Advanced Soccer Skills and Team Play of RoboCup 2017 TeenSize Winner NimbRo

Artificial Intelligence For Games

Yebei Hu

25.07.2019

Overview

- Introduction
- Robot Platforms
- Visual Perception
- Soccer Behavior & Team Play
- Game Performance

Introduction: RoboCup

"Robot Soccer World Cup"

· An annual international robotics competition proposed and founded in 1996

· Aims at promoting robotics and AI research by offering a publicly appealing but formidable challenge

· A team of fully autonomous humanoid robots shall beat the winner of the most recent World Cup

RoboCup 2017 TeenSize Winner: NimbRo

· Soccer tournament: 3 vs. 3
· Drop-in games: team vs. team
· Technical challenges: push recovery, high jump, high kick, goal kick from moving ball

The team NimbRo (from Universität Bonn)

Introduction: A short video

RoboCup 2017 NimbRo TeenSize highlights video:
https://youtu.be/6ldHWWHfeBc

Robot Platforms

Igus Humanoid Open Platform
Height: 92cm
Weight: 6.6kg

Dynaped
Height: 109cm
Weight: 7.5kg

Visual Perception: Field Detection

- Base on color segmentation in the HSV color space (the field used in RoboCup is green)

- Using a user-selected green color range, a binarized image is constructed

- All connected components that appear below the estimated horizon are found

- Connected regions that have an area greater than some chosen threshold are taken into consideration for the extraction of a field boundary

Visual Perception: Field Detection

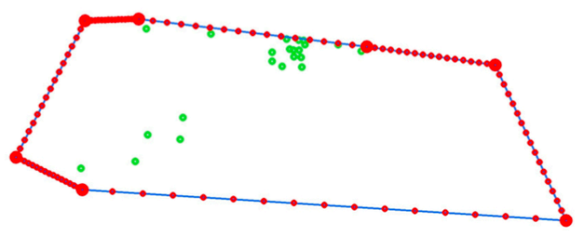
- Finding a convex hull of all green areas directly doesn't work well due to the significant image distortion (Fig. a)

- The vertices of the connected regions are first undistorted before calculating the convex hull (Fig. b)

- The convex hull points and intermediate points on each edge are then distorted back into the raw captured image

- The resulting polygon is taken as the field boundary (Fig. c)

(a) Convex hull of the green regions in the image (yellow), and the unwanted area (red arrows).



(b) Boundary points of the undistorted convex hull. Green points are vertices of the raw extracted regions.

(c) Final detected field area.

(d) An undistorted captured image.

Visual Perception: Ball Detection

- In previous years, most RoboCup teams used simple color segmentation and blob detection based approaches to find the orange ball

- Now that the ball is mostly white and with a pattern, such simple approaches no longer work well, especially since the lines and goal posts are also white

- A new two-stage method is used to detect the ball

Visual Perception: Ball Detection

In the first stage:

• White connected components in the image are found, and the Ramer-Douglas-Peucker algorithm is applied to reduce the number of polygon vertices in the resulting regions

• The detected white regions are searched for at least one third full circle shapes within the expected radius ranges

• Color histograms of the detected circles are calculated for each of the three HSV channels, and compared to expected ball color histograms using the Bhattacharyya distance

• Circles with a suitably similar color distribution to expected are considered to be ball candidates

Visual Perception: Ball Detection

In the second stage:

