RoboCup is a Stage which Impulse the Research of Basic Technology in Robot

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1. Introduction

RoboCup is an international joint project to promote Artificial Intelligence (AI), robotics, and related field. It is an attempt to foster AI and intelligent robotics research by providing a standard problem where wide range of technologies can be integrated and examined. RoboCup chose to use soccer game as a central topic of research, aiming at innovations to be applied for socially significant problems and industries. The ultimate goal of the RoboCup project is by 2050, develop a team of fully autonomous humanoid robots that can win against the human world champion team in soccer (Fig 1).

In order for a robot team to actually perform a soccer game, various technologies must be incorporated including: design principles of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning, robotics, and sensor-fusion. RoboCup is a task for a team of multiple fast-moving robots under a dynamic environment. RoboCup also offers a software platform for research on the software aspects of RoboCup (Burkhard02).

One of the major applications of RoboCup technologies is a search and rescue in large-scale disaster. RoboCup initiated RoboCup rescue project to specifically promote research in socially significant issues.

In the next section we will introduce the origin, organization and leagues of RoboCup. Section 3 we will discuss the relative technology in RoboCup.

Figure 1. Soccer racing in the future

2. The Origin, Organization and Leagues of Robocup

The concept of RoboCup was first introduced by professor of Alan Mackworth in 1993. The main goal of RoboCup is to propose a challenged research issue to develop robotic. Following a two-year feasibility study, in August 1995, an announcement was made on the introduction of the first international conferences and football games. Now RoboCup Soccer is divided into the following leagues: Simulation league(2D,3D), Small-size robot league (f-180), Middle-size robot league (f-2000), Four-legged robot league, Humanoid league.

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In July 1997, the first official conference and games were held in Japan. The annual events attracted many participants and spectators.

2.1 RoboCup 2D-Simulation League

The RoboCup 2D-simulation league uses a simulator called the Soccer Server to do the soccer simulation. The Soccer Server provides a standard platform for research into multi-agent systems. The Soccer Server simulates the players, the ball and the field for a 2D soccer match.22 clients (11 for each team) connect to the server, each client controlling a single player. Every 100ms the Soccer Server accepts commands, via socket communication, from each client. The client sends low level commands (dash, turn or kick) to be executed (imperfectly) by the simulated player it is controlling. Clients can only communicate with each other using an unreliable, low bandwidth communication channel built into the Soccer Server. The Soccer Server simulates the (imperfect) sensing of the players, sending an abstracted (objects, e.g. players and ball, with direction, distance and relative velocity) interpretation of field of vision to the clients every 150ms. The field of vision of the clients is limited to only a part of the whole field. The Soccer Server enforces most of the basic rules of (human) soccer including off-sides, corner kicks and goal kicks and simulates some basic limitations on players such as maximum running speed, kicking power and stamina limitations (Bom99).
An extra client on each team can connect as a "coach", who can see the whole field and send strategic information to clients when the play is stopped, for example for a free-kick. The Soccer Monitor (Fig 2) connects to the Soccer Server as another client and provides a 2D visualization of the game for a human audience. Other clients can connect in the same way to do things like 3D visualization, automated commentary and statistical analysis.
There are no actual robots in this league but spectators can watch the action on a large screen, which looks like a giant computer game. Each simulated robot player may have its own play strategy and characteristic and every simulated team actually consists of a collection of programmers. Many computers are networked together in order for this competition to take place. The games last for about 10 minutes, with each half being 5 minutes duration.

