

Hibikino-Musashi

Team Description Paper 2026

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Abstract. This paper presents the 2026 system of Hibikino-Musashi for the RoboCup Middle Size League (MSL). In this season, we focus on three key improvements: (1) quantitative characterization of a plunger-type solenoid kicking mechanism using displacement sensing, (2) a centrifugal-force-aware Dynamic Window Approach (CF-DWA) for stable omni-directional navigation at high speed, and (3) an optimized probabilistic passing strategy designed for real-time multi-agent coordination. In addition, the coachbox software has been partially migrated to a ROS2-based modular architecture to enhance structured communication and development scalability. These improvements contribute to improved mechanical reliability, motion stability, and cooperative decision-making under dynamic match conditions.

Keywords: RoboCup Middle Size League, Solenoid Kicking Mechanism, Stability-Aware Motion Planning, Probabilistic Passing Strategy, Multi-Agent Coordination.

1 Introduction

Hibikino-Musashi is a joint RoboCup Middle Size League (MSL) team founded in 2004 in the Kitakyushu Science and Research Park, Japan. The team consists of members from Nishinippon Institute of Technology, Kyushu Institute of Technology, and the National Institute of Technology, Kitakyushu College.

For the 2026 season, we emphasize:

- Mechanical reproducibility of the kicking mechanism
- Dynamic stability in high-speed omni-directional motion
- Real-time cooperative behavior under uncertain match environments

This year's development focuses on quantitative evaluation and gradual architectural modernization while preserving competition reliability.

2 System Architecture

Our current system adopts a hybrid architecture.

The on-board robot control system remains based on our established real-time framework to ensure stability and deterministic behavior during matches.

The coachbox system has been partially migrated to a ROS2-based modular structure.

This ROS2 implementation manages:

- Inter-robot communication
- High-level strategy coordination
- Monitoring and debugging tools

This hybrid configuration enables structured multi-agent communication and scalable development while maintaining proven on-field robustness.

The architecture is designed to support future integration of data-driven decision modules without disrupting the existing real-time control system.

3 Hardware System

3.1 Robot Platform

The “Musashi-150” robot employs a three-wheel omni-directional drive system powered by three 150 W Maxon DC motors (Fig. 1).

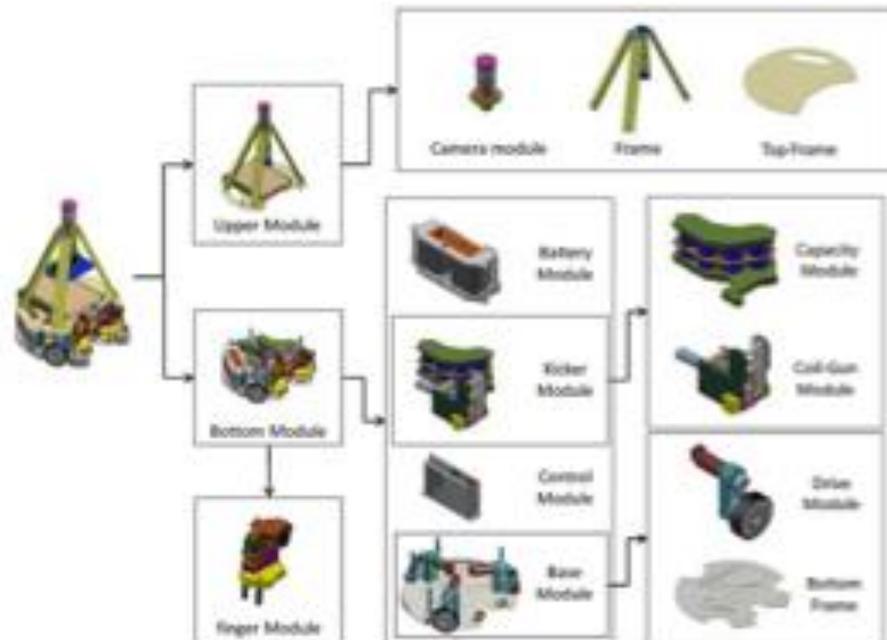


Fig. 1. Musashi-150 robot overview

Performance specifications:

- Maximum linear velocity: 3.5 m/s
- Maximum acceleration: 2.1 m/s²

Velocity feedback is obtained via 2000-pulse incremental encoders. Motor drivers communicate via CAN bus.

Sensors include:

- Omni-directional camera
- Digital compass
- Wheel encoders

Power is supplied by 24 V NiMH batteries.

