Tsinghua Hephaestus 2017 AdultSize Team Description

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Abstract. This document describes improvements in hardware and software of THU-Strider Pro, detailing its new specifications, which is upgraded from the RoboCup 2016 version in our effort to be qualified for the RoboCup 2017 Adult-Size HL competition. Strider Pro is developed by team Tsinghua Hephaestus as a platform for research in bipedal locomotion, robot self-localization and machine learning for real robotic application.

1 Introduction

Tsinghua Hephaestus is a RoboCup Humanoid League team running at the Dept. of Automation, Tsinghua University, China, since July 2006. Our current research interest is focused on integrating Model Predictive Control into closed-loop biped walking and on robot self-localization. We started taking part in the RoboCup Humanoid League from 2007 with excellent performance. We joined the AdultSize HL in 2011 and came 2nd soon after that in RoboCup 2012. In 2015, we decided to use modular actuators provided by ROBOTIS and waive the previously used parallel double crank mechanism to make the robot more flexible in manifold terrains not limited to the soccer field.

Before 2016, we used an offline open-loop gait planning algorithm based on passive dynamic walking (Virtual Slope Walking[1]), and ZMP for kicking. Its open-loop properties brought us success in Robocup Games, but we want to move on and challenge ourselves by using online closed-loop gait control like Model Predictive Control(MPC). In order to improve the intelligent ability of Strider Pro, deep neural network based soccer field object recognition and Monte Carlo localization are applied.

This document will give a general overview of Strider Pro, including the weak points we found during 2015-2016 and how we improved them on the upgraded Strider Pro.

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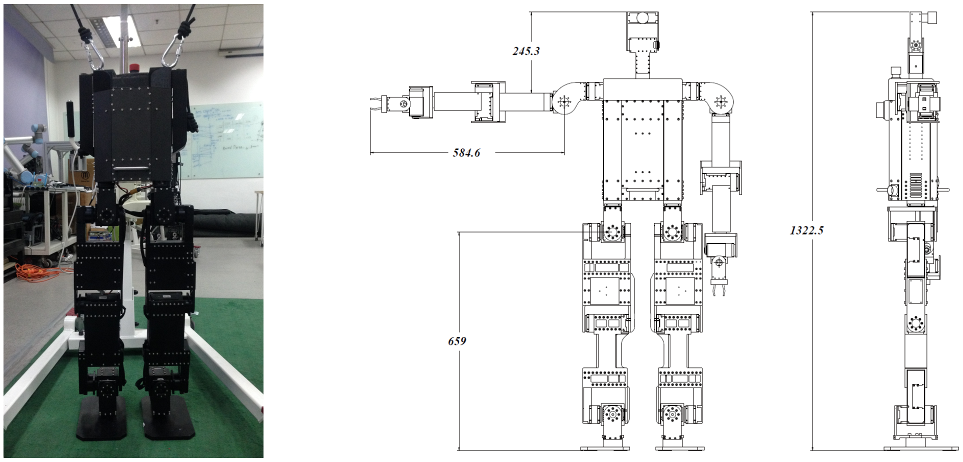
* preferred referee

2 The Hardware Design



(a) Strider Pro

(b) Strider Pro Dimensions

Fig. 1. Upgraded robot THU Strider Pro

Fig. 1(a) shows our upgraded robot Strider Pro. Its arms and head will be added later, according to the design in Fig.1(b). The latest Strider Pro has a height of 1322.5 mm, and weighs 38Kg with batteries.

2.1 Shortcomings in previous version

For Strider Pro, Robotis Dynamixel Pro servo motors are used as actuators for legs and arms. In Leipzig, we realized several weak points were in need of improvement in the Hardware design, including:

a) The backlash of the transmission gears is significant.

b) Strider needs a Real-Time Motion controller to maintain its high performance.

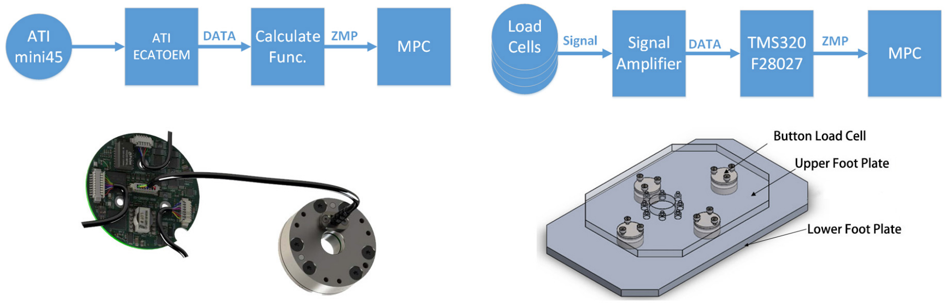
c) Exact ZMP is required for our online MPC algorithm in the real-time system.

