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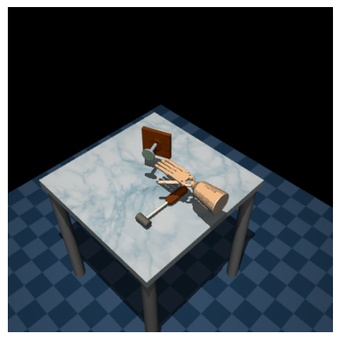

Description

This environment was introduced in "Learning Complex Dexterous Manipulation with Deep Reinforcement Learning and Demonstrations" by Aravind Rajeswaran, Vikash Kumar, Abhishek Gupta, Giulia Vezzani, John Schulman, Emanuel Todorov, and Sergey Levine.

The environment is based on the Adroit manipulation platform, a 28 degree of freedom system which consists of a 24 degrees of freedom ShadowHand and a 4 degree of freedom arm. The task to be completed consists on picking up a hammer with and drive a nail into a board. The nail position is randomized and has dry friction capable of absorbing up to 15N force. Task is successful when the entire length of the nail is inside the board.

Action Space

The action space is a `Box(-1.0, 1.0, (26,), float32)`. The control actions are absolute angular positions of the Adroit hand joints. The input of the control actions is set to a range between -1 and 1 by scaling the real actuator angle ranges in radians. The elements of the action array are the following:

v1.2.3 (latest)

Num	Action	Control Min	Control Max	Angle Min	Angle Max	Name (in corresponding XML file)	Joint	Un
0	Angular up and down movement of the full arm	-1	1	-0.4 (rad)	0.25 (rad)	A_ARRx	hinge	ang (rad
1	Angular left and right and down movement of the full arm	-1	1	-0.3 (rad)	0.3 (rad)	A_ARRy	hinge	ang (rad
2	Angular position of the horizontal wrist joint (radial/ulnar deviation)	-1	1	-0.524 (rad)	0.175 (rad)	A_WRJ1	hinge	ang (rad
3	Angular position of the horizontal wrist joint (flexion/extension)	-1	1	-0.79 (rad)	0.61 (rad)	A_WRJ0	hinge	ang (rad
4	Horizontal angular position of the MCP joint of the forefinger (adduction/abduction)	-1	1	-0.44 (rad)	0.44(rad)	A_FFJ3	hinge	ang (rad
5	Vertical angular position of the MCP joint of the forefinger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_FFJ2	hinge	ang (rad
6	Angular position of the PIP joint of the forefinger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_FFJ1	hinge	ang (rad
7	Angular position of the DIP joint of the forefinger	-1	1	0 (rad)	1.6 (rad)	A_FFJ0	hinge	ang (rad
8	Horizontal angular position of the MCP joint of the middle finger (adduction/abduction)	-1	1	-0.44 (rad)	0.44(rad)	A_MFJ3	hinge	ang (rad
9	Vertical angular position of the MCP joint of the middle finger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_MFJ2	hinge	ang (rad
10	Angular position of the PIP joint of the middle finger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_MFJ1	hinge	ang (rad
11	Angular position of the DIP joint of the middle finger	-1	1	0 (rad)	1.6 (rad)	A_MFJ0	hinge	ang (rad
12	Horizontal angular position of the MCP joint of the ring finger (adduction/abduction)	-1	1	-0.44 (rad)	0.44(rad)	A_RFJ3	hinge	ang (rad
13	Vertical angular position of the MCP joint of the ring finger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_RFJ2	hinge	ang (rad
14	Angular position of the PIP joint of the ring finger	-1	1	0 (rad)	1.6 (rad)	A_RFJ1	hinge	ang (rad
15	Angular position of the DIP joint of the ring finger	-1	1	0 (rad)	1.6 (rad)	A_RFJ0	hinge	ang (rad
16	Angular position of the CMC joint of the little finger	-1	1	0 (rad)	0.7(rad)	A_LFJ4	hinge	ang (rad
17	Horizontal angular position of the MCP joint of the little finger (adduction/abduction)	-1	1	-0.44 (rad)	0.44(rad)	A_LFJ3	hinge	ang (rad
18	Vertical angular position of the MCP joint of the little finger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_LFJ2	hinge	ang (rad
19	Angular position of the PIP joint of the little finger (flexion/extension)	-1	1	0 (rad)	1.6 (rad)	A_LFJ1	hinge	ang (rad
20	Angular position of the DIP joint of the little finger	-1	1	0 (rad)	1.6 (rad)	A_LFJ0	hinge	ang (rad

