by the process of dealing with localisation. We are so familiar with having complete navigation knowledge available from human senses, that it takes some time to understand the degree of "sensor poverty" that a robot faces. There is a distinct conceptual leap required here that is important. At the same time we don't want to spend the whole course just constructing robots.

Simulation or construction?

There is a widely held view that advocates a constructive approach to robotics. Brooks (1999) and the many *artificial life* researchers take this path. There are important philosophical issues here about how you might construct artificial intelligences, but for the moment we focus on educational issues. If we take the point of view that it is only through construction of robots that we are dealing with "real robotics" then what does this mean for students? It means that our concept map can only be learned through actual physical interaction.

This is closely related to the "hands on" argument in education. When we deal with junior school projects and even perhaps high school projects there are powerful psychological arguments. Perhaps it is the case that as we physically develop that actual engagement with physical movement is important. It may well also be the case that the experience for physical interaction is of a deeper and different nature. Certainly to take the concept map and to attempt to construct robots will quickly convince the students of what they do not know in mechanics and energy. But that is surely not the point for learning for adults in a University setting. In a philosophical sense, if we suggest that there are deep aspects of the learning experience that are beyond articulation, then we are heading away from the realms of logic and towards the view that learning is a mystical experience.

So for the course, the question is simply this: can we use simulators to learn the concepts or is it necessary to engage with physical robots? For the moment I am exploring the direction of simulation. In the future it may be possible to test the hypothesis by taking the simulated robots and transferring the designs to physical robots.

JSRSim: approach

There are a wide variety of Robocup simulators. They range from complex multi-node agent based simulators with detailed modelling through to simple abstract strategy evaluators. The robocup simulator league (Robocup 2003) attempts to model a hypothetical humanoid robot team. This simulator even includes some aspects of humanoid anatomy, with head rotation. In contrast, the physical modelling of the robocup "small size league" is incorporated into TeamBots (Balch 1998) for team development. The simulator I have developed (called Java Simple Robocup Simulator: JSRSim) models the physics of the robocup "middle size" league. It incorporates wheeled robots of approximately 30cm diameter with a small junior league soccer ball.

JSRSim (2003) includes the key physical modelling of ball collisions both with the field walls and with other players. The core objects of the software model are as follows. MovingObject encapsulates the physics of the objects on the field. Both the Ball and Robot classes inherit from this class, and Robot extends with sensors including cameras. To create Player style code, the Robot class is extended to incorporate individual strategies and tactics. The Network class incorporates a very simple model of an 802.11 style wireless LAN: there is no attempt to model imperfections in the network. An important simplification is to provide only for circular robots. This is to allow for calculation of the reflection of the ball from robots: it is very difficult to do the reflection calculations for odd-shaped robots.

Figure 2 shows the simulator. There are two modes of operation: practice and competition. In practice robots can be placed and a play sequence recorded. This sequence can then be replayed using a VCR style interface: fast forward, rewind and pause. The competition mode provides for a game of two halves, with a scoreboard. There are no free kicks implemented in the current version (JSRSim 1.1). JSRSim can be run directly on any computer supporting a Java Virtual Machine of JDK1.2 or greater.

