Spring 2024 6.484 Computational Sensorimotor Learning Assignment 3

In this assignment, we will implement PPO and go through the reward design process when you use reinforcement learning algorithms to solve a task.

You will need to **answer the bolded questions** and **fill in the missing code snippets** (marked by **TODO**).

There are **195** total points to be had in this PSET, plus 10 bonus points for filling out the survey. `ctrl-f` for "pts" to ensure you don't miss questions.

We strongly suggest using Colab Pro for this assignment. As mentioned in class up to 3 month of Google Colab Pro (30$) will be reimbursed.

```
!pip install pybullet > /dev/null 2>&1
!pip install git+https://github.com/idanshen/easyrl.git@sac >
/dev/null 2>&1
!pip install "setuptools<58.0.0" > /dev/null 2>&1
!pip install git+https://github.com/Improbable-AI/airobot.git >
/dev/null 2>&1
!pip install git+https://github.com/Farama-
Foundation/Minigrid.git@gym-minigrid-legacy &>/dev/null

# You can enable the GPU by changing the runtime (Runtime -> Change
runtime type -> Hardware accelerator -> GPU )
from typing import Tuple, List, Dict
import os
import torch
import torch.nn as nn
from torch.distributions.categorical import Categorical
import torch.nn.functional as F
import gym_minigrid
import numpy as np
import matplotlib.pyplot as plt
import gym
from tqdm.notebook import tqdm
from gym_minigrid.envs.doorkey import DoorKeyEnv
import pandas as pd
import random
import gym
import pprint
import pybullet as p
import pybullet_data as py_d
import airobot as ar
import numpy as np
import matplotlib.pyplot as plt
from matplotlib import animation
from IPython.display import HTML
from matplotlib import pylab
from airobot import Robot
from airobot.utils.common import quat2euler
from airobot.utils.common import euler2quat
from gym import spaces
from gym.envs.registration import registry, register
from tensorboard.backend.event_processing.event_accumulator import
EventAccumulator
from torch import nn
from pathlib import Path
from easyrl.agents.ppo_agent import PPOAgent
from easyrl.configs import cfg
from easyrl.configs import set_config
from easyrl.configs.command_line import cfg_from_cmd
from easyrl.engine.ppo_engine import PPOEngine
from easyrl.models.categorical_policy import CategoricalPolicy
from easyrl.models.diag_gaussian_policy import DiagGaussianPolicy
from easyrl.models.mlp import MLP
from easyrl.models.value_net import ValueNet
from easyrl.runner.nstep_runner import EpisodicRunner
from easyrl.utils.common import set_random_seed
from easyrl.utils.gym_util import make_vec_env
from easyrl.utils.common import load_from_json
from base64 import b64encode
%matplotlib inline
%load_ext tensorboard
import warnings
warnings.filterwarnings("ignore")
```

```
/usr/local/lib/python3.10/dist-packages/gym/envs/registration.py:307:
DeprecationWarning: The package name gym_minigrid has been deprecated
in favor of minigrid. Please uninstall gym_minigrid and install
minigrid with `pip install minigrid`. Future releases will be
maintained under the new package name minigrid.
  fn()
```

Part 1: Implementing PPO [30 pts]

In this part you will solve the same environment from the previous assignment, this time with PPO. Run the following code cells to set up the same environment and model as the last pset.

```
# Function from
https://github.com/ikostrikov/pytorch-a2c-ppo-acktr/blob/master/model.
```

```py
def init_params(m):
    """
    Initialize parameters of the network.
    m: torch.nn.Module
    """
    classname = m.__class__.__name__
    if classname.find("Linear") != -1:
        m.weight.data.normal_(0, 1)
        m.weight.data *= 1 / torch.sqrt(m.weight.data.pow(2).sum(1,
keepdim=True))
        if m.bias is not None:
            m.bias.data.fill_(0)

def preprocess_obss(obss, device=None):
    """
    Convert observation into Torch.Tensor

    Parameters
    ----
    obss: dictionary or np.ndarray
    device: target device of torch.Tensor ('cpu', 'cuda')

    Return
    ----
    Torch Tensor
    """
    if isinstance(obss, dict):
        images = np.array([obss["image"]])
    else:
        images = np.array([o["image"] for o in obss])

    return torch.tensor(images, device=device, dtype=torch.float)

class DoorKeyEnv5x5(DoorKeyEnv):
    def __init__(self):
        super().__init__(size=5)

    def _reward(self):
        """
        Compute the reward to be given upon success
        """
        return 1

class Config:
    def __init__(self,
                score_threshold=0.93,
                discount=0.995,
                lr=1e-3,
                max_grad_norm=0.5,
                log_interval=10,
                max_episodes=500,
                gae_lambda=0.95,
                use_critic=False,
                clip_ratio=0.2,
                target_kl=0.01,
                train_ac_iters=5,
                use_discounted_reward=False,
                entropy_coef=0.01,
                use_gae=False):

        self.score_threshold = score_threshold # criterion for early
stopping. If the rolling average reward (over the last 100 episodes)
is greater than it, it ends.
        self.discount = discount # discount factor
        self.lr = lr # learning rate
        self.max_grad_norm = max_grad_norm # the maximum gradient norm
(https://pytorch.org/docs/stable/generated/torch.nn.utils.clip_grad_no
rm_.html)
        self.log_interval = log_interval # logging interval
        self.max_episodes = max_episodes # the maximum number of
episodes.
        self.use_critic = use_critic # whether to use critic or not.
        self.clip_ratio = clip_ratio # clip_ratio of PPO.
        self.target_kl = target_kl # target KL divergence for early
stoping train_ac_iters for PPO
        self.train_ac_iters = train_ac_iters # how many time to train
ac_model using current computed old_logps
        self.gae_lambda=gae_lambda # lambda in Generalized Advantage
Estimation (GAE)
        self.use_discounted_reward=use_discounted_reward # whether use
discounted reward or not.
        self.entropy_coef = entropy_coef # entropy coefficient for PPO
        self.use_gae = use_gae # whether to use GAE or not.

class ACModel(nn.Module):
    def __init__(self, num_actions, use_critic=False):
        """
        Represents an Actor Crictic model that takes a 2d, multi-
channeled
        image as input.

        Parameters
        ----
        num_actions : int

                      The action space of the environment.
                      The action space for DoorKey5x5 is 7-
dimensional:
                      0: turn left,
                    1: turn right,
                    2: forward,
                    3: pickup an object,
                    4: drop an object,
                    5: activate an object,
                    6: done completing task

        use_critics : bool

                    Critic network will be used in forward pass if 
flag is set
                    to true.
        """
        super().__init__()
        self.use_critic = use_critic

        # Define actor's model
        self.image_conv_actor = nn.Sequential(
            nn.Conv2d(3, 16, (2, 2)),
            nn.ReLU(),
            nn.MaxPool2d((2, 2)),
            nn.Conv2d(16, 32, (2, 2)),
            nn.ReLU(),
            nn.Conv2d(32, 64, (2, 2)),
            nn.ReLU()
        )
        self.actor = nn.Sequential(
            nn.Linear(64, 64),
            nn.Tanh(),
            nn.Linear(64, num_actions)
        )

        # Define critic's model
        if self.use_critic:
            self.image_conv_critic = nn.Sequential(
                nn.Conv2d(3, 16, (2, 2)),
                nn.ReLU(),
                nn.MaxPool2d((2, 2)),
                nn.Conv2d(16, 32, (2, 2)),
                nn.ReLU(),
                nn.Conv2d(32, 64, (2, 2)),
                nn.ReLU()
            )
            self.critic = nn.Sequential(
                nn.Linear(64, 64),
                nn.Tanh(),
                nn.Linear(64, 1)
            )

        # Initialize parameters correctly
        self.apply(init_params)

    def forward(self, obs):
        """
        Performs a forward pass through the actor-critic network

        Parameters
        ----
        obs : int tensor. Shape [Batch size, ImWidth, ImHeight,
Channels]

              input to the network.
        ----

        returns:

        dist : torch.distribution
            The distribution of actions from policy. A Categorical
distribution
            for discreet action spaces.
        value : torch.Tensor (Batch size, 1)
            value output by critic network
        """
        conv_in = obs.transpose(1, 3).transpose(2, 3) # reshape into
expected order

        dist, value = None, None

        x = self.image_conv_actor(conv_in)
        embedding = x.reshape(x.shape[0], -1)

        x = self.actor(embedding)
        dist = Categorical(logits=F.log_softmax(x, dim=1))

        if self.use_critic:
            y = self.image_conv_critic(conv_in)
            embedding = y.reshape(y.shape[0], -1)

            value = self.critic(embedding).squeeze(1)
        else:
            value = torch.zeros((x.shape[0], 1), device=x.device)

        return dist, value

def compute_discounted_return(rewards, discount, device=None):
    """
         rewards: reward obtained at timestep.  Shape: (T,)
         discount: discount factor. float

    ----
    returns: sum of discounted rewards. Shape: (T,)
            """
    returns = torch.zeros(*rewards.shape, device=device)

    R = 0
    for t in reversed(range((rewards.shape[0]))):
        R = rewards[t] + discount * R
        returns[t] = R
    return returns

def compute_advantage_gae(values, rewards, T, gae_lambda, discount):
    """
    Compute Adavantage wiht GAE. See Section 4.4.2 in the lecture
notes.

    values: value at each timestep (T,)
    rewards: reward obtained at each timestep.  Shape: (T,)
    T: the number of frames, float
    gae_lambda: hyperparameter, float
    discount: discount factor, float

    -----

    returns:

    advantages : tensor.float. Shape [T,]

                 gae advantage term for timesteps 0 to T

    """
    advantages = torch.zeros_like(values)
    for i in reversed(range(T)):
        next_value = values[i+1]
        next_advantage = advantages[i+1]

        delta = rewards[i] + args.discount * next_value  - values[i]
        advantages[i] = delta + args.discount * args.gae_lambda *
next_advantage
    return advantages[:T]

def collect_experiences(env, acmodel, args, device=None):
    """Collects rollouts and computes advantages.
    Returns
    -------
    exps : dict
        Contains actions, rewards, advantages etc as attributes.
        Each attribute, e.g. `exps['reward']` has a shape
        (self.num_frames, ...).
    logs : dict
        Useful stats about the training process, including the average
        reward, policy loss, value loss, etc.
    """


    MAX_FRAMES_PER_EP = 300
    shape = (MAX_FRAMES_PER_EP, )

    actions = torch.zeros(*shape, device=device, dtype=torch.int)
    values = torch.zeros(*shape, device=device)
    rewards = torch.zeros(*shape, device=device)
    log_probs = torch.zeros(*shape, device=device)
    obss = [None]*MAX_FRAMES_PER_EP

    obs, _ = env.reset()

    total_return = 0

    T = 0

    while True:
        # Do one agent-environment interaction

        preprocessed_obs = preprocess_obss(obs, device=device)

        with torch.no_grad():
            dist, value = acmodel(preprocessed_obs)
        action = dist.sample()[0]


        obss[T] = obs
        obs, reward, done, _, _ = env.step(action.item())


        # Update experiences values
        actions[T] = action
        values[T] = value
        rewards[T] = reward
        log_probs[T] = dist.log_prob(action)


        total_return += reward
        T += 1

        if done or T>=MAX_FRAMES_PER_EP-1:
            break

    discounted_reward = compute_discounted_return(rewards[:T],
args.discount, device)
    exps = dict(
        obs = preprocess_obss([
            obss[i]
            for i in range(T)
        ], device=device),
        action = actions[:T],
        value  = values[:T],
        reward = rewards[:T],
        advantage = discounted_reward-values[:T],
        log_prob = log_probs[:T],
        discounted_reward = discounted_reward,
        advantage_gae=compute_advantage_gae(values, rewards, T, 
args.gae_lambda, args.discount)
    )

    logs = {
        "return_per_episode": total_return,
        "num_frames": T
    }

    return exps, logs

def run_experiment(args, parameter_update, seed=0):
    """
    Upper level function for running experiments to analyze reinforce 
and
    policy gradient methods. Instantiates a model, collects 
epxeriences, and
    then updates the neccessary parameters.

    args: Config arguments. dict
    paramter_update: function used to update model parameters
    seed: random seed. int

    return: DataFrame indexed by episode
    """
    random.seed(seed)
    np.random.seed(seed)
    torch.manual_seed(seed)

    device = torch.device("cuda" if torch.cuda.is_available() else 
"cpu")
    env = DoorKeyEnv5x5()

    acmodel = ACModel(env.action_space.n, use_critic=args.use_critic)
    acmodel.to(device)

    is_solved = False

    SMOOTH_REWARD_WINDOW = 50

    pd_logs, rewards = [], [0]*SMOOTH_REWARD_WINDOW
    optimizer = torch.optim.Adam(acmodel.parameters(), lr=args.lr)
    num_frames = 0

    pbar = tqdm(range(args.max_episodes))
    for update in pbar:
        exps, logs1 = collect_experiences(env, acmodel, args, device)
        logs2 = parameter_update(optimizer, acmodel, exps, args)

        logs = {**logs1, **logs2}

        num_frames += logs["num_frames"]

        rewards.append(logs["return_per_episode"])

        smooth_reward = np.mean(rewards[-SMOOTH_REWARD_WINDOW:])

        data = {'episode':update, 'num_frames':num_frames,
'smooth_reward':smooth_reward,
                'reward':logs["return_per_episode"],
'policy_loss':logs["policy_loss"]}

        if args.use_critic:
            data['value_loss'] = logs["value_loss"]

        pd_logs.append(data)

        pbar.set_postfix(data)

        # Early terminate
        if smooth_reward >= args.score_threshold:
            is_solved = True
            break

    if is_solved:
        print('Solved!')

    return pd.DataFrame(pd_logs).set_index('episode')
```

Proximal Policy Optimization

There are some surprisingly powerful additional tweaks we can make to our GAE implementation from the last pset to further improve performance.