3.2 Quantitative Evaluation of the Solenoid Kicking Mechanism

Reliable kicking performance is essential in MSL competitions. We employ a plunger-type solenoid kicking mechanism designed for stable energy transfer (Fig. 2).

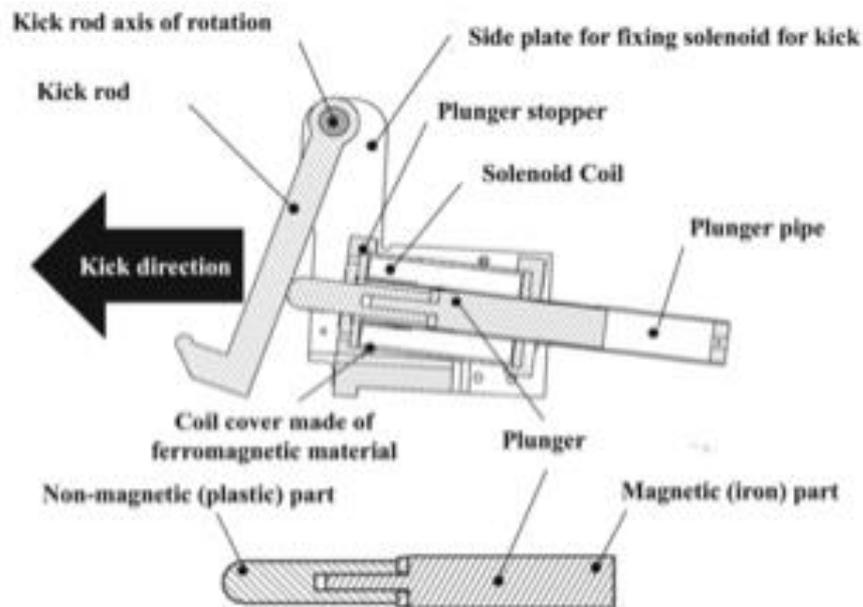


Fig. 2. Detailed structure of the plunger-type solenoid mechanism

To evaluate mechanical reproducibility, a one-dimensional Time-of-Flight (ToF) sensor (VL53L0X) was introduced to measure plunger displacement in real time (Fig. 3).

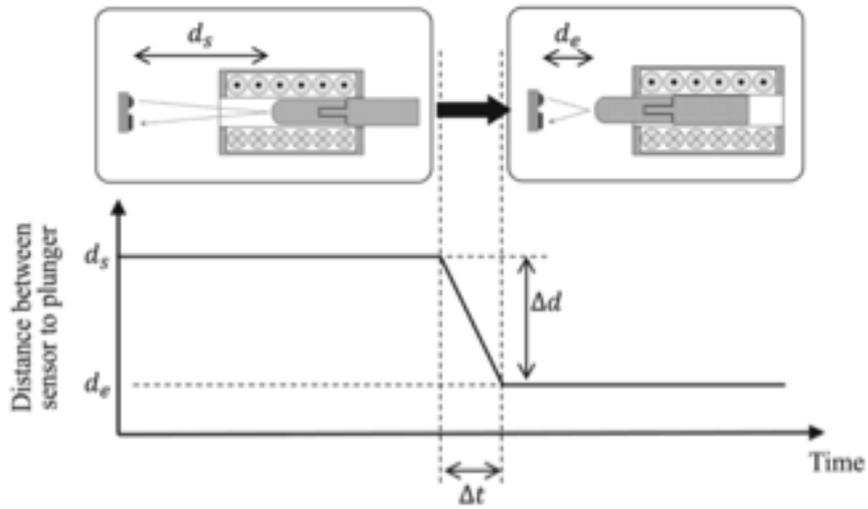


Fig. 3. Measurement scheme using the ToF sensor

Under 20 V input conditions (Fig. 4):

- Measured plunger stroke: approximately 50 mm
- Actuation duration: approximately 0.1 s
- Estimated initial plunger velocity: approximately 0.39 m/s
- The experimental setup including the manufactured housing is shown in Fig. 5.