2.2 Improvements in the newly-built Strider Pro

We made some significant modifications to hardware system in Strider Pro last year:

(a) The gear drive were replaced with belt drive to reduce the transmission backlash. **(b)** The NI RoboRIO is used as our Real-Time controller in the **Motion Control Layer**, instead of the previous single NUC-based Behavior Control[3].

(c) Two versions of ZMP measurement were designed(Fig. 2) for research and competetion respectively. In version A(Fig. 2(a)), we use two costly ATI's Force/Torque Sensors to get an accurate data flow. However, for the RoboCup competition we use version B(Fig. 2(b)) with a self-designed foot based on TMS320F28027 and 4 load cells, in order to reduce its cost.



(a) version A: for research (b) version B: for competition

Fig. 2. Sensory system for ZMP measurement

We use an Intel NUC(i7-5700) as the Behavior Controller of the robot(Host), and an NI RoboRIO as the Motion Controller(Client) to give commands to the DXL Motors on four RS-485 buses. Ethernet is being used for communication between Host and Client. We use a PointGrey Bumblebee 2 stereo camera and an XSENS gyrometer for Vision and Localization. The details of the control system are shown in Fig. 3.

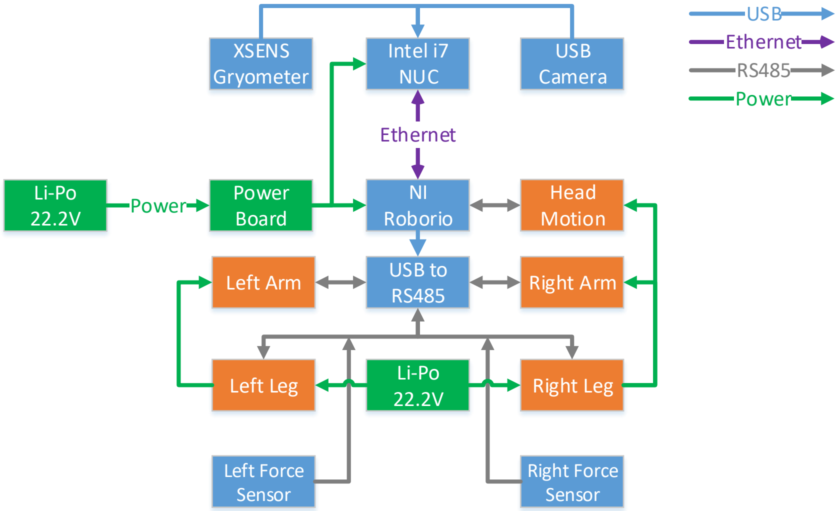


Fig. 3. Control System Architecture

3 Software Architecture

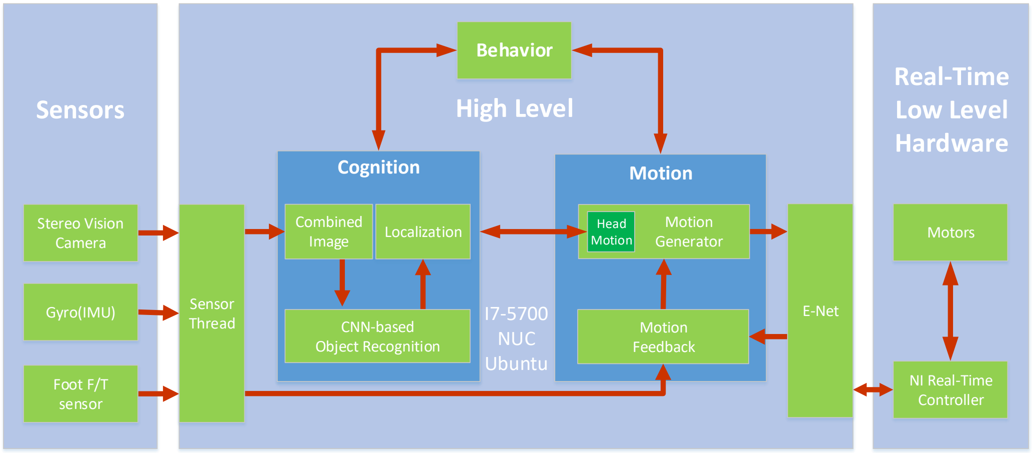


Fig. 4. Software Architecture

The software architecture is mainly developed on Robot-Operating-System(ROS) Kinetic Kame.

The whole software system consists of three main modules: Cognition, Behavior and Motion as we used before[2] except the Real-Time part in Motion has been moved into NI RoboRio. Each module runs several different nodes in parallel to realize a specific function. Module configurations and data flows are shown in Fig. 4.