The current standard in policy gradients today is Proximal Policy Optimization, which improves on GAE by taking multiply policy update steps per minibatch, enabled by policy update clipping (this is a specific variant called *PPO-Clip*). This leads to greater sample efficiency, as larger steps can be taken from the same data samples.

We've implemented most of PPO for you: all that's left for you are the policy and value loss computations (note that you'll have to evaluate the `acmodel` each time you compute them). Note that for the policy loss, we also ask that you return the approximate KL divergence between the new and old action distributions notated as `approx_kl`; this is used to facilitate an early stopping condition in policy updates. This blog post shares a simple formula for approximating KL divergence that you can use.

```
Algorithm 1 PPO-Clip
1: Input: initial policy parameters $\theta_0$, initial value function parameters $\phi_0$
2: for $k = 0, 1, 2, \ldots$ do
3:     Collect set of trajectories $\mathcal{D}_k = \{\tau_i\}$ by running policy $\pi_k = \pi(\theta_k)$ in the environment.
4:     Compute rewards-to-go $\hat{R}_t$.
5:     Compute advantage estimates, $\hat{A}_t$ (using any method of advantage estimation) based
       on the current value function $V_{\phi_k}$.
6:     Update the policy by maximizing the PPO-Clip objective:

       $\theta_{k+1} = \arg\max_{\theta} \frac{1}{|\mathcal{D}_k| T} \sum_{\tau \in \mathcal{D}_k} \sum_{t=0}^{T} \min\left( \frac{\pi_\theta(a_t|s_t)}{\pi_{\theta_k}(a_t|s_t)} A^{\pi_{\theta_k}}(s_t, a_t),\ \ g(\epsilon, A^{\pi_{\theta_k}}(s_t, a_t)) \right),$

       typically via stochastic gradient ascent with Adam.
7:     Fit value function by regression on mean-squared error:

       $\phi_{k+1} = \arg\min_{\phi} \frac{1}{|\mathcal{D}_k| T} \sum_{\tau \in \mathcal{D}_k} \sum_{t=0}^{T} \left( V_\phi(s_t) - \hat{R}_t \right)^2,$

       typically via some gradient descent algorithm.
8: end for
```

Where

$$g(\epsilon, A) = \begin{cases} (1+\epsilon)A & A \geq 0 \\ (1-\epsilon)A & A < 0. \end{cases}$$

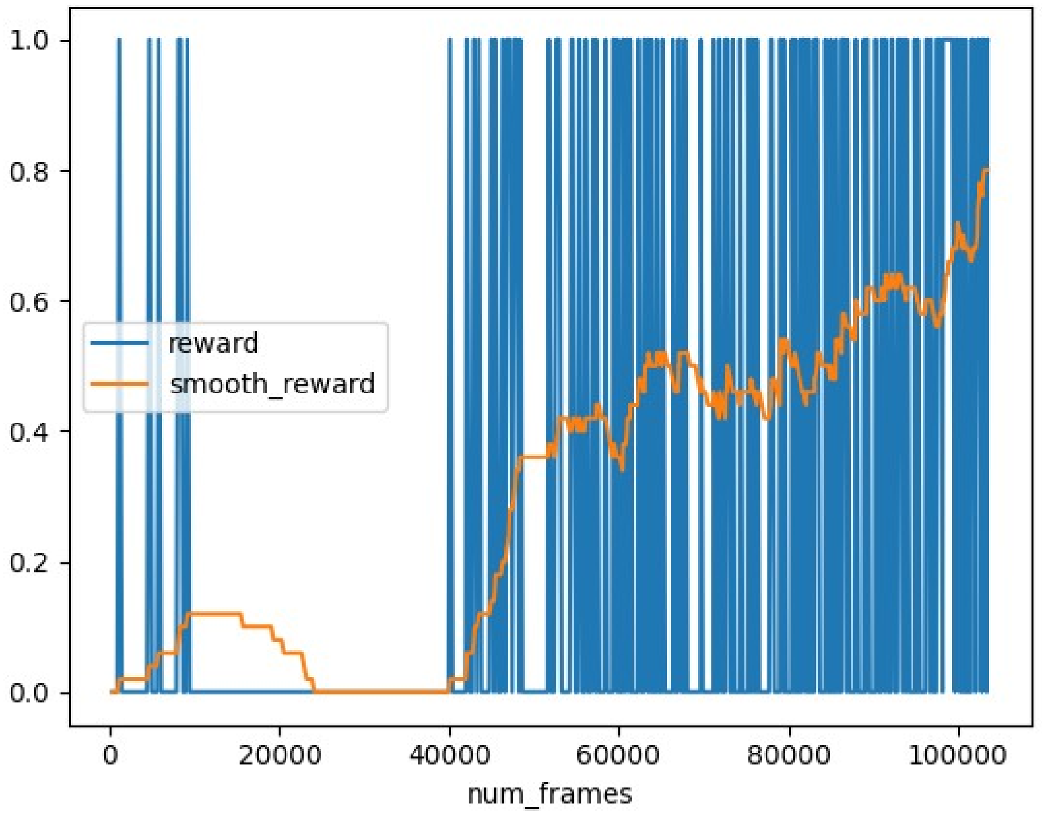
A commonly used technique is to add entropy regularization for policy gradient methods as shown in equation 9 of this paper. You should compute the policy loss as defined above and also add in an entropy term for the updated policy (note that we've provided to you an entropy coefficient in args.entropy_coef).

```python
def update_parameters_ppo(optimizer, acmodel, sb, args):
    def _compute_policy_loss_ppo(obs, old_logp, actions, advantages):
        '''
        Computes the policy loss for PPO.

        obs: observeration to pass into acmodel. shape: (T,)
        old_logp: log probabilities from previous timestep. shape:
```

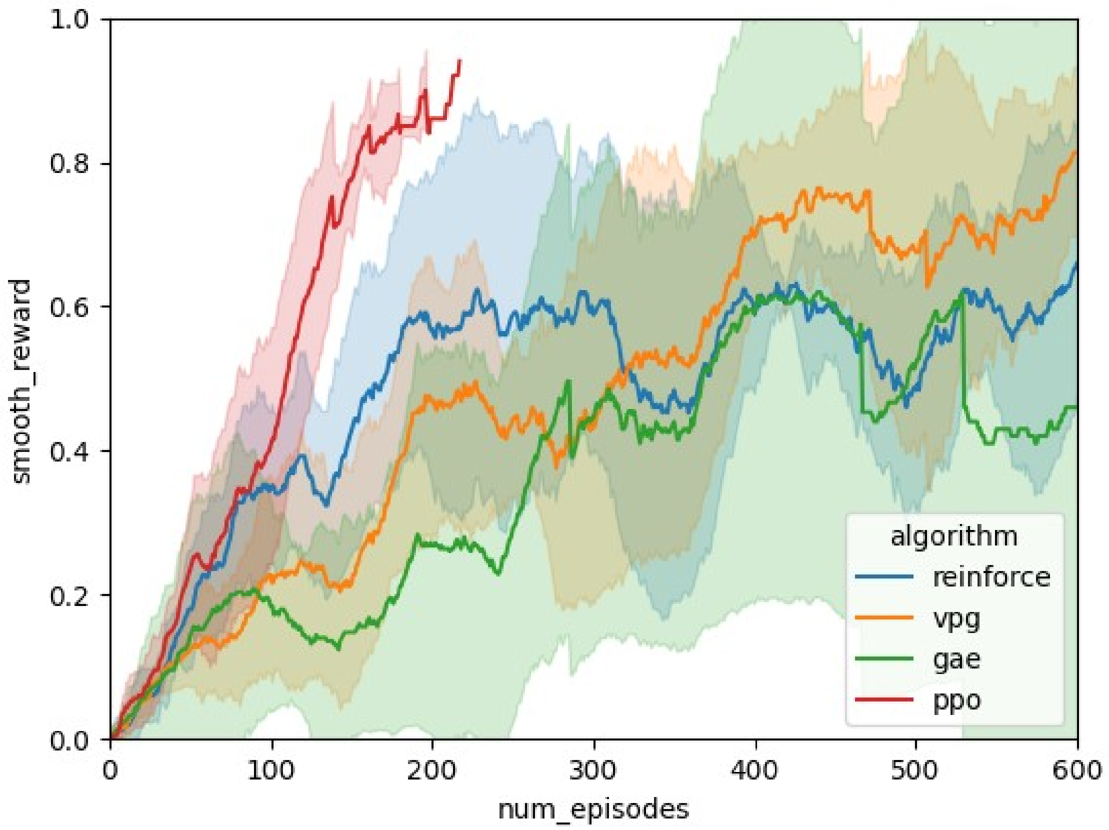
```
(T,)
        actions: action at this timestep. shape:
(T,ImWidth,ImHeight,Channels)
        advantages: the computed advantages. shape: (T,)

        ---
        returns

        policy_loss : ppo policy loss as shown in line 6 of PPO alg.
tensor.float. Shape (,1)
        approx_kl: an appoximation of the kl_divergence. tensor.float.
Shape (,1)
        '''
        policy_loss, approx_kl = 0, 0

        ### TODO: implement PPO policy loss computation (30 pts).
#######
        dist, value = acmodel(obs)
        logp = dist.log_prob(actions)
        ratio = torch.exp(logp - old_logp)

        surr1 = ratio * advantages
        surr2 = torch.clamp(ratio, 1 - args.clip_ratio, 1 +
args.clip_ratio) * advantages

        policy_loss = -torch.min(surr1, surr2).mean()

        # approximating the kl divergence from the blog post
http://joschu.net/blog/kl-approx.html
        r = logp / old_logp
        approx_kl = ((r-1) - torch.log(r)).mean().item()


##################################################################

        return policy_loss, approx_kl

    def _compute_value_loss(obs, returns):
        ### TODO: implement PPO value loss computation (10 pts)
##########


##################################################################
        dist, value = acmodel(obs)
        value_loss = F.mse_loss(value, returns)

        return value_loss


    dist, _ = acmodel(sb['obs'])
    old_logp = dist.log_prob(sb['action']).detach()

    advantage = sb['advantage_gae'] if args.use_gae else
sb['advantage']

    policy_loss, _ = _compute_policy_loss_ppo(sb['obs'], old_logp,
sb['action'], advantage)
    value_loss = _compute_value_loss(sb['obs'],
sb['discounted_reward'])

    for i in range(args.train_ac_iters):
        optimizer.zero_grad()
        loss_pi, approx_kl = _compute_policy_loss_ppo(sb['obs'],
old_logp, sb['action'], advantage)
        loss_v = _compute_value_loss(sb['obs'],
sb['discounted_reward'])

        loss = loss_v + loss_pi
        if approx_kl > 1.5 * args.target_kl:
            break

        loss.backward(retain_graph=True)
        optimizer.step()

    update_policy_loss = policy_loss.item()
    update_value_loss = value_loss.item()

    logs = {
        "policy_loss": update_policy_loss,
        "value_loss": update_value_loss,
    }

    return logs

args = Config(use_critic=True, use_gae=True)
df_ppo = run_experiment(args, update_parameters_ppo)

df_ppo.plot(x='num_frames', y=['reward', 'smooth_reward'])
```

{"model_id":"515935871a724c9a8a2240a310669cad","version_major":2,"version_minor":0}

```
<Axes: xlabel='num_frames'>
```



To help you observe more clearly the advantages of PPO compared to the previous algorithms, we include here the 'fancy plot' from the previous assignment, this time with PPO as well.



