ROBOTECH: Team Description Paper 2026

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Abstract. This article describes the development and improvements of the ROBOTECH team following our participation in RoboCup 2025, where the team achieved a **9th place global ranking**. Building upon the architecture introduced in previous work, our development efforts focused on improving defensive stability and expanding the operational capabilities of the goalkeeper agent. The new system introduces refined threat evaluation parameters, enhanced defensive reaction mechanisms, and a significantly expanded goalkeeper movement model that allows the agent to operate beyond the traditional small area boundaries.

Keywords: RoboCup · Soccer Simulation 2D · Tactical AI · Agent Coordination · Defensive Systems

1 Introduction

ROBOTECH is a multidisciplinary robotics and artificial intelligence development team from the Technological Institute of Nuevo León. Since its creation in early 2024, the team has focused on the development of intelligent agents for the RoboCup Soccer Simulation 2D League [1,3].

During the RoboCup 2025 competition, ROBOTECH achieved **9th place globally**, representing a significant milestone for both the team and the institution. This performance validated the architectural decisions introduced in our previous development cycle while also highlighting several areas where improvements could significantly enhance team performance.

Post-competition analysis revealed that while our offensive coordination and spatial positioning systems performed reliably, several defensive scenarios exposed limitations in threat evaluation and goalkeeper responsiveness, a common challenge identified in defensive behavior studies within soccer simulation environments [4].

The main objectives of the current development cycle include:

- Improving threat detection mechanisms for defensive agents
- Optimizing reaction parameters to reduce defensive response latency
- Expanding goalkeeper movement capabilities and field awareness

These changes aim to create a more adaptive defensive structure while preserving the offensive coordination system introduced in the previous architecture.

1.1 Related Work

The ROBOTECH architecture continues to build upon the Helios [1] base framework and incorporates several adaptations derived from the Cyrus [2] architecture.

Helios Base Integration remains the foundation of our agent framework, providing core implementations for perception, movement, and communication within the RoboCup 2D simulation environment. Our previous work introduced several modifications to formation positioning and decision parameters to improve spatial balance and passing efficiency.

Cyrus Architecture [2] elements continue to influence our defensive systems, particularly in areas related to unmarking behavior and formation detection. However, the current development cycle introduces additional custom modifications designed to improve defensive reaction capabilities and situational awareness among defensive agents.

2 Strategic Evolution

The experience gained during RoboCup 2025 provided valuable insight into the strengths and limitations of the ROBOTECH system.

Our team demonstrated strong positional balance and improved ball possession metrics during several matches. However, detailed match analysis revealed that certain defensive situations, particularly those involving fast offensive transitions, exposed weaknesses in defensive threat evaluation.

Opposing teams were occasionally able to exploit small reaction delays between the detection of an attacking threat and the defensive response of nearby agents.

To address these issues, we introduced a new set of defensive parameters that redefine how agents classify and react to potential threats.

The updated system evaluates threat conditions using a combination of variables including:

- relative distance between attacker and goal
- attacker movement velocity
- proximity of supporting defenders
- predicted ball trajectory

variables commonly used in interception and positioning models for autonomous soccer agents [5].

These parameters allow agents to classify potential threats with greater precision and react earlier to critical situations (Figure 1).

Fig. 1. This visualization illustrates the more tightly packed defensive formation of the updated ROBOTECH system, showing improved positional balance and spatial coverage.

3 Defensive Reaction Model

One of the primary improvements introduced in this development cycle involves the redesign of defensive reaction parameters.

In the previous architecture, defensive responses were largely triggered by threshold-based proximity conditions. While this system performed adequately in slower game scenarios, it occasionally produced delayed reactions when attackers approached the goal at high velocity.

The updated defensive system introduces an expanded threat evaluation model that prioritizes early intervention when attackers enter dynamically defined danger zones. When an attacker is classified as a high-priority threat, nearby defenders transition to an urgent response state, increasing their movement priority and adjusting their positioning behavior to intercept the ball or block potential passing lanes, an approach consistent with defensive behavior models explored previously [4].

This modification improves the defensive system's responsiveness while preserving overall team structure.

3.1 Adaptive Pressing Threshold

The core mechanism behind the improved defensive reaction is a role-dependent adaptive pressing model. In the previous architecture, all field players used a fixed interception threshold of $P = 13$ cycles, meaning a player would only attempt ball interception if its estimated arrival time satisfied $\mathrm{self\_min} < \mathrm{opp\_min} + P$. This conservative value was the primary cause of the delayed reactions described above.

