RECENT MIROSOT DEVELOPMENTS IN THE UK

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ABSTRACT

Recent Mirosot robot football developments in the UK are described and the factors which encourage UK universities to become involved in robot football are identified. It is shown that in most cases robot football supports other activities rather than being an end in itself. A brief overview of some relevant work at the Open University and the Universities of Warwick and Plymouth is presented. As a result of cooperation between these universities, and sponsorship by DVT Machine Vision, it is suggested that the outlook for Mirosot robot football in the UK is better than it has been for many years.

1. INTRODUCTION

The University of Plymouth Mirosot robot football project started in 1997[1]. Since that time there have been several attempts to create a viable UK Mirosot league but it is only in the last 12 months that momentum has developed which now makes this a realistic possibility. Over the years many UK universities and colleges have been attracted to the idea of robot football and identified the FIRA Mirosot league as the most cost effective introduction. It most cases it was the potential publicity value of robot football that was its main attraction. There is a very competitive market in the UK HE (higher Education) sector and most universities are struggling to attract high quality applicants to undergraduate engineering and technology based programmes. Several of these universities purchased basic Mirosot systems from Merlin Systems Corporation [2], a company closely linked to the University of Plymouth, without fully appreciating the complexity of robot football technology. Few of these purchasers were prepared to commit the time and effort necessary to produce competitive, operational teams and consequently fell by the way.

Engineering and technology, although crucial to the UK economy, are not subjects popular with young people looking to start university programme. From the beginning the major attraction of robot football at the University of Plymouth was as that it could be;

1. employed as an effective teaching and learning tool on a multidisciplinary, undergraduate engineering programme [3].
2. a help in attracting and enthusing prospective students.
3. used to foster interdisciplinary working for students and academic and technical staff from different departments such as mechanical engineering, electrical engineering and computing.
4. a support for relevant research projects.

A series of inexpensive, simply constructed, modular robots were designed specifically for use in project work and for module teaching aids. Programming a mobile robot to perform a series of manoeuvres using C is inherently much more interesting than some traditional programming exercises which, in the opinion of many students, have little relevance to the real world.

Similar reasoning persuaded Dr Ken Young of the University of Warwick (and also chairman of BARA – the British Automation & Robot Association [4]) to use Mirosot robot football as the focus for a 2003/2004 multidisciplinary final year M.Eng degree group project. The group consisted of six students from different discipline, i.e. two manufacturing engineers, two mechanical engineers, one electrical engineer and one computer systems engineer. The group was required to design, build and programme a Mirosot robot team in one year. The specification included all aspects of hardware design, construction and programming, publicity, marketing and obtaining sponsorship to hold the first UK robot football championship. One outcome of the group's work was the very successful UK FIRA Championship held at Warwick in March 2004 and kindly sponsored by DVT Machine Vision [5].This event was widely covered by both the press and national TV stations.

In contrast to both the universities of Warwick and Plymouth the attraction of robot football to the OU (Open University) is primarily as a support for autonomous, multi-agent research programmes. Interest in robot football at the OU has recently been reignited due to research programmes which can use and benefit from the technology.

Queens University, Belfast, also has an interest in robot football and has competed at several international events using Yujin machines. Although not part of the initial cooperative venture it is hoped that it will become part of a wider consortium in the near future.

2. WORK AT THE OPEN UNIVERSITY

Because of the generic nature of robot football technology its potential applications are many. Interplanetary robot exploration is one such application. With the recent revival in interest in placing the first human on mars, robotics research has benefited from a new drive for technology. One of the aims is to provide a robotic outpost capable of making preparations for the first human explorers [6]. These colonies of multiple cooperating robots will deploy and service solar arrays, in-situ resource utilization facilities, long-life robotic science stations, human habitat modules, and perform site preparation, infrastructure servicing and repair. Such outposts are seen as a cost effective solution to the deployment of a human habitat.

Two distinct approaches have been taken to the control of a robot outpost. Earlier work focused on distributed systems with no tight cooperation [7]. Here a swarm of bulldozer robots used simple behaviours to locate and level a suitable area to construct a lunar base. There is no explicit cooperation between robots, and the apparent collaboration emerges from the interaction of the agents. More recent work [8] focuses on the development of a distributed multi-robot controller for tightly coupled tasks. This allows for more dexterous object manipulation. Both approaches use distributed behavioral control architectures.

