Starkit – Global System and Robot Description

Humanoid soccer competition Kid-Size League, Robocup 2020 Bordeaux

A.Babaev, E.Davydenko, I.Khokhlov, N.Koperskii, V.Litvinenko, I.Osokin, I.Riakin, R.Savlaev, S.Semendiaev, P.Senichkin

7684067@mail.ru, egordv@gmail.com, khokhlov.iyu@gmail.com, koperskij.nyu@phystech.edu, litvinenko.vv@phystech.edu, kefir8888@gmail.com, ryakin.is@phystech.edu, ruhomor@icloud.com, robocup.mipt@gmail.com, senichkin.pm@phystech.edu

Moscow Institute of Physics and Technology, Dolgoprudny 141701, Russia

Abstract. This paper presents a brief overview of the design of the Kid-size humanoid robots from the *Starkit* team. It focuses on the description of our improvements in software, hardware and research projects related to playing soccer autonomously. As a base we took Rhoban 2019 Kid Size public release code[1].

1 Introduction and Last Participations

Starkit[2] is an on-going robotic project whose team members are students at Moscow Institute of Physics and Technology (Russia), Laboratory of wave processes and control systems.

The interest of the team is mainly focused on autonomous legged robots and their locomotion. Our two leading projects are a educational Kid-size and low cost humanoid bipedal robot based on Kondo servomotors that took first and third place in RoboCup Asia-Pacific Junior Football and a Kid-size humanoid robot with the RoboCup competition as major ambition (Sigmaban+ platform) that we bought from Rhoban Football Club[3] in 2018.

The very challenging problem of robots playing autonomous soccer in complex and semi-unconstrained environment has driven the team to propose new mechanical designs – spine-oriented robot have been tested, low-cost foot pressure sensors are experimented – and software methods – new custom servomotors firmware, learning algorithms applied to odometry, motion generation and navigation problems.

Our participation to Robocup 2020, up to the qualification procedure, would be the second one:

[1] Code available at: `https://github.com/Rhoban/kid_size_public/releases/tag/public_2019`
[2] The page of the team is accessible at: `http://starkit.ru`
[3] The page of the team is accessible at: `http://rhoban.com`

2019 (Sydney): Our first time in world competition was unsuccessful, but we got invaluable experience.

This short paper gives an overview of the Starkit robots hardware and software system in its current state with an emphasis on recent upgrades with the aim to participate to Robocup 2020 in Bordeaux, France.

Commitment

The Starkit commits to participate in RoboCup 2020 in Bordeaux (France) and to provide a referee knowledgeable of the rules of the Humanoid League.

2 Hardware Overview

The mechanical structure of the robot is a classic design using 20 degrees of freedom: 6 for each leg, 3 for each arm, and 2 for the head (pitch and yaw rotations). The global shape of the robot is mainly standard [4].

Our team uses Sigmaban+ model, developed by Rhoban[1] team, as a base and adds new features to it. It all focused on durability and robustness.

1. We design all possible part from carbon. It allows to reduce the weight of robot with saving durability. Also carbon details faster to produce.
2. Robot limbs was reworked. Previously each limb was connected only with servomotor axis. Now we use needle bearings. With this improvement we solve several issues. First of all, broken head and arms servos, that was really big problem. Secondly, we reduce legs backlash.
3. Battery connectors firmly fixed. This allows faster and more safe battery swap.
4. We change IMU to integrating one.
5. We started to use spring washer instead of glue. This extends screws lifetime.
6. We designed new springy arms. Now robot can take the ball with arms. Also it makes the falling softer.

3 Vision

This year our team sets a goal to minimize hand-tuning of vision system. First of all we started to tune green filter in HSV space, instead of in YCrCb space. This gives us significant improvement in green detection stability. Also now we are preparing goal posts and balls dataset to be able design neural network which can label new data itself. This will allow us to automate labeling process.

Also we changed our camera SDK from FlyCapture2 to spinnaker. It‘s very hard to buy FLIR camera that supports FlyCapture2 now.

[4] see the robot specification paper for a more complete description

4 Walk Engine

We took Rhoban Walk Engine without any changes.[5]

5 Localization

Default Rhoban code release 2018 localisation system is based on Particle Filter approach, utilizing only one type of detected features for filter update: the goal posts observations and field borders[6]. Goal posts detection is done similar to ball detection: windowed search in integral image domain for ROI (Region of interest) extraction, and found ROI filtering using lightweight neural network classifier. This approach of goal posts detection was initially introduced by SPL team Berlin United for limited onboard resources of NAO robot. Current Rhoban robot uses a NUC i5 computational platform which is much more powerful than NAO builtin low-power CPU. So to improve the localisation performance we tried in 2019 different approaches utilising unused rhoban platform computational power.

