Medium Size League: 2002 Assessment and Achievements

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Abstract. Robots in the Robocup Middle Size League (MSL) have dimensions comparable with robots that could be used in other real world applications. MSL provides a framework to test these robots in a challenging environment where actions should be decided in real-time. In many cases, the achievements shown in this competition are important also for real world applications, and have been exported there. Some other results put in evidence what can be done by focusing on specific issues with the aim of producing more interesting and effective entertainment by autonomous robots.

1 Introduction

Most of the present Medium Size League (MSL) robots are fully autonomous: they can take decisions by the on-board computational capabilities, using data that come from on-board sensors and radio communication devices linking the robots of a team. These achievements involve research and technology issues in fields ranging from mechanics to electronics, from sensors to actuators, from low-level control to team strategy and learning. We first discuss the main achievements in each area, then we summarize the most relevant aspects emerged during the 2002 competition. Finally, we present the future directions for the league.

2 Where Are We Now in MSL?

In this section, we discuss the main achievements for each technological area involved in the development of MSL robots, and we put in evidence the driving forces that lead us to this point.

2.1 Mechanics

he majority of MSL robots is based on the common kinematics consisting of two independent traction wheels, but an increasing number of teams have developed either omnidirectional robots, or robots with steerable wheels. In general, it has been noticed that these robots are more agile, and can produce a more

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interesting game, but also that this is not enough to be successful. At present, no omnidirectional base is commercially available for MSL, so all omnidirectional robots should be developed from scratch. Some teams use commercial bases having the more common kinematics, thus saving at least some of the efforts required to build mechanical stuff. MSL robots may change their configuration to kick or try to get the ball. According to the rules, they should occupy at most a square 50 cm by 50 cm, for the majority of time; for short periods they may extend up to 60 cm by 60 cm. These dimension boundaries have been selected to have a significant portion of the field free from robot bodies, and, at the same time, allow robots to bring on board the needed computational power, usually a full size PC board, or a portable computer, or a PC104 board. Almost all MSL robots have some kicking device, able to kick the ball up to 5-6 meters per second. Kicking devices are implemented by all sort of mechanical arrangements, from charged springs, to compressed air pistons. A couple of teams have also implemented devices that, while leaving the ball rolling as stated by the rules, can maintain the ball in contact with the robot body even when this is turning (Philips team) or it is going back (Muratec FC team). The last version of the rules allow robots moving back with the ball for at most 50 centimeters, so to avoid undesired situations that may make the game less interesting.

2.2 Electronics, Communication and On-board Computing

As mentioned above, almost all the teams perform on-board the computation needed to play. Some teams still send images to an off-line station that elaborates them and send back information to control the robots. Some other teams use external computational power to fuse the sensor information coming from the teammates and build a team plan. Electronics on board include power control for engines and kickers. In some cases it is implemented by the teams, otherwise it is taken from the market. This is one of the main sources for malfunctioning, and it is critical for the reliability of robots. Up to now, the most successful teams have also been those able to bring the majority of their robots through the whole set of matches up to the finals. Even brilliant teams have lost finals or semi-finals also due to HW problems with their robots. This issue is also relevant from a general application point of view: reliability is needed to go to the market. On the other side, presently available commercial robots usually do not run in the extreme conditions where MSL robots should operate, including sudden acceleration changes, fast speed, collisions with other robots or field elements. Communication in MSL is mainly concerned with wireless LAN: the rules explicitly state that robots can communicate only using the 2.4 GHz band, pos- sibly using the IEEE 802.11b standard. All the communication devices used in MSL are commercially available, and many teams had problems during games, only in part reduced by the introduction of access points on the fields; these are devices aimed at partitioning the wireless LAN and providing good coverage in limited environments. Also the communication issue has relevance for real-world applications, but no research is done in this area within MSL. In some cases the problem is in part reduced by adopting emerging behaviors that do not need communication (e.g., [6], or coordination architectures robust with respect to communication degradation (e.g., [3]).

2.3 Sensors and Vision

Sensor and vision systems are used both for (self-)localization, and to detect elements of the environment to interact with.