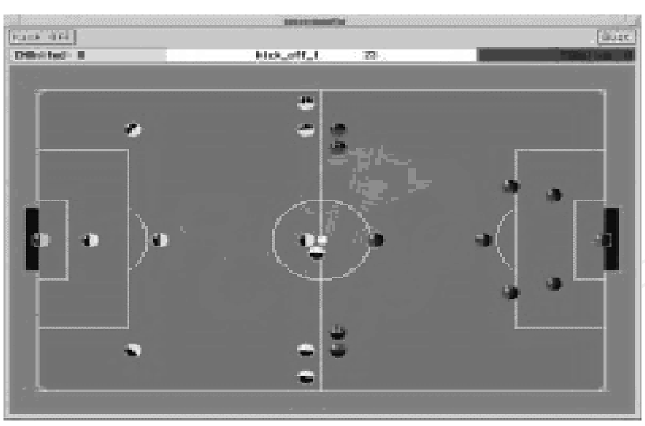

Figure 2. RoboCup 2D-Simulation league

Figure 3. RoboCup 3D-Simulation league

2. 2 RoboCup 3D-Simulation League

The 3D competition makes use of the simulator that is based on the simulation system introduced at the RoboCup 2003 symposium and the spades simulation middleware system introduced at the RoboCup 2002 symposium. It can be downloaded from source forge (Fig 3). One of the goals for future 3D soccer competitions is to have simulated robots with articulated bodies, for example like humanoid robots. Prior to compiling and installing the rcssserver3D, you need to install a few software packages. You can compile and install rcssserver3D in two different ways, a "light" installation and the full installation. With the full installation, you get an additional library (called kerosin), which is useful to visualize objects nicely, especially articulated objects (this are objects consisting of more than one geometry linked with joints). These features are not (yet) required for the soccer simulation. The light installation, which is the default, you get a not so fancy OpenGL visualization. To enable the full installation, pass the "--enable-kerosin" flag to the `configure' shell script. For the generic installation instructions, see the text below the specific instructions here.

Required libraries for the default installation:

(1) spades

- working versions: 1.0, older versions may also work;
- get it at: http://sourceforge.net/projects/ spades-sim;
- description: agent middleware, handles timing issues and networking;
- additional info: you need a recent version of expat for spades.

(2) ruby

- working versions: 1.8.0 or newer;
- get it at: http://www.ruby-lang.org/;
- description: scripting language;
- additional info: if you compile ruby yourself, configure with enable-shared.

(3) boost

- working versions: 1.30.2, 1.31.0;
- get it at: http://www.boost.org/;
- description: c++ programming extensions.

(4) ode

- working versions: 0.039;
- -get it at: http://sourceforge.net/projects/ open- de;
- -descriptions: for simulating articulated rigid body dynamics.

(5) OpenGL, GLUT

You need the OpenGL and GLUT headers for the visualization. This may be dependent on your graphics card. (GLUT is the OpenGL Utility Toolkit).

- part for example of XFree86-Mesa-devel;
- you should get it with your linux distro.

2.3 Small-size Robot League

The field of play must be rectangular. The dimensions include boundary lines. Length: 4900mm, Width:3400 mm. A small-size RoboCup takes place between two teams of five robots each (Fig 4).

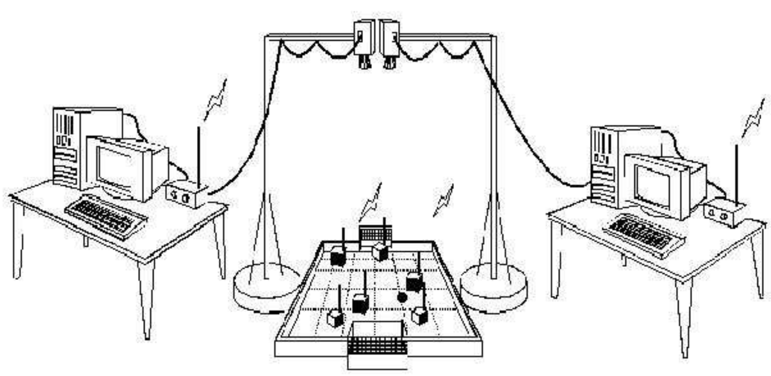

Figure 4. Small-size robot league

Each robot must conform to the dimensions as specified in the F180 rules: The robot must fit within a 180mm diameter circle and must be no higher than 15cm unless they use on-board vision. The robots play soccer on a green carpeted field that is 2.8m long by 2.3m wide with an orange golf ball. Robots come in two flavors, those with local on-board vision sensors and those with global vision. Global vision robots, by far the most common variety, use an overhead camera and off-field PC to identify and track the robots as they move around the field. The overhead camera is attached to a camera bar located 3m above the playing surface. Local vision robots have their sensing on the robot itself. The vision information is either processed on-board the robot or is transmitted back to the off-field PC for processing. An off-field PC is used to communication referee commands and, in the case of overhead vision, position information to the robots. Typically the off-field PC also performs most, if not all, of the processing required for coordination and control of the robots. Communications is wireless and typically uses dedicated commercial FM transmitter/receiver units although at least one team has used IRDA successfully.

2.4 Middle Size League

Two teams of 4 mid-sized robots with all sensors on-board play soccer on a field. Relevant objects are distinguished by colors. Communication among robots (if any) is supported on wireless communications. No external intervention by humans is allowed, except to insert or remove robots in/from the field.