Part 2: Reward Design

For part 2 of this assignment, you will design various rewards for a robotics task.

```
def play_video(video_dir: str, video_file: str = None) -> None:
    """
      Parameters:
      - video_dir (str): The directory path where video files are
located. This is used if `video_file` is not provided.
      - video_file (str, optional): The path to a specific video file
to play. If None, the function searches for
        'render_video.mp4' in `video_dir`.

      Returns:
        - None: This function does not return any value. It directly
displays the video within the IPython notebook.
    """
    if video_file is None:
        video_dir = Path(video_dir)
        video_files = list(video_dir.glob(f'**/render_video.mp4'))
        video_files.sort()
        video_file = video_files[-1]
    else:
        video_file = Path(video_file)
    compressed_file = video_file.parent.joinpath('comp.mp4')
    os.system(f"ffmpeg -i {video_file} -filter:v 'setpts=2.0*PTS' -
vcodec libx264 {compressed_file.as_posix()}")
    mp4 = open(compressed_file.as_posix(),'rb').read()
    data_url = "data:video/mp4;base64," + b64encode(mp4).decode()
    display(HTML("""
    <video width=400 controls>
        <source src="%s" type="video/mp4">
    </video>
    """ % data_url))


# read tf log file
def read_tf_log(log_dir: str) -> Tuple[List[int], List[float],
List[float]]:
    """
        Parameters:
      - log_dir (str): The directory path where TensorFlow log files
are located. The function searches for files
        starting with 'events.' within this directory and its
subdirectories.

      Returns:
      - Tuple[List[int], List[float], List[float]]: A tuple containing
three lists:
          - steps (List[int]): A list of steps at which each episode's
success rate was recorded.
          - returns (List[float]): A list of mean returns for each
episode.
          - success_rate (List[float]): A list of success rates for
each episode.
        Returns None if no log files are found or if there's an error
in extracting scalar values.
    """
    log_dir = Path(log_dir)
    log_files = list(log_dir.glob(f'**/events.*'))
    if len(log_files) < 1:
        return None
    log_file = log_files[0]
    event_acc = EventAccumulator(log_file.as_posix())
    event_acc.Reload()
    tags = event_acc.Tags()
    try:
        scalar_success = event_acc.Scalars('train/episode_success')
        success_rate = [x.value for x in scalar_success]
        steps = [x.step for x in scalar_success]
```

```python
        scalar_return = event_acc.Scalars('train/episode_return/mean')
        returns = [x.value for x in scalar_return]
    except:
        return None
    return steps, returns, success_rate


def plot_curves(data_dict: Dict[str, List[List[float]]], title: str) -
> None:
    """
        Parameters:
      - data_dict (Dict[str, List[List[float]]]): A dictionary where
each key is a label string and each value is a list
        containing two lists: the first list for x-values and the
second for y-values of the curve.
      - title (str): The title of the plot.

      This function does not return anything. It directly displays the
plot.
    """
    fig, ax = plt.subplots(figsize=(4, 3))
    labels = data_dict.keys()
    for label, data in data_dict.items():
        x = data[0]
        y = data[1]
        ax.plot(x, y, label=label)
    ax.set_title(title)
    ax.legend()

def check_collision_rate(log_dir: str) -> float:
    """
        Parameters:
      - log_dir (str): The directory path where 'info.json' log files
are stored. The function searches for files
        named 'info.json' within this directory and its
subdirectories, and uses the most recent file based on sorting.

      Returns:
      - float: The average collision rate extracted from the log file.

    """
    log_dir = Path(log_dir)
    log_files = list(log_dir.glob(f'**/info.json'))
    log_files.sort()
    log_file = log_files[-1]
    info_data = load_from_json(log_file)
    collisions = [v['collision'] for k, v in info_data.items()]
    return np.mean(collisions)
```

Environment

We will use AIRobot for this assignment. The task here is to move the end-effector of a UR robot from a fixed starting position (shown as the yellow ball in the figure below) to a fixed goal position (shown as the red ball in the figure below). The end-effector is constrained to move in xy-plane only (the horizontal plane).

State: the 2D position of the end-effector tip, (x, y)

Action: 2D continuous action space, $[\Delta x, \Delta y]$. The end-effector can move in x direction by Δx, y direction by Δy. We scale $\Delta x, \Delta y$ so that they are in the range of $[-1, 1]$.

The following figures visually show the robot environment:

The robot environment is defined in the following class (`URRobotGym`). Your task is to design and fill in the reward functions. You don't need to change other parts of the code in this class.

```
class URRobotGym(gym.Env):
    def __init__(self,
                 action_repeat: int = 10,
                 use_sparse_reward: bool = False,
                 use_subgoal: bool = False,
                 with_obstacle: bool = True,
                 apply_collision_penalty: bool = False,
                 # Set 'gui' to False if you are using Colab,
otherwise the session will crash as Colab does not support X window
                 # You can set it to True for debugging purpose if you
are running the notebook on a local machine.
                 gui: bool = False,
                 max_episode_length: int = 25,
                 dist_threshold: float = 0.05
                 ):
        """
        Initializes the URRobotGym environment.

        Parameters:
        - action_repeat (int): The number of times an action is
repeated per step in the environment.
        - use_sparse_reward (bool): If True, use sparse rewards;
otherwise, use dense rewards.
        - use_subgoal (bool): If True, include subgoals in the
environment.
        - with_obstacle (bool): If True, include obstacles in the
environment.
        - apply_collision_penalty (bool): If True, apply a penalty
for collisions.
        - gui (bool): If False, run the environment without a GUI to
prevent crashes in environments like Colab.
```

```
                        Set to True for debugging on local machines
where a GUI is supported.
          - max_episode_length (int): The maximum length of an
episode.
          - dist_threshold (float): The distance threshold to consider
a goal achieved.

          Initializes the robot, sets up the environment with optional
obstacles, subgoals, and visual markers,
          and configures the action and observation spaces.
        """
        self._action_repeat = action_repeat
        self._max_episode_length = max_episode_length
        self._dist_threshold = dist_threshold
        self._use_sparse_reward = use_sparse_reward
        self._use_subgoal = use_subgoal
        self._apply_collision_penalty = apply_collision_penalty
        self._with_obstacle = with_obstacle
        self.at_subgoal = False
        print(f'================================================')
        print(f'Use sparse reward:{self._use_sparse_reward}')
        print(f'Use subgoal:{self._use_subgoal}')
        print(f'With obstacle in the scene:{self._with_obstacle}')
        print(f'Apply collision penalty:
{self._apply_collision_penalty}')
        print(f'================================================')

        self._xy_bounds = np.array([[0.23, 0.78],  # [xmin, xmax]
                                    [-0.35, 0.3]])  # [ymin, ymax]
        self.robot = Robot('ur5e_stick',
                           pb_cfg={'gui': gui,
                                   'realtime': False,
                                   'opengl_render':
torch.cuda.is_available()})
        self._arm_reset_pos = np.array([-0.38337763,
                                        -2.02650575,
                                        -2.01989619,
                                        -0.64477803,
                                        1.571439041,
                                        -0.38331266])
        self._table_id =
self.robot.pb_client.load_urdf('table/table.urdf',
                                                        [.5, 0, 0.4],
                                                        euler2quat([0,
0, np.pi / 2]),
                                                        scaling=0.9)

        # create a ball at the start location (for visualization
purpose)
        self._start_pos = np.array([0.45, -0.32, 1.0])
        self._start_urdf_id = self.robot.pb_client.load_geom('sphere',
size=0.04, mass=0,

base_pos=self._start_pos,
                                                            rgba=[1,
1, 0, 0.8])

        # create a ball at the goal location
        self._goal_pos = np.array([0.5, 0.26, 1.0])
        self._goal_urdf_id = self.robot.pb_client.load_geom('sphere',
size=0.04, mass=0,

base_pos=self._goal_pos,
                                                           rgba=[1,
0, 0, 0.8])

        # disable the collision checking between the robot and the
ball at the goal location
        for i in
range(self.robot.pb_client.getNumJoints(self.robot.arm.robot_id)):

self.robot.pb_client.setCollisionFilterPair(self.robot.arm.robot_id,

self._goal_urdf_id,
                                                        i,
                                                        -1,

enableCollision=0)
        # disable the collision checking between the robot and the
ball at the start location
        for i in
range(self.robot.pb_client.getNumJoints(self.robot.arm.robot_id)):

self.robot.pb_client.setCollisionFilterPair(self.robot.arm.robot_id,

self._start_urdf_id,
                                                        i,
                                                        -1,

enableCollision=0)

        # create an obstacle
        if self._with_obstacle:
            self._wall_id = self.robot.pb_client.load_geom('box',
size=[0.18, 0.01, 0.1], mass=0,

base_pos=[0.5, 0.15, 1.0],
                                                          rgba=[0.5,
0.5, 0.5, 0.8])
```

```
        # create balls at subgoal locations
        if self._use_subgoal:
            self._subgoal_pos = np.array([[0.24, 0.15, 1.0], [0.76,
0.15, 1.0]])
            self._subgoal_urdf_id = []
            for pos in self._subgoal_pos:

self._subgoal_urdf_id.append(self.robot.pb_client.load_geom('sphere',
size=0.04, mass=0,

base_pos=pos,

rgba=[0, 0.8, 0.8, 0.8]))
            # disable the collision checking between the robot and the
subgoal balls
            for i in
range(self.robot.pb_client.getNumJoints(self.robot.arm.robot_id)):
                for sg in self._subgoal_urdf_id:

self.robot.pb_client.setCollisionFilterPair(self.robot.arm.robot_id,
                                                                sg,
                                                                i,
                                                                -1,

enableCollision=0)

        self._action_bound = 1.0
        self._ee_pos_scale = 0.02
        self._action_high = np.array([self._action_bound] * 2)
        self.action_space = spaces.Box(low=-self._action_high,
                                       high=self._action_high,
                                       dtype=np.float32)
        state_low = np.full(len(self._get_obs()), -float('inf'))
        state_high = np.full(len(self._get_obs()), float('inf'))
        self.observation_space = spaces.Box(state_low,
                                            state_high,
                                            dtype=np.float32)
        self.reset()

    def reset(self) -> np.array:
        """
          Resets the environment to its initial state.

          Returns:
          - obs (np.ndarray): The initial observation of the
environment after resetting.
        """
        self.robot.arm.set_jpos(self._arm_reset_pos,
ignore_physics=True)
        self._t = 0
        self._ref_ee_pos = self.robot.arm.get_ee_pose()[0]
        self._ref_ee_ori = self.robot.arm.get_ee_pose()[1]
        return self._get_obs()

    def step(self, action: np.ndarray) -> Tuple[np.ndarray, float,
bool, dict]:
        """
          Parameters:
          - action (np.ndarray): The action to be executed

          Returns:
          - state (np.ndarray): The next state of the environment
after executing the action.
          - reward (float): The reward received after executing the
action.
          - done (bool): A flag indicating whether the episode has
ended (True if the episode is done, False otherwise).
          - info (dict): Additional information such as whether a
collision occurred.
        """
        ...
        collision = self._apply_action(action)
        self._t += 1
        state = self._get_obs()
        done = self._t >= self._max_episode_length
        reward, info = self._get_reward(state=state, action=action,
collision=float(collision))
        info['collision'] = collision
        return state, reward, done, info

    def _get_reward(self, state: np.ndarray, action: np.ndarray,
collision: float) -> Tuple[float, dict]:
        """
          Parameters:
          - state (np.ndarray): The current state of the environment.
          - action (np.ndarray): The action taken from the current
state.
          - collision (float): A float indicating whether a collision
occurred (1.0 if yes, 0.0 if no).

          Returns:
          - reward (float): The calculated reward
          - info (dict): A dictionary containing additional
information about the reward calculation, including whether the goal
was achieved (success flag).
        """
        dist_to_goal = np.linalg.norm(state - self._goal_pos[:2])
        success = dist_to_goal < self._dist_threshold
        if self._use_sparse_reward:
            #### TODO: Q1 design a sparse reward
            reward = success
        elif self._use_subgoal:
            reward = self._get_reward_with_subgoal(state)

            if success:
              reward += 20
        else:
            #### TODO: Q2 design a dense reward based on only the
state and the goal position (no other information)
            # state -> current state of the robot,
get_reward_with_subgoal (reward based on the distance of the robot
from goal/subgoal)
            # closer the distance, higher the reward
            reward = -1 * dist_to_goal
        if self._apply_collision_penalty:
            #### TODO: Q4 apply a collision penalty
            reward = reward - 5 * collision

        info = dict(success=success)
        return reward, info

    def _get_reward_with_subgoal(self, state: np.ndarray) -> float:
        """
          Parameters:
          - state (np.ndarray): The current state of the environment.

          Returns:
          - reward: The calculated reward based on the proximity to
subgoals and the final goal.
        """
        #### TODO: Q5 design a reward based on the state, goal and
subgoal positions
        # we could initially optimize for the current state of the
robot to be close to one of the subgoals with collision checks
        # once the robot is in one of the subgoals, we could check for
its distance to the final goal -- REWARD HACKING!!
        # check if the min of the distance to any of the subgoal
positions is less than threshold,
        if not self.at_subgoal:
          dist_to_subgoal = min(np.linalg.norm(state -
self._subgoal_pos[0][:2]), np.linalg.norm(state - self._subgoal_pos[1]
[:2]))

          reward = -1 * dist_to_subgoal
          if dist_to_subgoal < self._dist_threshold:
            self.at_subgoal = True
        else:
          reward = -1 * np.linalg.norm(state - self._goal_pos[:2])

        return reward
    def _get_obs(self):
        """
          Returns:
          - state (np.ndarray): The current state observation, i.e.,
the x and y positions of the robot's end-effector.
        """
        gripper_pos = self.robot.arm.get_ee_pose()[0][:2]
        state = gripper_pos
        return state

    def _check_collision_with_wall(self):
        """
          Returns:
          - bool: True if a collision is detected, False otherwise.
        """
        if hasattr(self, '_wall_id'):
            return
len(self.robot.pb_client.getContactPoints(self.robot.arm.robot_id,

self._wall_id, 10, -1)) > 0
        else:
            return False

    def _apply_action(self, action: np.ndarray) -> bool:
        """
          Parameters:
          - action (np.ndarray): The action to be executed.

          Returns:
          - bool: Indicates whether a collision occurred as a result
of applying the action.

        """
        jnt_poses = self.robot.arm.get_jpos()
        if not isinstance(action, np.ndarray):
            action = np.array(action).flatten()
        if action.size != 2:
            raise ValueError('Action should be [d_x, d_y].')
        # we set dz=0
        action = np.append(action, 0)
        pos, quat, rot_mat, euler = self.robot.arm.get_ee_pose()
        pos += action[:3] * self._ee_pos_scale
        pos[2] = self._ref_ee_pos[2]
        # if the new position is out of the bounds, then we don't
apply the action
        if not np.logical_and(np.all(pos[:2] >= self._xy_bounds[:,
0]),
                              np.all(pos[:2] <= self._xy_bounds[:,
1])):
```

```
            return False

        # move the end-effector to the new position
        jnt_pos = self.robot.arm.compute_ik(pos, ori=self._ref_ee_ori)
        for step in range(self._action_repeat):
            self.robot.arm.set_jpos(jnt_pos)
            self.robot.pb_client.stepSimulation()

        # if collision occurs, we reset the robot back to its original
pose (before apply_action)
        collision = False
        if self._check_collision_with_wall():
            self.robot.arm.set_jpos(jnt_poses, ignore_physics=True)
            collision = True
        return collision


    def render(self, mode, **kwargs):
        """
          Renders the current state of the environment for
visualization.

          Parameters:
          - mode (str): The mode for rendering. 'human' for on-screen
rendering and potentially other modes
            for off-screen rendering or returning data arrays for
further processing.

          Returns:
          - np.ndarray: An image array representing the current visual
state of the environment, if applicable based on the rendering mode.

        """
        robot_base = self.robot.arm.robot_base_pos
        self.robot.cam.setup_camera(focus_pt=robot_base,
                                    dist=2,
                                    yaw=85,
                                    pitch=-20,
                                    roll=0)
        rgb, _ = self.robot.cam.get_images(get_rgb=True,
                                           get_depth=False)
        return rgb

    def seed(self, seed):
      return np.random.seed(seed)

module_name = __name__

env_name = 'URReacher-v1'
if env_name in registry:
    del registry[env_name]
register(
    id=env_name,
    entry_point=f'{module_name}:URRobotGym',
)
```

