Tsinghua Hephaestus 2016 AdultSize Team Description

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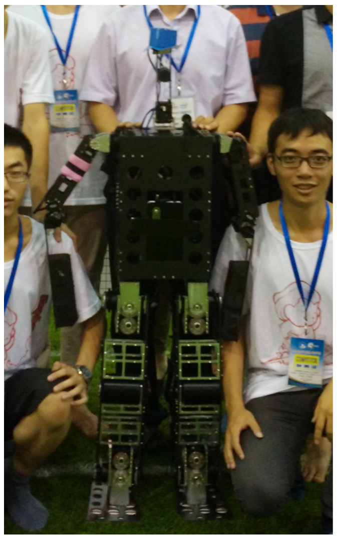
Abstract. This document describes both hardware and software specifications and practical functions of the humanoid robot Strider Pro, developed by team Tsinghua Hephaestus as a platform for research in bipedal locomotion, robot self-localization and machine learning in real robotic appication. The robot will also be used to participate in AdultSize competition in Humanoid League of RoboCup 2016, Leipzig.

1 Introduction

The Tsinghua Hephaestus is a RoboCup Humanoid League team running at Dept. of Automation, Tsinghua University, China, since July 2006. Our current research interest is focused on bipedal locomotion[1][2][3][4], robot self-localization[5][6] , reinforcement learning and model predictive control . The humanoid team had taken part in the RoboCup2007 and RoboCup2008 both in KidSize and TeenSize. In the RoboCup2008, our TeenSize team got the 2nd place and our KidSize team went into the Round Robin2. Moreover, our TeenSize team got the 3rd place in Robocup 2009 and 2010. From 2011 and on we started to participate in Adultsize. We got the 3rd place in RoboCup2011, 2rd in Robocup2012 and 3rd in 2013 and 2014. Now we have been getting prepared for Robotcup 2016 with our new designed Adultsize Humanoid robot Strider Pro. We developed an AdultSize humanoid soccer robot (THU-Strider) for Tsinghua Hephaestus RoboCup team in RoboCup 2011 to RoboCup 2015. Strider Pro is an upgrade version of THU-Strider. The main goal is to develop a stable and fast walking soccer robot. A gait algorithm based on passive dynamic walking (Virtual Slope Walking) is been adopt for walking gait generation and ZMP based Model Predictive Control is adopted for kicking and path planning. This document will give a general view of the robot.