This year, more elaborate sensors were added to gather information about the real-time ZMP and the depth of objects can be calculated from the Bumblebee 2 stereo camera.

4 Vision

The visual perception system depends on the input of a head-mounted PointGrey Bumblebee 2 stereo camera. The combined Field of View of the left and right camera reaches approximately 100° horizontally and 50° vertically at every instant, while the robot's head can rotate with a tilt range of approximately $[-60°, 30°]$. and a yaw range of approximately $[-90°, 90°]$.

After the combined image is reconstructed from the input of both the cameras obtained over ROS, we process each frame to realize object recognition, based on a Convolutional Neural Network (CNN[8]). At the same time, after comparing the left and the right image feeds, we extract depth information, which is also used for other **Behavior** module functions. An overview of the visual perception system can be seen in Fig. 5 below.

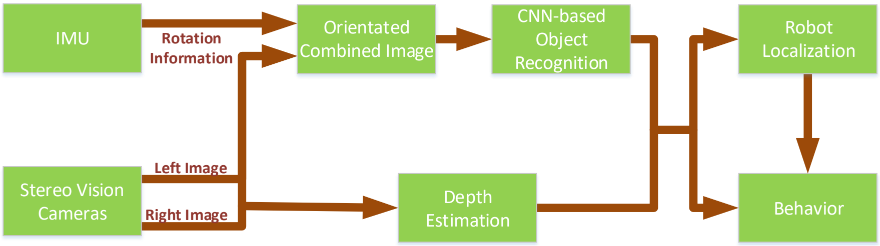


Fig. 5. Visual Perception System Overview

4.1 Object Recognition

Our object recognition algorithm comprises the detection and classification of the main soccer field static components, i.e. the ball and the opponent robot. We firstly utilize a combination of Breadth-First-Search[6] and Pyramid representation on a downsampled version of the image, in order to detect different areas of interest. Structural and color information are also used to provide early indicators of such areas. In continuation, we use a CNN to classify them into areas that contain the above components. The depth information is additionally calculated for the objects and the objects' location and size information is forwarded via a ROS message to the Localization and Behavior modules.

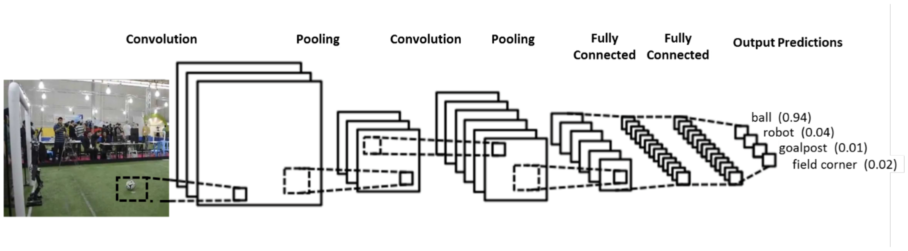


Fig. 6. CNN basic structure for object recognition

Regarding the CNN, we create the neural network as simple as possible, to avoid high computational demands and elongated process time. The implemented CNN is similar in structure to the one seen in Fig. 6. We train our CNN offline given series of recorded videos with positive and negative samples in various scales, viewing angles and lighting conditions. The resulting CNN can reliably differentiate among categories, providing a metric for the certainty level as well.

4.2 Localization

Given the newest rules[7], both adult-sized robots are able to move around the field simultaneously creating a great need for accurate localization of both robots. Assuming the accurate recognition of the field's static landmarks, and their depth calculation, we implement an algorithm of localization based on a Particle Filter (Monto Carlo Localization)[2]. Every time we get new Vision, Gyro and Odometry provided data, the likelihood of each particle is updated. After resampling the particle set, we can approximate the position and orientation of the robot by calculating the mean pose of the particles. If that estimation is accurate, we can obtain the opponent robot's relative location through its visual recognition and depth information. The end result of the localization algorithm looks similar to Fig. 7. Information about Strider Pro and ball locations is represented by circles, with radii proportional to the uncertainty of the localization estimation.

