ZJLabers Team Description Paper
Humanoid TeenSize League of Robocup 2019

Yun Liu, Hongjian Jiang, Qiang Hua, Te Li,
Yuehua Li, Senwei Xiang, and Sumian Song

Intelligent Robot Research Center,
Zhejiang Lab, Hangzhou, China
Email:liuy@zhejianglab.com
https://zjlabers.icoc.bz/

Abstract. This paper describes the humanoid robots developed by team ZJLabers from Zhejiang Lab as an experimental platform for research in areas of bipedal locomotion and control, visual perception, self-localization and autonomous decision-making. The robots will also be used to compete in TeenSize humanoid league at Robocup 2019, Australia. Further details of the robots are provided, including robot specifications, mechanical design, electronics, sensor specifications as well as software overview.

1 Introduction

ZJLabers is a humanoid robot soccer team running at Intelligent Robot Research Center of Zhejiang Lab in Hangzhou, China. Our team was newly established in July 2018 and it is our first time to participate in Robocup TeenSize humanoid league competition. However, we are not completely a rookie to this competition as our team leader is an experienced Robocup veteran who had consecutively taken part in RoboCup 2015-2017 in KidSize and won 2nd place for each time. The research interests of our team are bipedal locomotion and control, visual perception, self-localization and autonomous decision-making. We are dedicated to making substantial contributions to achieve the ultimate goal of building up a team of humanoid robots that can play against human soccer team in 2050.

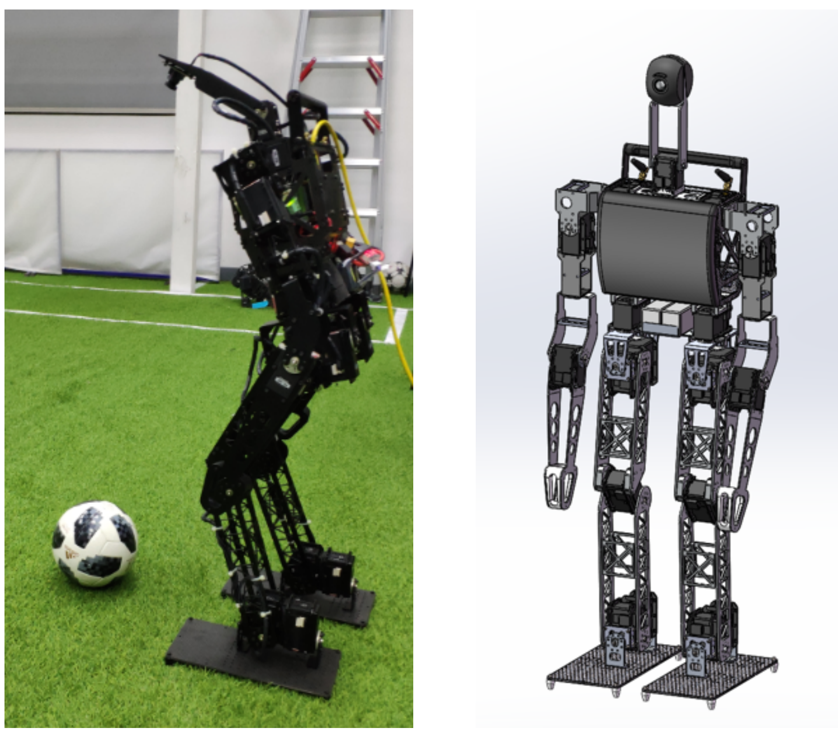
This document gives an overall description of the autonomous biped robots we built for the TeenSize humanoid competition at Robocup 2019 in Sydney, Australia. Our robot is developed based on the previous work of ZJUDancer and NimbRo[7,8]. In order to achieve superior performance, significant modifications and improvements have been made to the hardware and software of our robot. Details of our robot are provided in the following sections.

2 Robot Specifications

Table. 1 shows the general specifications of our robot. Referee directions can be sent to the robot through the wireless network. There are five roles in strategy named Striker, Defender, Support, Observer and Goalkeeper. Fig,1(a) shows our robot kicking the ball and (b) is the mechanical sketch of the robot. More details will be introduced in the following sections.