For this assignment, we will use PPO to train the policy. The training code is already complete. You don't need to modify any code here.

```
# DO NOT MODIFY THIS
def train_ppo(use_sparse_reward: bool = False, use_subgoal: bool =
False, with_obstacle: bool = False,
              apply_collision_penalty: bool = False, push_exp: bool =
False, max_steps: int = 200000) -> str:
    """
      Parameters:
      - use_sparse_reward (bool): Specifies whether to use sparse
rewards in the environment.
      - use_subgoal (bool): Specifies whether to include subgoals in
the environment.
      - with_obstacle (bool): Specifies whether to include obstacles
in the environment.
      - apply_collision_penalty (bool): Specifies whether to apply a
penalty for collisions.
      - push_exp (bool): Specifies whether to train on a pushing
experiment. Changes the environment to 'URPusher-v1'.
      - max_steps (int): The maximum number of steps to train the
agent.

      Returns:
      - str: The directory where training data and models are saved.
    """
    set_config('ppo')
    cfg.alg.num_envs = 1
    cfg.alg.episode_steps = 100
    cfg.alg.max_steps = max_steps
    cfg.alg.deque_size = 20
    cfg.alg.device = 'cuda' if torch.cuda.is_available() else 'cpu'
    cfg.alg.env_name = 'URPusher-v1' if push_exp else 'URReacher-v1'
    cfg.alg.save_dir =
Path.cwd().absolute().joinpath('data').as_posix()
    cfg.alg.save_dir += '/'
    if push_exp:
        cfg.alg.save_dir += 'push'
    else:
        cfg.alg.save_dir += 'sparse' if use_sparse_reward else 'dense'
        cfg.alg.save_dir += f'_ob_{str(with_obstacle)}'
        cfg.alg.save_dir += f'_sg_{str(use_subgoal)}'
        cfg.alg.save_dir += f'_col_{str(apply_collision_penalty)}'
    setattr(cfg.alg, 'diff_cfg', dict(save_dir=cfg.alg.save_dir))

    print(f'====================================')
    print(f'      Device:{cfg.alg.device}')
    print(f'      Total number of steps:{cfg.alg.max_steps}')
    print(f'====================================')

    set_random_seed(cfg.alg.seed)
    env_kwargs=dict(use_sparse_reward=use_sparse_reward,
                    with_obstacle=with_obstacle,
                    use_subgoal=use_subgoal,
                    apply_collision_penalty=apply_collision_penalty)
if not push_exp else dict()
    env = make_vec_env(cfg.alg.env_name,
                       cfg.alg.num_envs,
                       seed=cfg.alg.seed,
                       env_kwargs=env_kwargs)
    env.reset()
    ob_size = env.observation_space.shape[0]

    actor_body = MLP(input_size=ob_size,
                     hidden_sizes=[64],
                     output_size=64,
                     hidden_act=nn.Tanh,
                     output_act=nn.Tanh)

    critic_body = MLP(input_size=ob_size,
                     hidden_sizes=[64],
                     output_size=64,
                     hidden_act=nn.Tanh,
                     output_act=nn.Tanh)
    if isinstance(env.action_space, gym.spaces.Discrete):
        act_size = env.action_space.n
        actor = CategoricalPolicy(actor_body,
                                 in_features=64,
                                 action_dim=act_size)
    elif isinstance(env.action_space, gym.spaces.Box):
        act_size = env.action_space.shape[0]
        actor = DiagGaussianPolicy(actor_body,
                                   in_features=64,
                                   action_dim=act_size,
                                   tanh_on_dist=cfg.alg.tanh_on_dist,
                                   std_cond_in=cfg.alg.std_cond_in)
    else:
        raise TypeError(f'Unknown action space type:
{env.action_space}')

    critic = ValueNet(critic_body, in_features=64)
    agent = PPOAgent(actor=actor, critic=critic, env=env)
    runner = EpisodicRunner(agent=agent, env=env)
    engine = PPOEngine(agent=agent,
                       runner=runner)
    engine.train()
    stat_info, raw_traj_info = engine.eval(render=False,
                                           save_eval_traj=True,
                                           eval_num=1,
                                           sleep_time=0.0)
    pprint.pprint(stat_info)
    return cfg.alg.save_dir
```

Reaching Task without Obstacles

The first task we are going to solve is a reaching task without obstacles. We want to learn a policy that can move the robot's end-effector from the starting position to the goal position. And there is no obstacle in the scene.

Sparse Reward

First, let's see if we can solve the reaching task by just using a sparse reward. The agent gets $+1$ reward if the end-effector tip is close to the goal position, 0 reward otherwise.

$$r(s_t, a_t) = \begin{cases} 1 \text{ if } \|s_t - s_g\|_2 < d_{thresh} \\ 0 \text{ otherwise} \end{cases}$$

where s_g is the goal position, and d_{thresh} is the distance threshold.

Q1 [20 pts]: Fill in the code for sparse reward (`use_sparse_reward=True`) in `_get_reward` function in URRobotGym. Train the policy with sparse reward, and plot the return curve and the success rate curve using the code below.

For experiments in this assignment, if you run them locally (not suggested), then you will see that a folder `data` is created in your current working directory. And you can run `tensorboard --logdir=data` to track the experiment progress (check `train/episode_success` and `train/episode_return/mean`). If you are using colab, the `data` folder will also be created, and you can download them during the training to check the learning curves locally.

```
#### Q1 (expected running time on T4 GPU: 7:30 min)
sparse_save_dir = train_ppo(use_sparse_reward=True, use_subgoal=False,
with_obstacle=False, apply_collision_penalty=False)
```

```
[INFO][2024-03-14 23:18:52]: Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
INFO:EasyRL:Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
[INFO][2024-03-14 23:18:52]: Creating 1 environments.
INFO:EasyRL:Creating 1 environments.
```

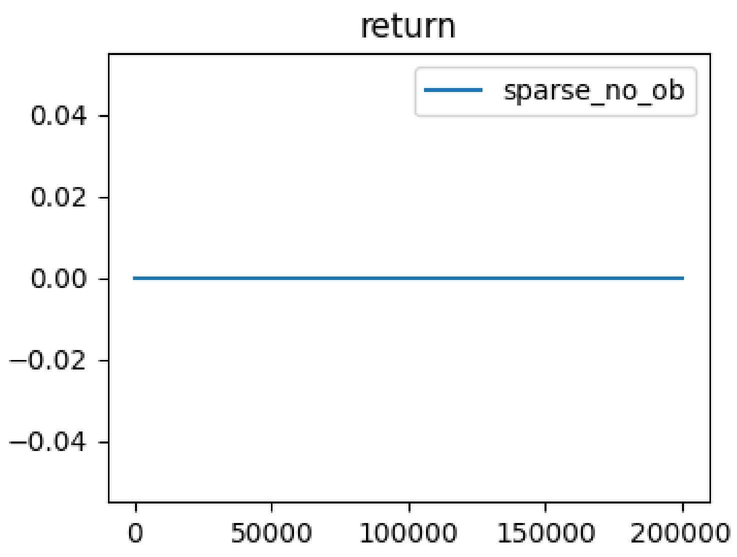
```
[INFO][2024-03-14 23:18:52]: Load in OpenGL!
INFO:AIRobot:Load in OpenGL!

====================================
      Device:cuda
      Total number of steps:200000
====================================
================================================
Use sparse reward:True
Use subgoal:False
With obstacle in the scene:False
Apply collision penalty:False
================================================

[ERROR][2024-03-14 23:18:55]: Not a valid git repo:
/usr/local/lib/python3.10/dist-packages
ERROR:EasyRL:Not a valid git repo: /usr/local/lib/python3.10/dist-
packages
[INFO][2024-03-14 23:18:55]: Exploration steps: 0
INFO:EasyRL:Exploration steps: 0
[INFO][2024-03-14 23:18:55]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000000000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000000000.pt.
[INFO][2024-03-14 23:18:55]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/model_be
st.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/model_be
st.pt.
[INFO][2024-03-14 23:19:21]: Exploration steps: 10000
INFO:EasyRL:Exploration steps: 10000
[INFO][2024-03-14 23:19:21]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000010000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000010000.pt.
[INFO][2024-03-14 23:19:45]: Exploration steps: 20000
INFO:EasyRL:Exploration steps: 20000
[INFO][2024-03-14 23:19:45]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000020000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000020000.pt.
[INFO][2024-03-14 23:20:09]: Exploration steps: 30000
INFO:EasyRL:Exploration steps: 30000
```