Human systems display both attributes. Humans are capable of working independently to achieve their own goals, which may or may not coincide with others, and also in tightly cooperating teams. For example, if a number of tidy individuals work together in a littered environment, it will gradually become tidy through their mutual desire to clean, without a group decision being involved. At the same time, they may decide that they want the furniture re-arranged, and will group together to carry a large desk or move a bookshelf. Although individual agents, people will regularly switch between operating individually, or as part of a team.

Although there is a rapidly growing literature on multi-robot systems devoted to both distributed swarms and close coupled teams, there is very little bridging the two. Algorithms for multi-robot task allocation and self organisation exist but have not been demonstrated for tightly coupled, evolving teams. It is argued that the ability to identify and form close-coupled teams from a set of otherwise distributed and discrete robots, provides greater flexibility in the organisation of multi-robot systems.

2.1 Robot football as an experiment

Mirosot robot football presents an ideal experimental set up for this investigation. Currently the majority of teams consist of robots with specific behaviours e.g. goal keeper, defender, or striker, which act independently. Some teams use dynamic role assignment techniques to swap player behaviours depending on robot-ball positions [9], but true cooperation has yet to be successfully demonstrated.

Human footballers, aside from the keeper, rarely stick to a certain area of the pitch. As the ball moves back and forth, so do the players, regardless of their roles. They also adapt to the situation. If the ball is threatening the home goal, both defenders and strikers may adopt defensive roles. Some players will act individually to move into space, or a useful position, trying to initiate a pass from another player, or gain better control of the pitch. Others will act together in smaller groups, trying to set up a shot, or gain/keep possession of the ball. These sub teams are formed dynamically in response to the current situation.

Essentially, a strategy is a string of consecutive tactics. On a football pitch, players seek to gain an advantageous position. This is an individual response to the situation on the pitch, but it is made in order to benefit the whole team. If the player’s position is seen as advantageous by a team mate with the ball, a pass may be initiated. At this moment, a tactical group is formed containing both players. However, tactical groups are not confined to only two members. The best football teams know many tactical plays which they learn through training. Players can see whole sequences of passes open up, which they and their team mates recognise from previous games and practices. In Mirosot matches, most teams use strategy as the means of coordinating players. However, there is no tactical control. In terms of robot football, the intention of this research is to investigate the use of tactics as a means of identifying and forming tightly coupled sub-teams for the purpose of achieving strategic objectives (goals).

It is proposed that a new dynamic task allocation architecture will provide greater flexibility and cooperation in robot teams. In the domain of robot soccer, this will extend ideas on dynamic role allocation. Aside from improved cooperation, this will also focus processing power on the most useful robots, and enable easy strategy scaling between the different league sizes. Robots will be allocated tasks based on a framework for identifying patterns of play. It will not require there to be a set number of attackers or defenders, but will allocate roles, and plays, based on the status of available robots, and the circumstances on the pitch. In wider applications, this architecture will allow the identification and formation of robot teams, from a swarm, to perform generalised group tasks. The problem is seen as a trade-off between resource utilisation and play identification.

2.2 Possible architecture design

The architecture will be behaviour based to allow fast response to the dynamically changing environment. A background thread will give each robot a simple, individually achievable task, such as move to a predefined position, move into space, or gain control of specific areas of pitch [10]. A 'strategy generator' will analyse the pitch, and identify the best sequence of ball movements to achieve a goal. A tactical layer will then calculate which robots are best endowed to perform each movement (pass, dribble etc.), and will send the required information to a set of behaviours for passing, dribbling, moving and shooting. Decisions made to select appropriate robots may be made simply on position or orientation, or more completely using information such as remaining battery power (a robot with low power is more suited to becoming a goal keeper than a striker). In wider applications, robot type and inventory will be contributing factors.