Algorithm 1: Defensive Interception Decision

Input: self_min, mate_min, opp_min, role, ball_pos

$P \leftarrow 25$; // base pressing threshold

if *role* $\in \{6,7,8\}$ ***and*** *ball_x* > -30.0 **then**

  $P \leftarrow 7$;

if *role* $\in \{4,5\}$ ***and*** $|$*ball_y*$| > 22.0$ ***and*** *ball_x* $\in (-36.5, 0)$ **then**

  $P \leftarrow 23$;

deep_press $\leftarrow$ (role $\in \{2,3,4,5\}$) $\wedge$ (ball_x < -20.0) $\wedge$ (self_min $<$ opp_min $+ P$) $\wedge$ (self_min < 20);

if no kickable teammate ***and*** *(self_min* ≤ 3 ***or*** *deep_press* ***or*** *(self_min* $\leq$ *mate_min* ***and*** *self_min* $<$ *opp_min* $+ P$*))* **then**

  Execute interception;

The updated system replaces this with role-specific thresholds. The base value was increased to $P = 25$ for defenders (roles 2–5), enabling significantly earlier interception attempts. Midfielders (roles 6–8) use a reduced threshold $P = 7$ when the ball is in the midfield region (ball_x > -30.0), and side-backs (roles 4–5) use $P = 23$ when the ball is on a wide lateral position ($|$ball_y$| > 22.0$, ball_x $\in (-36.5,\ 0)$).

A critical addition is the *defender deep press* rule: when the ball is in the defensive half (ball_x < -20.0), any defender (roles 2–5) will attempt interception if self_min $<$ opp_min $+ P$ **and** self_min < 20, bypassing the standard teammate-priority check. This ensures that the nearest defender reacts immediately to threats in the defensive zone. The complete interception decision is formalized in Algorithm 1.

Additionally, the blocking activation zone was expanded from ball_x < -10.0 to ball_x < 10.0, allowing defenders to initiate blocking behavior 20 meters further up the field. The blocking system predicts the opponent's most likely dribble direction using a scoring function $S(\theta) = -\text{target\_x} + \max(0,\ 40 - 2 \cdot \text{dist}(\text{target}, \text{goal}))$, then simulates the dribble trajectory at $v = 0.7$ m/cycle over 40 future cycles to identify the earliest teammate capable of intercepting the dribbler.

3.2 Threat-Based Marking with Anti-Duplication

To complement the pressing improvements, a new marking behavior was introduced for defenders (roles 2–5), activated when the ball is in the team's own half (ball_x < 5.0) and no teammate has possession. Each defender evaluates all visible opponents and assigns a threat score:

$$\text{threat}(\text{opp}) = -\text{dist}(\text{opp}, \text{goal\_center}) - 0.2 \cdot |\text{opp}_y| \tag{1}$$

This formulation prioritizes opponents closer to the goal center while penalizing wide positions that represent lower immediate danger. To prevent multiple

Algorithm 2: Defensive Marking Assignment

Input: agent position, visible opponents, teammate positions

best_score $\leftarrow -\infty$, mark_target $\leftarrow$ null;
foreach *opponent* opp *where* $opp_x < 5.0$ **do**
    foreach *teammate* tm *(roles 2–5, tm $\neq$ self)* **do**
        if $dist(tm, opp) < dist(self, opp) - 1.5$ **then**
            mark opp as CLAIMED $\rightarrow$ skip;
    score $\leftarrow -\text{dist}(\text{opp}, \text{goal\_center}) - 0.2 \cdot |\text{opp}_y|$;
    if *score* $>$ *best_score* **then**
        best_score $\leftarrow$ score, mark_target $\leftarrow$ opp;
if *mark_target* $\neq$ *null* **then**
    $\mathbf{d} \leftarrow$ normalize(goal_center − mark_target.pos);
    mark_pos $\leftarrow$ mark_target.pos + $\mathbf{d} \times 1.8$;
    Move to mark_pos;
    `ARM_POINT` to mark_target.pos; `// visual coordination`

defenders from converging on the same opponent, an anti-duplication check verifies whether any teammate defender is already closer to the opponent by a margin of 1.5 meters. If so, that opponent is excluded from the current agent's marking candidates.

