

# Half Field Offense Technical Manual

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## 1 Overview

This document describes the state and action spaces of the HFO domain.

## 2 State Spaces

The HFO domains provides a choice between a low-level feature set and a higher-level feature set. Selecting between the different feature sets is accomplished when connecting to the agent

server. See `examples/hfo_example_agent.cpp` and `examples/hfo_example_agent.py` for examples.

## 2.1 High Level Feature Set

A set of high-level features is provided following the example given by Barrett et al. pp. 159-160 [1]. Barrett writes “There are many ways to represent the state of a game of half field offense. Ideally, we want a compact representation that allows the agent to learn quickly by generalizing its knowledge about a state to similar states without over-constraining the policy.” All features are encoded as floating point values and normalized to the range of  $[-1,1]$ . Invalid features are given a value of -2. The features are as follows:

### 2.1.1 High Level State Feature List

- 0 **X position** - The agent's x position on the field.
- 1 **Y position** - The agent's y position on the field.
- 2 **Orientation** - The direction that the agent is facing.
- 3 **Ball Distance** - Distance to the ball.
- 4 **Ball Angle** - Angle to the ball.
- 5 **Able to Kick** - Boolean indicating if the agent can kick the ball.
- 6 **Goal Center Distance** - Distance from the agent to the center of the goal.
- 7 **Goal Center Angle** - Angle from the agent to the center of the goal.
- 8 **Goal Opening Angle** - The size of the largest open angle of the agent to the goal, shown as  $\theta_g$  in Figure 1. Invalid if agent is not playing offense.
- $T$  **Teammate  $i$ 's Goal Opening Angle** - For each teammate  $i$ : is goal opening angle. Invalid if agent is not playing offense.
- 1 **Distance to Opponent** - If an opponent is present, distance to the closest opponent. This feature is absent if there are no opponents.
- $T$  **Distance from Teammate  $i$  to Opponent** - For each teammate  $i$ : the distance from the teammate to the closest opponent. This feature is absent if there are no opponents. If teammates are present but not detected, this feature is considered invalid and given the value of -2.
- $T$  **Pass Opening Angle** - For each teammate  $i$ : the open angle available to pass to teammate  $i$ . Shown as  $\theta_p$  in Figure 1. If teammates are present but not detected, this feature is considered invalid and given the value of -2.

**2T Distance and Angle to Teammates** - For each teammate  $i$ : the distance and angle to that teammate.

There are a total of  $9 + 4 * \text{num\_teammates}$  features with an additional  $1 + \text{num\_teammates}$  features if at least one opponent is present.

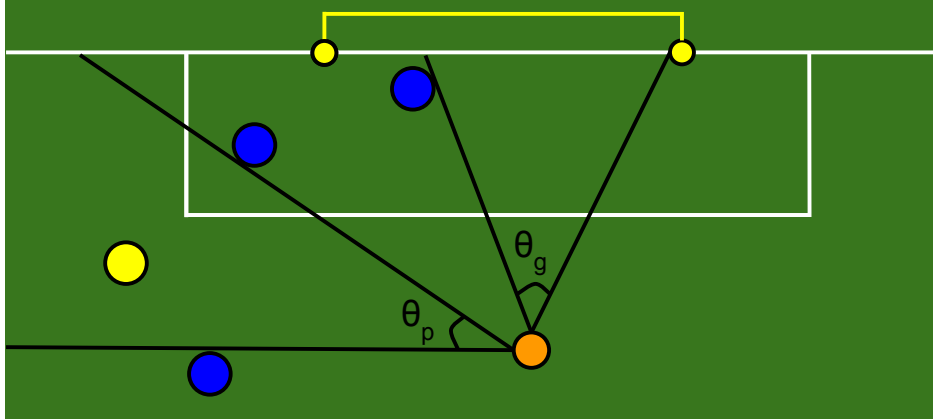


Figure 1: Open angle from ball to the goal  $\theta_g$  avoiding the blue goalie and the open angle from the ball to the yellow teammate  $\theta_p$ . Figure reproduced with permission from Samuel Barrett.