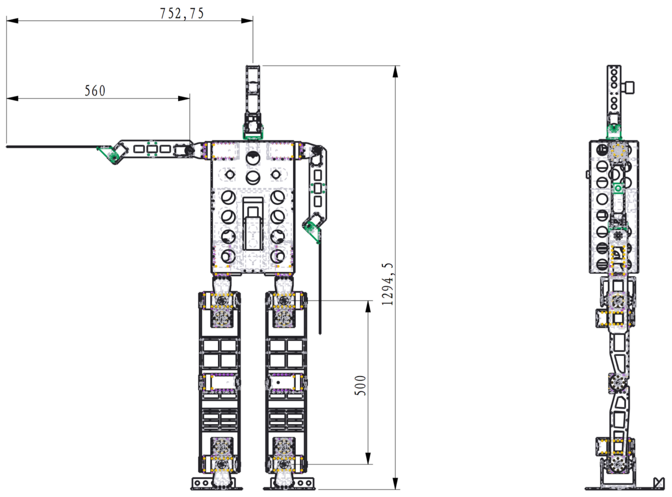


Fig. 1. 1) Strider Pro robots 2) Robot Dimension

2 The Robot Design

Fig 1-1) shows our Strider Pro robot in practice. The robot has a height of 1300 mm, and weights 32Kg, including batteries. The detailed dimensions are shown in Fig. 1-2). The robot has 20 DOFs: 6 in each leg, 3 in each arm, 2 in the head. For Strider Pro, Robotis Dynamixel Pro H54-100-S500-R high power and accuracy servo motors are used as actuators for legs and 8 Robotis MX106R are used for arms. We use use an Intel NUC DC32171YE as the Main Controller of the robot, with two USB ports, one for the motion-control, another for the gyro and the USB camera. Specifically, an Mti-28A83G25 Gyro is mounted on top of the robot head, while a PointGrey USB camera accompanied located in the robot head is employed as our visual sensor. Buttons and LEDs, located on the back, are set to control and indicate the robot state. The motors of upper body are connected in series on a RS-485 bus and lower body (leg) motors are connected in series on a LVTTL bus. The details of the control system are shown in Fig. 2.

3 Software Architecture

The software architecture is developed on Robot-Operating-System(ROS) and the distribution used is ROS Hydro. The whole software system consists of three main modules: Cognition, Behavior and Motion. Each module runs several different nodes in parallel to realize a specific function. Modules are arranged so that they are independent from each other.

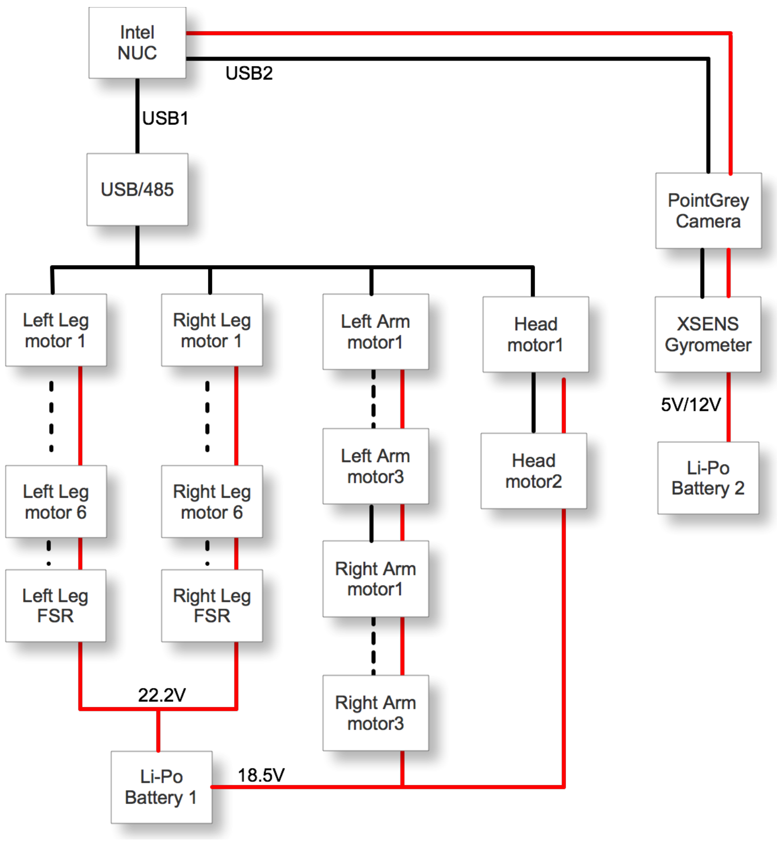


Fig. 2. Control System Architecture

Both Cognition and Motion interchange data with Behavior through ROS messages or services. Cognition is responsible for information gathering from both cam- era and Gyro, self-localization and perception. Motion is responsible for gait planning and motor controlling, while Behavior acts as the brain of the robot, analyzing the data from Cognition and sending orders to Motion. Module configurations and data flows are shown in Fig. 3.

Image Grabber grabs images from the vision sensor and generates related information of the image and the pose of the camera.

Image Processor processes the incoming images grabbed by Image Grabber, and yields information needed for Localization and Behavior Control.

Localization&Perception: implements the Particle Filter localization algorithm, manages position information of robots and the ball, so as to be used by Behavior Control.

