SSL-Humanoid

RoboCup Soccer Using Humanoid Robots under the Global Vision

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Abstract. We propose a new RoboCup league called "SSL-Humanoid". In the SSL-Humanoid league, the global vision system used in the RoboCup soccer Small Size Robot League (SSL) is also employed, and two teams of up to five humanoid robots play on a field whose size is half of the SSL field. This league aims to advance AI research for humanoid robots such as cooperation among robots, tactics and strategies. This contribution is possible due to the substitution of local to a global vision system. This is expected to attract new participants who have been interested in RoboCup but did not attend so far. We propose to organize this league as a sub-league of the original SSL. In this paper, we describe background of the proposal, research topics, road map toward 2014 and a summary of games played in 2009. Finally, we introduce team ODENS' system as an example of an SSL-Humanoid team.

1 Introduction

Fourteen years have passed since the RoboCup initiative [1] started in 1996. In those years, the technology used in the RoboCup soccer Small Size Robot League (SSL) [2] has developed rapidly to a great extent thanks to the global vision system. SSL games can now entertain audience as interesting robot soccer games. In terms of research and development, it seems that the SSL already matured quite rapidly. We believe that a core feature of the SSL is the global vision, which enables the stable detection of robots and ball positions.

In 2007 the authors unofficially proposed a new RoboCup league in which humanoid robot teams compete with each other under a global vision environment [3]. The idea of the new league arose from a local discussion when the authors gathered during the 2007 RoboCup Japan Open. The goal of the new league is to explore new research topics while keeping the characteristic features of the SSL. This offers the opportunity to easily participate in the RoboCup to those who are interested in it.

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In the new league, humanoid robots are used instead of conventional wheeled robots of the SSL, and the global vision system used in the SSL is also employed. We call this new league "SSL-Humanoid".

This proposal aims to introduce a league which establishes new research topics and to promote the world of RoboCup for new participants. We believe that the SSL-Humanoid will give young talents opportunity to actively participate in the RoboCup and bring a large amount of technical achievement towards the final goal in 2050.

In the following sections, first, we describe the background why we proposed the SSL-Humanoid. Then, we describe a way of running the competition, a number of possible research topics and expected effects of the new league, as well as a road map. Rules used in the 2009 demonstration are also outlined. Furthermore, we briefly discuss the demonstration games conducted at the RoboCup Japan Open and the RoboCup Competition in 2009. Finally, we introduce team ODENS' system as an example of an SSL-Humanoid team and conclude the paper.

2 Background

2.1 Current Small Size and Humanoid Robot Leagues

Teams of humanoids have soccer games with local vision in the Humanoid Robot League [4] and the Standard Platform League [5]. In both leagues, cameras and image processing units must be embedded in each robot. So far, great efforts were necessary to embed a local vision system in the small robot hardware. In our new league, such efforts are unnecessary due to the use of an off-board global vision system. Researchers can concentrate rather on their Artificial Intelligence (AI) research, such as cooperation among robots and strategy development to win the soccer games.

Meanwhile, the wheeled robots and the global vision of the SSL technically matured in recent years. Games in the SSL became more and more exciting each year. In 2009, the SSL vision [6] was proposed and tested. SSL vision is a common platform used to give teams position and orientation of each robot and ball in real-time. This system releases the burden of developing an image processing system for each team. Several games were played with SSL vision in 2009 and verified as working well.

However, the technological development of the robots seems to be turning into an arms race. This development makes it difficult for new teams to participate in the SSL because of the technical and economical difficulties. These problems especially arise when new teams try to catch up the latest advances. Therefore, we propose a new league, which aims to overcome the problems and make further advances in research and technological development.

2.2 Advances in Humanoid Robots for Hobby Use

Recently, small size humanoid robots are gaining popularity among hobbyists due to falling prices. Using these biped robots, many people enjoy soccer and Robo-One fighting games. Most of the participants currently operate their robots using remote radio control, while a fraction of people let their systems work autonomously. It seems that

most of participants have interests in creating and controlling the robot but not in automatic control. We believe that by giving incentives and proper tools to support autonomous robots in the new league we will attract a larger audience which did not join due to the inherent technical difficulties so far. The new league will be the key to capture their interests and provide the most suitable opportunity for them.