Table 1. General Specifications of the robot

Team Name	ZJLabers
Number of DOF	20
Height	88.5cm
Width	33cm
Weight	5.8kg
Computing Unit	Nvidia Jetson TX2



(a) Robot Kicking the Ball (b) Mechanical Sketch

Fig. 1. Robot of ZJLabers

3 Mechanical Design

Our robot has two legs, two arms, a trunk and a head, as shown in Fig.1. The robot has 20 DOFs with 6 in each leg, 3 in each arm and 2 in the head. In order to enable flexible leg movement, each leg is consisted of a 3-DOF hip joint, a 2-DOF ankle joint and a 1-DOF knee joint. Each DOF is realized by a servo motor. Table 2 shows the implementation details.

Compared to ZJUDaner, our robot is bigger to adjust to the TeenSize field. An extra DOF is added to the shoulder joint so that our robot is able to use arms to keep balance during movement. In addition, the forearms of the robot are longer, which proved to be very helpful for the robot to stand up from the ground when falling down. We changed the location of the computing unit for better heat dissipation. In contrast to Nimbro, the chest and feet of our robot are made of carbon fiber, which significantly reduces the weight and cost of our robot.

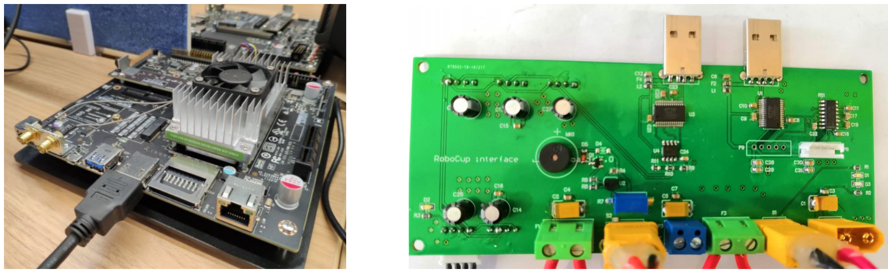
The battery is placed at the bottom. The handle is designed at the shoulder of the robot, which makes it convenient for the handler or referee to pick up the robot during the game. The emergency stop/power cut button is mounted on the shoulder of the robot.

Table 2. Motor types and Distributions of DOF

Part	Rotation Axis	Actuator
Neck joint	Yaw, Pitch	MX-28, MX-28
Shoulder joint	Roll, Pitch	MX-64, MX-64
Elbow joint	Pitch	MX-64
Hip joint	Roll, Yaw	MX-106, MX-64
Knee joint	Pitch, Pitch	MX-106, MX-106
Ankle joint	Pitch, Roll	MX-106, MX-106
	Total DOF	20

4 Electronics

The circuit architecture can be seen in Fig.2 and 3. Our circuit mainly includes the main controller and the expansion board. The main controller adopts Jetson TX2 as the core computing unit, specifications of which are shown in Table3. The main controller processes object detection, self-location, strategy selection and multi-robot communication. Furthermore, the movement and balance maintaining are implemented in the main controller. We use a USB hub as a medium for connections between the main controller and IMU, camera and the motor controller. The expansion board communicates with the main controller via USB and s provides hardware interfaces for external devices. The power management component is also realized in this board, which would alarm when the battery drops below a certain critical voltage.