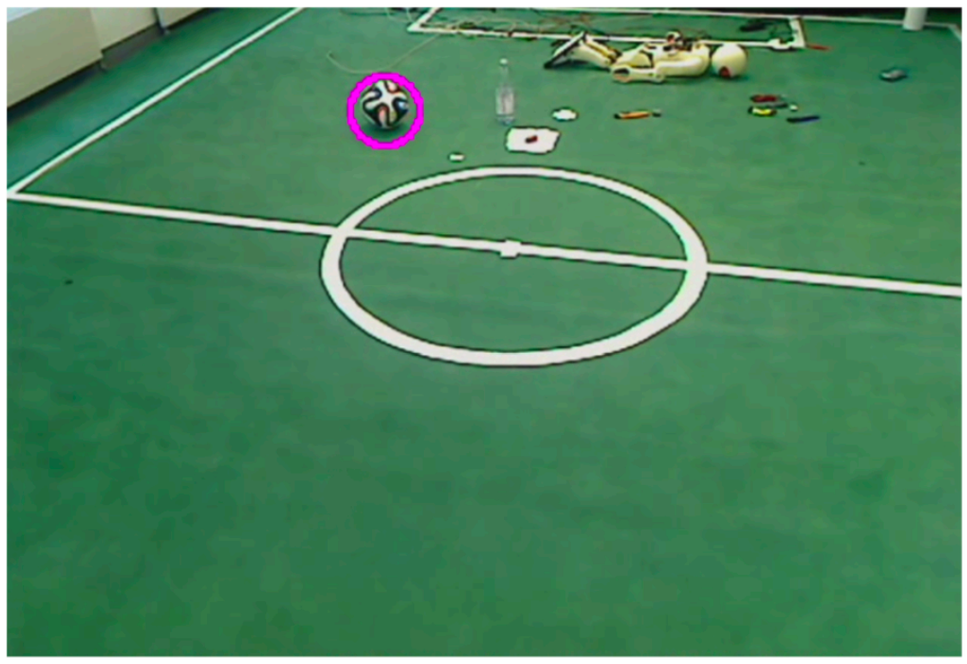
- A dense histogram of oriented gradients (HOG) descriptor is applied in the form of a cascade classifier, with use of the AdaBoost technique

- Using this cascade classifier, we reject those candidates that do not have the required set of HOG features

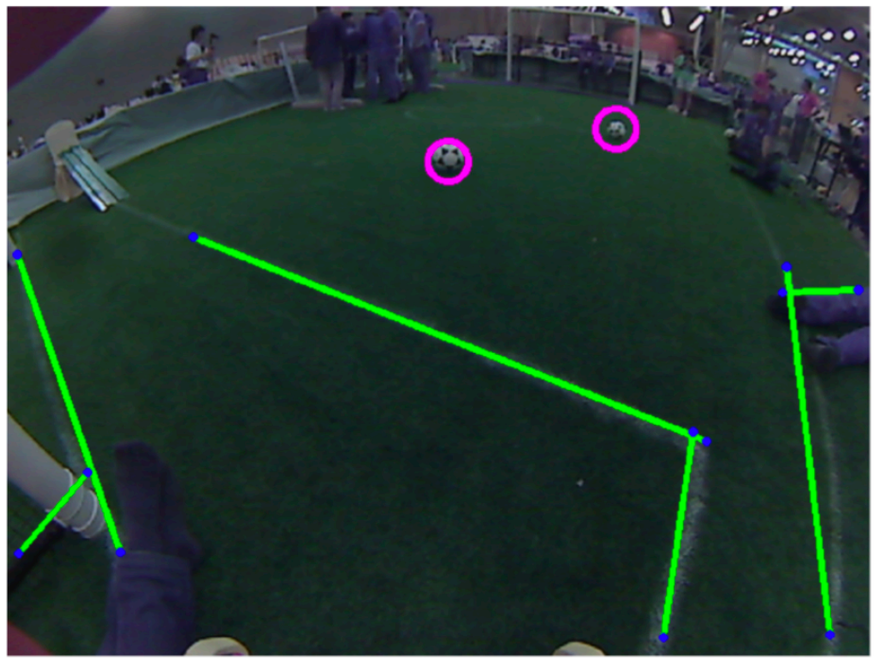
The aim of using the HOG descriptor is to find a description of the ball that is largely invariant to changes in illumination and lighting conditions

Visual Perception: Ball Detection

Each positive sample that the user provides is extended to a total of 10 positive samples



(a) Ball detection in an undistorted image, with other white objects.



(b) Multiple balls detected on a soccer field, with image distortion.