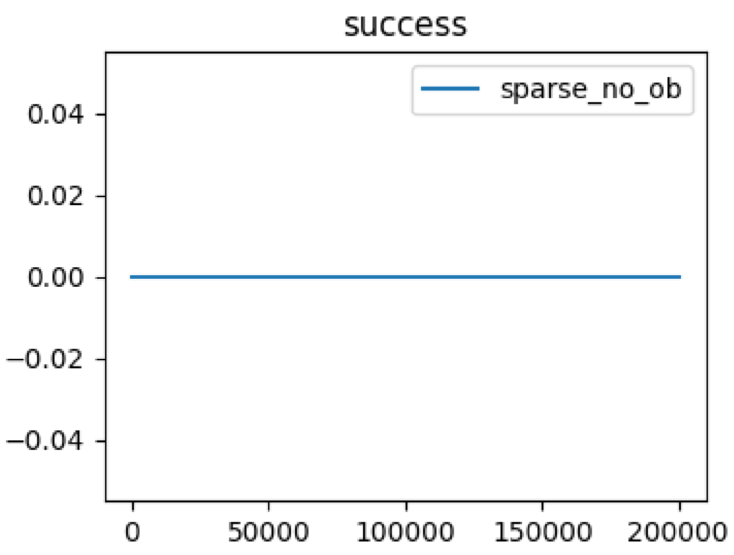
```
[INFO][2024-03-14 23:20:09]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000030000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000030000.pt.
[INFO][2024-03-14 23:20:31]: Exploration steps: 40000
INFO:EasyRL:Exploration steps: 40000
[INFO][2024-03-14 23:20:31]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000040000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000040000.pt.
[INFO][2024-03-14 23:20:54]: Exploration steps: 50000
INFO:EasyRL:Exploration steps: 50000
[INFO][2024-03-14 23:20:54]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000050000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000050000.pt.
[INFO][2024-03-14 23:21:16]: Exploration steps: 60000
INFO:EasyRL:Exploration steps: 60000
[INFO][2024-03-14 23:21:16]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000060000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000060000.pt.
[INFO][2024-03-14 23:21:38]: Exploration steps: 70000
INFO:EasyRL:Exploration steps: 70000
[INFO][2024-03-14 23:21:38]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000070000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000070000.pt.
[INFO][2024-03-14 23:22:01]: Exploration steps: 80000
INFO:EasyRL:Exploration steps: 80000
[INFO][2024-03-14 23:22:01]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000080000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000080000.pt.
[INFO][2024-03-14 23:22:23]: Exploration steps: 90000
INFO:EasyRL:Exploration steps: 90000
[INFO][2024-03-14 23:22:23]: Saving checkpoint:
```

```
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000090000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000090000.pt.
[INFO][2024-03-14 23:22:45]: Exploration steps: 100000
INFO:EasyRL:Exploration steps: 100000
[INFO][2024-03-14 23:22:45]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000100000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000100000.pt.
[INFO][2024-03-14 23:23:08]: Exploration steps: 110000
INFO:EasyRL:Exploration steps: 110000
[INFO][2024-03-14 23:23:08]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000110000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000110000.pt.
[INFO][2024-03-14 23:23:30]: Exploration steps: 120000
INFO:EasyRL:Exploration steps: 120000
[INFO][2024-03-14 23:23:30]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000120000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000120000.pt.
[INFO][2024-03-14 23:23:53]: Exploration steps: 130000
INFO:EasyRL:Exploration steps: 130000
[INFO][2024-03-14 23:23:53]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000130000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000130000.pt.
[INFO][2024-03-14 23:24:15]: Exploration steps: 140000
INFO:EasyRL:Exploration steps: 140000
[INFO][2024-03-14 23:24:15]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000140000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000140000.pt.
[INFO][2024-03-14 23:24:37]: Exploration steps: 150000
INFO:EasyRL:Exploration steps: 150000
[INFO][2024-03-14 23:24:37]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
```

```
000150000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000150000.pt.
[INFO][2024-03-14 23:25:00]: Exploration steps: 160000
INFO:EasyRL:Exploration steps: 160000
[INFO][2024-03-14 23:25:00]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000160000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000160000.pt.
[INFO][2024-03-14 23:25:22]: Exploration steps: 170000
INFO:EasyRL:Exploration steps: 170000
[INFO][2024-03-14 23:25:22]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000170000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000170000.pt.
[INFO][2024-03-14 23:25:45]: Exploration steps: 180000
INFO:EasyRL:Exploration steps: 180000
[INFO][2024-03-14 23:25:45]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000180000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000180000.pt.
[INFO][2024-03-14 23:26:07]: Exploration steps: 190000
INFO:EasyRL:Exploration steps: 190000
[INFO][2024-03-14 23:26:07]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000190000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000190000.pt.
[INFO][2024-03-14 23:26:30]: Exploration steps: 200000
INFO:EasyRL:Exploration steps: 200000
[INFO][2024-03-14 23:26:30]: Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000200000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/sparse_ob_False_sg_False_col_False/seed_0/model/ckpt_000
000200000.pt.

{'eval/episode_length/max': 25,
 'eval/episode_length/mean': 25.0,
 'eval/episode_length/median': 25.0,
 'eval/episode_length/min': 25,
 'eval/return/max': 0.0,
 'eval/return/mean': 0.0,
 'eval/return/median': 0.0,
 'eval/return/min': 0.0,
 'eval/smooth_return/mean': 0.0,
 'eval/success': 0.0}
```

```
steps, returns, success_rate = read_tf_log(sparse_save_dir)
return_data = dict(
    sparse_no_ob=[steps, returns]
)
plot_curves(return_data, 'return')
success_data = dict(
    sparse_no_ob=[steps, success_rate]
)
plot_curves(success_data, 'success')
```





You can visually see what the robot is doing in the testing time by running `play_video(sparse_save_dir)`. You can use this function to check the trajectories of each policy you trained.

```
## assume the saving directory is `save_dir` (returned by
`train_ppo`), then run:
# play_video(save_dir)
play_video(sparse_save_dir)

<IPython.core.display.HTML object>
```

Dense Reward

As we can see from the previous section, it is easy to specify a sparse reward. However, it makes the training much harder and the agent may fail to reach the goal. Can we provide a richer learning signal to the agent? One possibility is to provide a dense reward based on the distance between the current end-effector position and the goal position.

$$r(s_t, a_t) = -\|s_t - s_g\|_2$$

Q2 [20 pts]: Fill in the code for dense reward (`use_sparse_reward=False`), train the policy, and plot the return curve and the sucess rate curve.

```
#### Q2 (expected running time on T4 GPU: 9:00 min)
dense_save_dir = train_ppo(use_sparse_reward=False, use_subgoal=False,
with_obstacle=False, apply_collision_penalty=False)

[INFO][2024-03-14 23:26:35]: Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
INFO:EasyRL:Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
[INFO][2024-03-14 23:26:35]: Creating 1 environments.
```

```
INFO:EasyRL:Creating 1 environments.
[INFO][2024-03-14 23:26:35]: Load in OpenGL!
INFO:AIRobot:Load in OpenGL!

====================================
      Device:cuda
      Total number of steps:200000
====================================
================================================
Use sparse reward:False
Use subgoal:False
With obstacle in the scene:False
Apply collision penalty:False
================================================

[ERROR][2024-03-14 23:26:37]: Not a valid git repo:
/usr/local/lib/python3.10/dist-packages
ERROR:EasyRL:Not a valid git repo: /usr/local/lib/python3.10/dist-
packages
[INFO][2024-03-14 23:26:37]: Exploration steps: 0
INFO:EasyRL:Exploration steps: 0
[INFO][2024-03-14 23:26:37]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00000000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00000000.pt.
[INFO][2024-03-14 23:26:37]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:27:07]: Exploration steps: 10000
INFO:EasyRL:Exploration steps: 10000
[INFO][2024-03-14 23:27:07]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00010000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00010000.pt.
[INFO][2024-03-14 23:27:07]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:27:32]: Exploration steps: 20000
INFO:EasyRL:Exploration steps: 20000
[INFO][2024-03-14 23:27:32]: Saving checkpoint:
```

```
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00020000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00020000.pt.
[INFO][2024-03-14 23:27:32]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:27:57]: Exploration steps: 30000
INFO:EasyRL:Exploration steps: 30000
[INFO][2024-03-14 23:27:57]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00030000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00030000.pt.
[INFO][2024-03-14 23:27:57]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:28:22]: Exploration steps: 40000
INFO:EasyRL:Exploration steps: 40000
[INFO][2024-03-14 23:28:22]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00040000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00040000.pt.
[INFO][2024-03-14 23:28:22]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:28:47]: Exploration steps: 50000
INFO:EasyRL:Exploration steps: 50000
[INFO][2024-03-14 23:28:47]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00050000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00050000.pt.
[INFO][2024-03-14 23:28:47]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
```

```
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:29:12]: Exploration steps: 60000
INFO:EasyRL:Exploration steps: 60000
[INFO][2024-03-14 23:29:12]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00060000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00060000.pt.
[INFO][2024-03-14 23:29:12]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:29:36]: Exploration steps: 70000
INFO:EasyRL:Exploration steps: 70000
[INFO][2024-03-14 23:29:36]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00070000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00070000.pt.
[INFO][2024-03-14 23:29:36]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:30:01]: Exploration steps: 80000
INFO:EasyRL:Exploration steps: 80000
[INFO][2024-03-14 23:30:01]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00080000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00080000.pt.
[INFO][2024-03-14 23:30:01]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:30:26]: Exploration steps: 90000
INFO:EasyRL:Exploration steps: 90000
[INFO][2024-03-14 23:30:26]: Saving checkpoint:
```

```
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00090000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00090000.pt.
[INFO][2024-03-14 23:30:26]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:30:50]: Exploration steps: 100000
INFO:EasyRL:Exploration steps: 100000
[INFO][2024-03-14 23:30:50]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00100000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00100000.pt.
[INFO][2024-03-14 23:30:50]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:31:15]: Exploration steps: 110000
INFO:EasyRL:Exploration steps: 110000
[INFO][2024-03-14 23:31:15]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00110000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00110000.pt.
[INFO][2024-03-14 23:31:15]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:31:39]: Exploration steps: 120000
INFO:EasyRL:Exploration steps: 120000
[INFO][2024-03-14 23:31:39]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00120000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00120000.pt.
[INFO][2024-03-14 23:31:39]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
```

```
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:32:03]: Exploration steps: 130000
INFO:EasyRL:Exploration steps: 130000
[INFO][2024-03-14 23:32:03]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00130000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00130000.pt.
[INFO][2024-03-14 23:32:03]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:32:27]: Exploration steps: 140000
INFO:EasyRL:Exploration steps: 140000
[INFO][2024-03-14 23:32:27]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00140000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00140000.pt.
[INFO][2024-03-14 23:32:27]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:32:52]: Exploration steps: 150000
INFO:EasyRL:Exploration steps: 150000
[INFO][2024-03-14 23:32:52]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00150000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00150000.pt.
[INFO][2024-03-14 23:32:52]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:33:16]: Exploration steps: 160000
INFO:EasyRL:Exploration steps: 160000
[INFO][2024-03-14 23:33:16]: Saving checkpoint:
```

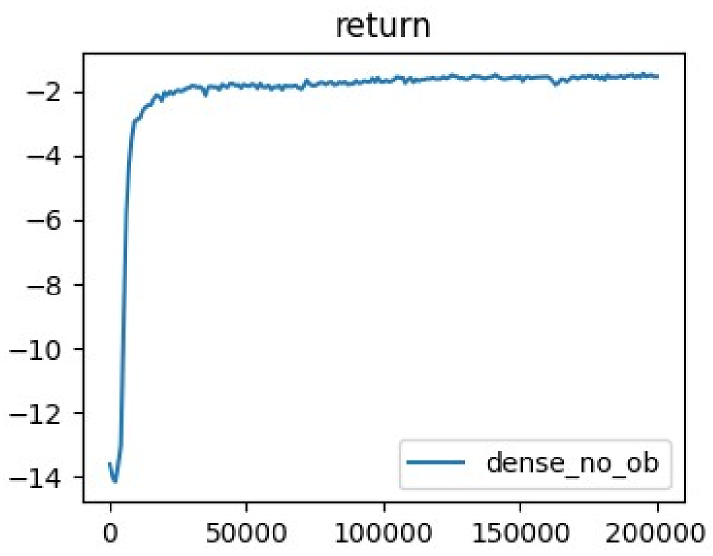
```
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00160000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00160000.pt.
[INFO][2024-03-14 23:33:16]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:33:40]: Exploration steps: 170000
INFO:EasyRL:Exploration steps: 170000
[INFO][2024-03-14 23:33:40]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00170000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00170000.pt.
[INFO][2024-03-14 23:33:40]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:34:04]: Exploration steps: 180000
INFO:EasyRL:Exploration steps: 180000
[INFO][2024-03-14 23:34:04]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00180000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00180000.pt.
[INFO][2024-03-14 23:34:04]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
[INFO][2024-03-14 23:34:29]: Exploration steps: 190000
INFO:EasyRL:Exploration steps: 190000
[INFO][2024-03-14 23:34:29]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00190000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00190000.pt.
[INFO][2024-03-14 23:34:53]: Exploration steps: 200000
INFO:EasyRL:Exploration steps: 200000
```