Figure 5. Middle Size League

2. 5 The Four-Legged League

In The Four-Legged League, participating teams have to use robots specified by the Competition Committee without any modification on its hardware.
In 2004 there are choices of either using
-Sony Entertainment Robot AIBO ERS-210/210A, or
-Sony Entertainment Robot AIBO ERS-7, or
-A combination of both in the team
The four main technical issues associated with the SSL are the following:

Robust color processing and color tracking. The lighting at tournament halls is very irregular; there are shadows and unpredictable variations during a game. The software has to surmount these difficulties while processing video frames provided by inexpensive cameras. In recent years, most good teams have solved these issues, and we do not see them losing the robots or the ball.
Robust mechanical design. A robot able to play at a good level in the SSL must be fast (1-2 m/s maximal speed) and able to resist strong collisions. Typically, SSL robots can fall from a table and continue playing. There has been a new emphasis in mechanical design during the last two years with the introduction of such innovations as omni directional drive (Cornell 2000) and dribbling bars that allow robots to control the ball and pass it (Cornell 2001).
Robust wireless communications. This might be considered the single most important unsolved issue in the SSL. Most teams use the same RF chips and this has led to significant interference problems in the past. Tournaments have become too long because it is very difficult to schedule simultaneous games. A solution such as WaveLan cards or Bluetooth

modules will be explored in the future.
Good programming of robot behavior. It can be safely said that most teams in the SSL have adopted a pure reactive design with simple strategic goals. The fact that the field of play is too small relative to the size of the robots means that it does not pay to compute too complicated strategies. The horizon of most systems is just a few frames into the future, since the robots are so fast relative to the size of the field. Thus, enlarging the field has to become a major research issue if more sophisticated strategies are to be programmed.

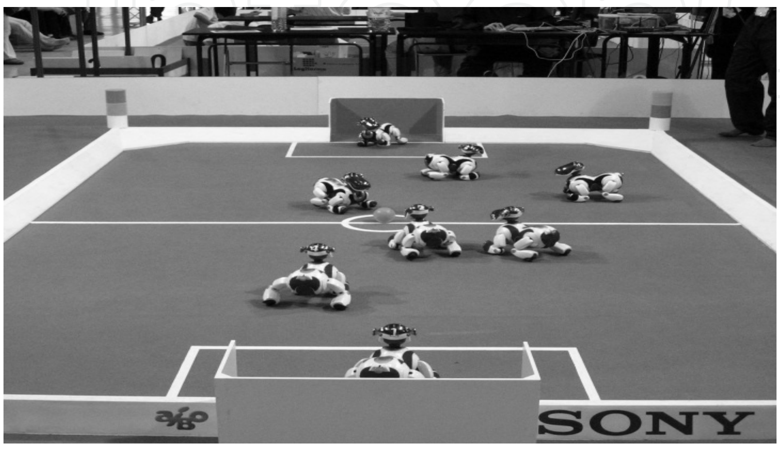

Figure 6. 4 legged league

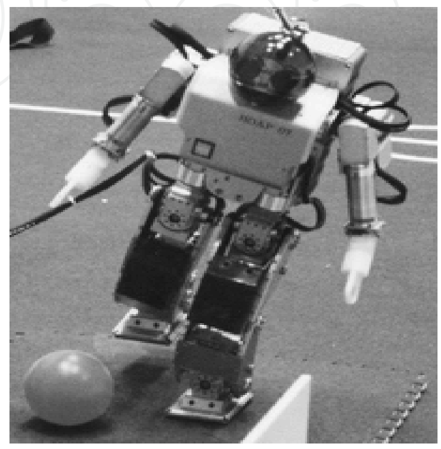

Figure 7. Humanoid league

2.6 Humanoid League

Humanoid robots show basic skills of soccer players, such as shooting a ball, or defending a goal. Relevant objects are distinguished by colors. External intervention by humans is allowed, as some of the humanoid robots are tele-operated.

3. Viewing a Soccer Game as a Multi-Agent Environment

A soccer game is a specific but very attractive real time multi-agent environment from the viewpoint of distributed artificial intelligence and multi-agent research. If we regard a soccer team as a multi-agent system, a lot of interesting research issues will arise.
In a game, we have two competing teams. Each team has a team-wide common goal, namely to win the game. The goals of the two teams are incompatible. The opponent team can be seen as a dynamic and obstructive environment, which might disturb the achievement of the common team goal. To fulfill the common goal, each team needs to score, which can be seen as a sub-goal. To achieve this subgoals, each team member is required to behave quickly, flexibly, and cooperatively; by taking local and global situations into account.
The team might have some sorts of global (team-wide) strategies to fulfill the common goal, and both local and global tactics to achieve subgoals. However, consider the following challenges:
-the game environment, i.e. the movement of the team members and the opponent team, is highly dynamic.
-the perception of each player could be locally limited.
-the role of each player can be different.
-communication among players is limited; therefore, each agent is required to behave very

