

MRL Team Description 2010

Standard Platform League

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Abstract. This paper is presented to describe the MRL SPL team which going to participate in RoboCup 2010 Standard Platform League in Singapore. The presented article includes various sub sections such as perception, dynamic simulation and path planning, behavior control, and world modeling which are explained in brief. Previous experience and future research topics are also described here in this paper. Research topics of the MRL-NAO team are mainly focused on the optimization of the available path planning, modifying localization and object modeling methodology improvement.

Keywords: RoboCup, Standard Platform League, Bipedal Locomotion, Control, Object Modeling, Path Planning.

1. Introduction

Mechatronics Research Laboratory, MRL, works under supervision of Qazvin Azad University and its main research interests are artificial intelligence and robotics. We are active participant of RoboCup from 2002 in different leagues. MRL SPL team participated in RoboCup2009 competitions for the first time without any previous background in Standard Platform League. Our team reorganized entirely this year with new team members and sub sections in which associated groups are allocated to perform team strategy tasks and requirements. These tasks will be described in the following sections.

Bipedal locomotion has been a topic of great attention in a various researches performed on legged robots since it is probably the most suitable method for robots to execute assigned maneuvers in a real environment with various obstacle conditions and geometry [1-3]. Aldebaran Co. proposed an appropriate platform for research on high level programming with the NAO humanoid robot in which biped robots behavior optimization in different positions and environmental conditions together with the trajectory generation during a soccer match are motivating issues. Biped robots have to generate the dynamically balanced gait in order to reach stability. Research topics for design and development of a suitable gait planner for the above mentioned robots have become an interesting area in humanoid motion analysis [4].

Generating natural motion is physically described as finding the motion which minimizes the total energy consumption and is required for all actuators in the robot system [5]. B-Human software is utilized at the first stage as a reliable and practical base since creating new software from scratch is complex and a time consuming process [6]. Our research topics are mainly focused on adding new features such as robots cooperation and proposing newly modified robot detection. In addition, our research groups are trying to improve or replace the existing solutions for available modules with the new and dissimilar proposed ones. Dynamic balance margin, DBM, is also studied for the fundamental motion analysis. This margin is calculated based on the concept of zero moment point (ZMP) proposed by Vukobratovic [7].

2. Team Structure

The main body of the team is formed with four groups including Perception, World Modeling, Behavior Control, Bipedal locomotion simulation and development.

Undergraduate Students: Amirreza Karimi, Reza Hashemifard, Mohammad Ali Zakeri Harandi, Majid Lashgarian, Mohammad Shafiei, Koosha Zarei, Faraz Faraji, Mohammad H. Amiri, Kian Kashfi, and Somayeh Jangi.

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Team Leader: Ehsan Hashemi

3. Software Framework

Developed control software is based on the software framework of the GermanTeam [8] with some modification.

4. Perception

The following paragraphs describe the team approach for building up the perception modules. It is desired to check field conditions for possible solutions with the assistant of computational techniques to accomplish high level programming. Performance of middle and high level algorithms mainly depends on the quality of image segmentation results.

MRL Perception team studied several segmentation methods such as Global Knowledge based, Regional based and Edge-based algorithms. In addition, we are working on improving current object detection system. All object detection techniques could be classified within pattern recognition which uses some basic styles [9]. The fundamental methods which are required for an accurate perception include Descriptors or Features [10, 11], Predicate Logic [12], Production Rules, and Fuzzy logic [13]. Object detection in the mentioned platform and league has three major tasks including ball, goal, and line perception. Segmentation modification on a captured image by employing smoothing method is illustrated in figure 1.