## 2.2 Low Level Feature Set

The state features used by HFO are designed with the mindset of providing an overcomplete, basic, egocentric viewpoint. The features are basic in the sense that they provide distances and angles to relevant points of interest, but do not include higher level perceptions such as the largest angle between a goal post and goalkeeper.

All features are encoded as floating point values normalized to the range of  $[-1,1]$ . Different types of features are discussed next.

### 2.2.1 Boolean Features

Boolean features assume either the minimum feature value of -1 or the maximum feature value of 1.

### 2.2.2 Valid Features

Since feature information is attained from the Agent's world-model, it is possible that, the world model's information may be stale or incorrect. *Valid features* are boolean features indicating consistency of world model predictions. For example, if the world model's estimate of the agent's position is known to be flawed, the *valid feature* for self position would assume the minimum value of -1. Otherwise it will assume the maximum value of 1.

The features associated with a valid feature are given the value of zero if an inconsistency is detected. For example, if the world model detects that the agent’s velocity is invalid, the feature that encodes the magnitude of self velocity will be set to zero.

### 2.2.3 Angular Features

*Angular features* (e.g. the angle to the ball), are encoded as two floating point numbers – the  $\sin(\theta)$  and  $\cos(\theta)$  where  $\theta$  is the original angle.

This encoding allows the angle to vary smoothly for all possible angular values. Other encodings such as radians or degrees have a discontinuity that when normalized, could cause the feature value to flip between the maximum and minimum value in response to small changes in  $\theta$ .

### 2.2.4 Distance Features

*Distance features* encode the distance to objects of interest. Unless otherwise indicated, they are normalized against the maximum possible distance in the HFO playfield (defined as  $\sqrt{l^2 + w^2}$  where  $l, w$  are the length and width of the HFO playfield). A distance of zero will be encoded with the minimum feature value of -1 while a maximum distance will be encoded with 1.

### 2.2.5 Landmark Features

Landmark features encode the relative angle and distance to a landmark of interest. Each landmark feature consists of three floating point values, two to encode the angle to the landmark and one to encode the distance. Note that if the agent’s self position is invalid, then the landmark feature values are zeroed.

### 2.2.6 Player Features

Player features are used to encode the relationship of the agent to another player or opponent. Each player feature is encoded as 1) a landmark feature of that player’s location 2) the global angle of that player’s body 3) the magnitude of the player’s velocity and 4) the global angle of the player’s velocity. Eight floating point numbers are used to encode each player feature.

### 2.2.7 Other Features

Some features, such as the agent’s stamina, do not fall into any of the above categories. These features are referred to as *other features*.

### 2.2.8 Low Level State Feature List

Basic Features are always present and independent of the number of teammates or opponents. The 32 basic features are encoded using 58 floating point values (*angular features* require

two floats, *landmark features* require 3). Additionally a variable number of *player features* are then added. This number depends on the number of teammates and opponents in the HFO game, but 8 floating point values are required for each player feature. Thus, the total number of features is  $58 + 8 * \text{num\_teammates} + 8 * \text{num\_opponents}$ .

- 0 **Self\_Pos\_Valid** [Valid] Indicates if self position is valid.
- 1 **Self\_Vel\_Valid** [Valid] Indicates if the agent's velocity is valid.
- 2–3 **Self\_Vel\_Ang** [Angle] Angle of agent's velocity.
- 4 **Self\_Vel\_Mag** [Other] Magnitude of agent's velocity. Normalized against the maximum observed self speed, 0.46.
- 5–6 **Self\_Ang** [Angle] Agent's Global Body Angle.
- 7 **Stamina** [Other] Agent's Stamina: The amount of remaining stamina the agent has. Normalized against the maximum observed agent stamina of 8000.
- 8 **Frozen** [Boolean] Indicates if the agent is Frozen. Frozen status can happen when being tackled by another player.
- 9 **Colliding\_with\_ball** [Boolean] Indicates if the agent is colliding with the ball.
- 10 **Colliding\_with\_player** [Boolean] Indicates if the agent is colliding with another player.
- 11 **Colliding\_with\_post** [Boolean] Indicates if the agent is colliding with a goal post.
- 12 **Kickable** [Boolean] Indicates if the agent is able to kick the ball.
- 13–15 **Goal Center** [Landmark] Center point between the goal posts.
- 16–18 **Goal Post Top** [Landmark] Top goal post.
- 19–21 **Goal Post Bot** [Landmark] Bottom goal post.
- 22–24 **Penalty Box Center** [Landmark] Center of the penalty box line.
- 25–27 **Penalty Box Top** [Landmark] Top corner of the penalty box.
- 28–30 **Penalty Box Bot** [Landmark] Bottom corner of the penalty box.
- 31–33 **Center Field** [Landmark] The left middle point of the HFO play area. True center of the full-field.
- 34–36 **Corner Top Left** [Landmark] Top left corner HFO Playfield.
- 37–39 **Corner Top Right** [Landmark] Top right corner HFO Playfield.

