Improvements of SYCU Humanoid Robot

Xin Jin¹, Zhehai Yang, Hao Wang, Jingyao Yin, Chengye Wang, Fenghua Wu
Shenyang City University, Shenyang, Liaoning, China
ajoujinxin@163.com
ayhuk3@leyoujiagroup.com

Abstract. This paper summarizes and describes our SYCU-Legendary team in terms of humanoid robot design and the progress that we have made. Aiming to win a higher ranking on the upcoming 2020 RoboCup Humanoid Kid-Size competition, some changes made on our robot soccer players, such as mechanical design, electrical configuration, sensors and the control system, are introduced. The robot intelligence is improved by optimizing the computation. Also, information about our past participations and honours in humanoid robot soccer championships held in Montreal of Canada, Sydney of Australia, respectively, are presented.

1. Introduction
Being one of the ultimate research goals in robotics, humanoid has become the hot focus and preferred platform for artificial intelligent application [1] such as the RoboCup competition where a team consisting of fully autonomous humanoid robot soccer players is expected to beat the champion of the most recent World Cup under FIFA official rules by the mid-21st century [2]. Although many distinguished humanoid robots have been reported consecutively including Atlas [3], Hubo [4], HRP series [5], Robot soccer requires humanoid robots to play soccer games similar to human beings, especially from the aspects of the autonomous capability, the compliance with rules, the sensing system configuration as well as the whole-body structure. Hence many research teams have introduced their humanoids taking part in RoboCup annually [6,7]. Coming from Shenyang City in Liaoning Province of China, SYCU-Legendary [8] is a competitive team for 2020 RoboCup humanoid league since we won the champion on 2018 and 2019 RoboCup China Open and ranked the fourth place on 2019 Sydney Competition. Our team has been preparing robots in accordance with the requirements of the Robocup competition since 2016 when we started to contract and learn from the teams from Zhejiang University, Tsinghua University, Southeast University and Beijing Information Technology University. During 2018 we imported two robots from Rhoban team [9] who helps us improving the robot significantly in aspects of mechanical optimal design, electrical system design, sensor configuration and some software work. All members of SYCU-Legendary are familiar with the RoboCup rules and often discuss the development trend of the rules with the peers. We have outputted several publications this year relating to overall design of the humanoid robot [10], the summary technology of robot [11] and the robotics subject establishment [12].

2. Overall Design of SYCU-Legendary Robot
In accordance to RoboCup requirements, SYCU-legendary robot has two legs, two arms, one body and one head. Except for the Servos, most structural parts of the robot are made of aluminum alloy while the protection block on each arm and some slight stress parts are made by 3D-print with ABS.
material. In order to let the robot walk on 3cm height artificial grass ground, four anti-slip protruding parts are equipped at the corners under each foot of the robot to provide enough supporting force, which has been proved to work well. Servo is the most important mechanical driving part of the robot, so Dynamixel products of MX-106T and MX-64AT are selected after ADAMS [13] dynamic analysis since they are well-designed for composition of humanoid. Each robot is driven by 20 servos: two for the head, three for each arm and six for each leg that ensure the robot acts flexible without hinder which is undoubtedly crucial for football player. We will continue to improve the performance of the robot while reduce its cost. We believe RoboCup competition is the best opportunity for us to learn from other teams who we expect to share our technique with.

2.1. Improvements on mechanical design of SYCU-Legendary Robot

Last year the front metal cover of the robot was fixed on the trunk of the robot by many screws, which brings a great trouble of dismantle it to handle the circuit boards in the chest cavity. This year we adopt Rhoban team’s method that making a flexible cover with velcro for easily remove. The shape and area of the cover is not changed except that two slots should be designed so that the piano wire can pass through the cover. The second change is the diameter of protection piano wire. We find that the 2.5mm-thickness wire is too forceless to protect the fallen robot since it would be seriously distorted after the robot falling once or twice, as seen in Fig. 1. This year we plan to use 4.0mm piano wire instead of 2.5mm ones so their fixing block should be larger and stronger with an adding mounting point. The third change lies in the back of the trunk where the enclosing bar for Mini PC is designed wider, taking account of the installation of emergency push button. Consequently, the shape of handle and back piano wire are modified slightly. In 2019 competition, the throw-in behavior of Rhoban robot has earned enough eye-balls so we hope our robots can do so in 2020. Obviously, the hands of Rhoban robots were made from rigid circle parts as in Fig. 2. Such design has strict requirements on the shoulder joint pitch angle for the robot holding ball. We plan to design flexible hands for the robot so that it can clip the ball with different forces without damaging the shoulder motor. At present we are preparing these changed parts and we will test and apply them on the six robots for Bordeaux Competition.

(a) Distortion of front wire (b) Distortion of back wire

Fig. 1 Distortion of the protection piano wire.