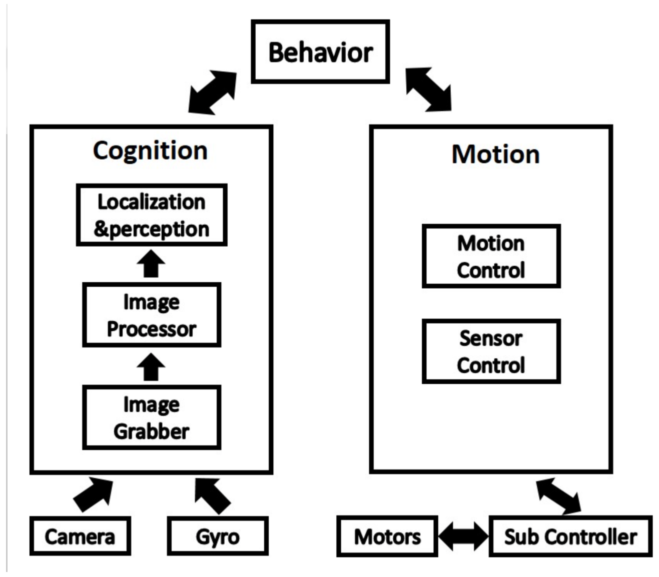


Fig. 3. Software Architecture

Behavior controls the game process and makes behavior decisions.

Motion Control manages all the actuators of the robot, and controls locomotion or any other actions of the robot according to the requests from Behavior.

Sensor Control manages other sensors, and interacts with the Sub-Controller.

4 Vision

A Point Grey camera is employed as our visual sensor. The Vision module has two tasks: object recognition and relative position estimation. We first map the RGB pixels to 8 color space simultaneously. Then, we resize the original image into a smaller one and use it for the detection of our objects, thus saving computational resources. This procedure takes full advantage of the tools the newly applied ROS middle-ware provides us with.

4.1 Vision Sensor

A Point Grey camera (BFLY-PGE-13E4C-CS) is used to provide the visual input of our robot. This combination yields a eld of view of about 90o(horizontal) 90o(vertical). The robot has to rotate its head to widen this field. The connection to the main controller via USB 2.0 provides real-time image series of a resolution of 800 600 of 30 fps, but as

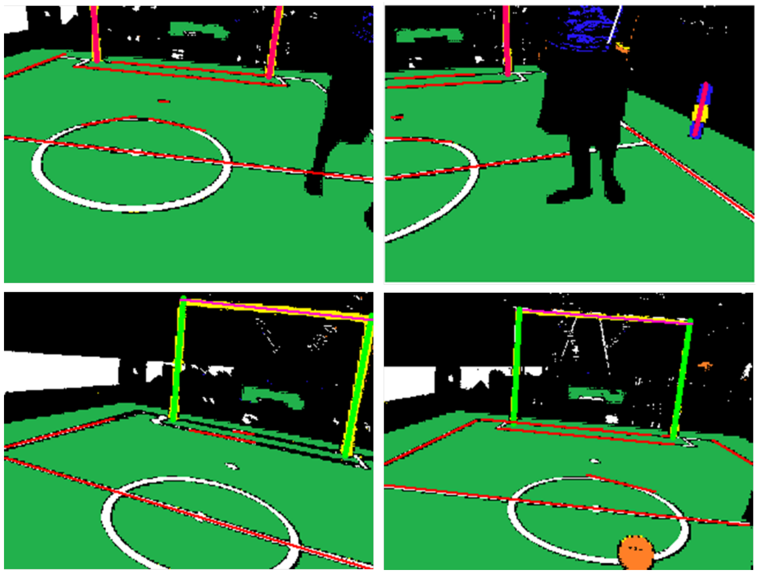


Fig. 4. Result of Recognition

explained earlier, the resized images used for object detection have a resolution of 480 360.