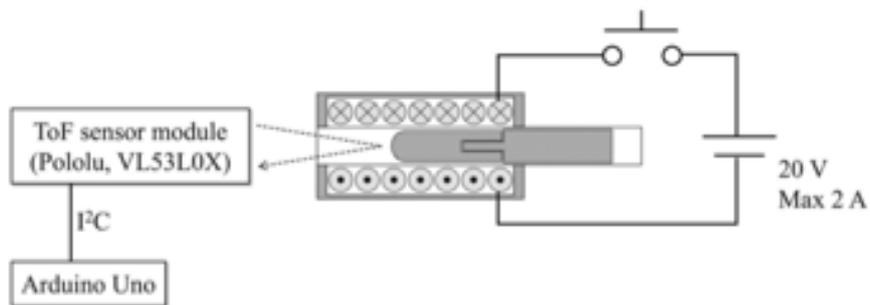


Fig. 4. Measurement system structure

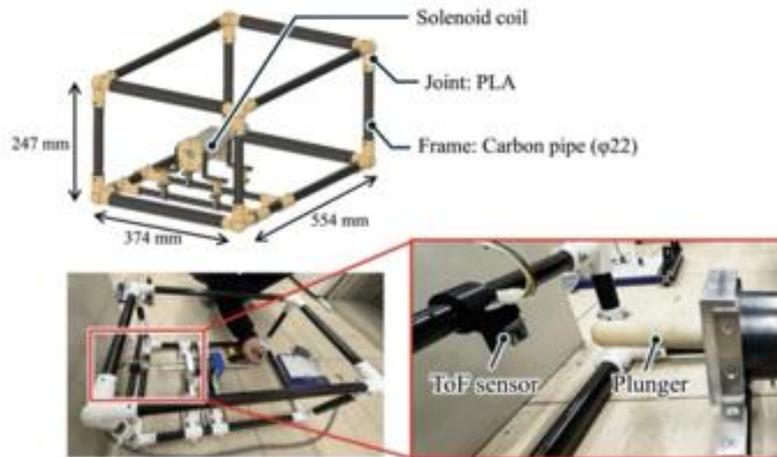


Fig. 5. Manufactured solenoid housing and experimental setup

These measurements allow estimation of kinetic energy and provide a quantitative basis for improving consistency and mechanical efficiency. The measured displacement curve over time is presented in Fig. 6.

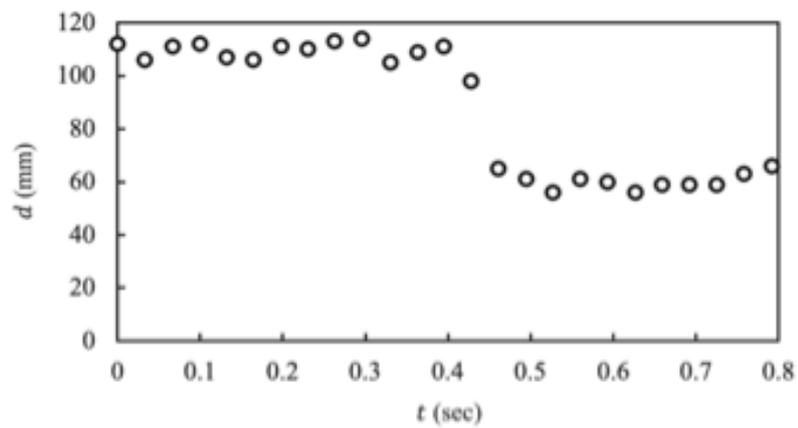


Fig. 6. Plunger displacement result (t-d graph)

This evaluation framework supports systematic tuning of input voltage and structural parameters for enhanced repeatability.

4 Motion Planning

4.1 Centrifugal-Force-Aware Dynamic Window Approach (CF-DWA)

Obstacle avoidance in high-speed MSL environments requires consideration of dynamic stability.

Conventional Dynamic Window Approach (DWA) does not explicitly account for lateral slip caused by centrifugal force. We introduce CF-DWA, which restricts velocity pairs that generate lateral acceleration exceeding predefined slip thresholds.

The velocity space is constrained by:

- Maximum velocity
- Maximum acceleration
- Obstacle proximity
- Centrifugal force limitation

The resulting velocity space is illustrated in Fig. 7.

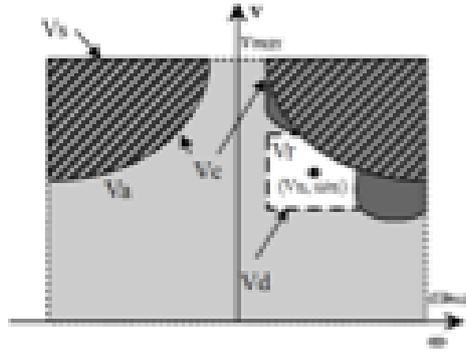


Fig. 7. CF-DWA velocity space

Simulation results indicate smoother trajectories and reduced peak lateral acceleration compared to conventional DWA (Fig. 8).

