ZJUDancer Team Description Paper

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Abstract. ZJUDancer is a humanoid robot soccer team participating in RoboCup competitions. This paper presents the team's technical framework, summarizes lessons learned from previous competitions, describes current system improvements, and outlines future research directions. Our work covers hardware reliability, vision systems, localization, navigation, behavior planning, and motion control. Through systematic upgrades, we aim to enhance robustness, autonomy, and multi-robot cooperation in dynamic competition environments.

Keywords: Humanoid Robot · RoboCup · Localization · Motion Control · Multi-Robot Cooperation

1 Introduction

ZJUDancer is a humanoid robot soccer team participating in RoboCup competitions. This paper describes the team's technical framework, lessons learned from previous competitions, current developments, and future plans. Our work spans hardware reliability, vision systems, localization, navigation, behavior planning, and motion control.

2 Lessons Learned and Major Problems Identified

2.1 Hardware Issues

In previous RoboCup competitions, our circuits often encountered failures after falls or collisions. This significantly impacted performance, especially compared to other teams with more robust systems. Although we simplified our circuit design last year, problems persisted under certain conditions.

Additionally, mechanical limitations in leg joints restricted stride length during walking, affecting mobility.

2.2 Software Challenges

Our particle filter-based localization system showed limitations in accuracy and robustness. Experiments with visual-inertial odometry revealed stability issues in certain environments.

In motion control, while our ZMP preview-based method was functional, it represents relatively outdated technology. Furthermore, the robot required a full reboot after being picked up, including Ethernet reconnection and host computer restart, which wasted valuable competition time.

3 Current Technical Framework

3.1 Hardware Improvements

We have reconfigured our circuitry to improve stability against impacts. For mechanical enhancements, we have increased the motion range limits of leg joints and are currently testing these modifications to optimize walking performance.

3.2 Vision System

To address varying lighting conditions, we manually adjust camera exposure based on image histogram analysis. This compensates for limitations in the camera's auto-exposure functionality. Histogram computation is triggered selectively based on preliminary cognition results to balance computational efficiency and image quality.

3.3 Cognition Module

Field and line detection employs traditional computer vision techniques, including Hough transform, Canny edge detection, and thresholding.

For dynamic object detection (ball, goals, robots), we upgraded from YOLOv3-tiny to YOLOv5 with TensorRT optimization, significantly improving detection accuracy, especially for distant objects. Additionally, field corners are recognized using line features to enhance localization.

3.4 Localization and Navigation

We use Adaptive Monte Carlo Localization (AMCL) with multiple landmarks, including circles, lines, goals, and corners. The IMU provides orientation data, while the particle filter estimates the (x, y) position.

Odometry data, refined by detected landmarks, is used to update particle states. Improvements in odometry reliability have enabled reduced noise parameters, resulting in more stable localization.

3.5 Behavior and Cooperation

Our behavior module combines behavior trees and finite state machines implemented in Python. To mitigate localization uncertainty, we employ decentralized decision-making based on relative positions.

A dynamic role-switching mechanism is implemented between attacking robots ("kicker" and "assistant") to prevent collisions and improve coordination. Robots determine kicking direction based on visually perceived goal positions rather than fixed coordinates.

3.6 Motion Control System

The motion control system consists of four modules:

IO Module Manages communication with servos, IMU, and foot pressure sensors, including data filtering and preprocessing.

Kinematics Module Performs inverse kinematics for joint angle computation and forward kinematics for center-of-mass estimation, enabling flexible scheduling between predefined and planned motions.

Planner Module Generates smooth paths using Dubins curves while considering motion constraints to maintain balance.

Trajectory Module Combines a curve generator based on piecewise cubic splines and a trajectory optimizer implemented with CasADi to produce smooth joint and center-of-mass trajectories.

4 Ongoing Developments and Future Plans

4.1 Current Implementation Status

- Circuit redesign: Completed and under testing
- Mechanical modifications: Joint limit adjustments in testing phase
- Visual-inertial odometry: Optimized version under testing
- MPC controller: Code debugging in progress
- Power detection module: Not yet started
- Reinforcement learning framework: Established and under training, but not competition-ready

4.2 Competition-Specific Improvements

We are developing a power detection system that enables the robot to automatically restore its initial state after servo power loss, eliminating the need for full system reboot. This is expected to significantly reduce downtime during competitions.

4.3 Research Directions

- Further refinement of visual-inertial odometry
- Completion of MPC-based motion control implementation
- Enhancement of localization using additional field features
- Implementation of obstacle avoidance in the planner module
- Continued development of cooperation algorithms and role-switching strategies

5 Conclusion

The ZJUDancer team has systematically addressed previous weaknesses through hardware redesign, software upgrades, and algorithmic improvements. The current framework demonstrates enhanced robustness in vision, more stable localization, effective multi-robot cooperation, and advanced motion control.

We continue to improve system reliability and performance in dynamic competition environments, with a focus on stability, autonomy, and coordinated team play for future RoboCup competitions.