flexibly and autonomously in real-time under the resource bounded situation.
Summarizing these issues, a soccer team can be viewed as a cooperative distributed real-time planning scheme, embedded in a highly dynamic environment. In cooperative distributed planning for common global goals, important tasks include the generation of promising local plans at each agent and coordination of these local plans. The dynamics of the problem space, e.g. the changing rate of goals compared with the performance of each planner, are relatively large, reactive planning that interleaves the plan generation and execution phases is known to be an effective methodology at least for a single agent to deal with these dynamic problems.
For cooperative plan schemes, there are frequent changes in the problem space or the observation of each agent is restricted locally. There is a trade-off between communication cost, which is necessary to coordinate the local plans of agents with a global plan, and the accuracy of the global plan (this is known as the predictability/responsiveness tradeoff). The study of the relationship between the communication cost and processing cost concerning the reliability of the hypotheses in FA/C, and the relationship between the modification cost of local plans and the accuracy of a global plan in PGP illustrate this fact.
Schemes for reactive cooperative planning in dynamic problem spaces have been proposed and evaluated sometimes based on the pursuit game (predator-prey) (Hiroaki01). However, the pursuit game is a relatively simple game, the environment is basically for the study of a single agent architecture.
We see that a robot soccer game will provide a much tougher, fertile, integrated, exciting, and pioneering evaluation environment for distributed artificial intelligence and multi-agent research.

4. Research Issues for Robocup with Real Robots

In this section, we discuss several research issues involved in realizing real robots for RoboCup.
(1) Design of RoboCup player and their control: Existing robot players have been designed to perform mostly single behavior actions, such as pushing/dribbling/rolling. A RoboCup player should be designed so that it can perform multiple subtasks such as shooting (including kicking), dribbling (pushing), passing, heading, and throwing a ball; which often involves the common behavior of avoiding the opponents. Roughly speaking, there are two ways to build RoboCup players:

- Design each component separately, which is specialized for a single behavior and then assemble them into one.
- Design one or two components that can per form multiple subtasks.

Approach 1 seems easier to design but more difficult to build and vice versa. Since the RoboCup player should move around quickly it should be compact; therefore, approach 2 should be a new target for the mechanical design of the RoboCup player. We need compact and powerful actuators with wide dynamic ranges. Also, we have to develop sophisticated control techniques for as few as possible multiple behavior components with low energy consumption. The ultimate goal of a RoboCup player would be a humanoid type, that can run, kick and pass a ball with its legs and feet; can throw a ball with its arms and hands, and can do heading with its head. To build a team of humanoid type robots currently seems impossible.
(2) Vision and sensor fusion: Visual information is a rich source of information to perceive, not only the external world, but the effects of the robot's actions as well. Computer Vision researchers have been seeking an accurate 3D geometry reconstructing

from 2D visual information, believing in that the 3D geometry is the most powerful and general representation. This could be used in many applications, such as view generation for a video database, robot manipulation and navigation. However, the time-consuming 3D reconstruction may not be necessary nor optimally suited for the task given to the RoboCup player. In order to react to the situation in real time, the RoboCup player quickly needs information to select behavior for the situation, we are not suggesting a special-purpose vision system, just that the vision is part of a complex system that interacts in specific ways with the world. RoboCup is one of these worlds, which would make clear the role of vision and evaluate the performance of image processing which has been left ambiguous in the computer vision field. In addition to vision, the RoboCup player might need other sensing devices such as: sonar, touch, and force/torque, to discriminate the situations that cannot be discriminated from only the visual information nor covered by visual information. Again, the RoboCup player needs the real time processing for multi-sensor fusion and integration. Therefore, the deliberative approaches with rough estimation using multi-sensor system do not seem suitable. We should develop a method of sensor fusion/integration for the RoboCup.

(3) Learning RoboCup behaviors: The individual player has to perform several behaviors, one of which is selected depending on the current situation. Since programming the robot behaviors for all situations, considering the uncertainties in sensory data processing and action execution is unfeasible, robot-learning methods seem promising. As a method for robot learning, reinforcement learning has recently been receiving increased attention with little or no a priori knowledge giving higher capability of reactive and adaptive behaviors (Balch00). However, almost all of the existing applications have been done only with computer simulations in a virtual world, real robot applications are very few(Silvia 99). Since the prominence of the reinforcement learning role is largely determined by the extent to which it can be scaled to larger and complex robot learning tasks, the RoboCup seems a very good platform. At the primary stage of the RoboCup tournament, one to one competition seems feasible. Since the player has to take the opponent's motions into consideration, the complexity of the problem is much higher than that of simple shooting without an opponent. To reduce the complexity, task decomposition is often used. Fredrik proposed a method for learning a shooting behavior avoiding a goal keeper (Fredrik00). The shooting and avoiding behaviors are independently acquired and they are coordinated through the learning. Their method still suffers from the huge state space and the perceptual liaising problem, due to the limited visual field. Kum proposed a reactive deliberation approach to the architecture for real time intelligent control in a dynamic environment (Kum99. He applied it to a one to one soccer-like game. Since his method needs global sensing for robot positions inside the field, it does not seem applicable to the RoboCup that allows the sensing capability only through the agents (see the rule section). At the final stage, a many-to-many competition is considered.In this case, collective behaviors should be acquired. Defining all the collective behaviors, as a team seems infeasible, especially, the situations where one of multiple behaviors should be performed. It is difficult to find a simple method for learning these behaviors, definition of social behaviors. A situation would not be defined as the exact positions of all players and a ball, but might be perceived as a pattern. Alternatives, such as "coordination by imitation," should be considered.