2.3 Intelligent Space and Humanoid Robots

Intelligent Space (IS) is an environment in which vision sensors, auditory sensors, and Radio Frequency (RF) tags are embedded [7]. Intelligent Spaces are actively studied since it can be one of the core tools to realize a symbiotic life platform between humans and robots. The benefit of this approach is that one can reduce the number of sensors locally embedded in each robot. We believe that in the future many robots will be used in the IS, which helps to considerably reduce the number of sensors necessary in the robots. Then, the robot in the IS might be the best approach to enable humanoid-like robots to play an important role in our everyday environment.

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3.1 The Objective of SSL-Humanoid

In the SSL-Humanoid, cameras and computers, which perform the image processing and the behavior decision, can be placed outside of the soccer field. We can utilize the key technologies such as image processing systems and radio systems that were developed in the SSL. Moreover, it is possible to use hobby type humanoid robots in the SSL-Humanoid. These lower both technological and economical barriers at the same time. We can establish a new way to participate in RoboCup for those who gave up to participate in the humanoid league due to economical issues as well as for those who just enjoy playing with humanoid robots in their spare time.

In addition, the SSL-Humanoid league shares the same idea as the intelligent space approach and the system can be regarded as one of the intelligent systems. We believe that many application fields will benefit from the SSL-Humanoid's results, most notably the research on symbiotic life of humans and robots.

3.2 Starting SSL-Humanoid

SSL-Humanoid will start as a sub-league of the SSL. We use half of the SSL field as the new playing field for the time being and share over-field cameras and markers (team markers and sub markers) with SSL. Each team may use three to five robots in a game.

In order to ensure the fairness of the competition and provide an easy-to-participate environment, the organizing committee will provide over-field cameras and the image processing unit, i.e. the SSL-Vision [6] itself or a similar one. Markers specified by the rules[3] should be placed on the top of each robot. The output of the image processing unit is a pair of position and orientation of each object on the field. These are delivered

Table 1. Roadmap of the SSL-Humanoid

Year	Description
2009	Demonstration games were played. Each robot had markers and each team used its camera and its radio system.
2010	All teams share one over-field camera and use the SSL-Vision.
2012	Unify the radio system.
2013	Start using corner pole cameras.
2014	Start a marker-less class and three dimensional vision class .

to the computer of each team through a network. To avoid conflict of radio communication, the committee will clearly define the type of radio system allowed to use. The use of software libraries such as the Robot Technology Middleware (RTM) [8] is encouraged to promote the participation of new teams. It is also useful for the accumulation of know-how.

On the other hand, teams are still allowed to use their own image processing system in order to develop an improved global vision system if they choose to do so. One example of such systems we consider is a vision system that processes the images given by the cameras slantingly mounted at poles around four corners of the game field. Such arrangement become important when a wider field will be used. Of course, such a system will be a next generation of the shared SSL-Humanoid vision system if it is approved.

3.3 Roadmap

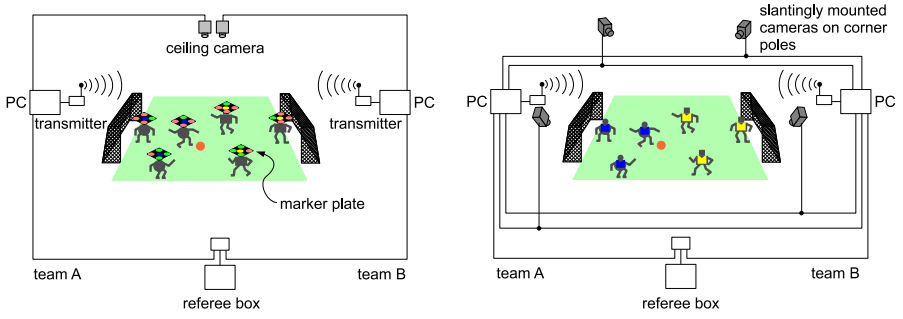
We propose a concrete timetable in order to smoothly shift to new stages as shown in Table 1. To clarify the system images, those of the SSL-Humanoid in 2009 and around 2014 competitions are shown in Figure 1. The year 2009 was a preparation phase. Using the technology developed in the SSL, the demonstration games of the SSL-Humanoid were conducted.