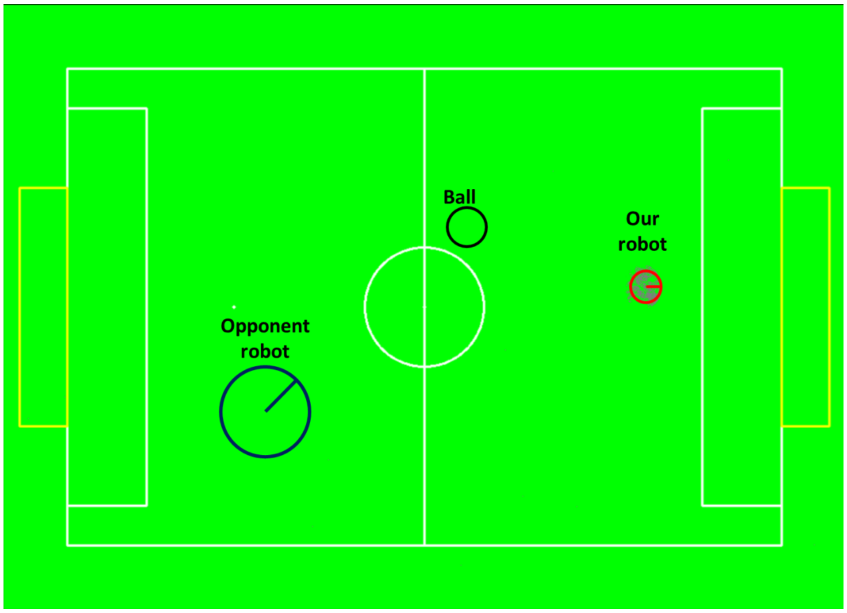


Fig. 7. Localization result visual representation

5 Behavior Control

A specific Hierarchical State Machine is designed for the Robocup HL Game using the XABSL(Extensible Agent Behavior Specification Language) as we used before[2].

The Behavior Control module plays an important role in the game, just as shown in the Fig. 4. It extracts useful data from massive information so as to plan an appropriate action for the Strider Pro to execute.

6 Gait Planning

Overall, for low level motion control, we implement several gaits in legged locomotion: ***(1) the Passive Gait***[1], which can achieve a maximum forward walking speed of 0.6m/s on Strider Pro. ***(2) the Preview Gait***, using the cart-table model[4] and MPC to generate optimal walking pattern with accurate tracking. ***(3) the Capture Gait***, which uses Capture Point[5] to generate a robust walking pattern or recover from unknown disturbances. ***(4) the Special Gait*** obtains some special motions like kicking, turning around or transition between standing and walking. Finally, a state-machine is designed for handling switching of different gaits.

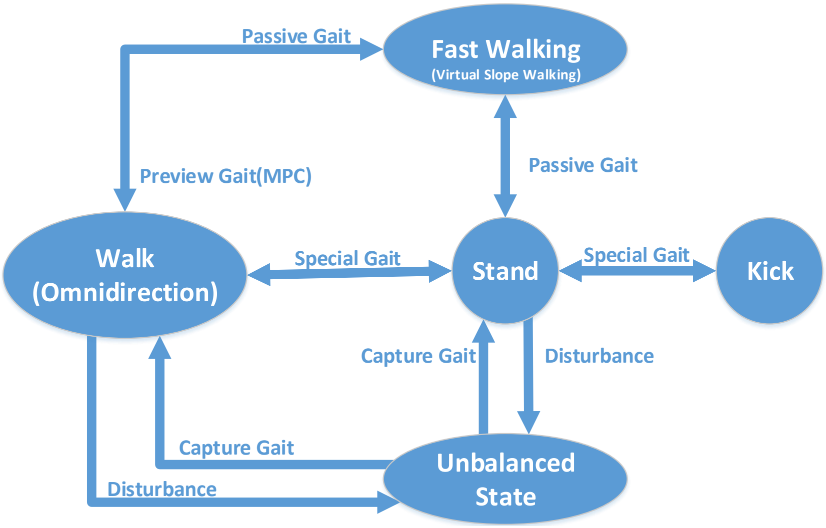


Fig. 8. State Machine of Gait Switching

Instruction sent by behavior module is translated into sequence of joint angle by different Gait Algorithm. The sequence is treated as a reference in NI RoboRIO to Control motors' angle at 200Hz in real-time.

7 Conclusion

In this paper we presented the specifications and functions of the Strider Pro, as well as some related works on vision, localization, gait planning and control. Our adult-sized robot Strider Pro is a completely autonomous humanoid robot, with a stereo camera, an IMU and 26 actuators integrated on body, controlled by an NUC and an NI-RoboRIO.

7.1 Team Members

Tsinghua Hephaestus commits to participate in RoboCup 2017 in Nagoya and to provide a referee knowledgable of the rules of the Humanoid League. Currently, the Tsinghua Hephaestus AdultSize soccer team consists of the following members:

Team Leader: Haitao Wang

Team members: Rongge Zhang**(Preferred Referee)**, Sotirios Stasinopoulos, Kaidan Yuan, Siyuan Yu, Yicheng Kang, Guangjun Hei, Lee Boon Shen and Mingguo Zhao.

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