In addition to the above, the problems related to the RoboCup such as task representation and environment modeling are also challenging ones. Of course, integration of the solutions for the problems mentioned above into a physical entity is the most difficult one.

5. Relative Technology in Robocup

The robot football game is taken on by hardware or imitated robot human. The rule is similar to the true human football game. The research of robot football match taken by hardware is concerned with computer, automatic control, sensing technology, wireless communication, precise mechanism, imitated materials and numerous forward-position researches and synthesizes integration. Imitated robot football game is carried on the standard software platform and it fully embodies the technologies of control, communication, sensing and some other aspects. The key points of the researches are some advanced functions, such as cooperation in the system, dynamic decisions, timely plans, the learning of machine and some hot points in the current artificial intelligence. Therefore, in the realm of international artificial intelligence, robot football is regarded as a standard problem in the future 50 years, just as the international chess games between human and computer.

The robot football game can do benefit to apply the theories of AI to practice. It also can help to examine the new thoughts, new techniques, and promote the related development of technology. A series of new techniques used by Robot football games will do favor to the development of social economy and culture. Robot football games are not only a kind of front competition with high techniques, but also provide amusement, enjoyment and incentive, which the true game provides. We can anticipate that this activity will produce tremendous market's need and new industrial opportunities, and will bring inestimable utilities of economy and society.

The target of the research of RoboCup is to provide a test platform for the distributed system. In a specific way, it includes the research targets as follows:

- The posture of robot. Now the robot uses wheel and bedrail, the human player don't play with it in court. So we must build the robot like human such as gesture, structure and weight.

- The body of robot. If the robot is full of iron and plastic, people are afraid of touch in it. So the robot must own the muscle and can collide with people.

- The energy of robot. Now the soccer robot's power is battery, but can only use few minutes. in the future, the soccer robot must run and move in 45-50 minutes, that means the battery must has little volume, the light weight and full of power.

- The skill of robot. Now the two-logger robot can move in stair. The best soccer robot is four-legged dog of SONY corporation. After 50 years, the robots must can run, move jump, shoot, dribble like human being. People can do, so the robots can do.

- Intelligence of robot. The high level player plays with ball using their brain, so the intelligence of star must high-class. In 1997,IBM's deep blue beat down Kasparov , but IBM use 16 RISK6000.so in the future, the micro computer in soccer robot must very well.

- The sense of robot. The sense parts are arranged at will. for example, it can own six eyes, use sonar and wireless communication network, now the tech of sense can not solve the comprehension of image, the power of touch and the function and efficiency of inside sensor. So we must solve these problems.

6. The Relationship Between Robocup and MAS

6.1 Agent, MAS and RoboCup

RoboCup is a typical model of MAS(Multi-Agent System). We can take on the eleven robots as eleven Agents. This will involve some related techniques within MAS such as communication and coordination. These techniques are exactly the core in the MAS.

The Agent is an important concept within realm of computer science in recent years. This concept has already been extensively applied to the realm of AI, distributed system of computer science and so forth, and provides a brand-new path for distributed open system. It is regarded as "an important breakthrough of software development once more". In the AI realm, people treat Agent as a computerized entity, which can play a role independently and has the life cycle's calculation under some environments. People also call the systems that be consisted of multi Agents and full of interactions and connections within them as a MAS.

Generally think, the research of Agent can mostly be divided into the Intelligent Agent, MAS and Agent Oriented Programming (AOP). They are not isolated with each other. The Intelligent Agent can be seen as a micro level in the Agents' researches, but AOP and the developing tool or platform of AOP are aimed to serve for MAS researches. Therefore, we can come up to say from a certain degree, the three can be unified to the researches of MAS. This is also consistent with our realistic circumstance because the most of the realistic systems are belong to the MAS.

MAS are the basic technology of RoboCup. RoboCup is a prototype of MAS. Obviously, the technology of RoboCup involves some relative technology in Agents such as coordination, regulation, valid communication, dead lock and some other technologies. These technologies are core in MAS.

For a researcher who wants to attend the RoboCup team, the basic problem is to design a Multi Agent System. The systems can response in time. It also performs a rational action toward the target. Because of the enormous space of soccer game, it is impossible coding all of the possible conditions, situations and behaviors of Agents. Therefore it is vital to make Agents learn strategies. And this is related closely to some technology in the researches of Agents.