(a) Rhoban Robot forearm in 2019 (b) SYCU Robot forearm in 2019

Fig. 2 Comparison of robot forearm of Rhoban and ours in 2019.
2.2. Improvements on electrical configuration of SYCU-Legendary Robot

According to the 2020 rule, the robot should be equipped with an emergency stop switch. But our robot has been designed so compactly that it is a thorny problem for us to add such a component on the robot body. With careful consideration, we chose a small self-locking flat button with a diameter of about 16mm in Fig. 3 (a) and plan to fix it on the widened mini PC enclosing bar in Table 1. We hope this will work and give a reference for other teams.

During 2019 game, we suffered many times of low battery capacity alarm that the robot was forced to be serviced when it is attacking. So this year we decide to replace 4000mAh battery with 6000mAh which is obviously larger and heavier as shown in Fig. 3 (b). Thereby we should change the structure of battery box designed last year in Fig. 4 by removing the cover and fix the battery by sticking and squeezing. Meanwhile we will check the mass and size of the robot again to ensure it meeting the rules.

In this year most components of the robot such as batteries, STM32 control board, two-position switches on hot-swap board, pressure sensors, some resistors and capacitors are purchased from domestic supplier instead of overseas sailor. All these parts work well so we can obtain these materials in short time.

Camera is the most important sensor on the robot thus we carry out an investigation on it. The Point Grey camera with Lensagon BM3516NDC lens is adopted by Rhoban team, our team as well as Starkit team. A common feature of these three teams is that the robot must turn its head left-right-up-down continuously otherwise the robot would not find the object out of its narrow field of vision, i.e., 53°. By contrast some other teams, for example ZJUDancer, CIT Brains and MRL HSL, do not need to let the robot turn head so frequently. From their TDP we know their robot adopts wide field camera. From the point of human-like sensor capacity, a vision angle near 180° should be proper for soccer where no one always shaking head to tracking the ball. Then we take Point Grey camera, Logitech C930e and S-YUE from left to right to contrast as shown in Fig. 5 where their horizontal vision angle is 53°, 90° and 170° respectively.
Table 1 indicates their imaging effect on the same site point facing the same direction. If this case is what the robot sees through Point Grey camera and its head has turned to the right end, the robot would turn its body to left and shaking head to find the ball continuously so that the robot body will turn a circle before finding this ball. This may lose chance to challenge the ball compared to the robot equipped with 170°S-YUE camera. But contrast to Logitech C930e, S-YUE remains certain of aberration although it has been corrected. Maybe it does not impact the behavior of the robot since it will gaze the ball when detecting it while the central area of the image bearing little distortion. Another problem of using 170°S-YUE is that there may exit more than two goal posts on image. So we think the identification of goal can be changed to recognize the whole goal rather than the bottom of the goal, as human-being does. Last problem is the data transmission port. As TDP of Rhoban described, USB port of camera would interfere with the WiFi module so that the team-play of the robot group maybe hindered. We think this maybe overcome by using USB-RJ45 adapter.

| Cameras      | Resolution      |
|--------------|-----------------|
| Point Grey   | 1280×960        |
| Logitech C930e | 640×480      |
| S-YUE        | 53°         |

In a word, we plan to change Point Grey camera to cheaper and wide-angle S-YUE camera. However, we do not have full confidence to success because of unpredictable difficulties. So we
sincerely hope that we can do this job together with Rhoban and Starkit. We would glad to provide several S-YUE cameras to them for free (it is really very cheap) and these teams research the image collection, camera calibration, object detection, localization, and behaviors respectively. Then we share our technology and improve the vision system to human-like level, which would be a great step toward 2050 goal.

3. Some Plans on Software Work for SYCU-Legendary

The structure and algorithm of the software for our robot is still following that of Rhoban team in 2018. However, we are tracking their newly published code on github and we are making some changes. We believe that after two months we can share something with them and hope we can give some help to our kind and respected mentor. Based on practiced operation and debugging, we are making the following improvements:

1. The walking speed of the robot is faster. In 2019 RoboCup, Rhoban team has improved their robot speed for more than twice as before. We can also increase the stride length of our robot after 2019 game but the robot is often falling down. We are adjusting them to a stable state now.

2. The self-localization precision of our robot should be improved. The robots often give up the match during 2019 competition. It will not happen in 2020 RoboCup since we are modifying the software to let the robot identify two more targets on the field to help the self-localization algorithm converging more accurately.

3. The data from foot stress sensor is essential for robot localization in current software. But sometimes the stress signal fails to give to up-level computer so that the robot does not work at all. We plan to prepare a set of standby software that if the stress signal misses, the output of dynamic model is used to compute the rough position of the robot and then the particle filter compensate its deviation.