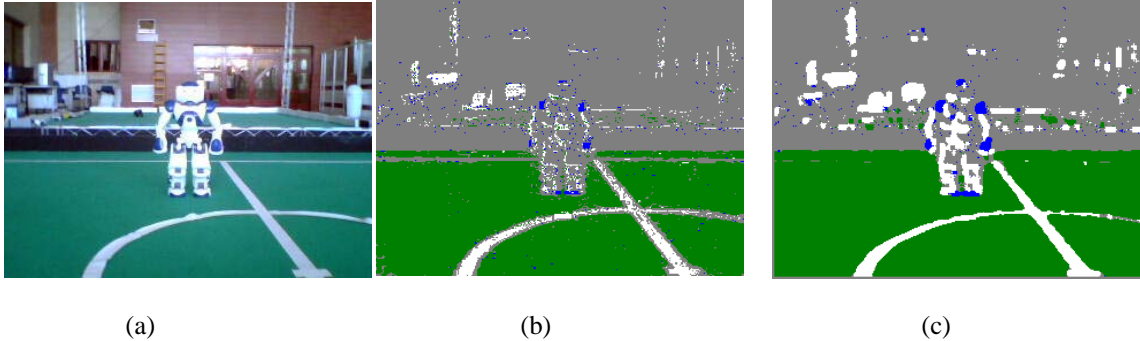


Fig 1. (a) Original captured image; (b) Segmented image; (c) Filtered image

4.1 Ball Perception

Ball recognition basic approach is based on perceiving a circle and filtering any undesired noise. Circular shapes are most frequently detected objects in a captured image due to some inevitable noises such as light conditions, man-made disturbances, and surrounding objects. Therefore, many recognition methods have been studied to omit noises [14]. One of the most powerful and effective techniques in circular shape detection is called “Circle Hough Transform” (CHT). Disadvantage of this algorithm is the searching approach for a circular item with determined radius within an image which may cause some great faults produced by different distances of the ball from the camera, thus some modifications and utilizing other sensible methods are highly requested to remove this drawback. The following paragraph describes a new proposal and idea for the ball perception duty.

The process begins with regular image segmentation and image scanning to find orange spots. After performing a search for 8×8 pixels around the detected pixel (to be sure it is not just a pixel color fault), the image is scanned in four different directions (positive and negative horizontal and vertical directions) starting at detected pixel. Therefore, it is possible to realizing an object with specific height and width. The recognized object is most likely to be a square or a circle when the two measured dimensions are equal. The process of detecting the circular shapes such as ball is graphically depicted in figure 2. Detected ball is shown with the black border in figure 2-d

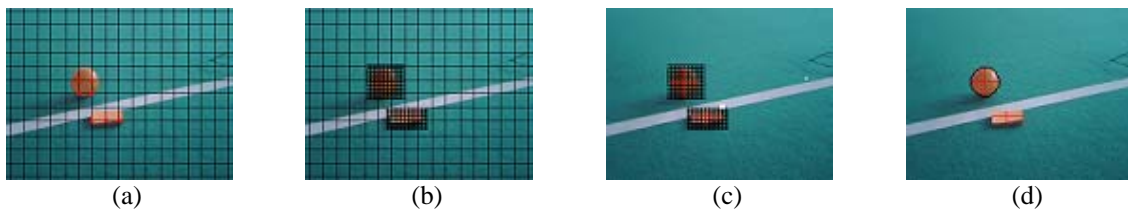


Fig 2. (a) Fast search; (b) Detail search; (c) Search for radius based on maximum width and height; (d) detecting circular shape based on CHT

4.2 Goal Perception

Goal perception is a complicated task in the game field because of some undesired disturbances. Classical run length segmentation, classical grid based segmentation, and scan-lines segmentation [15] are well-known techniques which examined to arrive at the best solution for goal detection with minimum response time. Scan-lines segmentation combined with fuzzy logic detection [13] is our perception group main approach for goal detection among above mentioned methods.

5. World Modeling

5.1 Detecting a fall

Fall and rise detection for robots are executed by received acceleration component direction on z-axis by accelerometer and correction with the pressure sensors for state confirmation.