Vision is implemented either by single front cameras, single mobile cam- eras (e.g., Osaka Trackies), multiple cameras (e.g., Philips), or panoramic sensors (e.g., [5], Artisti Veneti, and Osaka Trackies). External cameras are not allowed. Panoramic sensors have been adopted by many teams, since in the time needed to elaborate a frame image it is possible to collect information all around the robot. Some teams (e.g., Osaka Trackies) use commercial sensors, while others have developed special purpose sensors, including multi-part mirrors and isometric mirrors [5] that do not introduce deformation at the ground level; these teams have developed mirror design algorithms, calibration methods, and interpretation algorithms ad hoc, contributing to the scientific progress in the area.

The main vision activities concern recognizing objects in the field, and localizing them. Object recognition is mainly done by color analysis, since the MSL rules associate different colors to the different elements in the environment: the ball is red, the field green, the goals respectively blue and yellow, robots and peo- ple in the field black, markers on robots cyan and magenta for the two teams. One of the main issues each team has to face is color calibration, which also depends on light intensity. The present rules limit the acceptable range of light intensity in each part of the field (shadows included), but most of the teams have been able to cope with variations due to settings that couldn't be modified. Color calibration is done either manually, or by all sort of algorithms, including neural networks. Color interpretation models go from the simpler "sliced pizza", to irregular patchwork, to neural networks. Robustness with respect to light variation is still seen as an important challenge to be faced. Once the elements of the environment have been recognized and localized, they may be used for self localization. This is not a trivial task, due to the MSL setting. All the fixed elements of the field can be (partially) covered at each time by other robots; moreover, some positions on the field with respect to landmarks do not satisfy the applicability conditions for standard localization algorithms. Some teams have developed innovative self-localization algorithms (e.g., [8]).

The only other significant sensors used in MSL are laser range finders (LRF), which have been one of the keys of success for some teams in the past [8]. In 2002, the wall on the field borders has been removed, thus making the LRF task more difficult, and the research in this area even more challenging.

2.4 Control

Control issues in MSL concern different aspects, from motor control to behaviors. The typical control architecture for a MSL robot includes low level controllers able to reach and eventually maintain set points for the engines. In most cases these controllers are commercial or standard ones. Someone has implemented fuzzy controllers to face this task [2]. Set points to motors are provided by higher level controllers either implemented as behaviors (in some cases fuzzy behaviors [2]), or as standard programs (such as planners, e.g., [8]) or even as interacting dynamical systems [4]. Behaviors are usually considered as control models triggered by some conditions, and issuing some action to the lower level controllers. The relationship with the original behaviors and the subsumption architecture proposed by Rodney Brooks in the eighties is usually weak. The input to higher level controllers is given by sensors, eventually filtered by a world modeler that can fuse data coming from different sensors and from other teammates in a reliable situation description (e.g., [8] [7]). The world modelling activity is done by most teams on each robot, while others adopt a centralized world modeler integrating information from all the robots once for all.

2.5 Multi-robot Cooperation

Multi-robot cooperation is an important issue not fully exploited, yet, mainly due to the physical limitations of the robots. Up to now, robots are able to share their knowledge and to cooperate to select the best action (for instance to decide which one has to go to the ball). There have been also some demonstrations about the possibility to substitute a robot no longer able to perform its task or drive a robot no longer able to perceive directly the environment due to sensor malfunctioning. Some interesting collaboration forms may emerge from interaction without communication as seen, among the others, in games where Freiburg CS and the Artisti Veneti teams played, still in 2001. More complex collaboration has not been fully developed, yet. One of the current challenges is ball passing, up to now successfully seen in an official game only once, giving the impression that it was not so effective. The problems seem to concern the reliability and effectiveness of this kind of concerted actions, more than the difficulty in coordination. More complex forms of cooperation have been announced (e.g., [3]) but not yet seen in official matches.

2.6 Learning

Learning in MSL have to face the problem of scarce information flow. Usually, in a game, a robot is involved in a small number of actions, compared with the quantity needed by most of the present learning algorithms. At least one team is using reinforcement learning to develop off-line both single behaviors, and cooperating behaviors [9]. Another team claim to be able to adapt on-line the behavior of the team to that of the opponents [1], but it has not been demonstrated in an official match, yet.

3 The 2002 Games

The Robocup 2002 games have been held in the Fukuoka Dome, a baseball stadium. The location had some potential problems, successfully faced by most of the teams.