Visual Perception: Field Line Detection

- Detect spatial changes in brightness in the image using a canny edge detector on the V channel of the HSV color space

- A probabilistic Hough line detector is used to extract line segments of a certain minimum size from the detected edges

- Line segments are filtered to avoid false positives

- The remaining similar line segments are merged to produce fewer larger lines

- The final result is a set of line segments that relates to the lines and center circle on the field (shorter line segments are used for detecting the field circle)

Visual Perception: Goal Detection

First stage:

- The image is binarized using color segmentation of the color white

- Horizontal and vertical lines are then extracted from the binarized image using probabilistic Hough line detection

- The detected vertical and horizontal line segments are merged together to produce fewer, bigger lines

(a) White color segmented image in which pixels that are not considered to be white have been painted black.

(b) Result after merging all extracted horizontal and vertical white line segments (annotated in blue).

Visual Perception: Goal Detection

The vertical line segments that do not meet the following criteria are rejected:

· The length of the line segment must be within a certain range, dependent on the distance from the robot to the projected bottom point of the line

· The bottom of the line must be within the field

· The top of the line must be above the estimated horizon if the goal post candidate is more than 2m from the robot there must be one horizontal line segment close to the candidate

Visual Perception: Obstacle Detection

• Based on color segmentation of black (The rules of the RoboCup humanoid league state that all robots should have mostly black feet)

• Search for black connected components within the field boundary, and if a detected component is large enough and within a certain predefined distance interval from the robot, the component is accepted as an obstacle

• To prevent the detection of own body parts as obstacles, an image mask is implemented that is dependent on the position of the head. This allows the regions of the image that are expected to contain parts of the own body to be ignored

Soccer Behavior & Team Play

• Based on the visual perception of the game state, including ball detections, obstacle detections, etc., our robots still need to decide on and execute a strategy for playing soccer

• This primarily involves localizing the ball and scoring a goal while avoiding obstacles, but also extends to team communications, team play, and coordination of the game

• A two-layered hierarchical finite state machine (FSM) has been implemented for this purpose and runs in a separate behaviors node