- 40–42 **Corner Bot Right** [Landmark] Bot right corner HFO Playfield.
- 43–45 **Corner Bot Left** [Landmark] Bot left corner HFO Playfield.
- 46 **OOB Left Dist** [Distance] Distance to the nearest point of the left side of the HFO playable area. E.g. distance remaining before the agent goes out of bounds in left field.
- 47 **OOB Right Dist** [Distance] Distance remaining before the agent goes out of bounds in right field.
- 48 **OOB Top Dist** [Distance] Distance remaining before the agent goes out of bounds in top field.
- 49 **OOB Bot Dist** [Distance] Distance remaining before the agent goes out of bounds in bottom field.
- 50 **Ball Pos Valid** [Valid] Indicates if the ball position estimate is valid.
- 51–52 **Ball Angle** [Angle] Angle to the ball from the agent’s perspective.
- 53 **Ball Dist** [Distance] Distance to the ball.
- 54 **Ball Vel Valid** [Valid] Indicates if the ball velocity estimate is valid.
- 55 **Ball Vel Mag** [Other] Global magnitude of the ball velocity. Normalized against the observed maximum ball velocity, 3.0.
- 56–57 **Ball Vel Ang** [Angle] Global angle of ball velocity.
- 8*T* **Teammate Features** [Player] One teammate feature set (8 features) for each teammate active in HFO, sorted by proximity to the agent.
- 8*O* **Opponent Features** [Player] One opponent feature set (8 features) for each opponent present, sorted by proximity to the player.

### 3 Action Space

The HFO domain provides support for both low-level primitive actions and high-level strategic actions. Basic, parameterized actions are provided for locomotion and kicking. Additionally high-level strategic actions are available for moving, shooting, passing and dribbling. Control of the agent’s head and gaze is not provided and follows Agent2D’s default strategy. Selection between high-level and low-level actions spaces is performed when connecting to the agent server.

### 3.1 Low Level Actions

- **Dash**(power, degrees): Moves the agent with power  $[-100, 100]$  where negative values move backwards. The relative direction of movement is given in degrees and varies between  $[-180, 180]$  with 0 degrees being a forward dash and 90 degrees dashing to the agent's right side. Note, dashing does not turn the agent.
- **Turn**(degrees): Turns the agent in the specified direction. Valid values range between  $[-180, 180]$  degrees where 90 degrees turns the agent to directly to its right side.
- **Tackle**(degrees): Contest the ball. Direction varies between  $[-180, 180]$ . TODO: Better description.
- **Kick**(power, degrees): Kick the ball with power  $[0, 100]$  in relative direction  $[-180, 180]$ . Has no effect if the agent does not possess the ball.
- **Quit**: Indicates to the agent server that you wish to terminate the HFO environment.

### 3.2 High Level Actions

- **Move**(): Re-positions the agent according to the strategy given by Agent2D. The *move* command works only when agent does not have the ball. If the agent has the ball, another command such as *dribble*, *shoot*, or *pass* should be used.
- **Shoot**(): Executes the best available shot. This command only works when the agent has the ball.
- **Pass**(): Finds the best teammate to pass to and the type of pass to use. This command only works when the agent has the ball.
- **Dribble**(): Advances the ball towards the goal using a combination of short kicks and moves.

## References

- [1] S. Barrett. *Making Friends on the Fly: Advances in Ad Hoc Teamwork*. PhD thesis, The University of Texas at Austin, Austin, Texas, USA, December 2014.