Num	Action	Control Min	Control Max	Angle Min	Angle Max	Name (in corresponding XML file)	Joint	Un
21	Horizontal angular position of the CMC joint of the thumb finger	-1	1	-1.047 (rad)	1.047 (rad)	A_THJ4	hinge	ang (rad
22	Vertical Angular position of the CMC joint of the thumb finger	-1	1	0 (rad)	1.3 (rad)	A_THJ3	hinge	ang (rad
23	Horizontal angular position of the MCP joint of the thumb finger (adduction/abduction)	-1	1	-0.26 (rad)	0.26(rad)	A_THJ2	hinge	ang (rad
24	Vertical angular position of the MCP joint of the thumb finger (flexion/extension)	-1	1	-0.52 (rad)	0.52 (rad)	A_THJ1	hinge	ang (rad
25	Angular position of the IP joint of the thumb finger (flexion/extension)	-1	1	-1.571 (rad)	0 (rad)	A_THJ0	hinge	ang (rad

Observation Space

The observation space is of the type `Box(-inf, inf, (46,), float64)`. It contains information about the angular position of the finger joints, the pose of the palm of the hand, the pose of the hammer and nail, and external forces on the nail.

Num	Observation	Min	Max	Joint Name (in corresponding XML file)	Site Name (in corresponding XML file)	Joint Type	Unit
0	Angular position of the vertical arm joint	-Inf	Inf	ARRx	-	hinge	angle (rad)
1	Angular position of the horizontal arm joint	-Inf	Inf	ARRy	-	hinge	angle (rad)
2	Angular position of the horizontal wrist joint	-Inf	Inf	WRJ1	-	hinge	angle (rad)
3	Angular position of the vertical wrist joint	-Inf	Inf	WRJ0	-	hinge	angle (rad)
4	Horizontal angular position of the MCP joint of the forefinger	-Inf	Inf	FFJ3	-	hinge	angle (rad)
5	Vertical angular position of the MCP joint of the forefinge	-Inf	Inf	FFJ2	-	hinge	angle (rad)
6	Angular position of the PIP joint of the forefinger	-Inf	Inf	FFJ1	-	hinge	angle (rad)
7	Angular position of the DIP joint of the forefinger	-Inf	Inf	FFJ0	-	hinge	angle (rad)
8	Horizontal angular position of the MCP joint of the middle finger	-Inf	Inf	MFJ3	-	hinge	angle (rad)
9	Vertical angular position of the MCP joint of the middle finger	-Inf	Inf	MFJ2	-	hinge	angle (rad)
10	Angular position of the PIP joint of the middle finger	-Inf	Inf	MFJ1	-	hinge	angle (rad)
11	Angular position of the DIP joint of the middle finger	-Inf	Inf	MFJ0	-	hinge	angle (rad)
12	Horizontal angular position of the MCP joint of the ring finger	-Inf	Inf	RFJ3	-	hinge	angle (rad)
13	Vertical angular position of the MCP joint of the ring finger	-Inf	Inf	RFJ2	-	hinge	angle (rad)
14	Angular position of the PIP joint of the ring finger	-Inf	Inf	RFJ1	-	hinge	angle (rad)
15	Angular position of the DIP joint of the ring finger	-Inf	Inf	RFJ0	-	hinge	angle (rad)
16	Angular position of the CMC joint of the little finger	-Inf	Inf	LFJ4	-	hinge	angle (rad)
17	Horizontal angular position of the MCP joint of the little finger	-Inf	Inf	LFJ3	-	hinge	angle (rad)
18	Vertical angular position of the MCP joint of the little finger	-Inf	Inf	LFJ2	-	hinge	angle (rad)
19	Angular position of the PIP joint of the little finger	-Inf	Inf	LFJ1	-	hinge	angle (rad)
20	Angular position of the DIP joint of the little finger	-Inf	Inf	LFJ0	-	hinge	angle (rad)
21	Horizontal angular position of the CMC joint of the thumb finger	-Inf	Inf	THJ4	-	hinge	angle (rad)
22	Vertical Angular position of the CMC joint of the thumb finger	-Inf	Inf	THJ3	-	hinge	angle (rad)
23	Horizontal angular position of the MCP joint of the thumb finger	-Inf	Inf	THJ2	-	hinge	angle (rad)
24	Vertical angular position of the MCP joint of the thumb finger	-Inf	Inf	THJ1	-	hinge	angle (rad)
25	Angular position of the IP joint of the thumb finger	-Inf	Inf	THJ0	-	hinge	angle (rad)
26	Insertion displacement of nail	-Inf	Inf	nail_dir	-	slide	position (m)
27	Linear velocity of the hammer in the x direction	-1	1	OBJTx	-	free	velocity (m/s)
28	Linear velocity of the hammer in the y direction	-1	1	OBJTy	-	free	velocity (m/s)
29	Linear velocity of the hammer in the z direction	-1	1	OBJTz	-	free	velocity (m/s)