There was a strong illumination source external to the fields (the one used for baseball matches in the Dome), producing undesired shadows, and biasing the light color temperature. Illumination conditions were different among the different fields, but most teams were able to play after a relatively short calibration activity. Nobody seemed to have on-line calibration, but this also seemed to be unnecessary.

Fields were closed by black and white pole ranges, one every 40 centimeters, 1 meter away from the border lines. On the sides behind the poles, there were advertisement panels, about 120 cm long and 50 cm high, placed in a way similar to those on real soccer field. One advertisement range was also put at the last moment on 40 cm boxes to make them visible from the camera positioned on the opposite side. Public could go all around the field. This arrangement was compatible with the rules designed to have some security border around the field, but at the same time to allow unexpected situations outside the field that may cause problems to standard vision systems. Some teams asked to people wearing blue shirts or orange caps to move away from the field, but most teams had no particular problems. Such kind of requests will be strongly discouraged from the next tournament.

The ball provided by the organization was different from that of the previous year, more yellowish, and much more bright. Many teams complained not to be able to distinguish it either from the yellow goal (which was reddish) or from white lines, but this did not seem to be a big problem during matches. The field was 2 meters shorter than expected (8 meters instead of 10), and seemed a little bit too crowded.

Despite these potential problems, most teams were able to play interesting matches, after a couple of days of set up, dedicated, as usual, to recover HW problems and to tune SW. Most teams had some HW problems in many matches, thus bringing in evidence once more that the reliability of our machines is not yet high enough for the market or a live TV show.

The fields were equipped by access points having directional antennas to improve communication reliability. Only three channels were assigned to the league, two for playing and 1 for practicing. Many teams had problems to use the access points, so the matches were played both by teams using the access points provided by the organization, and teams using their own access point or directly broadcasting on wireless LANs. This also put in evidence one of the major problems of the league, not faced by any research effort: the reliability of communication devices in the Robocup environment, where wireless LANs should support intensive band occupation.

At the game start, according to the rules, only teams whose robots were able to reach autonomously their initial position could take a preferred position in the field, the others had to place their robots on fixed points. Almost no teams were able to leave robots to reach reliably their starting positions. Precise self-localization and self-positioning are still problems to be solved.

The absence of walls on the borders of the field, introduced this year for the first time, came up to be quite easy to manage, also because rules did not include any sanction against teams kicking the ball off the field. Most of the teams did not care to keep the ball in, but referees were always ready to put the ball in again, at their own risk. Some referees have been injured by robots and this opened a discussion about the inclusion of at least the first Asimov's robotic law[1] in our robot control programs. MSL robots can be dangerous if badly programmed, and this should be taken into account on the way to the match with human players in 2050 (the long-term Robocup goal). Notice also that this law is not included in any commercial or industrial robot, yet.

Some teams were able at least to show the intention to keep the ball inside the field. This is a challenging control problem, if you consider also that manoeuvering space is small in a MSL field, and that robots can move faster than 1 meter per second. There have been many situations where robots continuously kicked off the ball, when operating in 1 meter from the corner pole. This was one of the undesired game slow down. Another one was due to the strategy of some teams to place more than one robot on the ball, thus creating a corner, or a sort of wall, hard to be passed.

Most of the teams shown a good obstacle avoidance behavior, and charging, which was quite strictly sanctioned according to the rules, was common only in the first games.

The game has not improved a lot with respect to the previous year. Some teams were able to plan a trajectory to (try to) keep the ball inside the field. Some teams had strategies to have robot cooperating in managing difficult situations; we have seen a robot leaving the possible trajectory of a teammate that was bearing the ball, another robot helped by a teammate (or substituted by it) when the ball was stuck.

3.1 Challenges

A MSL competition parallel to soccer matches concerned scientific challenges.

The first one consisted of dribbling the ball between a couple of black poles from the home area to the opposite goal. The aim was to push teams to face ball control problems. Very few teams have been able to show interesting behaviors and a lot of work should still be done. The winner was GMD-Musashi whose robot matched a pole by few millimeters, and scored the goal in about 10 seconds. The suspicion among spectators was that the whole task had been performed in open-loop, without any feedback from sensors. Probably, next challenges will have obstacles in positions a priori unknown.