(a) Nvidia Jetson TX2 (b) The expansion board

Fig. 2. Electronic Specifications

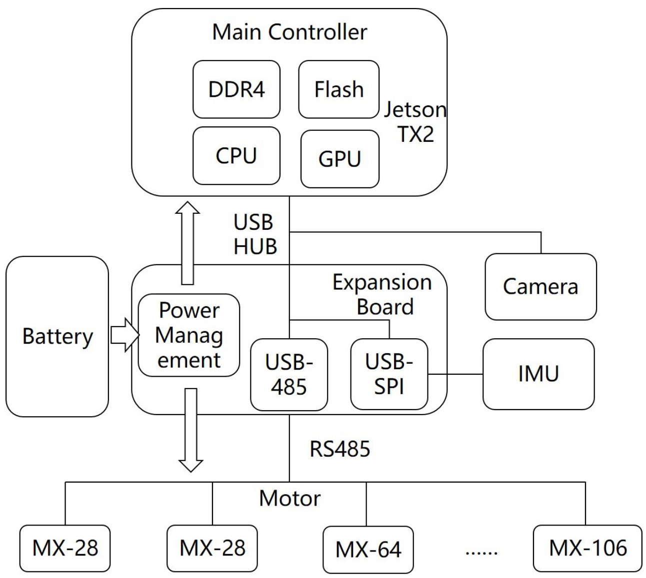


Fig. 3. Robot's Electronic Architecture

Table 3. Electronic Specifications

	Main Controller
GPU	NVIDIA 256 cores
CPU	ARMv8 (64-bit)
RAM	8GB LPDDR4
FLASH	32 GB eMMC

5 Sensor Specifications

There are 3 types of sensors equipped on our robot, which are image sensor, IMU, and servo motor.

- Image sensor. We use OmniVision OV2710 with 150degree FOV. This kind of camera has a wide view and it helps to improve the efficiency of perception.
- IMU. Analog device ADIS16405. Featured with tri-axis gyroscope, and tri-axis accelerometer. It returns the angular velocity for the trunk of humanoid robot. After the design, the IMU remained at the center of the chest.
- Servo motor. We use Dynamixel MX-28R, MX-64R, MX-106R[4,5,6] to get angle feedback from the joints of the robot, such as shoulders and knees etc.

6 Software Overview

There are several separate modules for different tasks. The whole software architecture can be seen in Fig.4.

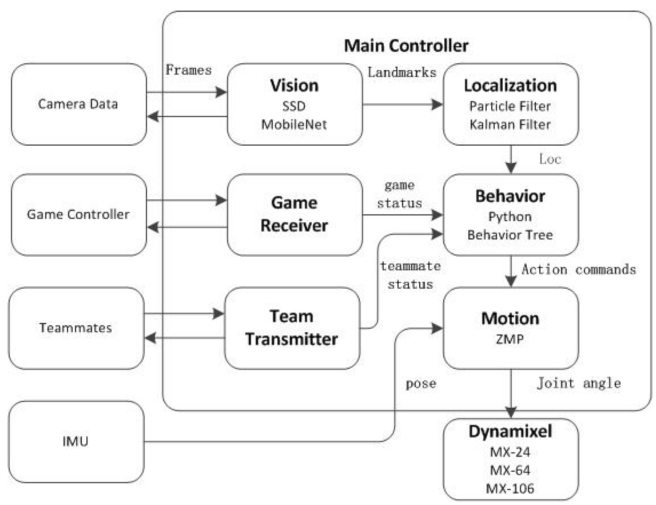


Fig. 4. Software Architecture

The key modules in software architecture can be described as below:

- Vision[1,2]:This module is designed to detect key objectives from the real-time video obtained by the OmniVision OV2710 camera. These objectives include the filed, lines, circle, goal, obstacles and the ball. We mainly use color filtering method to achieve the detection tasks based on the prior knowledge that different objects have different colors, for example, the filed is green while the lines are drawn in white. For details, the image data will first be converted to HSV color space and a green color filter is applied to extract the field. Then the filed image is binarized by using the Canny edge detector to get a preliminary result. The classical Hough Line Transform and the Hough Circle Transform are further applied to the binary image and a set of verification procedure is used to eliminate noises and detect the lines, the goal and the circle in the field. The designed verification procedure fully utilizes the domain-specific knowledge by encoding any relevant information about objects, including shape, area, length and included angle. Contrary to the above, the ball is recognized based on a deep learning approach named Darknet. Thanks to the supe-fast Darknet and powerful NVIDIA Jetson TX2, the ball can be detected in real time.