Soccer Behavior & Team Play

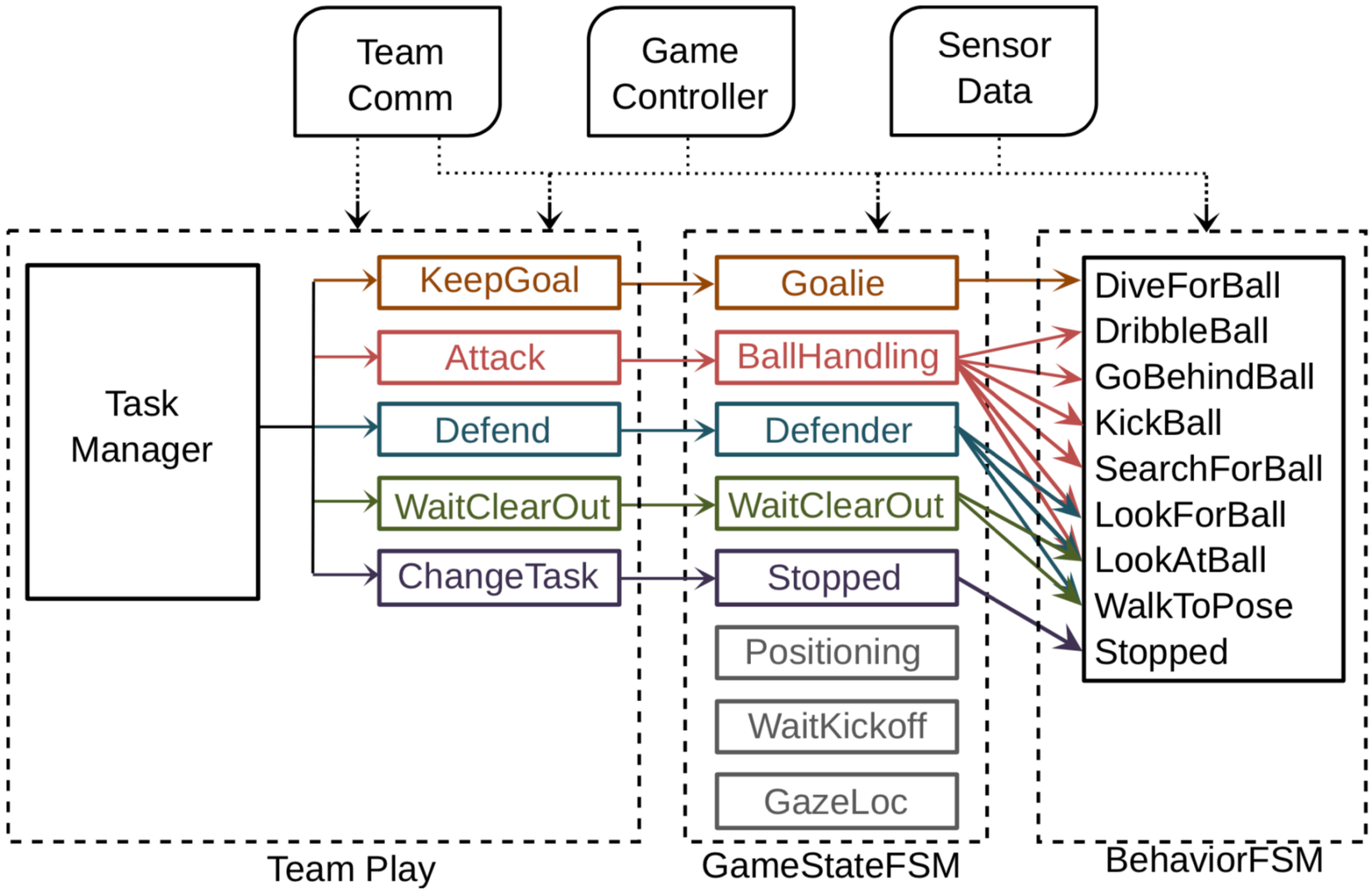


Fig. 4. Based on sensor data, the game controller and the team communication, the task manager assigns a task to each robot. Each task is associated to a state of the Game FSM, which triggers a sequence of behaviors in a lower-level Behavior FSM.

Team Play: 3 vs. 3

- Teams in RoboCup2017: 1 goalkeeper and 2 field players (1striker & 1defender)
- Define dynamic Player Tasks which are frequently reassigned during the game
- A goalkeeper can only be assigned the task KeepGoal, while a field player can alternate between Attack, Defend, ChangeTask and WaitClearOut

Striker & Defender

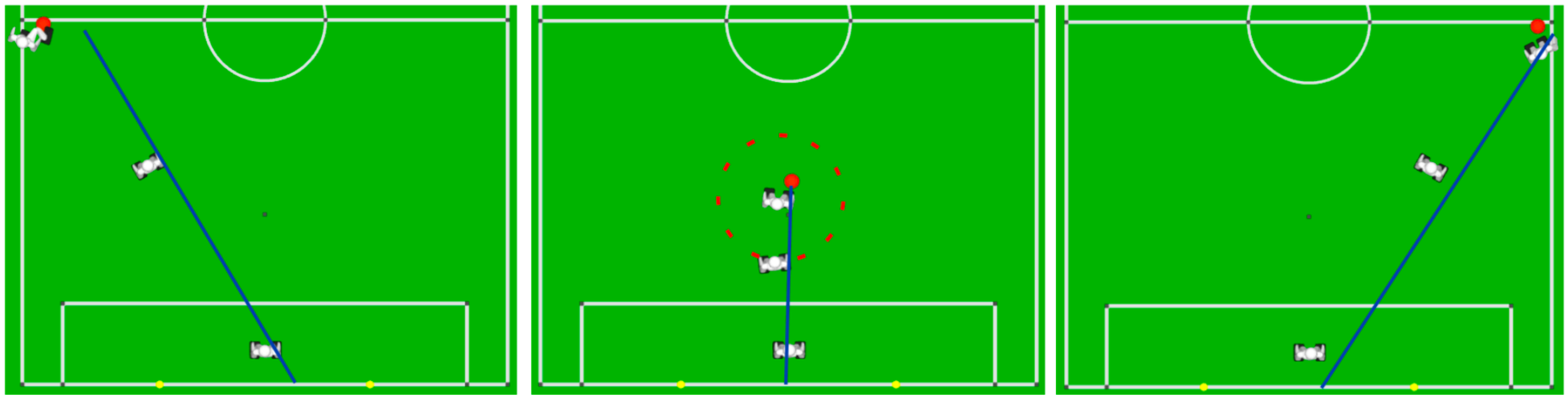


Fig. 5. Different poses that the defender might have according to the ball pose. On the middle the minimum distance between field players is shown in red.