Once a target is selected, the marking position is computed at 1.8 meters from the opponent along the vector toward the goal center. The marking agent uses the `PointTo` arm gesture to signal which opponent it is covering, enabling implicit coordination between defenders without consuming the limited voice message bandwidth.

4 Goalkeeper Behavioral Expansion

One of the most significant improvements introduced in the current development cycle involves the redesign of the goalkeeper agent behavior model [6].

In the previous ROBOTECH architecture, the goalkeeper primarily operated within a conservative defensive region close to the goal line and inside the small box. While this approach provided positional safety, it limited the agent's ability to actively intervene in attacking situations before they became critical threats.

Post-competition analysis of RoboCup 2025 match logs revealed that several goals conceded occurred in situations where the goalkeeper had the theoretical ability to intercept the ball earlier but did not attempt intervention due to restrictive movement parameters (Figure 3).

To address this limitation, the goalkeeper behavior model was redesigned with three primary objectives:

- expanding the operational movement area of the goalkeeper
- improving environmental awareness and field scanning

Algorithm 3: Goalkeeper State Machine

```
Input: ball_dist, opp_dist_to_area, self_step, tm_step, game_mode
Persistent: was_pressing (boolean);
/* State 0 -- Set Piece Safety */
if game_mode ∈ {KickIn, CornerKick} then
    Move to conservative position (−49.0, 0.0) at 50% dash power;
    return;
/* State 1 -- Close Ball Response */
thr ← was_pressing ? 18.0 : 15.0;                         // hysteresis
if ball_dist < thr then
    was_pressing ← false;
    if 1v1 detected then execute 1v1 protocol;
    else move to home (−51.0, 0.0);
    return;
/* State 2 -- Active Pressing */
press_thr ← was_pressing ? 7.0 : 5.0;
tm_covers ← kickable_tm ∨ (tm_step < self_step − 1);
if was_pressing and tm_covers then
    was_pressing ← false;                                  // release immediately
if opp_dist_to_area < press_thr and not tm_covers and ball_dist ≥ thr
  then
    was_pressing ← true;
    Execute chase ball behavior;
    return;
/* State 3 -- Positional Play */
target ← getTargetPoint();                                 // base_x = −42.0
Execute standard positioning;
```

– enabling proactive interception of dangerous passes and loose balls

The new system allows the goalkeeper to move beyond the traditional small area boundaries (Figure 4) when the system detects a high probability of ball interception or defensive intervention.

This modification effectively transforms the goalkeeper from a purely reactive defender into an active defensive agent capable of contesting possession in early phases of an attacking play.

4.1 State-Based Decision Model

The redesigned goalkeeper behavior is implemented as a priority-ordered state machine with four states, evaluated every simulation cycle. Each state uses hysteresis thresholds to prevent oscillation between behaviors. The system maintains a persistent boolean `was_pressing` across cycles to track behavioral continuity.

The hysteresis mechanism is critical for behavioral stability: entering a state requires a stricter threshold than remaining in it. For example, the pressing state activates when the nearest opponent is within 5.0 m of the penalty area center, but once active, the goalkeeper continues pressing until the opponent moves beyond 7.0 m. This 2-meter hysteresis band eliminates the oscillation behavior observed in the previous architecture. Figure 2 illustrates the state transitions and their triggering conditions.