2.3 Examples

1) Defensive - A defensive strategy will be launched by a threatening event, e.g. opponents and ball near the home goal. In this situation, the strategy will declare that opponent shots on goal should be blocked. A tactical response will depend on the availability of home players. If only one player is available, it will adopt the goal keeper behaviour, positioning itself on a line between the ball and goal. If a second robot is available, it will attack the ball. A third player may protect the back post in case of a cross into the box, and so on.

2) Aggressive - The strategy generator identifies a possible set of moves, advancing the ball toward the opponent goal, whilst best avoiding opposing team members. This could be based simply on robot positions, identifying large gaps in the defence, or more completely on a map of pitch ownership. This will enable the strategy to identify areas the opponents will find difficult to move into quickly. The tactical level will then select the best home robots to complete each move. A key objective will be pairing robots that are in a position to pass the ball. By this we mean one robot is able to push the ball into the path of another, allowing faster changes in ball direction than are currently achieved. If no suitable robots are available, control will be passed back to the strategy generator to provide an alternative play.

3) Promotional - In this situation, there are no good aggressive plays, and the goal is not threatened. Instead, the strategy looks to promote the team position by trying to open up gaps in the defence, win the ball, and move home players into more advantageous positions.

2.4 Future work

We are collaborating with the University of Plymouth and the University of Warwick to develop an improved England team for future international Mirosot competitions. To enable better cooperation the Open University is acquiring two 7-a-side teams of the Plymouth Mark 4 Miabot robots. Our initial experiments will focus on performing benchmark tests into shooting and passing. Stable close-coupled passing control should enable the building of reliable tactical controllers. Subsequently work will concentrate on developing search patterns for the strategy generator. It is hoped that this will evolve into a new cooperative controller for multi-agent systems.

3. WORK AT THE UNIVERSITY OF WARWICK

From the Warwick perspective the primary benefit of the robot football project is that it enables undergraduate engineers to gain first hand experience of multidisciplinary team working. The team requires a range of skills and must establish methods and systems to optimise the teams' talents. The project also acts as a promoter for systems engineering and clearly demonstrates how engineering can be fun. In terms of the group members it provides an opportunity to apply the skills that have been learnt over the course of four years of engineering education. A further major aim of the project is to enthuse and challenge prospective students.

The University of Warwick 'Evolution Robot Football Team' took its first steps in the academic year 03/04 in achieving the teams' mission, namely "to become a nationally and internationally respected Robot Football Team." [11]. As with most teams in the UK the University of Warwick began by purchasing Miabot robots from Merlin Systems Corp. The initiative was taken by Dr Ken Young as a means of researching into autonomous robots.

It was later seen that undergraduate projects would be a superb way of both improving/redesigning the system and aiding the education of students at the university, particularly in the promotion of robotics. The system was researched by a small number of individual projects before Dr Peter Jones, viewing the idea as an excellent example of systems engineering, agreed to supervise a group of multidisciplinary final year M.Eng students. The group's mandate was to manage all aspects of the project including mechanical, electrical & electronic plus software development while keeping in mind the ultimate goal of achieving an internationally competent team. Emphasis during the first year was on the design of the robot. Low cost was a major consideration and because of the 'no cost' availability of steriolythography rapid prototyping technology was used.

3.1 Chassis Design

The Warwick chassis has gone through many incarnations during the last twelve months. The main requirements that guided the development were:

1. To lower the center of gravity
2. To maximise space for PCBs
3. To maximise weight in order to increase friction
4. To produce an effective opto-encoder arrangement

Requirements 1 through 3 were broadly achieved by machining the base of the robot out of a solid aluminium block, and providing only sufficient space for the low cost motors, wheels and opto-encoders. The wheels were also machined out of aluminium with a standard gear added. In addition, in order to produce maximum force when pushing other robots the base was tapered so that any contact with an opposition robot should be towards the base of that robot. This will then allow the robot to push below the opposition's center of gravity.