These include:

- Machine learning in cooperative environment.
- Construction of MAS; Timely regulation and execution of MAS for team cooperation.
- Modeling opponents.

Some readers maybe ask that MAS is a type of science and technology while football

6.2 Coordination in MAS

Since RoboCup is Multi Agent system, the problem of coordination and regulation between Agents is then the most important to resolve. If could be properly resolved, it would bring advantages to MAS, Such as:

Low the expenses of coordination; speed up the response of system.

Establish the relationship between the utility of the community and individual behavior.

Protect the Agent which with poor ability of reasoning and benefit the Agent which with strong spirit of enterprise.

Settle the problems such as waiting for others' success, coordination within teams, and so on. The problems of coordination and regulation in MAS are actually triggered by the

Agent social activity (the concept of sociality means that in the social activities, the actors will benefit itself in the way that it exchange resources with others which are insignificant to itself). Therefore study the MAS' sociality is then becoming the most basic problem.
Now, the researches in sociality of MAS have already risen to certain step. But because of lacking further analysis of MAS' sociality, the current researches of coordination and regulation still exist some problems to settle, such as:

- Lack popularity.
- It is difficult to weigh the advantages and disadvantages within all kinds of methods.
- Too many researches toward individuals etc.

The coordination methods can be classified as Fig 8(Cheng03). Here, we only discuss the implicit of collective target.

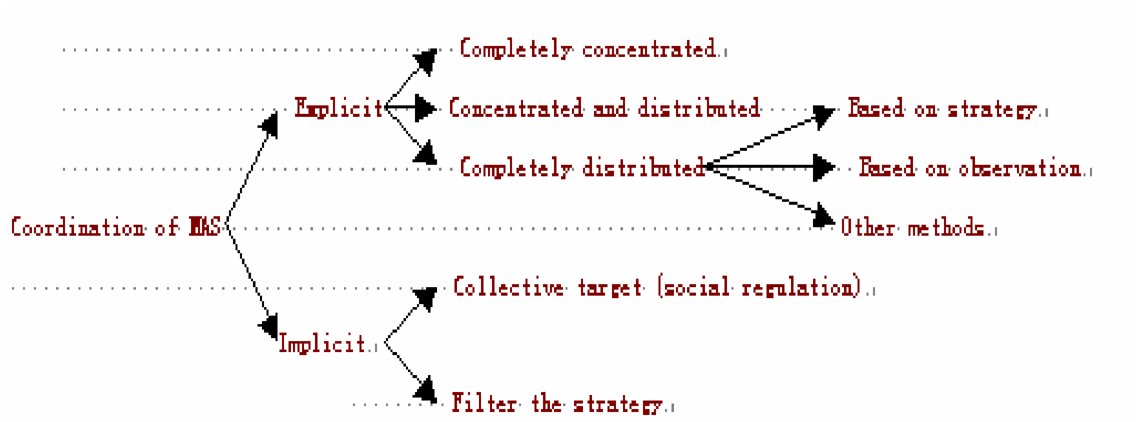

Figure 8. Coordination methods classified

As a method of implicit, the collective target can not only be used to low the coordination expenses, but also be used to embody the MAS sociality, balances the benefits between the individuals and the collective. Collective target is a good breakthrough to the researches of MAS. If the p is a collective target, then: (the c is collective)

- Each Agent i regards p as its own target.
- Each member in c has intention to accomplish the aim with others.
- Each member regards p as its own object because they trust each other.
- They trust each other that if the member Agent i in c reach its target p, then the other members reach target p too.

Now, the research of the collective target contains two kinds of tendencies. One is the research before the collective of Agent come into being other is after it.

6.3 Communication Technique in MAS

The communication problem in MAS researches is also very important. It can judge the advantage and disadvantage of the communications in Agents. If they communicate fluently, it will do benefit to the speed of communications in Agents. Therefore, under the circumstance of having settle the communication problem, we are to discuss the methods of how to make this kind of communication more efficient.
A main reason that the computer is difficult to comprehend the natural language is that it needs of many resources of knowledge. If the side of sending message could mostly understand the side of accepting message, he then would send out the more short and less

information. For this reason, validating communications needs to resolve two problems as follows.

The first is the use of the context. If the side of the accepting message can share the same context with the side of the sending message, then the context can decide the meaning of the conversation as a resource of knowledge. The context includes the pronoun, index, current environments, and so on. For example: Tom left home and he would back soon. If the side of the accepting message comprehended the first half sentence 'Tom left home', he then could suppose that 'he' is pointed to 'Tom'. Thus, 'he' can replace 'TOM'. Although this is just a very little economy, lots of economy like this can be added up to raise efficiency. Here, the environment of the contexts can also be called the pre-established of using language, and the pre-established reasonability will do favor to sending out the speech behavior correctly, and make the side of the accepting message comprehend this speech behavior correctly.