Striker & Defender

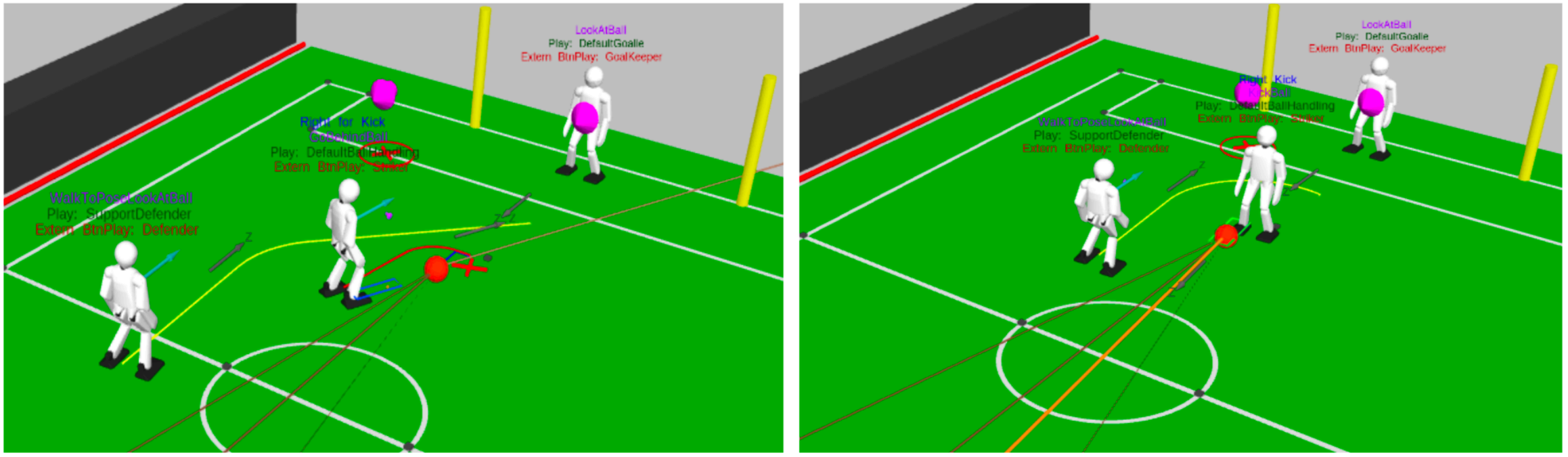


Fig. 6. Collision avoidance between field players. The defender considers the pose of the striker and surrounds it.

Team Play: Goalkeeper

- KeepGoal Task: dive in some direction or clean out the ball (managed by the task manager)