We will introduce shared vision in 2010. The image data captured by the cameras and/or their processing results are shared between teams. The shared vision for the SSL-Humanoid will be modified to make it possible to recognize the three dimensional robots rather than two dimensional markers. Unified radio and marker-less class are introduced in 2012 and 2014, respectively. The marker class will be phased out in 2014. In the marker-less class, three-dimensional recognition of the robots is necessary. In order to acquire three dimensional information, we will introduce cameras slantingly mounted on poles around the corners of the field in 2013.

3.4 Research Directions

There are two main research directions in the SSL-Humanoid, i.e. AI and robotics research using global vision, and developing higher-level global vision.

AI and Robotics Research Using Global Vision. The local vision of the robots in the Humanoid League determines the entire performance of their robots. However, there



(a) the configuration in 2009 (b) the configuration in around 2014

Fig. 1. These figures show configurations of SSL-Humanoid in 2009 and around 2014. In 2014, robots play without markers on their head. The global vision system consists of over-field cameras in 2009 and slantingly mounted cameras in 2014.

are many technical difficulties such as restrictions of viewing field, resolution and processing speed since whole local vision system must be embedded in the robot.

Global vision does not have these difficulties, which helps in the promotion of humanoid robot research. Participants can focus on the research of mechanics, motion control of humanoid robots, the research of strategies and tactics of multiple agents as well as cooperation.

Developing Higher-Level Global Vision. From the view point of the vision system, the features of the SSL are "two dimension" and "markers" on the top of the robots. So, the global vision system of the SSL is not so difficult to develop. However, we have to go one step further toward the final goal, where "three dimension" and "no marker" become main features. This means that the new global vision system should recognize the three dimensional humanoid robots which have no markers on their top. SSL-Humanoid will give the best opportunity for developing such global vision system.

The goal of the global vision in the SSL-Humanoid is to recognize what kind of posture (joint transformation) and motion robots make. In order to correctly observe three dimensional objects, it is necessary to view the objects from a slanted direction not directly above. Cameras around the corners of the field will play this role. Another goal is the unification of all camera images to acquire 3-D information in real-time. The ultimate goal is to construct an automatic referee system and a play-by-play broadcasting system for all soccer games.

3.5 Research Topics

Main research topics in the SSL-Humanoid are the following:

Motion Control of Humanoids. In the current humanoid league, the performance of the robots seems to be restricted by weight, volume, power consumption and processing speed of the image processing unit embedded in the robot. The global vision will allow fast and light-weight robots, which will promote the research and learning of skills.

Cooperation Among Humanoid Robots. Not only the research on strategy and tactics based on the global information but also the research on cooperation between humanoid robots will be promoted due to the use of global vision.

Recognition and Understanding of Humans Based on Images. The occlusion problem among humanoid robots is one of the most important problems to be solved in the SSL-Humanoid vision. Recognition and understanding technology developed in the new league can also be applied to the field of human actions' recognition and understanding. The SSL-Humanoid can contribute to the solution of these problems.

Building Intelligent Space. In the SSL-Humanoid, it is easy to build an Intelligent Space (IS) since the global vision is embedded in the environment and humanoid robots are playing a soccer game by using the information provided by the IS. This means that the new league can take a leading role in the IS research by providing good test benchmarks for its development. Typical research topics in this area are an effective arrangement of sensors, information synthesis from multiple (heterogeneous) sensors, and compensation methodology for processing/communication delays under an environment where robots move dynamically.

4 Competitions Held in 2009

4.1 Outline of the 2009 Rules

A great portion of the SSL-Humanoid rules is in common with the rules of the SSL, which eases a transition from the SSL to the SSL-Humanoid. The 2009 rules are partially outlined here. Full version of the 2009 rules is available on the website [9]. The readers are encouraged to visit the website for further details.