The next is to solve the different meanings. Person who uses the natural language can distinguish the expected meanings of the words and phrases of different meanings by kinds of resources of knowledge. But for the Agents, even this kind of information was delivered with no second meanings that also needs of plenty of words and very complicated expressions. There are many kinds of different aspects, primarily include:

(1) Different meanings of words
The same word may have several different meanings, for example: Tom is hot. This not only can mean 'Tom does well in his work', but also can mean 'Tom is very hot'. The different meanings caused by this are called different meanings of words. Resolving it needs of additional knowledge and environments about the subject of a sentence.

(2) Different meanings of sentence construction
Sometimes the sentence can be expressed not only by a method, namely a phrase can be constituted in different ways. The different meanings caused by this are called different meanings of sentence construction. For example, He saw she at home. This not only can suggest that 'he' is doing the action 'see', but also can mean that 'he' is at home. The method to resolve it is to let the side of accepting words knows the position of 'he' or 'she'.

(3) Different meanings of quotations
The repeated usage of the pronoun and other headwords may cause different meanings. The procedure of solving it is concerned with the complicated reasoning of some contents of the sides of sending and accepting.

(4) Different meanings of the use of language

If the common knowledge and the learning of the contexts of the side of accepting is uncertainty, this is called the different meanings of the use of language. The method to solve it is to determine the knowledge of the contexts or make the two sides have common knowledge.

7. Learning in Robocup

The key problem in RoboCup research is how to enhance the agent intelligence by learning, namely how to improve the competitive ability of player. Among many learning approaches, reinforcement learning, which tends to solve the problem how a self-rule agent capable of apperceiving environment can select the optimal actions to attain its goal, has gained widespread attentions. The mechanics of a reinforcement learning can be showed as in Fig.9: let the environment an agent in be state set S, and the arbitrary action set the agent can possibly take is A, if at state S_t perform action a_t, then the agent get a reward of r_t, which is the immediate value of state-action transformation, so as to the ensemble of (S_t, a_t, r_t), the agent's task is to learn the control policy π: $S \rightarrow A$, which can maximize the expectation of the reward sum(Cai03) that is when there is $S_0 \xrightarrow{a_0,\gamma_0} S_1 \xrightarrow{a_1,\gamma_1} S_2 \xrightarrow{a_2,\gamma_2} \cdots$ to maximize the $r_0 + \gamma r_1 + \gamma^2 r_2 + \ldots \; (0 \le \gamma < 1)$.

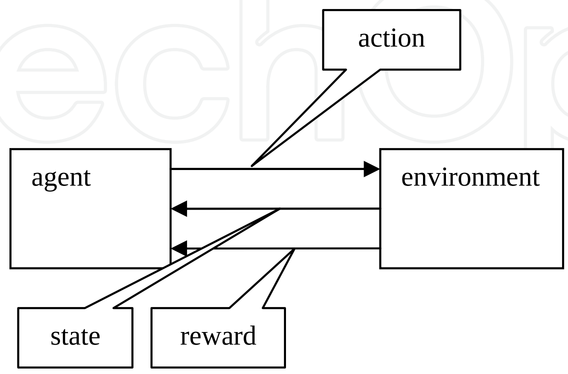

Figure 9. Sketch map of reinforcement learning

As to a RoboCup emulation competition, the competing pattern is a model of Client/Server, in which the environment adopts software platform of SoccerServer standard, participating teams write their own Client programs to simulating a really football game, and every player in Client program can be look upon as agent interacting with the environment. In this game, every agent's actions such as kick, dash, turn, etc. are not only bottom strategies, but also are the key problem to the competition. Taking kick as interaction with the environment namely SoccerServer, and the feedback of ports as the return state, then the task of a player is to design a strategy to maximize the effect of the kick, that is, to control the ball and make good kicks, and at the same time, how to coordinate the whole team to obtain a cooperation learning is also key to winning.

As showed in Fig.9 besides agent and environment, there are four important parts in reinforcement learning include policy, reward function, and value function and environment model as a selective part. Policy is the mapping from some observed state to the action taking which will arrive the state; Reward function defines the goal of reinforcement learning, it maps an apperceived environmental state(or a pair of state and action) to a value which implies the inherent needs of a state, namely a reward. Since the target of single agent in reinforcement learning is to maximize the whole rewards got in the long learning, so the value function shows what is useful in the learning. Because the value of state is the sum of all reward get from current time to the future, and the reward determines the immediate inherent need of environment, so the state value indicates the needs of state followed by possible states in the long future, and the reward that will be obtained in those future states. Since environment model simulates the model action, so using such a model, agent can forecast that how environment will react to agent's action.