Num	Observation	Min	Max	Joint Name (in corresponding XML file)	Site Name (in corresponding XML file)	Joint Type	Unit
30	Angular velocity of the hammer around x axis	-1	1	OBJRx	-	free	angular velocity (rad/s)
31	Angular velocity of the hammer around y axis	-1	1	OBJRy	-	free	angular velocity (rad/s)
32	Angular velocity of the hammer around z axis	-1	1	OBJRz	-	free	angular velocity (rad/s)
33	Position of the center of the palm in the x direction	-Inf	Inf	-	S_grasp	-	position (m)
34	Position of the center of the palm in the y direction	-Inf	Inf	-	S_grasp	-	position (m)
35	Position of the center of the palm in the z direction	-Inf	Inf	-	S_grasp	-	position (m)
36	Position of the hammer’s center of mass in the x direction	-Inf	Inf	-	Object	-	position (m)
37	Position of the hammer’s center of mass in the y direction	-Inf	Inf	-	Object	-	position (m)
38	Position of the hammer’s center of mass in the z direction	-Inf	Inf	-	Object	-	position (m)
39	Relative rotation of the hammer’s center of mass with respect to the x axis	-Inf	Inf	-	Object	-	angle (rad)
40	Relative rotation of the hammer’s center of mass with respect to the y axis	-Inf	Inf	-	Object	-	angle (rad)
41	Relative rotation of the hammer’s center of mass with respect to the z axis	-Inf	Inf	-	Object	-	angle (rad)
42	Position of the nail in the x direction	-Inf	Inf	-	S_target	-	position (m)
43	Position of the nail in the y direction	-Inf	Inf	-	S_target	-	position (m)
44	Position of the nail in the z direction	-Inf	Inf	-	S_target	-	position (m)
45	Linear force exerted on the head of the nail	-1	1	-	S_target	-	Newton (N)

Rewards

The environment can be initialized in either a `dense` or `sparse` reward variant.

In the `dense` reward setting, the environment returns a `dense` reward function that consists of the following parts:

- `get_to_hammer`: increasing negative reward the further away the palm of the hand is from the hammer. This is computed as the 3 dimensional Euclidean distance between both body frames. This penalty is scaled by a factor of `0.1` in the final reward.
- `take_hammer_head_to_nail`: increasing negative reward the further away the head of the hammer if from the head of the nail. This reward is also computed as the 3 dimensional Euclidean distance between both body frames
- `make_nail_go_inside`: negative cost equal to the 3 dimensional Euclidean distance from the head of the nail to the board. This penalty is scaled by a factor of `10` in the final reward.
- `velocity_penalty`: Minor velocity penalty for the full dynamics of the environments. Used to bound the velocity of the bodies in the environment. It equals the norm of all the joint velocities. This penalty is scaled by a factor of `0.01` in the final reward.
- `lift_hammer`: adds a positive reward of `2` if the hammer is lifted a greater distance than `0.04` meters in the z direction.
- `hammer_nail`: adds a positive reward the closer the head of the nail is to the board. `25` if the distance is less than `0.02` meters and `75` if it is less than `0.01` meters.

The `sparse` reward variant of the environment can be initialized by calling `gym.make('AdroitHandHammerSparse-v1')`. In this variant, the environment returns a reward of 10 for environment success and -0.1 otherwise.

Starting State

To add stochasticity to the environment the z position of the board with the nail is randomly initialized each time the environment is reset. This height is sampled from a uninform distribution with range `[0.1,0.25]`.

The joint values of the environment are deterministically initialized to a zero.

For reproducibility, the starting state of the environment can also be set when calling `env.reset()` by passing the `options` dictionary argument (https://gymnasium.farama.org/api/env/#gymnasium.Env.reset) with the `initial_state_dict` key. The `initial_state_dict` key must be a dictionary with the following items:

- `qpos`: np.ndarray with shape `(33,)`, MuJoCo simulation joint positions
- `qvel`: np.ndarray with shape `(33,)`, MuJoCo simulation joint velocities
- `board_pos`: np.ndarray with shape `(3,)`, cartesian coordinates of the board with the nail

The state of the simulation can also be set at any step with the `env.set_env_state(initial_state_dict)` method.

Episode End

The episode will be `truncated` when the duration reaches a total of `max_episode_steps` which by default is set to 200 timesteps. The episode is never `terminated` since the task is continuing with infinite horizon.

Arguments

To increase/decrease the maximum number of timesteps before the episode is `truncated` the `max_episode_steps` argument can be set at initialization. The default value is 50. For example, to increase the total number of timesteps to 400 make the environment as follows:

```
import gymnasium as gym

env = gym.make('AdroitHandHammer-v1', max_episode_steps=400)
```

Version History

- v1: refactor version of the D4RL environment, also create dependency on newest mujoco python bindings maintained by the MuJoCo team in Deepmind.
- v0: legacy versions in the D4RL.

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