5.1 ORB-SLAM integration attempt (unsuccessful)

As a first attempt we decided to use the well-known Monocular Visual SLAM system called ORB-SLAM[4] [7] initially developed by Raúl Mur-Artal for localisation because we already had a good experience in Visual SLAM systems from our other research projects by that time. Not to integrate the whole ORB-SLAM system into rhoban code release, we installed onboard ROS[5] (Robot Operating System) as a middleware and developed a bi-directional linkage of rhoban visual pipeline and ROS. Rhoban Flycapture SDK based frame capturing system was extended to publish captured frames to ROS subsystem in real time with appropriate timestamping. Then this frames were processed by modified ORB-SLAM system inside ROS running in parallel with Rhoban visual pipeline. Resulting localisation guess was injected backwards to Rhoban particle filter as a special type of observation with high potential. ORB-SLAM localisation system was extended by us to be able to generate, save and load the map of the environment. Also we developed a visual tool and mapping procedure from SLAM output map to the field in which Rhoban performs it's actions by marking the distinct field features (central circle, goal posts) in generated 3D map from SLAM system and performing the coordinate system transformation. This system showed stable performance in our lab so we decided to use it during Sydney 2019 Robocup competition with no success. Sydney 2019 environment had much less distinctive features surrounding playing field close enough to it for the monocular SLAM system to be stable and robust. The playing fields were mostly surrounded with

[5] Code available at: `https://github.com/Rhoban/kid_size_public/blob/master/Motion/engines`
[6] `https://github.com/Rhoban/hl_kid_public/tree/master/Vision/Filters/Goal`
[7] `https://github.com/raulmur/ORB_SLAM`

a plain white fence without any advertising materials/etc usually exists in other competitions similar to human soccer competitions, and the ceiling was very high and repetitive. This forced us to disable the SLAM system and use the default rhoban goal posts detection which led to bad localisation performance and unsuccessful results in this competition, especially because of the different material and visual appearance of goal posts used in our lab and in Sydney forcing us to tune the ROI extraction system and retrain the neural network classifiers. The SLAM system we used is similar to the so-called "Visual Compass" approach [8] of Rhoban's team which as far as we know also wasn't used by them in Sydney 2019 competition. Visual Compass and SLAM utilise the same underlying principle of prior environment mapping and leading visual feature detection and classification, but Visual Compass gives only orientation guess and SLAM gives both position and orientation.

5.2 Using observations with embedded orientation

After Sydney 2019 competition we done extensive research to improve the particle filter performance by introducing new types of observations to it rather than completely changing the localisation system like SLAM attempt was. For the proper debugging of different observations we extended the rhoban particle filter subsystem to generate so-called ≪heatmap≫ of found observation to visualise its effect on the particle filtering potential. The observation effect to particle filter being visualised as an image with areas of high particle potential marked as a ≪hot≫ spots and areas with almost zero potential marked as a ≪cold≫ spots similar to the output of an imaging infrared thermometer. Debugging using heatmap approach showed us that the low performance of a goal posts detection localization mainly follows from omni-directional nature of the goal posts. Single goal post observation gives no information of robot orientation on the field, only the distance guess from robot to goal post can be extracted. To get an orientation guess required for good localisation the robot has to observe at least two of the goal posts simultaneously or close in time. In game situations when one of the two closest to robot goal posts being occluded by other robot or being seen from a bad viewing angle (in the corner of the field, inside the goal, etc) the single goal post observation gives not enough information for stable localisation. So we introduced a new type of observation to particle filter using the detection of field marking white lines features. Comparing to the goal post observation, the ≪L≫-shaped white lines corner observation has an embedded information not only about the distance from which it was observed, but also about the orientation of the robot required to be for exactly this visual appearance of line corner feature. Using the heatmap approach it's clear to see that the single goal post observation gives a large ring-shaped potential in the particle filter domain, comparing to the line corner observation which gives a small local blob which has much less area than the goal post leading to better localisation performance.