Reinforcement learning can solve a large dynamic programming without any a prior. A general form of reinforcement learning is:

(1)Initial the inherent state I of learner as I_0,

(2)Loop:

observe the current state S;

using value function V to select an action $a = V(I, S)$;
perform action a;
let r the immediate reward by performing action a at state s;
using updating function to update the inherent state $I = U(I, s, a, r)$.

Usually, using a table of state and action data, the inherent state I will code the environment information stored by learning algorithm. Abide by command of reinforcement adjusting the current state, updating function maps current inherent state, input, action and reinforcement to a new inherent state, and according to information stored in inherent state, value function V maps inherent state and inputs to an action. There are a few difference of definition of U and V between different reinforcement learning.

Q-learning is just a typical reinforcement learning, in which training sample does not like $< s, a >$, but is the reward of agent's action, so it is difficult to obtain the optimal policy $\pi : S \to A$ though learning, this can be solved by learning a value function defined on the state and action, by learning the value function, an agent obtain the primal policy. A distinctively good value function is V^*, when $V^*(s_1) > V^*(s_2)$, agent will hope to enter state s_1, because thus can get a larger reward, and of course, agent only can select among actions, not among states (Cheng04).

8. The Significance of Researching Robocup

Thinking carefully, we can suggest more contents and difficult points. We seem to have reasons to deny the imagination of "the battle between human and machine". Because it is unimaginable to reach such achievement today.

But look back to the history, nowadays, there are so many scientific achievements which are unimaginable for the forefathers, aren't there? People will have an unusual eye on the scientific development in 50 years.

It's about half century from the first plane of which the Wright brothers' having trial flight to the successful landing on the moon of Aporo airship. While it's also 50 years from the first computer to computer of "Deep blue" defeating human genius. Now we can see that we should not say "no" in advance for "the battle between human and machine" about 50 years later.

Which we need now is the spirit of innovation, active participation. What we should do is to try our best to improve this process.

It's easy to see that we should innovate more. It contains outstanding progress of artificial life, energy power, material and so on. And it's also contains the great break of many sciences about the project of mechanics, electricity, control, information and computer which are related to the robot. We also need the intersection and combination of multi sciences.

It's the deep meaning of having the research of robot's football.

Although RoboCup is high-tech, only three players' game, there shows some intricate scene. Such as robot bump the wall, two robots badger with each other, and some robots are in the daze, don't concern about ball. People don't understand why the robots' intelligence is not as good as the children.

That is to say, it is not easy to make robot own the human's intelligence-sense, thinking, and action, even the three older children. By 2050, scientists want to develop a team of fully autonomous robots, which can win against the human world champion team in soccer. It is a great goal.

9. Conclusions

This thesis discussed some main technologies in MAS and RoboCup. The aim is to let readers know more about Multi Agent System and cause the Agent-oriented technology mature faster.

There are four steps in the development of programming: procedure oriented Programming, module oriented Programming, object oriented Programming and the last step of Agent oriented Programming. Each process is a more and more abstract procedure, a more and more obscure modeling procedure, till in the end reaches to automatic design of programming. Therefore the emergence of Agent-oriented is inevitable for programming. RoboCup is a stage which impulse the research of basic technology in robot.

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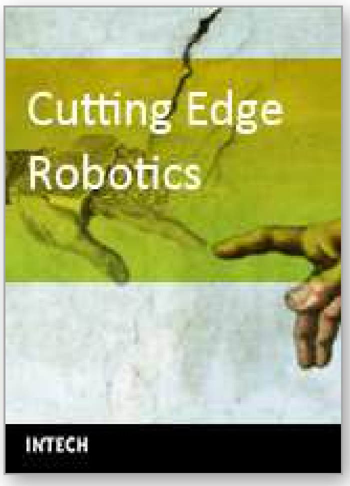

Cutting Edge Robotics

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This book is the result of inspirations and contributions from many researchers worldwide. It presents a collection of wide range research results of robotics scientific community. Various aspects of current research in robotics area are explored and discussed. The book begins with researches in robot modelling & design, in which different approaches in kinematical, dynamical and other design issues of mobile robots are discussed. Second chapter deals with various sensor systems, but the major part of the chapter is devoted to robotic vision systems. Chapter III is devoted to robot navigation and presents different navigation architectures. The chapter IV is devoted to research on adaptive and learning systems in mobile robots area. The chapter V speaks about different application areas of multi-robot systems. Other emerging field is discussed in chapter VI - the human- robot interaction. Chapter VII gives a great tutorial on legged robot systems and one research overview on design of a humanoid robot.The different examples of service robots are showed in chapter VIII. Chapter IX is oriented to industrial robots, i.e. robot manipulators. Different mechatronic systems oriented on robotics are explored in the last chapter of the book.

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