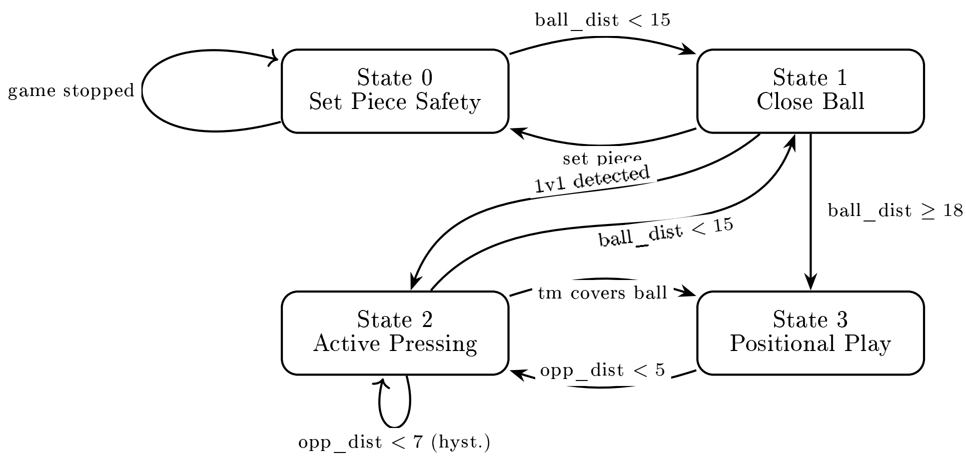

Fig. 2. Goalkeeper state machine transition diagram. Hysteresis thresholds (e.g., enter pressing at 5.0 m, exit at 7.0 m) prevent oscillation between states. Arrows indicate transition conditions evaluated every simulation cycle.

4.2 Expanded Field Awareness

To support this behavioral change, the perception model used by the goalkeeper was expanded to include a broader evaluation of nearby attackers, ball trajectory predictions, and spatial threat assessment.

The agent continuously evaluates several variables including:

- ball velocity and direction
- goalkeeper travel time to interception point
- defender support availability (tm_step < self_step − 1)

These variables are used to estimate an interception opportunity score (Figure 4), which determines whether the goalkeeper should remain in a conservative defensive position or move aggressively toward the predicted ball location [5]. The teammate support verification ensures the goalkeeper only presses when no field player can arrive first, preventing situations where the goal is left unattended.

This expanded perception model significantly increases the goalkeeper's situational awareness and allows earlier responses to developing attacking scenarios.

4.3 One-versus-One Protocol (In Development)

The current architecture includes a preliminary 1v1 detection mechanism that identifies situations where an opponent with ball possession is inside the penalty area (opp_x $<$ penalty_line_x) in a central position ($|$opp_y$| < 8.0$) with no field teammate within 8.0 meters of the ball.

When these conditions are met, the goalkeeper advances forward to reduce the shooting angle. The current implementation uses a simplified target calculation:

$$\text{target\_x} = -44.0 \tag{2}$$

$$\text{target\_y} = \text{clamp}(\text{opp\_y} \times 0.3,\ -\text{goal\_half\_width} + 0.5,\ \text{goal\_half\_width} - 0.5) \tag{3}$$

While this behavior has shown promising initial results in reducing the effective shooting angle during isolated 1v1 encounters, the protocol remains under active development. Current limitations include the absence of a probabilistic shot prediction model and limited handling of lateral 1v1 approaches. Refinement of this module, including integration of opponent velocity vectors and shot angle prediction, is planned as part of future work (Section 7).

4.4 Effective Goalkeeper Area Expansion

The combined effect of the state machine produces a significant expansion of the goalkeeper's operational region. The base positioning x-coordinate was moved from $x = -49.0$ to $x = -42.0$, extending the goalkeeper's default position 7 meters forward. During active pressing, the goalkeeper can reach the penalty area boundary. During 1v1 situations, the goalkeeper advances to $x = -38.0$ or $x = -44.0$, up to 14 meters beyond the previous default position.

This expansion allows the goalkeeper to:

- intercept through passes earlier
- contest loose balls in the defensive zone (Figure 4)
- assist defenders during high-pressure situations

As a result, the goalkeeper now contributes more actively to defensive stability and transition control.

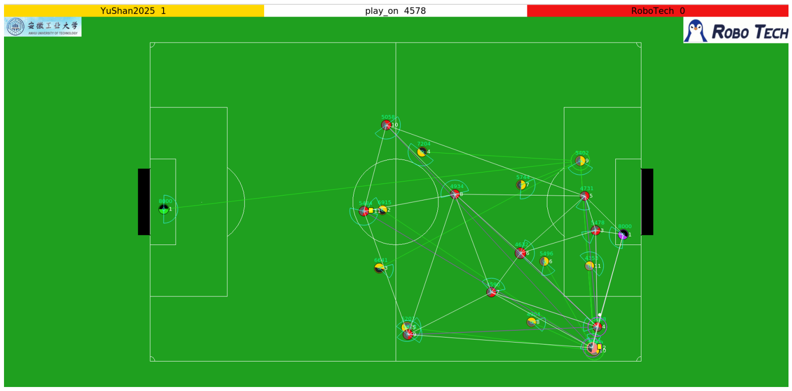

Fig. 3. This visualization shows the ROBOTECH goalkeeper moving toward the direction of the ball rather than remaining centered in the goal area, illustrating the proactive positioning behavior of the updated goalkeeper model.