1. **The Game field**
   - The field size is 4050 $\times$ 3025 [mm] (half of the SSL field).
   - The playing surface is a green felt mat or the like.
   - The size of each goal is 1000 $\times$ 600 [mm] (width $\times$ height).
2. **The Ball**
   - An orange tennis ball is used.
3. **The Number of robots**

   Each team consists of up to three robots, where one of those may be the goalkeeper.
4. **The Structure of robots**
   - A robot has two legs and two arms.
   - The height is in the range between 200 and 400 [mm].
   - The weight is 4 [kg] or less.
   - The number of joints is at least 5 for each leg and at least 3 for each arm.
   - A marker plate, with a size of 120 $\times$ 120 [mm], must be mounted on the top of each robot.

Fig. 2. An SSL-H game in the RoboCup Japan Open 2009 Osaka

Table 2. Standings of the SSL-Humanoid in the RoboCup Japan Open 2009. Note, RoboDragons' games were forfeit games.

	KIKS	ODENS++	Ow aribito-CU	RoboDragons	Point	Rank
KIKS		3-1	4-0	10-0	9	1
ODENS++	1-3		4-0	10-0	6	2
Owaribito-CU	0-4	0-4		10-0	3	3
RoboDragons	0-10	0-10	0-10		0	4

5. **Cameras, Radio and Autonomy**
   - The over-field cameras and the external computers are allowed.
   - Radio communication between robots and external computers is allowed.
   - Robots must be controlled by computers. Remote control by humans is prohibited.
6. **The Referee**

   A (human) referee controls the game.
7. **The Assistant Referee**

   A referee box similar to the one used in the SSL is employed to control the game. A system referee (an assistant referee) controls the referee box, acts as timekeeper and keeps a record of the match.
8. **The Duration of the Match**

   The match lasts for two equal periods of five minutes, unless otherwise mutually agreed between the referee and the two participating teams. The half-time interval should not exceed five minutes. Each team may have up to four timeouts in the game. A total of 10 minutes is allowed for all timeouts.

Table 3. Standings of the SSL-Humanoid in the RoboCup 2009

	KIKS	ODENS	Ow aribito-CU	RoboDragons	Point	Rank
KIKS		1-0	0-0	0-1	4	2
ODENS	0-1		0-1	1-0	3	4
Owaribito-CU	0-0	1-0		0-0	5	1
RoboDragons	0-0	0-1	1-0		4	2

4.2 RoboCup Japan Open 2009 in Osaka

From 8 to 10 May 2009, the RoboCup Japan Open was held in Osaka. In this competition, we established official games of the SSL-Humanoid for the first time as a sub-league of the SSL. Four teams participated: KIKS (Toyota National College of Technology), ODENS++ (Osaka Electro-Communication University and Osaka Prefectural College of Technology), Owaribito-CU (Chubu University) and RoboDragons (Aichi Prefectural University). We used the SSL's field alternatively with the SSL games and shared the PCs and cameras with the SSL's. Total of six games were played during the period. Figure 2 shows a scene from one of the games and Table 2 shows the standings. Figure 3 shows examples of a robot and basic skills seen in demonstration games in 2009.