The second challenge consisted of a free demonstration of collaboration among robots. This gave also an idea of what the teams thought was possible to show in this area. Four teams tried to pass the ball (only one succeeded, but with a quite frontal dash). The robot of another team provided to a blind teammate the position of the ball and the blind one was able to reach it. The

[1] A robot may not injure a human being, or, through inaction, allow a human being to come to harm, unless this would violate a higher order law". This law, first appeared in the short story "Runaround" published by Isaac Asimov in 1942.

robot of the Artisti Veneti team was able to take autonomously the role of the goal keeper when this was turned off, so dynamically changing its role. This last had the highest score from the jury composed by team leaders of all the other teams and technical committee members.

3.2 Mixed Teams Match

The third MSL event was the match done by two teams made up with robots belonging to different teams, excluded from the tournament after round robin. The participants had only few hours to set up the teams. It turned out that robots were not able to communicate with each other, due to the different communication modes and types of messages; anyway, both teams could perform a quite exciting game ended 3-2, including a goal scored in the home goal by a strong kick bounced on a well-positioned opponent goal keeper.

This experience put in evidence some interesting questions. Communication is not needed to have an amusing game, since robots can be arranged to play reasonably also without exchanging information. It would be interesting to compare the performance of teams adopting communication to coordinate the robots, and teams adopting emergent behaviors. To exploit communication, a common background is needed: this question has not been faced in this league, yet. It has been decided to set up a research effort to define a common language to exchange information, studying what it is actually needed to exchange.

Finally, this experience demonstrated that a team can be set up in few hours, starting from running robots, and this is an encouraging result.

4 Conclusion and Future Directions

In conclusion, we are far away from the long term goal of playing against human players, but we are on the way. Our robots can show complex behaviors, interesting enough to keep excited spectators around the field for the whole match.

Many teams have applied their scientific results outside Robocup, by using their localization algorithms, their world modelers, or their sensors in service robotics, and even space robotics. Robocup seems to play the role of catalyst for research efforts that have a recognized importance for the society and the scientific community in the large, as shown by the large number of Robocup-related papers published in international conferences and journals.

The next steps MSL will take are in large part directed towards the destructuration of the playing environment. In the next years we aim to be able to play with natural light, possibly changing during the day, with a regular FIFA ball (no longer red, but multi-colored), with nets in the the goals instead of colored panels. The size of the field will also be enlarged, to make it possible more interesting actions, possibly coordinated. More ball control will be achieved to have robots able to really dribble the opponents, and to keep the ball inside the field. The teams will also be more coordinated, with robots able to understand the situation and possibly to decide what to do without any explicit exchange of information. In the short term also a “referee box” sending to the robots the decisions of the referee will be implemented, so making the robots aware of the referee decisions and enabling them to behave accordingly. This is on the way of having robots able to understand the FIFA referee signals, as needed to play against human champions.

The qualified teams and the results aregiven in the following tables:

Table 1. Qualified f-2000 Middle Size Teams

Agilo RoboCuppers	Munich University of Technology	Germany
Artisti Veneti	University of Padua	Italy
Eigen	Keio University	Japan
FU-Fighters 2002	Freie Universität Berlin	Germany
Fusion	Kyushu University, Hitachi Information and Control Systems, Fukuoka University	Japan
KIRC	Kyushu Institute of Technology	Japan
MINE	Mie University	Japan
Muratec FC	Murata Machinery LTD	Japan
Osaka University Trackies 2002	Osaka University	Japan
Philips Cyber Football Team	Philips Centre for Industrial Technology	The Netherlands
RFC Uppsala	Uppsala University	Sweden
Sharif CE	Sharif University of Technology	Iran
UTTORI United	Utsunomiya University	Japan
WinKIT	Kanazawa Institute of Technology, Yumekobo	Japan
GMD-Musashi	Fraunhofer Institute AIS, GMD-JRL, Kyushu Institute of Technology, University of Kytakyushu, University of Lecce	Germany, Japan

Table 2. Results: f-2000 Middle Size Robot League

1	EIGEN	Keio University	Japan
2	WinKIT	Kanazawa Institute of Technology	Japan
3	Trackies 2002	Osaka University	Japan

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