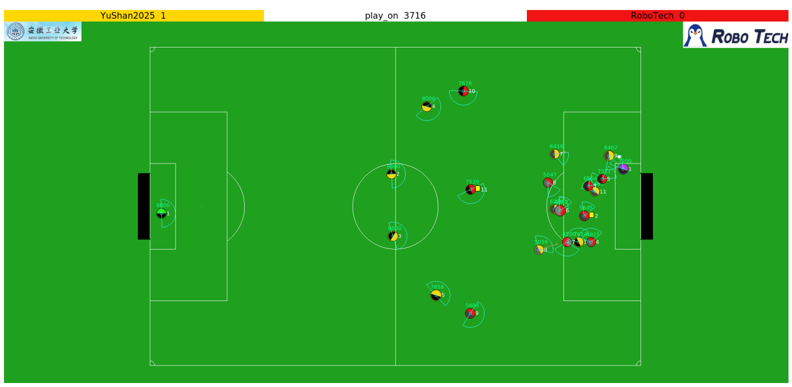

Fig. 4. ROBOTECH goalkeeper moving outside the small area to intercept an incoming pass, illustrating the expanded defensive range and proactive intervention behavior of the updated goalkeeper system.

5 Experimental Results

To evaluate the effectiveness of the redesigned goalkeeper system and updated defensive threat evaluation parameters, a series of controlled simulation experiments were conducted.

The ROBOTECH team executed 150 simulated matches against a set of teams from the 2025 RoboCup competition top 4 team binaries.

The experiments compared the previous system architecture used during RoboCup 2025 with the updated defensive and goalkeeper models introduced in the current development cycle.

The evaluation focused on 4 primary metrics (Table 1):

- average number of goals conceded per match
- effective goalkeeper intervention area
- effective goalkeeper coverage area
- early interceptions outside small box

The effective intervention area represents the spatial region in which the goalkeeper successfully interacts with the ball or disrupts opponent possession.

Results from the experiment demonstrate a significant improvement in defensive performance. The updated system achieved a 37% reduction in goals conceded compared to the previous architecture. Additionally, the goalkeeper's effective intervention area increased by approximately 100%, indicating a substantial expansion of defensive coverage.

These improvements confirm that the redesigned goalkeeper model successfully increases defensive resilience while maintaining tactical stability across the team structure.

Table 1. Experimental comparison between the ROBOTECH RoboCup 2025 architecture and the updated defensive system with expanded goalkeeper behavior. Controlled experiment across 150 simulated matches.

Metric	**Baseline System (RoboCup 2025)**	**Updated System (GK Expansion)**	**Improvement**
Matches Simulated	150	150	—
Avg. Goals Conceded / Match	2.16	1.36	−37%
Goalkeeper Ball Interventions	4.8 per match	7.9 per match	+64%
Effective GK Coverage Area	1.0× baseline	2.0× baseline	+100%
Early Interceptions Outside Small Box	1.2 per match	3.4 per match	+183%
Through-Pass Interruptions	1.1 per match	3.0 per match	+172%
Defensive Response Time	0.72 s	0.44 s	−39%

6 Conclusion

The ROBOTECH team continues to evolve its architecture through iterative development informed by competitive experience.

Following our 9th place finish at RoboCup 2025, the current development cycle focused primarily on strengthening defensive capabilities and improving goalkeeper intervention behavior.

The introduction of refined threat evaluation parameters and an expanded goalkeeper movement model significantly improves the team's ability to respond to high-risk attacking situations.

These improvements represent an important step toward creating a more resilient and adaptive team architecture capable of competing at higher levels within the RoboCup Soccer Simulation 2D.

7 Future Work

Future development efforts will focus on several areas aimed at further improving team coordination and tactical adaptability.

Key research directions include:

- Improved prediction models for opponent movement
- Enhanced communication between defensive agents
- Development of coordinated defensive pressing strategies
- Optimization of goalkeeper positioning algorithms

Through continued experimentation and participation in international competitions, the ROBOTECH team aims to further refine its architecture and achieve stronger competitive performance in future RoboCup events.

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