5.2 Ball Position Prediction

Reaching the ball in an optimized manner could be attainable by estimating ball speed, detecting the direction of ball, and appropriate direction prediction. The final ball settlement position is estimated by accurate ball kinetics formulation and the new state is updated by the perception module. Distance between the ball and robot is calculated by a comparison between perceived ball radius and original radius. Therefore, this ratio is used for determination of the ball distance from camera, and then the absolute distance could be achievable by filtering the elevation between camera and robot's feet. The easiest way to find the direction of ball is comparing current and the latest ball positions.

5.3 Obstacle Model

This section is used for Identifying the robots and obstacle in the field. There are two sensible solutions for this issue:

1. Detecting robots with vision procedure
2. Identifying obstacles with Ultra Sonic retrieved data

Scanning the field at the beginning and at specific periods shall be performed due to the fact that detecting robots is not affordable for processor and may cause unpredictable lower process speed in some aspects. Therefore, it is preferred not involving the processor in detecting procedure when there is no object in front of robots. Ultra Sonic retrieved data is executed with a sensor fusion process to detect an obstacle in front of robots, then vision is admitted to detect that obstacles. Afterward, robots are modeled in the world state and their location and orientation in each period are updated successively.

5.4 Localization

Vision based localization as defined for localizing objects in indoor applications is an extensively practiced method for navigation. In RoboCup SPL league the robots must determine their locations in a 3D environment without any stereo vision. Novel and optimized algorithms are needed to specify the robot position and orientation in the match field. NAO provides vision and inertial sensors for detecting features and physical parameters such as lines, borders, and acceleration that is suitable for employing in sensor fusion algorithms to determine the robot location more precisely. Kalman Filter and Particle Filter are prominent techniques and broadly used in localization for many navigating systems. Vision as a global positioning system, IMU sensor and odometry as relative positioning mechanisms plays an essential role as adequate inputs for the Kalman Filter method (KF) to estimate and correct the robot location in the field. KF based approaches are recursive which brings the practical specifications that not all data are needed to be set aside in storage and re-processed every time when for example a new measurement arrives. Perturbation Kalman Filter, PKF, is implemented to perform the approximation of the state of nonlinear systems by linearizing its nonlinearities [16]. A nominal trajectory is defined then a first order Taylor series approximation is utilized to linearize the perturbations that occur around the nominal trajectory considering this fact that direction of the derivatives at a point on a surface will affect extrapolation. Extended Kalman Filter, EKF, is an efficient filtering method due to some disadvantages of using the same nominal trajectory all through the estimation process in PKF method which results into a large deviation of nominal state from the real state [17]. This would be achievable with estimating measurement functions at trajectories with the latest state estimates instead of calculation of the Taylor series expansions of the measurement functions at the nominal trajectories. Based on above mentioned approaches MRL SPL team intends to develop a localization process in order to improve the robot behavior. Initial development will be focused on sensor fusion between vision and odometry respectively as global and relative positioning and orientation data for feeding Kalman or Extended Kalman Filters. Adding IMU sensor outputs to the localization module could be a future choice to strengthen the previous scheme.

6. Behavior Control

Behavior Control is part of the software control system that makes the decision based on World Model (World Modeling layer output). We use PYTHON as a programming language that is used for modeling and orchestrating nao behavior. It's convenient and powerful tool that alleviates creation of complicated behaviors. Thanks to PYTHON, it's not very sophisticated to add new skill. We are working on some skills development to satisfy our strategy requirements and try to reach a reliable behavior in different conditions and maneuvers.