4. The two-level algorithm of ROI+DNN used by the robot to identify the targets is an ingenious design. However, after many competitions, we realize that the robot's vision system is difficult to adapt to various field environments. Every time the robots are taken to a new competition venue, some never-touched basic vision parameters should be adjusted to let the robot see the targets. Therefore we believe that we should do some work in image preprocessing to make the robot adapting new environment more easily.

5. In order to make the visual recognition model of the robot adapting to various lighting environment, we plan to sample the field under various light conditions so as to provide more complete sample sets for training neural networks which may resort to GPU.

4. Conclusion

In this paper we present the overall design and development of autonomous humanoid robot SYCU-legendary. The robot team of SYCU-legendary can fulfill soccer game without human control by virtue of its high intelligence that integrating the methods of D-H kinematics functions, particle filter, SLAM and deep-learning. The robot team of SYCU-legendary performed well and won the champion on 2018 and 2019 RoboCup competition China Open. In 2019 Sydney game, we ranked the forth. We are confident of gaining good achievements on 2020 World Games. Of course, we are looking forward to this opportunity to communicate with all the teams from various countries and areas. We also wish to assist both organizing committee and technical committee to make the competition favorable and successful. In the future we plan to establish an International Joint Laboratory with Rhoban team to research the key technologies to make the robot playing soccer with human as well as to popularize the humanoid robot to wide-spread application areas.

Acknowledgments

This research was financially supported by Liaoning Natural Science Foundation Project: Research on Intelligent Behavior of Humanoid Robot Combining v-slam and Deep Learning(2019-ZD-0345) and Research on visual environment cognition and brain like intelligent behavior of humanoid robot(2020-CSLH-41), Shenyang High Level Innovative Talent Project: Research and application of some key
technologies of humanoid robot(RC190324) and Shenyang Scientific and Technical Innovation Platform Establishment Plan Municipal-level Key Laboratory Project: Shenyang Humanoid Robot Key Laboratory (18-007-0-10).

References
[1] Toshio Fukuda, Paolo Dario, et al. Humanoid robotics—History, current state of the art, and challenges. Science Robotics, 2017,2(13):eaar4043.
[2] H.Kitano, M.Asada, et al. Robocup: The robot world cup initiative. Robocup: The robot world cup initiative.
[3] R. J. Griffin, G. Wiedebach, et al. Walking stabilization using step timing and location adjustment on the humanoid robot, Atlas. 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2017: 667-673(Vancouver).
[4] Taejin Jung, Jeongsoo Lim, et al. Development of the Humanoid Disaster Response Platform DRC-HUBO+. IEEE TRANSACTIONS ON ROBOTICS, 2018,34(1):1-17.
[5] Albert Mukovskiy, Christian Vassallo, et al. Adaptive synthesis of dynamically feasible full-body movements for the humanoid robot HRP-2 by flexible combination of learned dynamic movement primitives. Robotics and Autonomous Systems,2017,91:270-283.
[6] Hofer, Ludovic and Rouxel, Quentin. An Operational Method Toward Efficient Walk Control Policies for Humanoid Robots. Proceedings of the Twenty-Seventh International Conference on Automated Planning and Scheduling, ICAPS 2017, Pittsburgh, Pennsylvania, USA, June 18-23, 2017.
[7] K. Genter, T. Laue, et al. Benchmarking robot cooperation without pre-coordination in the RoboCup Standard Platform League drop-in player competition," 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2015: 3415-3420(Hamburg).
[8] https://www.robocuphumanoid.org/uploads//SYCU_Legendary-tdp-5c4de7e03b326.pdf
[9] https://github.com/Rhoban
[10] Wu Fenghua, Li Liande, et al. Design and Development of Autonomous Soccer Humanoid Robot CU-legendary. Journal of Physics: Conference Series, 2019:1176(3): 266-271. 2018 International Seminar on Science and Engineering Technology, SCSET 2018-Robotics and Artificial Intelligence, March 26, 2019. (EI:20191406738791).
[11] Wu fenghua, Li Liande,et al. Research on Key Technologies of Humanoid Robot[J]. Artificial Intelligence and Robotics Research, 2017,06(03): 97-105.
[12] Fenghua Wu, Tingxue Li, et al. Robot Subject Establishment through Popularity, Scholar, Research and Employer[J]. Laboratory research and exploration: 2019,38(08):189-196+208.
[13] Sudharsan, Jayabalan, et al. Simulation of 8-Degrees of Freedom Based Bio-Inspired Humanoid Robotic Arm Using MATLAB/ADAMS Co-Simulation Environment. Applied Mechanics and Materials. 2015,799-800:1054-1057.
[14] https://submission.robocuphumanoid.org/uploads//Rhoban-tdp-5c05011865144.pdf
[15] https://humanoid.robocup.org/qualification/2018/KidSize/Rhoban%20Football%20Club/tdp.pdf