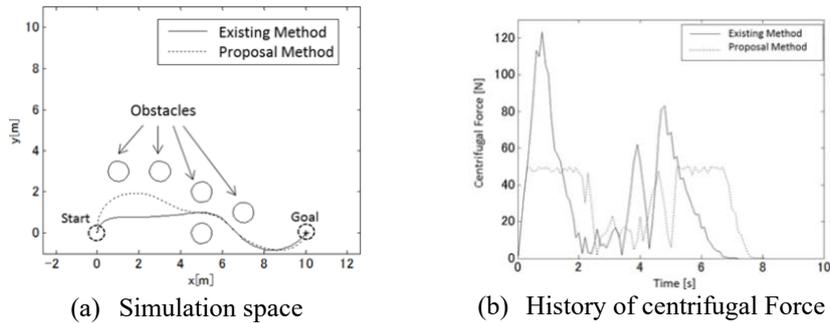


Fig. 8. CF-DWA simulation result

5 Cooperative Passing Strategy

Passing behavior is implemented using a probabilistic selection map generated from multivariate Gaussian distributions.

The pass selection map considers:

1. Passing range of the passer
2. Receiving range of the receiver
3. Opponent interception range
4. Goal-oriented strategy weighting
5. Opponent positional constraints

The passing range map is illustrated in Fig. 9, which represents feasible ball travel distances from the passer. The receiving range of the teammate robot is shown in Fig. 10. This map defines effective regions for ball reception while avoiding excessively close positions.

Opponent interception probability is modeled as shown in Fig. 11. Regions where opponents are likely to block the pass are assigned lower values. Strategic weighting toward the opponent's goal is illustrated in Fig. 12. Additionally, positional constraints related to opponent blocking behavior are represented in Fig. 13.

These maps are combined to generate the final pass selection map, shown in Fig. 14. The brightest region in Fig. 14 corresponds to the optimal pass target point under current field conditions.

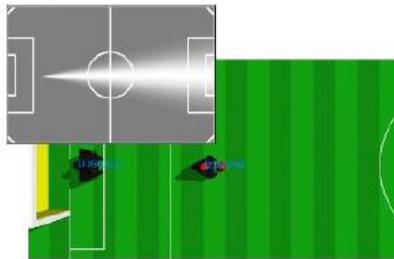


Fig. 9. Passing range map



Fig. 10. Receiving range map



Fig. 11. Opponent interception map

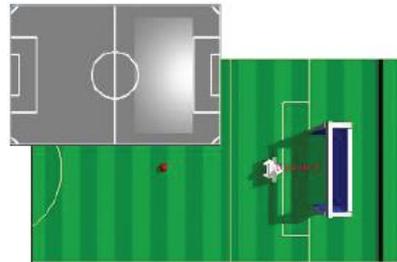


Fig. 12. Strategy weighting map

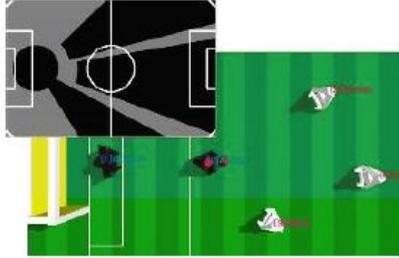


Fig. 13. Opponent positional constraint map

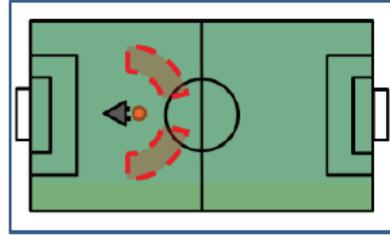


Fig. 14. Target map for receiver moving

6 Preparation for Learning-Based Coordination

Our previous research has demonstrated the effectiveness of Tensor Self-Organizing Maps (Tensor-SOM) for multi-agent behavior modeling and decision support in dynamic environments. For the 2026 season, the current architecture has been prepared to allow future integration of such data-driven modules. Preliminary compatibility tests confirm that the hybrid system design can accommodate learning-based extensions without affecting match reliability.

7 Conclusion

For RoboCup 2026, Hibikino-Musashi focuses on:

- Quantitative mechanical evaluation of the kicking mechanism
- Stability-aware motion planning
- Optimized probabilistic cooperative behavior
- Gradual modernization of system architecture via ROS2 in the coachbox

These developments enhance robustness, scalability, and preparation for future intelligent integration while maintaining reliable match performance.

References

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