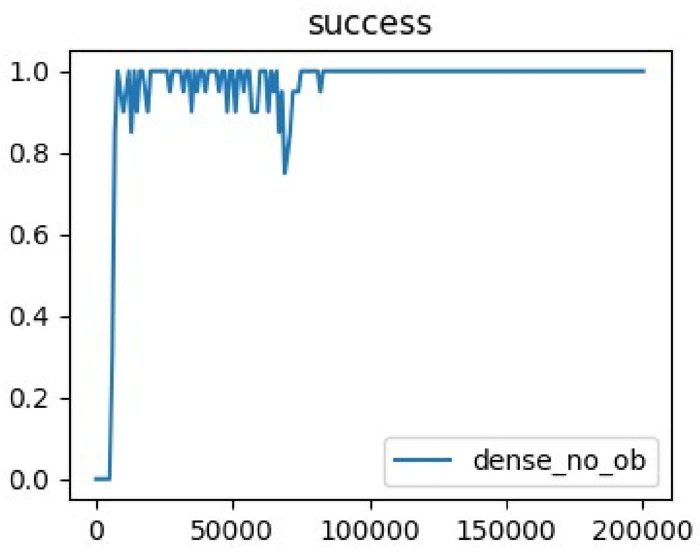
```
[INFO][2024-03-14 23:34:53]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00200000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/ckpt_0000
00200000.pt.
[INFO][2024-03-14 23:34:53]: Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_False_sg_False_col_False/seed_0/model/model_bes
t.pt.
```

```
{'eval/episode_length/max': 25,
 'eval/episode_length/mean': 25.0,
 'eval/episode_length/median': 25.0,
 'eval/episode_length/min': 25,
 'eval/return/max': -1.4888358,
 'eval/return/mean': -1.4888358,
 'eval/return/median': -1.4888358,
 'eval/return/min': -1.4888358,
 'eval/smooth_return/mean': -1.4396754428327072,
 'eval/success': 1.0}
```

```python
steps, returns, success_rate = read_tf_log(dense_save_dir)
return_data = dict(
    dense_no_ob=[steps, returns]
)
plot_curves(return_data, 'return')
success_data = dict(
    dense_no_ob=[steps, success_rate]
)
plot_curves(success_data, 'success')
play_video(dense_save_dir)
```

```
<IPython.core.display.HTML object>
```





Reaching Task with an Obstacle

Now that you can solve the reaching task without any obstacles in the environment. Let's make the task harder. What if there is a wall (obstacle) between the starting location and the goal location. The agent will need to learn to bypass the obstacle in order to reach the goal.

Now, the environment looks like this:

Simple Dense Reward

As we have seen in the previous simpler task, using a sparse reward does not work. It's safe to say that using the sparse reward will not lead to success in this harder task either. So let's jump right into the dense reward case. Let's use the distance reward that is used in the previous section and try it on this task.

Q3 [20 pts]: Fill in the code for dense reward when there is an obstacle (`use_sparse_reward=False, with_obstacle=True`), train the policy, and plot the return curve and the sucess rate curve.

```
#### Q3 (expected running time on T4 GPU: 11:00 min)
obs_dense_save_dir = train_ppo(use_sparse_reward=False,
use_subgoal=False, with_obstacle=True, apply_collision_penalty=False)
```

```
[INFO][2024-03-14 23:34:57]: Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
INFO:EasyRL:Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
[INFO][2024-03-14 23:34:57]: Creating 1 environments.
INFO:EasyRL:Creating 1 environments.
[INFO][2024-03-14 23:34:57]: Load in OpenGL!
INFO:AIRobot:Load in OpenGL!

====================================
      Device:cuda
      Total number of steps:200000
====================================
================================================
Use sparse reward:False
Use subgoal:False
With obstacle in the scene:True
Apply collision penalty:False
================================================

[ERROR][2024-03-14 23:34:59]: Not a valid git repo:
/usr/local/lib/python3.10/dist-packages
ERROR:EasyRL:Not a valid git repo: /usr/local/lib/python3.10/dist-
packages
[INFO][2024-03-14 23:34:59]: Exploration steps: 0
INFO:EasyRL:Exploration steps: 0
[INFO][2024-03-14 23:34:59]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0000000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0000000.pt.
[INFO][2024-03-14 23:34:59]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
```

```
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:35:30]: Exploration steps: 10000
INFO:EasyRL:Exploration steps: 10000
[INFO][2024-03-14 23:35:30]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0010000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0010000.pt.
[INFO][2024-03-14 23:35:30]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:36:02]: Exploration steps: 20000
INFO:EasyRL:Exploration steps: 20000
[INFO][2024-03-14 23:36:02]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0020000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0020000.pt.
[INFO][2024-03-14 23:36:02]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:36:35]: Exploration steps: 30000
INFO:EasyRL:Exploration steps: 30000
[INFO][2024-03-14 23:36:35]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0030000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0030000.pt.
[INFO][2024-03-14 23:36:35]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:37:08]: Exploration steps: 40000
INFO:EasyRL:Exploration steps: 40000
[INFO][2024-03-14 23:37:08]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
```

```
0040000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0040000.pt.
[INFO][2024-03-14 23:37:08]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:37:40]: Exploration steps: 50000
INFO:EasyRL:Exploration steps: 50000
[INFO][2024-03-14 23:37:40]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0050000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0050000.pt.
[INFO][2024-03-14 23:37:40]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:38:13]: Exploration steps: 60000
INFO:EasyRL:Exploration steps: 60000
[INFO][2024-03-14 23:38:13]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0060000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0060000.pt.
[INFO][2024-03-14 23:38:13]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:38:45]: Exploration steps: 70000
INFO:EasyRL:Exploration steps: 70000
[INFO][2024-03-14 23:38:45]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0070000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0070000.pt.
[INFO][2024-03-14 23:38:45]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
```

```
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:39:17]: Exploration steps: 80000
INFO:EasyRL:Exploration steps: 80000
[INFO][2024-03-14 23:39:17]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0080000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0080000.pt.
[INFO][2024-03-14 23:39:17]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:39:49]: Exploration steps: 90000
INFO:EasyRL:Exploration steps: 90000
[INFO][2024-03-14 23:39:49]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0090000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0090000.pt.
[INFO][2024-03-14 23:39:49]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:40:21]: Exploration steps: 100000
INFO:EasyRL:Exploration steps: 100000
[INFO][2024-03-14 23:40:21]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0100000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0100000.pt.
[INFO][2024-03-14 23:40:21]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:40:53]: Exploration steps: 110000
INFO:EasyRL:Exploration steps: 110000
[INFO][2024-03-14 23:40:53]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
```

```
0110000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0110000.pt.
[INFO][2024-03-14 23:40:53]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:41:25]: Exploration steps: 120000
INFO:EasyRL:Exploration steps: 120000
[INFO][2024-03-14 23:41:25]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0120000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0120000.pt.
[INFO][2024-03-14 23:41:25]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:41:57]: Exploration steps: 130000
INFO:EasyRL:Exploration steps: 130000
[INFO][2024-03-14 23:41:57]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0130000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0130000.pt.
[INFO][2024-03-14 23:41:57]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:42:30]: Exploration steps: 140000
INFO:EasyRL:Exploration steps: 140000
[INFO][2024-03-14 23:42:30]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0140000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0140000.pt.
[INFO][2024-03-14 23:42:30]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
```

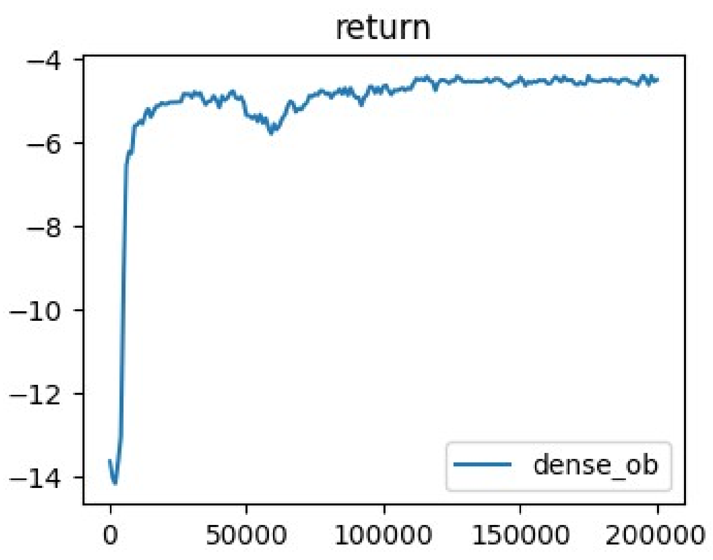
```
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:43:02]: Exploration steps: 150000
INFO:EasyRL:Exploration steps: 150000
[INFO][2024-03-14 23:43:02]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0150000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0150000.pt.
[INFO][2024-03-14 23:43:02]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:43:35]: Exploration steps: 160000
INFO:EasyRL:Exploration steps: 160000
[INFO][2024-03-14 23:43:35]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0160000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0160000.pt.
[INFO][2024-03-14 23:44:07]: Exploration steps: 170000
INFO:EasyRL:Exploration steps: 170000
[INFO][2024-03-14 23:44:07]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0170000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0170000.pt.
[INFO][2024-03-14 23:44:39]: Exploration steps: 180000
INFO:EasyRL:Exploration steps: 180000
[INFO][2024-03-14 23:44:39]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0180000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0180000.pt.
[INFO][2024-03-14 23:44:39]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
[INFO][2024-03-14 23:45:11]: Exploration steps: 190000
INFO:EasyRL:Exploration steps: 190000
```

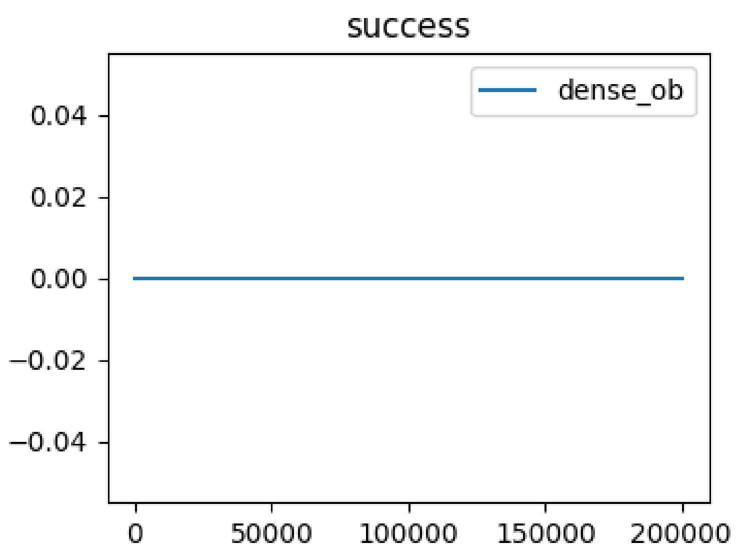
```
[INFO][2024-03-14 23:45:11]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0190000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0190000.pt.
[INFO][2024-03-14 23:45:44]: Exploration steps: 200000
INFO:EasyRL:Exploration steps: 200000
[INFO][2024-03-14 23:45:44]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0200000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/ckpt_00000
0200000.pt.
[INFO][2024-03-14 23:45:44]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_False/seed_0/model/model_best
.pt.
```

```
{'eval/episode_length/max': 25,
 'eval/episode_length/mean': 25.0,
 'eval/episode_length/median': 25.0,
 'eval/episode_length/min': 25,
 'eval/return/max': -4.204511,
 'eval/return/mean': -4.204511,
 'eval/return/median': -4.204511,
 'eval/return/min': -4.204511,
 'eval/smooth_return/mean': -4.329435416620877,
 'eval/success': 0.0}
```

```
steps, returns, success_rate = read_tf_log(obs_dense_save_dir)
return_data = dict(
    dense_ob=[steps, returns]
)
plot_curves(return_data, 'return')
success_data = dict(
    dense_ob=[steps, success_rate]
)
plot_curves(success_data, 'success')
play_video(obs_dense_save_dir)
```

```
<IPython.core.display.HTML object>
```





Avoid the obstacle

As we can see that using a dense reward based on the distance between the current end-effector position and the goal position does not solve the task sucessfully. What's even worse is that the end-effector is hitting the wall repeatedly. This can cause safety issues on a real robot. Idealy, we don't want the robot to hit the obstacles.

Q4 [30 pts]

Q4.1 [5 pts]: Let's first check the collision rate ($\frac{\text{\# of steps in collision}}{\text{total \# of episode steps}}$) of the policy learned in the previous case. We have saved the testing results in `data/`, all we need to do is just read out the collision information from the saved data. We have provided you with the utility function `check_collision_rate`. What's the collsion rate for the policy you trained with the simple dense reward?

```
#### TODO
# path =
'/content/data/dense_ob_True_sg_False_col_False/seed_0/eval/000000_suc
cess_False'
path = obs_dense_save_dir
collisions = check_collision_rate(path)
print(collisions)

0.84
```

Now we want to train the robot to avoid the obstacle. A simple way to achieve this is to give the agent some penalty when it collides with the obstacle.