7. Locomotion Study and Simulation

Widespread studies have been conducted on bipedal walking, and now biped robots are capable of walking with a certain amount of stability. Trajectory control,

motion planning and locomotion modeling is completely related to the kinematic analysis as it is fundamental in the study of linkage systems [18]. Forward and Inverse Kinematics are commonly implemented to determine main parameters affecting humanoid robots behavior and specify the reliable method to control motion and preserve stability [19, 20]. The most frequently practiced parameters to be defined are joint parameters, including required driver torques, angles, and rotational velocities for revolving joints, translational displacements for prismatic joints, and related twists. Transformation between the Cartesian end effector orientation, location vector, and the corresponding vector of joint angular position are generally performed as a common practice, and then actuating signals and their values for drivers and appropriate motion controller factors will be determined. Performing this transformation and mapping is known as solving the inverse kinematic problems. The humanoid bipedal locomotion requires sensible solutions of the inverse kinematics and localization problems with optimized computations. Since the end effector configurations and its exact locations are related to the above mentioned joint parameters with nonlinear characteristics, inverse kinematics problems are usually complicated.

MRL SPL locomotion group has been studied free model approach for NAO locomotion in RoboCup 2009, Graz. Team approach changed to acceptable kinematic, dynamic, and relatively accurate modeling, due to some hardware limitations of the NAO main processor. One of main objectives of the motion study team is proposing model based humanoid locomotion simulator which shall be able to accomplish any determined maneuvers and specify the variation of joint parameters in any state. Employing a newly developed mathematical simulation as a test bed for designing diverse control methods such as PID, Adaptive PID, Fuzzy, etc. is a valuable advantage which facilitates dedication of desired controller. More efficient controller design and stable NAO performance is manageable by development of closed form formulation for forward and inverse kinematics.

Closed form formulation for NAO inverse kinematics is more complicated to derive than other ordinary series robot [6]. Numerical methods and some simplifications for inverse kinematic equations will be investigated and may cause acceptable consequences. D-H convention and classic methods are used to derive forward kinematics equations, and then closed form solution for inverse kinematics is developed. Utilizing dynamic model of the robot will lead to appropriate results of trajectory planning and designing appropriate force and torque controllers to increase stability and locomotion performance enhancement in diverse situations, fields, and unpredictable conditions during the match. Input energy is another important index for natural walking motion which helps the analytic solutions of the closed form method and is under comprehensive study in the motion group.

Main constraints such as inertial forces and joint angles for the given position and nominal conditions are simulated and verified through experimental results from the real robot sensory data. As an example, simulation and experimental results are graphically illustrated and compared in figure 3

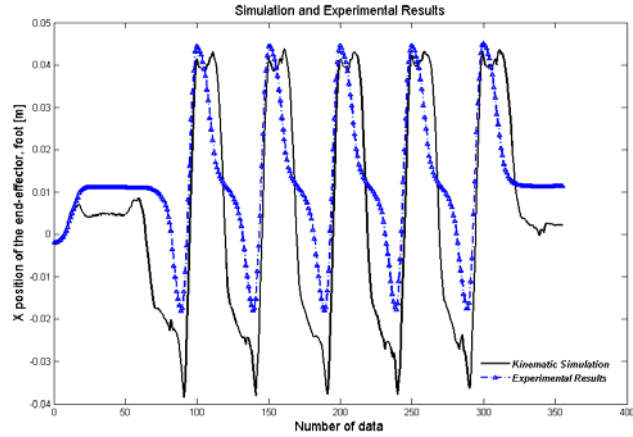


Fig 3. Simulation and experimental results of the end effector (foot); forward movement of the robot.

8. Future Works

As we explained before our research topics are mainly focused on adding new features such as robots cooperation and proposing newly modified robot detection to the current system. For the robot detection, it has been decided to use "k-means clustering" method for this section, in order to keep speed and straightforwardness [1]. Therefore, after successful perception of goal, line and ball, rest of the segments are sent to k-means algorithm for detecting Nao. This method enables robots to find out whether they are facing robots from front, back or lateral sides.

The process of obtaining inverse kinematic formulation and dynamic model contains some numerical modifications and optimization on the solution and boundary condition specifications which are under study and could be mentioned as this group's next approach.

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