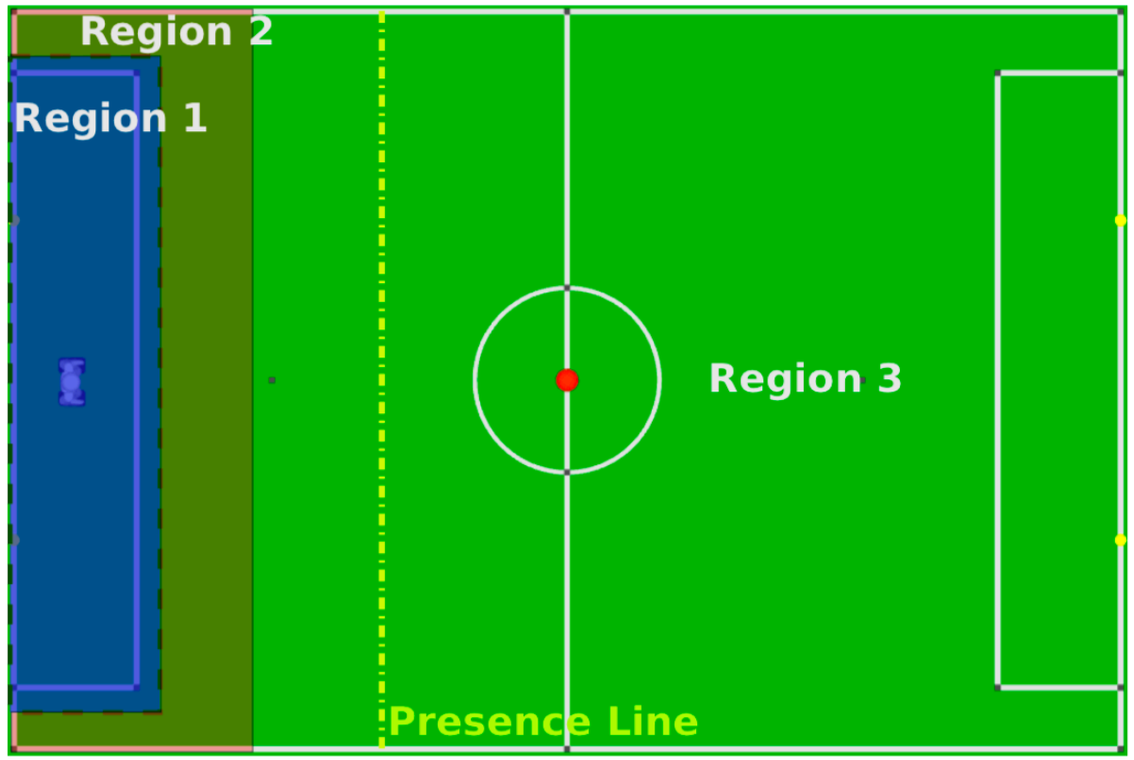


Fig. 8. Areas determining goalkeeper ball clearing behavior. In Region 1, goalkeeper needs to clear out the ball. In Region 3, the robot is remains in its goal. In Region 2, the goalkeeper clears out the ball if there is no field player between the own goal and the presence line (yellow dotted line).

Team Play: WaitClearOut

- The RoboCup Humanoid League has a special rule that prohibits more than one robot to be in the own area for more than 10s

- When a robot announces that it will clear out the ball from the own goal area, a WaitClearOut task reassignment occurs

- Other robots go closer to the ball without entering the own goal area to avoid the illegal defense

- The path is planned such that the robot will not block the shot from an other robot clearing out the ball and two robots will not collide with each other

Team Play: WaitClearOut

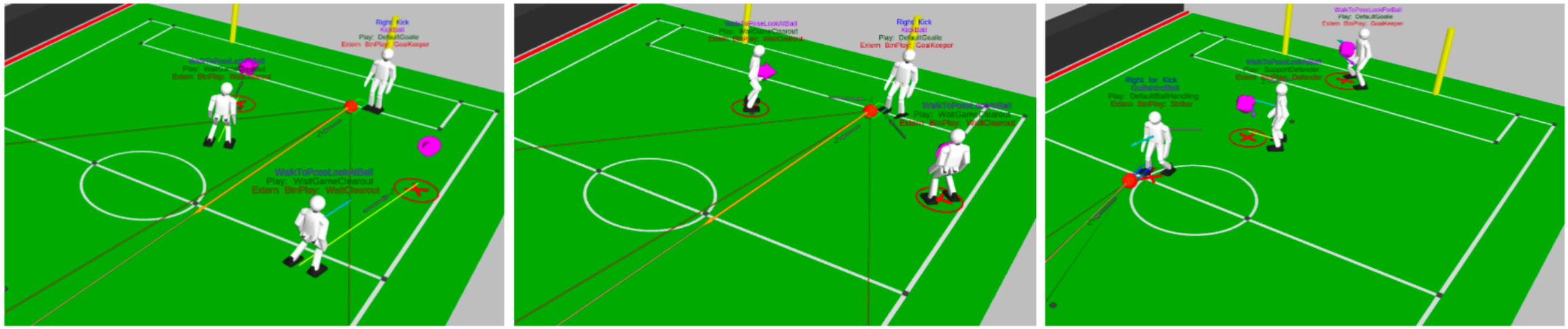


Fig. 7. Ball clear out by the goalkeeper. The yellow line represents the planned path, while the surrounded red cross refers to the instantaneous 2D target pose. Note that the robots always look at the ball. The figure at the rightmost shows the game after the clear out.