4.2 Color Segmentation

After images are captured, firstly we use the manual calibration, and then use machine learning method to map the RGB pixels to 8 color space simultaneously. In this way, we can minimize the storage cost, using a monochromatic image to greatly reduce the storage space required and avoid the waste of bandwidth for the transmission of the image to the object detecting modules.

4.3 Feature Extraction

Objects are distinguished by colors and shapes. As the features, clusters of different colors were extracted along the scan line from top to bottom or left to right. And the process would end if no more special colors appear. The special color found calls further object recognition in related areas. For instance, consecutive orange pixels (maybe white this year) call the process of ball detector. Single special colored point would not be considered as a target object, in case there is some expected error spot in the image especially under walking or other dynamic situations.

4.4 Object Recognition

Features, characteristic series of colors or a pattern of colors, are used for object recognition, e.g., a sequence of some orange pixels (maybe white this year) is an indication of a ball. Fig. 4 shows the recognized ball, goal and obstacles in the image.

Ball detector After Color Segmentation, Breath First Search (BFS) is used in order to find candidate regions of the ball. Then for each candidate regions, the convex set of the region is calculated and three points are sampled randomly on its edge. At last, a circle is fitted with these points and the fitting error is evaluated. If the error is less than a certain threshold, this region is accepted as a ball.

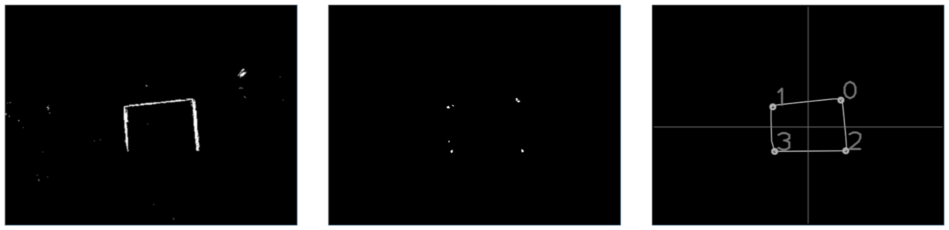


Fig. 5. Goal detector
1) Original image 2) Harris corner of the convex hull 3) Result

Goal detector Goal is a reasonably large rectangle area with yellow pixels. We use an algorithm based on moment-method just like linear regression searching the goal from the bottom of the frame and checking the minimum eigenvalue of the inertia matrix simultaneously. We stop when the eigenvalue increases greatly and suddenly. Then we check the direction of the goal and the existence of a goalkeeper.

Goal is a reasonably large rectangle area with yellow pixels (maybe white this year), whose main character is four corner points. The goal detector first searches all the connected domains in yellow and find the contours of these domains. Those contours in relatively small size will be considered as noise and ignored. Afterwards, convex hull of these contours is calculated, and then, corner points of the hull is calculated using Harris algorithm[8]. Where corner points concentrate in is regarded as the corner of the goal. The result is shown in Fig. 5

Field and Obstacle detector After the field is detected using its characteristic green color and already known shape, we look for black or dark colored objects that interrupt the field pattern and categorize them accordingly, calculating their width and distance.

Field Line detector A square frame with a specific width is the area in which we detect whether white spots exist. Since the penalty spot is isolated, if there is no white spot in a square frame, while its central point is white, this central point will be regarded as one pixel of the penalty spot. The result of penalty spot detector and the information of the boundary line of the field are used in the same time to detect the field line and the method is Hough transformation.The result of recognition is shown in fig. 4.

5 Localization&Perception

Apparently, in the game, the position of the robot is indispensable in making a proper decision of behaviour control. We implement an algorithm of localization based on Particle Filter (Monte Carlo Localization), using the information through our visual, gyro sensors as well as odometry data from the movement commands given.

One of the key ideas of the algorithm is Bayes Filter. Recursively applying the Bayes formula, $\mathrm{P}\left(B\,|A\right) = \frac{P(B \cap A)}{P(A)}$, we can update the belief of each state, i.e. the probability P(A) of the position of the robot, in real time. Therefore, we are able to estimate the position by the method of maximum likelihood.