Q4.2 [20 pts]: Apply the collision penalty when computing the reward value. Let's give -5 as the additional penalty whenever the agent hits the obstacle. Train the policy, and plot the return curve and the sucess rate curve.

```
#### Q4 (expected running time on T4 GPU: 10:00 min)
obs_colli_dense_save_dir = train_ppo(use_sparse_reward=False,
use_subgoal=False, with_obstacle=True, apply_collision_penalty=True)

[INFO][2024-03-14 23:46:21]: Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
INFO:EasyRL:Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
[INFO][2024-03-14 23:46:21]: Creating 1 environments.
INFO:EasyRL:Creating 1 environments.
[INFO][2024-03-14 23:46:21]: Load in OpenGL!
INFO:AIRobot:Load in OpenGL!

====================================
      Device:cuda
      Total number of steps:200000
====================================
================================================
Use sparse reward:False
Use subgoal:False
With obstacle in the scene:True
Apply collision penalty:True
================================================

[ERROR][2024-03-14 23:46:22]: Not a valid git repo:
/usr/local/lib/python3.10/dist-packages
ERROR:EasyRL:Not a valid git repo: /usr/local/lib/python3.10/dist-
packages
[INFO][2024-03-14 23:46:22]: Exploration steps: 0
INFO:EasyRL:Exploration steps: 0
[INFO][2024-03-14 23:46:22]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
000000.pt.
```

```
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
000000.pt.
[INFO][2024-03-14 23:46:22]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:46:53]: Exploration steps: 10000
INFO:EasyRL:Exploration steps: 10000
[INFO][2024-03-14 23:46:53]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
010000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
010000.pt.
[INFO][2024-03-14 23:47:23]: Exploration steps: 20000
INFO:EasyRL:Exploration steps: 20000
[INFO][2024-03-14 23:47:23]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
020000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
020000.pt.
[INFO][2024-03-14 23:47:23]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:47:54]: Exploration steps: 30000
INFO:EasyRL:Exploration steps: 30000
[INFO][2024-03-14 23:47:54]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
030000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
030000.pt.
[INFO][2024-03-14 23:47:54]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:48:25]: Exploration steps: 40000
INFO:EasyRL:Exploration steps: 40000
[INFO][2024-03-14 23:48:25]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
```

```
040000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
040000.pt.
[INFO][2024-03-14 23:48:25]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:48:55]: Exploration steps: 50000
INFO:EasyRL:Exploration steps: 50000
[INFO][2024-03-14 23:48:55]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
050000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
050000.pt.
[INFO][2024-03-14 23:48:55]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:49:26]: Exploration steps: 60000
INFO:EasyRL:Exploration steps: 60000
[INFO][2024-03-14 23:49:26]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
060000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
060000.pt.
[INFO][2024-03-14 23:49:26]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:49:57]: Exploration steps: 70000
INFO:EasyRL:Exploration steps: 70000
[INFO][2024-03-14 23:49:57]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
070000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
070000.pt.
[INFO][2024-03-14 23:49:57]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
```

```
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:50:28]: Exploration steps: 80000
INFO:EasyRL:Exploration steps: 80000
[INFO][2024-03-14 23:50:28]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
080000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
080000.pt.
[INFO][2024-03-14 23:50:28]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/model_best.
pt.
[INFO][2024-03-14 23:50:58]: Exploration steps: 90000
INFO:EasyRL:Exploration steps: 90000
[INFO][2024-03-14 23:50:58]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
090000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
090000.pt.
[INFO][2024-03-14 23:51:27]: Exploration steps: 100000
INFO:EasyRL:Exploration steps: 100000
[INFO][2024-03-14 23:51:27]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
100000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
100000.pt.
[INFO][2024-03-14 23:51:54]: Exploration steps: 110000
INFO:EasyRL:Exploration steps: 110000
[INFO][2024-03-14 23:51:54]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
110000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
110000.pt.
[INFO][2024-03-14 23:52:21]: Exploration steps: 120000
INFO:EasyRL:Exploration steps: 120000
[INFO][2024-03-14 23:52:21]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
120000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
120000.pt.
```

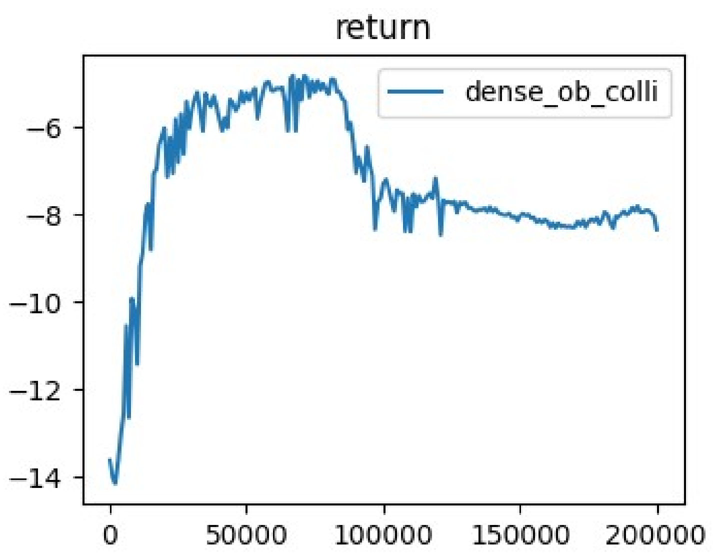
```
[INFO][2024-03-14 23:52:47]: Exploration steps: 130000
INFO:EasyRL:Exploration steps: 130000
[INFO][2024-03-14 23:52:47]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
130000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
130000.pt.
[INFO][2024-03-14 23:53:13]: Exploration steps: 140000
INFO:EasyRL:Exploration steps: 140000
[INFO][2024-03-14 23:53:13]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
140000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
140000.pt.
[INFO][2024-03-14 23:53:39]: Exploration steps: 150000
INFO:EasyRL:Exploration steps: 150000
[INFO][2024-03-14 23:53:39]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
150000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
150000.pt.
[INFO][2024-03-14 23:54:06]: Exploration steps: 160000
INFO:EasyRL:Exploration steps: 160000
[INFO][2024-03-14 23:54:06]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
160000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
160000.pt.
[INFO][2024-03-14 23:54:33]: Exploration steps: 170000
INFO:EasyRL:Exploration steps: 170000
[INFO][2024-03-14 23:54:33]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
170000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
170000.pt.
[INFO][2024-03-14 23:55:01]: Exploration steps: 180000
INFO:EasyRL:Exploration steps: 180000
[INFO][2024-03-14 23:55:01]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
180000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
180000.pt.
[INFO][2024-03-14 23:55:29]: Exploration steps: 190000
```

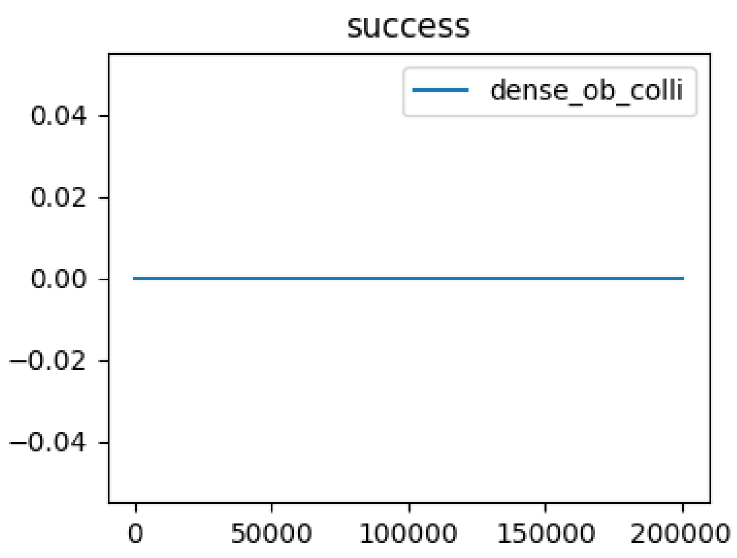
```
INFO:EasyRL:Exploration steps: 190000
[INFO][2024-03-14 23:55:29]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
190000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
190000.pt.
[INFO][2024-03-14 23:55:55]: Exploration steps: 200000
INFO:EasyRL:Exploration steps: 200000
[INFO][2024-03-14 23:55:55]: Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
200000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_False_col_True/seed_0/model/ckpt_000000
200000.pt.
```

```
{'eval/episode_length/max': 25,
 'eval/episode_length/mean': 25.0,
 'eval/episode_length/median': 25.0,
 'eval/episode_length/min': 25,
 'eval/return/max': -8.0379305,
 'eval/return/mean': -8.0379305,
 'eval/return/median': -8.0379305,
 'eval/return/min': -8.0379305,
 'eval/smooth_return/mean': -8.004836266332196,
 'eval/success': 0.0}
```

```
steps, returns, success_rate = read_tf_log(obs_colli_dense_save_dir)
return_data = dict(
    dense_ob_colli=[steps, returns]
)
plot_curves(return_data, 'return')
success_data = dict(
    dense_ob_colli=[steps, success_rate]
)
plot_curves(success_data, 'success')
play_video(obs_colli_dense_save_dir)
```

```
<IPython.core.display.HTML object>
```





Q4.3 [5 pts] What's the collision rate now?

```
#### TODO
path = obs_colli_dense_save_dir
collisions = check_collision_rate(path)
print(collisions)

0.0
```

Dense reward with subgoals

As we can see in the previous section, if we add a collision penalty to the reward function, the agent can learn not to collide with the obstacle. However, it is still unable to reach the goal position as it gets stuck on the left side of the wall and never gets a chance to bypass it. We would need to design a better reward function.

Let's assume that we know two subgoal locations in the scene (shown as the light blue ball in the figures below). They are on the two sides of the obstacle. Can we use these two subgoal locations to design a better reward function such that the robot can finally reach the goal location?

Q5 [30 pts]: Can you come up with a reward function with the subgoal information (`use_subgoal=True`) and make the robot reach the goal location? Write down the reward function $r(s_t, a_t)$ mathematically. Same as before, train the policy and plot the return curve and the success rate curve. What's the collision rate in this case?

A:

$$r(s_t, a_t) = ???$$

$$r(s_t, a_t) = \begin{cases} -min(\| s_t - s_{sg_1} \|_2, \| s_t - s_{sg_2} \|_2), & \text{if } \| s_t - min(\| s_t - s_{sg_1} \|_2, \| s_t - s_{sg_2} \|_2) \|_2 > d_{threshold} \text{and not } self.a \\ - \| s_t - s_g \|_2, & \text{if } \| s_t - s_g \| \geq d_{threshold} \text{and } self.at_s ubgoal \\ +10, & \text{if } \| s_t - s_g \| < d_{threshold} \end{cases}$$

Where, \ s_t is the current state (position of the robot), s_{sg_1} and s_{sg_2} indicate the subgoals and s_g is the goal, and \ $self.at_s ubgoal$ is set to true when $\| s_t - min(\| s_t - s_{sg_1} \|_2, \| s_t - s_{sg_2} \|_2) \|_2 \leq d_{threshold}$ for the first time

```
#### Q5 (expected running time on T4 GPU: 9:00 min)
obs_colli_subgoal_dense_save_dir = train_ppo(use_sparse_reward=False,
use_subgoal=True, with_obstacle=True, apply_collision_penalty=True)

[INFO][2024-03-15 00:57:17]: Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
INFO:EasyRL:Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
[INFO][2024-03-15 00:57:17]: Creating 1 environments.
INFO:EasyRL:Creating 1 environments.
[INFO][2024-03-15 00:57:17]: Load in OpenGL!
INFO:AIRobot:Load in OpenGL!

====================================
      Device:cuda
      Total number of steps:200000
====================================
================================================
Use sparse reward:False
Use subgoal:True
With obstacle in the scene:True
```

```
Apply collision penalty:True
================================================

[ERROR][2024-03-15 00:57:19]: Not a valid git repo:
/usr/local/lib/python3.10/dist-packages
ERROR:EasyRL:Not a valid git repo: /usr/local/lib/python3.10/dist-
packages
[INFO][2024-03-15 00:57:19]: Exploration steps: 0
INFO:EasyRL:Exploration steps: 0
[INFO][2024-03-15 00:57:19]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
00000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
00000.pt.
[INFO][2024-03-15 00:57:19]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 00:57:49]: Exploration steps: 10000
INFO:EasyRL:Exploration steps: 10000
[INFO][2024-03-15 00:57:49]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
10000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
10000.pt.
[INFO][2024-03-15 00:57:49]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 00:58:16]: Exploration steps: 20000
INFO:EasyRL:Exploration steps: 20000
[INFO][2024-03-15 00:58:16]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
20000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
20000.pt.
[INFO][2024-03-15 00:58:16]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 00:58:43]: Exploration steps: 30000
```