Fig.5 shows the detection result by using our vision module. The right image is the binary result by using the Canny detector and the left image shows the final detection of the site. The field is drawn by orange lines and the goal is represented by two orange rectangles. The lines and the circle are marked in purple while the yellow rectangle indicates the ball. It can be seen that the detection result is basically correct, and we still have a long way to go to further eliminate noises and improve detection accuracy.

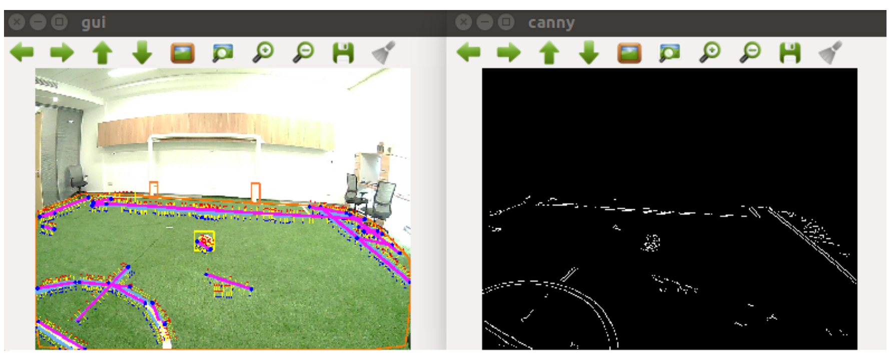


Fig. 5. The detection result of our vision module

- Localization[3]: It is very important to maintain a current global position of the robot. We achieve this by using a localization model shown in Fig.6. The robot starts from a known position and we can get its current location through odometer algorithm. During positioning, IMU data is used to improve the localization performance and get the posture of robot. After a period of motion, the robot's position will become very inaccurate because of accumulated error. In order to increase the accuracy of positioning, the robot must consider using the external environment to locate itself. In this project, we use visual method to achieve this. The position of the center circle and goal relative to the field is fixed. Therefore, we trained a deep learning framework to recognize goals and center circles. After recognition, we can get the relative position between the robot and the goal or center circle. Then, the global position of the robot can be obtained and updated.

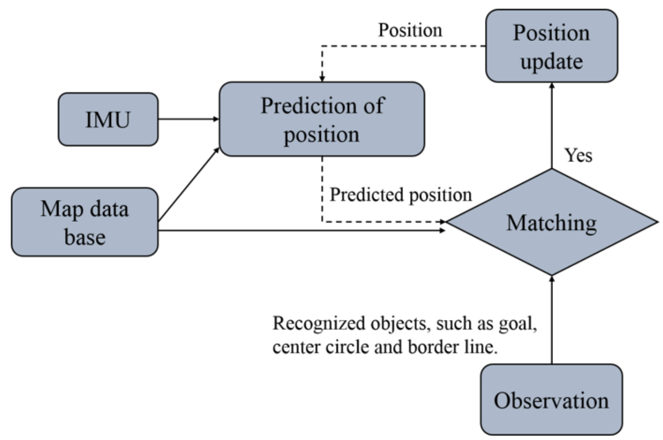


Fig. 6. Localization model

- Behavior: Based on behavior tree and finite state machine, this package processes location messages from Localization package and control commands from Game Receiver, and then outputs the action commands to Motion package.
- Motion: The aim of this package is to realize some key motions, e.g., walking, turning, hunkering, kicking etc., through driving those serve motors. Specifically, the walking gait is designed basing on the model of three-dimensional linear inverted pendulum. By planning the trajectories of the hip joint (approximate center of mass) and swing foot, the target trajectory of each motor is finally obtained. As for the kicking action, the entire action is split into several sub-phases (lifting foot, kicking, and recovering). In each sub-phase, joint trajectory planning is achieved by planning the postures of the upper body and the foot.

7 Conclusion

This paper presents the hardware and software overview of the robots developed by the members of team ZJLabers. As a newcomer to Robocup TeenSize humanoid league, we have put a lot of effort and time to be prepared for the competition, especially building our robot from scratch. We are excited to start a journey at Robocup 2019 and look forward to competing and sharing experience with other teams from all over the world.

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