Team Play: Task Assignment & Reassignment

• The task assignment is based on an asynchronous request-and- response system that ensures that there is only one robot actively inter- acting with the ball (This prohibits, for example, that two robots try to kick the ball simultaneously which could lead to team self-collisions)

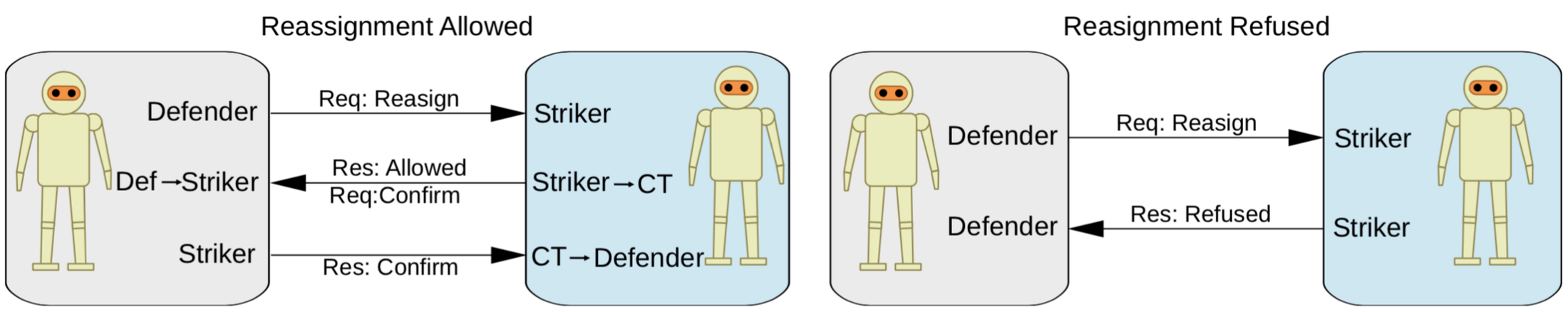


Fig. 9. Task assignment. A defender sends a request to change task. If the request is accepted, the striker is assigned to ChangeTask. It requests a confirmation, and the defender changes its task. If the request is refused, both robots keep their current tasks.

Game Performance

- In RoboCup 2017, robots of NimbRo scored 37 goals in 12 matches and did not receive any goal

- 27 goals were scored during seven games of the TeenSize tournament and the remaining 10 goals were scored in five Drop-in games

- In the Drop-in games, the individual skills were tested and their robots have obtained 21 points in total, having a margin of 19 points to the team in second place

- Dynaped withstanded the push from a 1.5 kg pendulum which was retracted by 55 cm, and also completed high kick with a height of 8 cm. Igus performed a jump of height 4.5 cm, remaining 0.192 s in the air and stand stable afterwards

- This proved the robustness of the methods they used

Sources

• Rodriguez et al, “Advanced Soccer Skills and Team Play of RoboCup 2017 TeenSize Winner NimbRo”, 2017

• H. Farazi, P. Allgeuer, and S. Behnke, “A Monocular Vision System for Playing Soccer in Low Color Information Environments”, 2015

• U. Ramer, “An iterative procedure for the polygonal approximation of plane curves”, *Computer graphics and image processing*, vol. 1, no. 3, pp. 244–256, 1972

• J. Canny, “A computational approach to edge detection,” *Pattern* Analysis and Machine Intelligence, IEEE Transactions on, no. 6, pp. 679–698, 1986

• J. Matas, C. Galambos, and J. Kittler, “Robust detection of lines using the progressive probabilistic Hough transform,” *Computer Vision and Image Understanding*, vol. 78, no. 1, pp. 119–137, 2000

• https://www.robocup2017.org/

• http://nimbro.net/Humanoid/

Thank you for your attention!