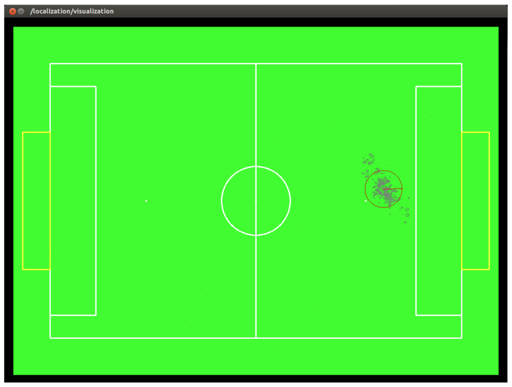


Fig. 6. A Demo of Particle Filter

However, in practice, its impossible to calculate the posterior by an infinite number of parameters, so the alternative idea is to perform an approximation, which is implemented by the particle filter. It uses a finite number of particles to represent concrete instantiations of states in real time, with a positive weight denoting the possibility of the position. In that way, we can approximate the belief of each state recursively by constructing the particle set X_t from the set X_{t-1}.

Hence, we can derive the position of the robot effectively from the mean pose of the particles.

6 Behavior Control

The data provided by the sensors and localization modules is used to plan a more complex behavior series. And the module of Behavior Control takes charge of this task. The main task is separated into subtasks until they can be described as a set of basic behaviors which can be executed by the robot. All this is done by a hierarchical state machine described in XABSL (Extensible Agent Behavior Specification Language). The basic motion actions are transferred to and interpreted by the motion module, while other basic actions are processed in further modules.

It can output the following variables: 1) A motion request of basic behaviors to inform the motion module of the robot's next action. 2) A head motion request of head mode to inform the motion module of the robot's next head action. 3) 3 LED's state. An XABSL behavior specification is comprised by a set of behavior modules called options and a set of different simple actions called basic behaviors. Each option consists of various numbers of states or subordinate options. Each state has two parts of information, decisions and actions. Decisions describe the conditions whether to jump out or stay in the current state according to the input variable, while the actions consist of the outputs such as the basic behaviors, LEDs etc.

7 Gait Planning

For low level motion control, we implemented legged locomotion for our robot in both passive and active way. A state-machine for gait control is designed for handling switching of different gaits.

7.1 Passive Gait

The implementation of passive forward walking is applying Virtual Slope Walking in the sagittal plane with the Lateral Swing Movement for lateral stability[1]. We have achieved a maximum forward walking speed of 0.6m/s on Strider Pro. The side-walking and turning are realized by carefully designing the key frames. The entire gait is generated by connecting the key frames with smooth sinusoids.

7.2 Active Gait

A ZMP based online motion generation scheme is adopted for kicking gait and small steps motion design and control. Kinematic teaching is used to enable fast, flexible motion generation[9]. Human motion captured from Kinect is modified to ensure the static balance during the robot playback.We further enable the algorithm to run online, with dynamic balance using a hierarchal approach: Firstly use an IP model for pattern generation, then use a full-body model for whole-body motion control.

Gait planning is mainly done by the ROS program running on the NUC. When we get basic motion requests from a higher in hierarchy module, motion is translated into instructions for each joint actuator. Instructions keep being sent out to every motor at 20Hz so as to make robot move as expected.

8 Conclusion

Our AdultSize robot Strider Pro is a completely autonomous humanoid robot, with 1 camera, 1 gyro and 20 actuators integrated on body, controlled by a NUC directly. In this paper we present the specifications and functions of the Strider Pro, as well as some related works on vision, localization, gait planning and control.

Tsinghua Hephaestus commits to participate in RoboCup 2015 in Brazil and to provide a referee knowledgable of the rules of the Humanoid League.

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