The fourth objective was a more significant challenge. The concept of this design was to make it possible to track the robots movements via two photo-interrupter wheels which are in direct contact with the pitch surface and which freely rotate as the robot moves. These 'encoder' wheels are placed in line with the robots drive wheels, either side of the robots center of rotation. This design presented a number of problems. Firstly, in order to ensure constant contact with the pitch whilest not lifting the drive wheels off the pitch surface, the encoders require some type of suspension. Secondly, the slotted opto-encoders must be incorporated into the suspension system so that it moves in unison with the encoder wheel, otherwise the encoders could confuse vertical wheel movement as rotation. The solution was a cradle that holds both the wheel and opto-encoder in position and then the entire arrangement is attached to the chassis using a thin metal leaf; this leaf provides the suspension to allow the cradle to move independently of the chassis. Due to problems of obtaining dual slot encoders of a reasonable size the cradle has to hold two encoders in order to obtain the necessary quadrature signal. The arrangement of soldering two separate encoders per wheel has provend to be difficult to realise in a robust manner. These problems have severely hampered the development of the prototype robot.

Prototype chassis designs were constructed using steriolythography rapid prototyping technology. Once finalised the designs were entered into a CNC machine to produce the aluminium chassis. However, the robot top/lid remained in the non-conductive material produced by the steriolythography method. As a consequence PCB's were able to be positioned close to the chassis walls without fear of short circuits. The resulting chassis is mechanically very robust

3.2 Control

Due to time constraints the robot is currently let down by both the prototype electronics and embedded firmware. It is hoped to perform much of the closed loop control locally therefore removing some of the problems of dead time in the system. Work has been performed using dead reckoning to control the robot but very little work has been done in conjunction with the opto-encoder arrangement. It is believed that when the encoders have been fully integrated into the robots' firmware then reliable, accurate closed loop control can be performed.

A number of potential problems have been identified that must be overcome in order to achieve accurate closed loop control. Primarily the issue of mounting and connecting the encoders in a robust manner must be solved. At the same time the issue of micro controller power also needs to be addressed. At full speed the encoders can easily generate enough interrupts to overwhelm the processor. In practice this usually results in loss of robot control until an external force providentially slows the robot down thus reducing the number of interrupts generated.

3.3 The Future

The 2004/2005 Warwick team will once again contain a group of multidisciplinary M.Eng students with the addition of one PhD student chosen from the 2003/2004 robot football group. To ensure further continuity the M.Eng team is likely to contain two students who worked on the project during their penultimate year, i.e. third year of study. It is currently thought that the focus of work during the next year will be upon localised sensing. As previously stated it is believed that by doing much of the robot's control locally many of the problems of dead time and global sensing can be overcome. It is also thought that this will offer an advantage, particularly for 11 a side teams, where global sensors start to become stressed while attempting to track the increased number of objects over a larger pitch area. A greater reliance upon the robots own perceptual capability and decision making will hopefully link with the mobile robot research on-going at the OU where the robots may be operating in hostile environments devoid of global sensing. Under these conditions the robots will have to interpret their environment, communicate and co-ordinate as individuals as opposed to being instructed as drones by a central decision making machine. Localised visual detection, using compact "smart sensors" as opposed to large image processing computers is a further area of interest.

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4. WORK AT THE UNIVERSITY OF PLYMOUTH

Originally the main incentives for robot football work at Plymouth were to support undergraduate teaching and to enthuse students. However the technology was rapidly adapted to support a number of research projects [12]. A major aim was to minmise complexity and costs. For many years software development, both vision recognition & strategy, were given a low priority. Without a reliable and robust robot there seems little point in trying to develop complex software and vision systems. This problem now seems to be solved. The Miabot Mark 4 robot was tested internationally for the first time at the European 2004 FIRA Championships held in Munich and acquitted itself very well.

4.1 A new electronics board

A new electronic control board, designed specifically for the Miabot Mark 4 has been produced. The most recent board design is a hybrid including both surface mount and through-hole technology. Part of the reason for this is that the latest Atmel microprocessors are manufactured in surface mount form only thus making this change necessary.

The new control board design uses a Motorola MC33887 MOSFET dual full bridge driver, which exhibits a low drain to source on resistance and addresses power efficiency issues as well as providing some additional features. Again it is only available as surface mount part. By using this device it has been possible to easily design in a hardware current limit using the provided ground referenced current feedback facility. This supplies an output current of 0.00266 of the H-bridge high side current. This relatively simple, single electronic control board based around a single microprocessor has been successfully tested with a variety of robots including the standard Yujin robot body.