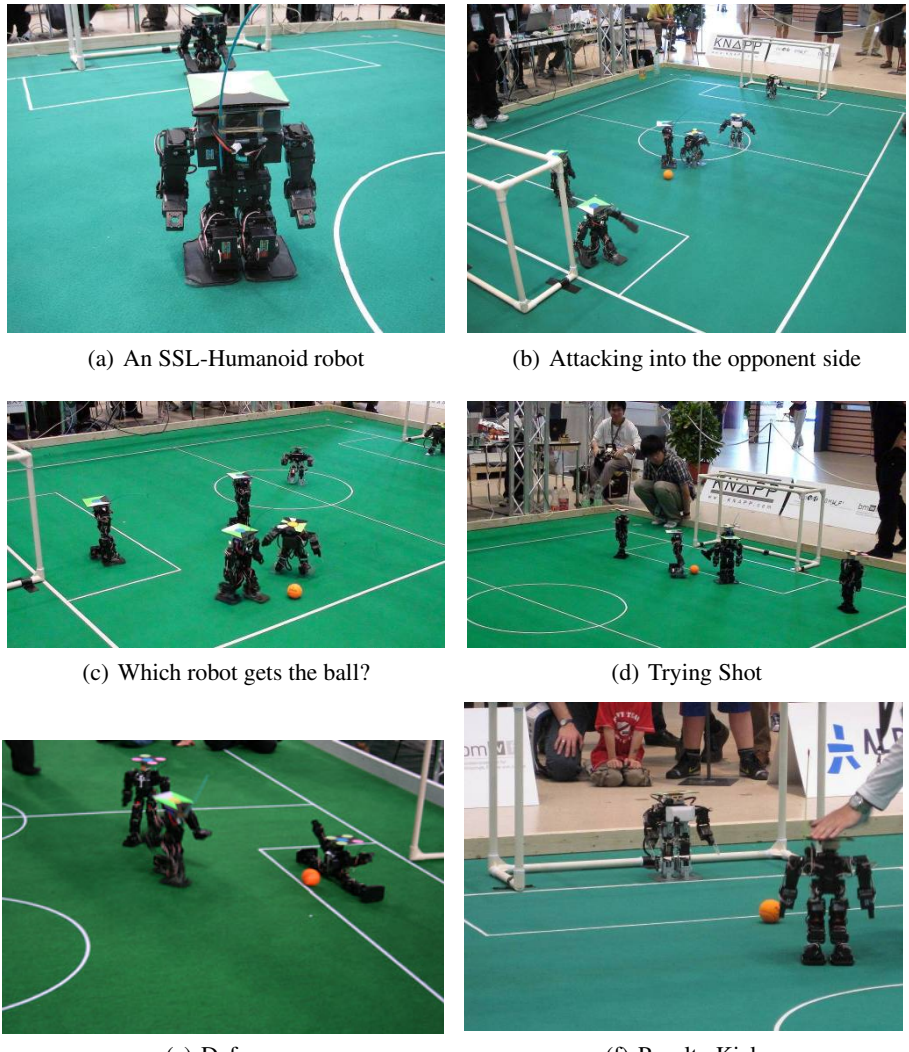
In the competition impressive games were played, although it was the first competition. Highlight movies of the games are available on the web site of SSL-Humanoid[3]. Each of the participated teams built up their humanoid system and implemented basic and advanced skills such as kicking, shooting, clearing a shot, and struggling for the ball in rather short period. It seems very hard to implement them under the local vision system, although both teams had enough experience in the SSL games. Based on these experiences, we are certain that the SSL-Humanoid will successfully promote the research topics as described in section 3.5.

4.3 RoboCup 2009 in Graz Austria

From 28 June to 5 July 2009, the RoboCup was held in Graz Austria. In the competition, we had demonstration in the SSL on 4 and 5 July, the final days. Four teams participated: KIKS (Toyota National College of Technology), ODENS (Osaka Electro-Communication University), Owaribito-CU (Chubu University) and RoboDragons (Aichi Prefectural University). We used a field which was not used in finals. Six round-robin matches were played. Figure 3 shows some scenes from the demonstration games and Table 3 shows the standings. In the competition, impressive games were played as well and spectators were very much interested in the games. Highlight movies of the games are also available on the web site[3].

4.4 Osaka Electro-Communication University's Team

Here, we introduce the team ODENS from Osaka Electro-Communication University. Figure 4 shows the system configuration of the team ODENS. A marker plate is attached



(a) An SSL-Humanoid robot (b) Attacking into the opponent side

(c) Which robot gets the ball? (d) Trying Shot

(e) Defence (f) Penalty Kick

Fig. 3. Typical actions of humanoid robots in the RoboCup 2009 demonstration games ((e) was taken in the RoboCup Japan open 2009)

to the head of each humanoid robot. Over the field, a camera is attached to the torus. It takes the image of the robots and the ball on the field and sends it to the server PC every 16 msec. In the server PC, positions and orientations of the robots and the ball are computed from the image, then they are sent to the client PCs through the network. In the client PCs, robot motions are computed through a decision making program. In each robot, motions such as a forward-walk, a backward-walk and a kick are implemented in advance. Therefore, motion number is sent to each robot through the radio. This process is executed repeatedly to realize the soccer game autonomously by humanoid robots.