[8] `https://github.com/Rhoban/hl_kid_public/blob/master/Vision/Filters/Features/VisualCompass.cpp`

Further the ≪T≫ and ≪X≫-shaped line corners of the field marking gives two and four observations in one detection accordingly, leading for more information to be used by the particle filter improving its performance. According to the new 2019 code release, Rhoban's team also uses the same principle of line features observations in particle filtering, but our realisation was developed completely independent (and prior to 2019 code release) and diverges from Rhoban's 2018 code release initially without this feature. Using this localisation approach we were able to win the Robocup Asia-Pacific 2019 event in Moscow, compelling with only single Iran MRL-HSL[3] team which was kind enough to visit Moscow for this competition and we are very appreciate it.

We have expanded space for new particle generation. Now robot can localize itself outside the main field markup.

6 Kick

Direction of the grass greatly influences kick strategy. When robot performs kick counter grass, it is much profitable to kick the ball over the grass. We reworked forefoot to do this kick available. Now it has more sloping surface. Also there is dependency between stability and force of kick. Now we are balancing with arms while kicking. This allows us to do stronger and more stable kick.

7 High-Level Decision Making

7.1 Active Falling

Our team has quite big robot for Kid Size competition regarding to other teams. This makes it hard to stand up fast. We note that this fact highly influences on our ability to control ball. Using fact, that we significantly improve durability of shoulder, we developed motion, that activated when robot falling forward or backward. We designed this motion in way to get more comfortable pose for starting stand up motion. Home tests show that using this we cut down time of inactive because of falling on 30 percent when it falls forward and on 65 percent when it falls backward.

7.2 Dribbling

Ball control is very important part of football. All teams used to just kick ball towards the goal. We want to add new element of game - ball dribbling. Now we use quite simple dribbling algorithm. Robot approaches the ball and instead of kick goes to the opponent goal controlling ball using lateral step. We divided field into dribbling and kicking zones. For example, when robot near our or opponent goal it is much safer to kick. We faced several problems:

– Robot needs to look at the ball too often. This cuts down number of visual observations for particle filter.

– It is need to do much complicated solver between kick and dribbling. We believe that enemy detection and better localization will improve it significantly.
– When robot walks fast - ball rolls far and unpredictable.

Our team believes that this feature will improve quality and entertainment of the game. We plan to solve all enumerated problems to RoboCup 2020.

8 Contributions

– Robocup Asia-Pacific 2019 – 1st place in Humanoid KidSize
– Robocup 2019 – 1st place in SPL Challenge Shield
– Robocup German Open 2019 – 3rd place in Humanoid KidSize
– Robocup Russia Open 2019 – 1st place in Humanoid KidSize

Our team was an active organizer of Robocup Asia-Pacific 2019 Moscow. We made and provided the field, gates, Wi-Fi router, and also we were the TC/OC of the competitions in the Humanoid league of RCAP 2019 Moscow. In general, our activity is aimed at popularizing RoboCup in Russia. Moreover, we plan to organize a tournament in the Humanoid soccer league in Russia on the basis of our institute in the spring of 2020. We gave a lot of interviews to newspapers and magazines. Our interviews were shown on Russian television. An article in the popular Russian magazine "Popular Mechanics" was dedicated to our team and robosoccer. An article in a scientific journal is listed in the Publications section of this application[2].

References

1. J. Allali, L. Gondry, L. Hofer, P. Laborde-Zubieta, O. Ly, S. N'Guyen, G. Passault, A. Pirrone, and Q. Rouxel. Rhoban football club–team description paper. Technical report.
2. R. Gorbachev, S. Semendyaev, I. Khokhlov, V. Litvinenko, and I. Ryakin. The robosoccer as a modern educational platform in the field of artificial intelligence. *IEEE Proceedings of international conference on artificial intelligence: applications and innovations (IC-AIAI 2019)*, pages 55–57.
3. Hamed Mahmudi, Alireza Fatehi, Amir Gholami, Mohammad Delavaran, Soheil Khatibi, Bita Alaee, Saeed Tafazol, Maryam Abbasi, Mona Doust, Asal Jafari, and Meisam Teimouri. Mrl team description paper for humanoid kidsize league of robocup 2019. 04 2019.
4. Montiel J. M. M. Mur-Artal, Raúl and Juan D. Tardós. ORB-SLAM: a versatile and accurate monocular SLAM system. *IEEE Transactions on Robotics*, 31(5):1147–1163, 2015.
5. Morgan Quigley, Josh Faust, Tully Foote, and Jeremy Leibs. Ros: an open-source robot operating system.