4.2 Battery endurance experiments

The original Plymouth robots were powered using a 9.6V power pack consisting of eight AA, Ni-MH cells. This arrangement was suited to the low cost dc motor/gear box combination. As battery technology improved and the capacity of Ni-MH cells increased the AA cells were replaced by eight 650mAh AAA, Ni-MH cells. This reduced both the weight and volume of the power pack. The Mark 4 robot with its more efficient 6V series Faulhaber motors does not require the higher voltage and experiments have recently been performed using a 7.2V power pack consisting of six AAA, 650mAh Ni-MH cells. One Mark4 robot was chosen and used for all battery life tests in order to eliminate effects due to different robot characteristics. The robot was instructed to follow a rectangular track 160cm long and 115cm wide, i.e. each lap theoretically 550cm but in practice nearer to 590cm due to oval nature of the movement, i.e. the four corners of the rectangle acting as way points. Between the way points the robot followed a velocity profile, accelerating up to a programmed speed of 1.2 m/S (equivalent to a motor speed of 3700 rpm) before decelerating as it approached the next way point. It then turned 90 degrees to repeat the process and so on until the battery pack became exhausted. At the beginning and then at five minute intervals the lap time was measured by taking the average of five laps thereby reducing the estimated error measurement to +/- 0.2 seconds.

During these endurance tests the 7.2V pack performed much better than the 9.6V pack, Figure 3. Average lap times were reduced and more consistent. The 7.2V pack lasted for 93 minutes compared to 64 minutes for the 9.6V pack, i.e. reducing the power pack from 9.6V to 7.2V resulted in a 45.3% increase in operational time. The experiment was repeated at about half the above speed and again the same reduction in battery capacity resulted in no reduction in performance but the lower capacity battery pack lasted for 177 minutes compared to 103 minutes, i.e. a massive improvement of 71%.

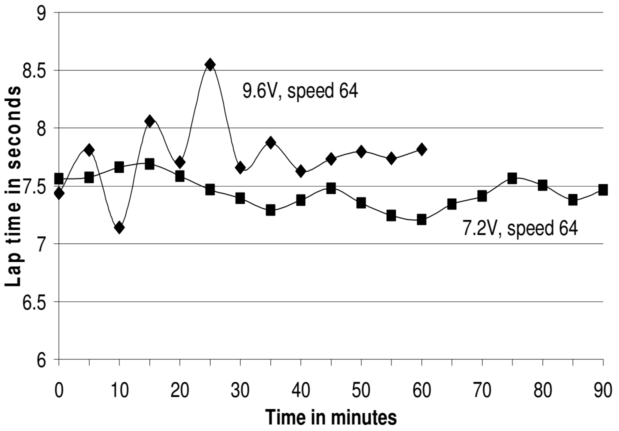

Figure 1. The performance of 6 and 8 cell power packs.

The most likely reason for these results is that when operating at above the rated voltage the motors are driven into saturation. Efficiency is significantly decreased and energy wasted through electrical heating. This was confirmed by measuring the temperature of the motors, H bridges and voltage regulators at the beginning and end of each of the experiment. For the 9.6V tests the motors operated for only 69% of 7.2 V test times but experienced an average temperature increase of 4.50C compared to 2.6^{0}C for the 7.2V tests. Further experiments are planned.

5. CONCLUSION

For the first time three UK universities are actively cooperating in FIRA robot football research and development. Each university is motivated by a combination of factors which include support for undergraduate teaching, technology transfer into research projects and positive publicity for engineering and technology based programmes. A new robot, the Miabot Mk.4, has been developed which may be used in the future by all three universities. Experience gained at the FIRA 2004 in Munich confirmed the robustness of the new machine. Initial experiments show the Miabot Mk.4's performance to be significantly improved when the battery pack voltage is reduced from 9.6V to 7.2V.

Sponsorship from DVT Machine Vision has provided some necessary financial support for U.K. cooperative activities. It is anticipated that in the future DVT cameras will be the preferred vision sensor all three teams. It is early days for this cooperative project but the potential now exists to move FIRA activities in the UK to a higher level and perhaps produce an internationally competitive team.

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