Table 4. Specifications of the camera and PCs

camera	maker & model	Basler Vision Technologies, A311fc (658×492pixel,60fps)
	lens	Tamron Co., Ltd 12VM412ASIR
server PC	maker & model	Seiko Epson Corporation, NJ3100
	CPU	Intel Core2Duo P8700 2.53GHz
	RAM	2GB
	IEEE1394	Sonnet Technologies, Inc. FWUSB2-E34
	OS	Windows XP
client PC1	maker & model	Panasonic Corporation, CF-W7
	CPU	Intel Core2Duo U7700 1.33GHz
	RAM	1GB
	OS	Ubuntu 8.10
client PC2	maker & model	Panasonic Corporation, CF-W5
	CPU	Intel Core Solo U1300 1.05GHz
	RAM	512MB
	OS	Ubuntu 8.10

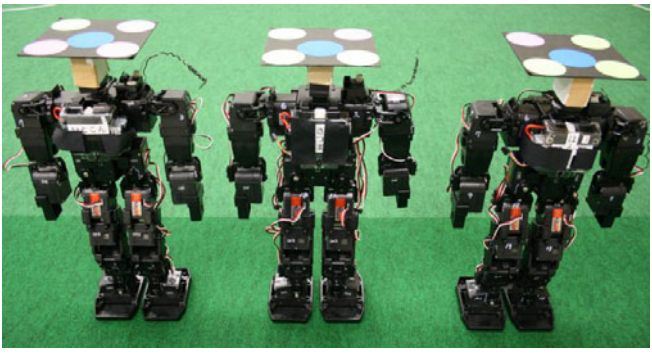


Fig. 4. Humanoid robots employed in team ODENS

Humanoid robots used are MANOI AT01 robots, product of KYOSHO Corporation. They are shown in figure 4. Motors driving foot joints are high torque RC servo motors, KRS-4013HV, products of Kondo Kagaku Co. Ltd, which are replaced from original ones. Also, the radio receiver (25MHz band) and gyro / acceleration sensor, which are also the products of Kondo Kagaku Co. Ltd, are embedded in the robot. The battery is a lithium polymer battery[1], 3 cells, 1350 mAh. The specifications of camera and PCs of team ODENS are shown in Table 4. The client PC1 controls two robots and the client PC2 controls one robot.

[1] Misusing the battery may cause the battery to get hot, rupture, or ignite and cause serious injury.

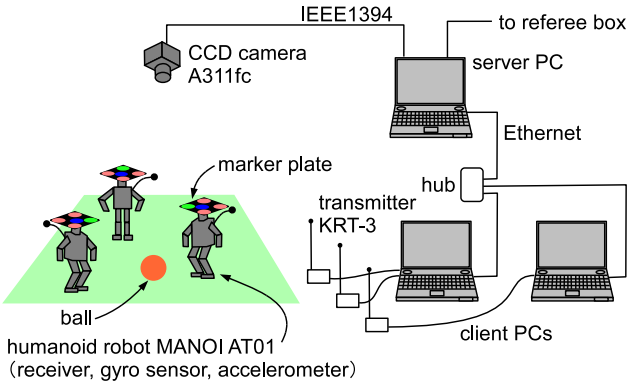


Fig. 5. System configuration of team ODENS

5 Concluding Remarks

We proposed a new league "SSL-Humanoid" in this paper. In the league, humanoid robot teams compete with each other under a global vision system, and discussed the research directions and topics. Under the stable global vision, AI research will be promoted greatly. During the SSL-Humanoid games held in the Japan Open and other international events, it was shown that the robots were moving smoothly in the field and various actions including kicks and defenses were successfully demonstrated. Higher-level cooperative plays will be implemented within a few years.

The SSL-Humanoid started in the Japan Open 2009. We hope that the new league is approved and will start in the RoboCup international event as an SSL's sub-league from 2011. We encourage everybody interested in this to join and participate in the new SSL-Humanoid league.

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