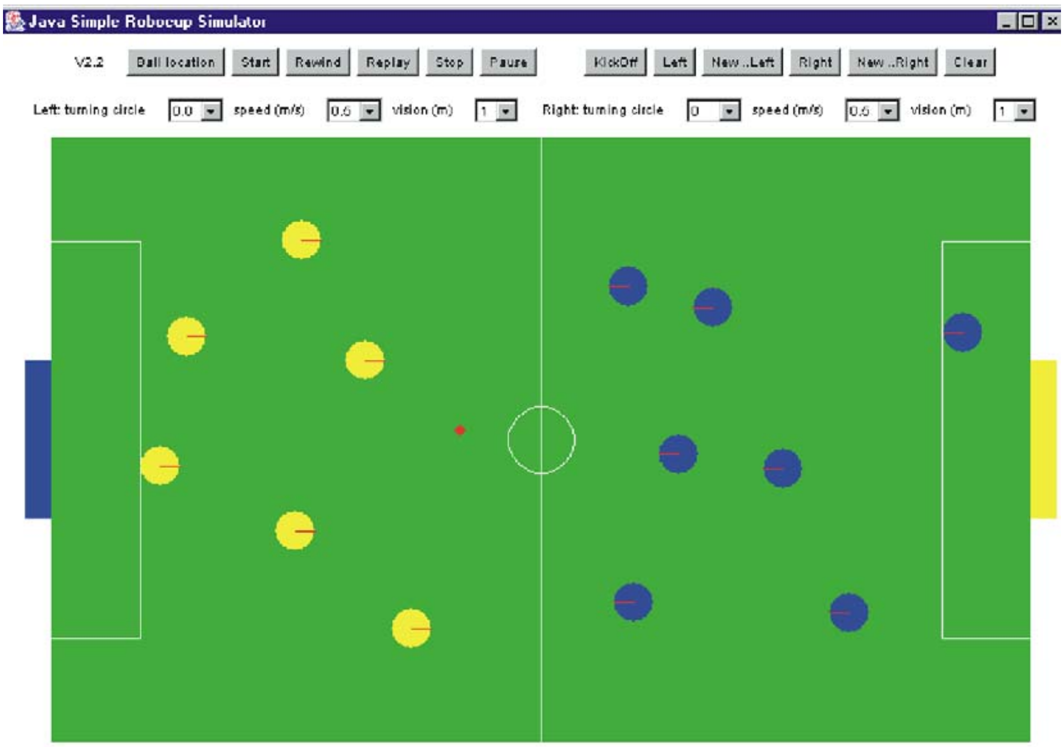

Figure 2: JSRSim Simulator screen view

Since this is the first class use of the simulator, there is naturally a concern to deal with bugs and errors in the simulation. I have adopted an "open source" approach where course credit is offered both for finding bugs and for fixing them. This has been very successful, with many bugs posted and fixed. It is interesting how successful this mode of operation is in working through software problems.

The mode of operation of the subject “Robotics and Control” based around this simulator is in a learner-centered mode (Sparkes, 1999; Kiyoshi 2000). Students work primarily with simulator and interaction with the tutor and lecturer take place continuously. The first task is for students to develop code for localisation of the robots. They execute some standard tests of localisation ability. Following this they prepare a design proposal for their team. This is presented in detail, and they then prepare for the competition. Assessment is weighted roughly 30% for the final team and the remainder of assessment on the technical tasks leading up to the competition. A final essay on team robotics completes the subject. There is no exam.

There are many positive aspects of robot competitions for the curriculum, but we should take care to consider the positives with some important problems and issues.

The course consists of a short series of lectures that introduce the core concepts of Figure 1. This is augmented by a research kit that gives literature references and further guides for study. Significant theoretical material is only treated in the references, and requires the students to explore this material independently. As a fourth year course students are already skilled in these aspects.

Midway through the semester, students are required to present their proposal for team design. This is a critical phase of the subject, and constitutes a large part of the assessement.

Integration

Why are robot competitions so popular? So much of University study is analytical in nature, and pedagogical in approach. But engineers signed up to be engineers primarily to make things. Robotics is inherently integrative in nature: many disciplines and technologies must come together to make things happen. Creativity is essential for competitive success. Perhaps it is a comment on the rest of the curriculum that students flock to these competitions (Boyer, 1998).

Human Team

What sort of teams wins robot competitions? Certainly strong technology helps, but it is often not a deciding factor. The strength of the human team is very important. As is often said: "execution is everything". Often teams with great promise fail due to a clash of egos. Here many valuable lessons can be learned in creating success of human teams operating under pressure.

Setting

A robot competition is a microcosm of some important threads in modern commercial life. Two or three people come together to create something. They have a small budget, a fixed deadline: the date of the competition cannot be moved. Commitment and long hours in pursuit of victory (Manseur 2000) are commonplace. If we take the experiences of a small start-up company or project then there are some similar paths here. The competition is between peers in a public setting. It is not the quiet of the exam room in which the results are decided.

Curriculum hijacking

Given the level of engagement, the real problem here is complete hijacking of the whole curriculum. Students (especially bright ones) neglect their studies and focus entirely on victory. In this setting, a simulator has many advantages. The total hours of effort required to get a team working are much reduced. The costs are dramatically reduced. Nevertheless there is much for the course leader to do in putting competition in perspective.

Assessment through competition is quite different to an exam setting. But there are some similarities: the team must perform on the day and there are no chances for postponement. Since every team performs with the whole class as an audience, it is difficult to plagiarise, as the team behaviour will be recognised. At the same time it is always possible to aim solely for a competition place with little attention to the course concepts or outcomes. Design of assessment is quite difficult but critically important.

If competitions are public events then pressure to get the highest place will become intense. Even worse is when the media becomes involved. My experience of the private course competition is that a private competition can be fairly friendly. For all these reasons I restricted reward for a place in the final standings to approximately 10% of total final subject mark. The other criteria included: originality of team proposal, quality of implementation, documentation and testing reports.

Overall results of the course were interesting. Since the course demanded strong commitment, the team results were quite strong. The highest level teams were very impressive. Balanced against this, there was a distinct "two peaks" to the final result, indicating that weaker students struggled to stay with the course. This is an ongoing challenge for the learner-directed approach: how to recognise difficulties early and provide assistance for students who are having difficulty. In this case the presentation of a design proposal was not a good indicator, and it remains to create better pathways through the subject material.

In design of the course, the approach was to minimise the effect of the competition, and on reflection I will continue to further minimise the role.

Conclusion

Robot competitions have much to offer educationally. If the competitive aspects can be kept in perspective, then there is a fertile learning environment for students. It offers a highly dynamic learning experience that has a healthy mix of competition and disclosure. My experience so far is that a simulated environment can produce strong results in understanding the core concepts without the incredibly difficult workload of constructing physical robots. The approach described here attempts to balance the positives of competition with the demands of the pursuit of excellence in robot team development. I expect that we will see a growth in the use of robot competitions in the University curriculum as we continue to grapple with these issues.

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