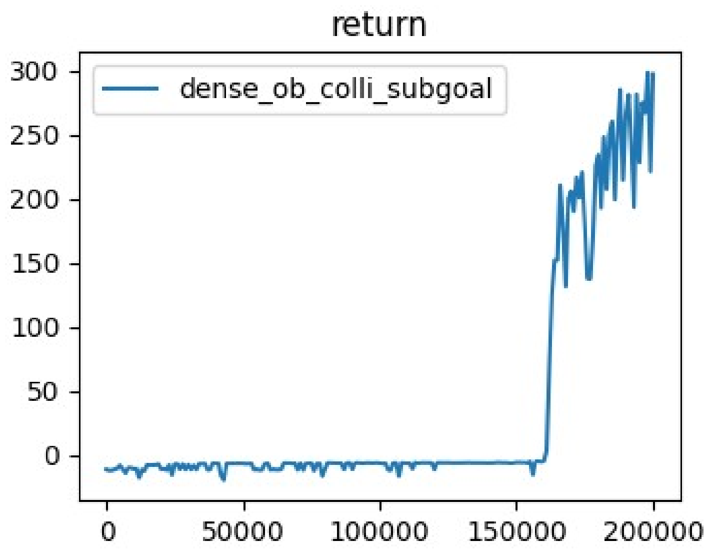
```
INFO:EasyRL:Exploration steps: 30000
[INFO][2024-03-15 00:58:43]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
30000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
30000.pt.
[INFO][2024-03-15 00:58:43]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 00:59:08]: Exploration steps: 40000
INFO:EasyRL:Exploration steps: 40000
[INFO][2024-03-15 00:59:08]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
40000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
40000.pt.
[INFO][2024-03-15 00:59:08]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 00:59:32]: Exploration steps: 50000
INFO:EasyRL:Exploration steps: 50000
[INFO][2024-03-15 00:59:32]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
50000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
50000.pt.
[INFO][2024-03-15 00:59:32]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 00:59:57]: Exploration steps: 60000
INFO:EasyRL:Exploration steps: 60000
[INFO][2024-03-15 00:59:57]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
60000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
60000.pt.
```

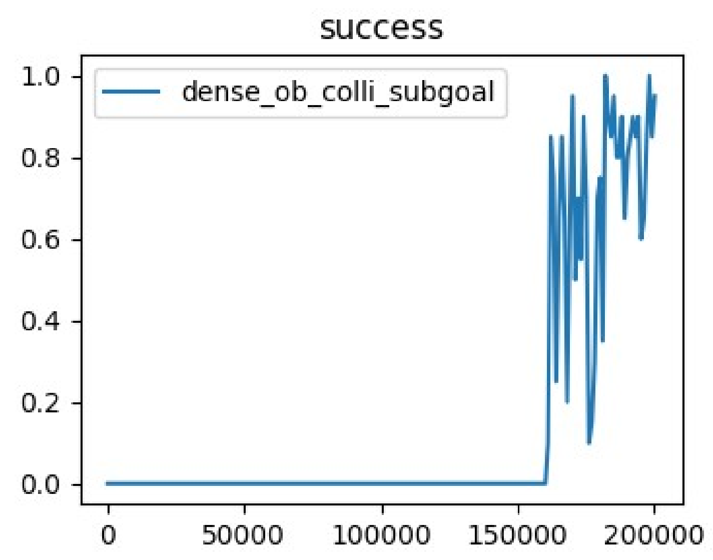
```
[INFO][2024-03-15 00:59:57]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:00:21]: Exploration steps: 70000
INFO:EasyRL:Exploration steps: 70000
[INFO][2024-03-15 01:00:21]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
70000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
70000.pt.
[INFO][2024-03-15 01:00:21]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:00:45]: Exploration steps: 80000
INFO:EasyRL:Exploration steps: 80000
[INFO][2024-03-15 01:00:45]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
80000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
80000.pt.
[INFO][2024-03-15 01:00:45]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:01:10]: Exploration steps: 90000
INFO:EasyRL:Exploration steps: 90000
[INFO][2024-03-15 01:01:10]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
90000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000000
90000.pt.
[INFO][2024-03-15 01:01:10]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:01:34]: Exploration steps: 100000
```

```
INFO:EasyRL:Exploration steps: 100000
[INFO][2024-03-15 01:01:34]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
00000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
00000.pt.
[INFO][2024-03-15 01:01:34]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:01:58]: Exploration steps: 110000
INFO:EasyRL:Exploration steps: 110000
[INFO][2024-03-15 01:01:58]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
10000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
10000.pt.
[INFO][2024-03-15 01:01:58]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:02:22]: Exploration steps: 120000
INFO:EasyRL:Exploration steps: 120000
[INFO][2024-03-15 01:02:22]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
20000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
20000.pt.
[INFO][2024-03-15 01:02:22]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:02:47]: Exploration steps: 130000
INFO:EasyRL:Exploration steps: 130000
[INFO][2024-03-15 01:02:47]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
30000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
30000.pt.
```

```
[INFO][2024-03-15 01:02:47]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:03:11]: Exploration steps: 140000
INFO:EasyRL:Exploration steps: 140000
[INFO][2024-03-15 01:03:11]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
40000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
40000.pt.
[INFO][2024-03-15 01:03:37]: Exploration steps: 150000
INFO:EasyRL:Exploration steps: 150000
[INFO][2024-03-15 01:03:37]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
50000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
50000.pt.
[INFO][2024-03-15 01:03:37]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:04:04]: Exploration steps: 160000
INFO:EasyRL:Exploration steps: 160000
[INFO][2024-03-15 01:04:04]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
60000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
60000.pt.
[INFO][2024-03-15 01:04:04]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:04:32]: Exploration steps: 170000
INFO:EasyRL:Exploration steps: 170000
[INFO][2024-03-15 01:04:32]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
70000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
```

```
70000.pt.
[INFO][2024-03-15 01:04:32]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:05:00]: Exploration steps: 180000
INFO:EasyRL:Exploration steps: 180000
[INFO][2024-03-15 01:05:00]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
80000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
80000.pt.
[INFO][2024-03-15 01:05:00]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:05:27]: Exploration steps: 190000
INFO:EasyRL:Exploration steps: 190000
[INFO][2024-03-15 01:05:27]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
90000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000001
90000.pt.
[INFO][2024-03-15 01:05:27]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/model_best.p
t.
[INFO][2024-03-15 01:05:53]: Exploration steps: 200000
INFO:EasyRL:Exploration steps: 200000
[INFO][2024-03-15 01:05:53]: Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000002
00000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/dense_ob_True_sg_True_col_True/seed_0/model/ckpt_0000002
00000.pt.

{'eval/episode_length/max': 25,
 'eval/episode_length/mean': 25.0,
 'eval/episode_length/median': 25.0,
 'eval/episode_length/min': 25,
 'eval/return/max': 317.54514,
 'eval/return/mean': 317.54514,
 'eval/return/median': 317.54514,
 'eval/return/min': 317.54514,
 'eval/smooth_return/mean': 165.54529262164942,
 'eval/success': 1.0}

steps, returns, success_rate =
read_tf_log(obs_colli_subgoal_dense_save_dir)
return_data = dict(
    dense_ob_colli_subgoal=[steps, returns]
)
plot_curves(return_data, 'return')
success_data = dict(
    dense_ob_colli_subgoal=[steps, success_rate]
)
plot_curves(success_data, 'success')
play_video(obs_colli_subgoal_dense_save_dir)

<IPython.core.display.HTML object>
```





```
#### TODO: check collision rate for this run
path = obs_colli_subgoal_dense_save_dir
collisions = check_collision_rate(path)
print(collisions)

0.0
```

Pushing Task

Now that you can solve the reaching task, let's try another harder task. We would like our robot to push a box (the pink object shown in the figure below) on the table from its initial position to a goal position (the red ball in the figure).

State: $[x_e, y_e, x_o, y_o]$, where $[x_e, y_e]$ is the 2D position of the end-effector tip, $[x_o, y_o]$ is the 2D position of the box.

Action: same as before.

```
class URRobotPusherGym(gym.Env):
    def __init__(self,
                 action_repeat: int = 10,
                 gui: bool = False,
                 max_episode_length: int = 25,
                 dist_threshold:float = 0.05):
        """
          Parameters:
          - action_repeat (int): The number of times an action is
repeated per step in the environment.
```

```
          - gui (bool): If False, run the environment without a GUI to
prevent crashes in environments like Colab.
                        Set to True for debugging on local machines
where a GUI is supported.
          - max_episode_length (int): The maximum length of an
episode.
          - dist_threshold (float): The distance threshold to consider
a goal achieved.
        """
        self._action_repeat = action_repeat
        self._max_episode_length = max_episode_length
        self._dist_threshold = dist_threshold

        self._xy_bounds = np.array([[0.23, 0.78],  # [xmin, xmax]
                                    [-0.35, 0.3]])  # [ymin, ymax]
        self.robot = Robot('ur5e_stick',
                           pb_cfg={'gui': gui,
                                   'realtime': False,
                                   'opengl_render':
torch.cuda.is_available()})
        self._arm_reset_pos = np.array([-0.38337763,
                                        -2.02650575,
                                        -2.01989619,
                                        -0.64477803,
                                        1.571439041,
                                        -0.38331266])
        self._table_id =
self.robot.pb_client.load_urdf('table/table.urdf',
                                                        [.5, 0, 0.4],
                                                        euler2quat([0,
0, np.pi / 2]),

                                                        scaling=0.9)

        # create a ball at the start location (for visualization
purpose)
        self._start_pos = np.array([0.45, -0.32, 1.0])
        self._start_urdf_id = self.robot.pb_client.load_geom('sphere',
size=0.04, mass=0,

base_pos=self._start_pos,
                                                             rgba=[1,
1, 0, 0.8])

        # create a ball at the goal location
        self._goal_pos = np.array([0.5, 0.2, 1.0])
        self._goal_urdf_id = self.robot.pb_client.load_geom('sphere',
size=0.04, mass=0,

base_pos=self._goal_pos,
                                                            rgba=[1,
0, 0, 0.8])

        # disable the collision checking between the robot and the
ball at the goal location
        for i in
range(self.robot.pb_client.getNumJoints(self.robot.arm.robot_id)):

self.robot.pb_client.setCollisionFilterPair(self.robot.arm.robot_id,

self._goal_urdf_id,
                                                        i,
                                                        -1,

enableCollision=0)
        # disable the collision checking between the robot and the
ball at the start location
        for i in
range(self.robot.pb_client.getNumJoints(self.robot.arm.robot_id)):

self.robot.pb_client.setCollisionFilterPair(self.robot.arm.robot_id,

self._start_urdf_id,
                                                        i,
                                                        -1,

enableCollision=0)

        self._box_pos = np.array([0.35, -0.1, 0.996])
        self._box_id = self.robot.pb_client.load_geom('cylinder',
size=[0.05, 0.05], mass=1.,

base_pos=self._box_pos,
                                                      rgba=[1., 0.6,
0.6, 1])

        self.robot.pb_client.changeDynamics(self._box_id, -1,
lateralFriction=0.9)

        self.robot.pb_client.setCollisionFilterPair(self._box_id,

self._start_urdf_id,
                                                    -1,
                                                    -1,
                                                    enableCollision=0)
        self.robot.pb_client.setCollisionFilterPair(self._box_id,

self._goal_urdf_id,
                                                    -1,
                                                    -1,
                                                    enableCollision=0)
        self._action_bound = 1.0
        self._ee_pos_scale = 0.02
        self._action_high = np.array([self._action_bound] * 2)
        self.action_space = spaces.Box(low=-self._action_high,
                                       high=self._action_high,
                                       dtype=np.float32)
        state_low = np.full(len(self._get_obs()), -float('inf'))
        state_high = np.full(len(self._get_obs()), float('inf'))
        self.observation_space = spaces.Box(state_low,
                                            state_high,
                                            dtype=np.float32)

        self.robot_at_block = False
        self.robot_radius = 0.03
        self.block_radius = 0.05
        self.reset()

    def reset(self) -> np.array:
        """
          Resets the environment to its initial state.

          Returns:
          - np.array: The initial observation of the environment after
resetting.
        """
        self.robot.arm.set_jpos(self._arm_reset_pos,
ignore_physics=True)
        self.robot.pb_client.reset_body(self._box_id,
base_pos=self._box_pos)
        self._t = 0
        self._ref_ee_pos = self.robot.arm.get_ee_pose()[0]
        self._ref_ee_ori = self.robot.arm.get_ee_pose()[1]
        return self._get_obs()

    def step(self, action: np.ndarray) -> Tuple[np.ndarray, float,
bool, dict]:
        """
          Parameters:
          - action (np.ndarray): The action to be executed

          Returns:
          - state: The next state of the environment after executing
the action.
          - reward: The reward received after executing the action.
          - done: A flag indicating whether the episode has ended
(True if the episode is done, False otherwise).
          - info: Additional information such as whether a collision
occurred.
        """
        previous_state = self._get_obs()
        collision = self._apply_action(action)
        self._t += 1
        state = self._get_obs()
        done = self._t >= self._max_episode_length
        reward, info = self._get_reward(state=state, action=action,
previous_state=previous_state)
        info['collision'] = collision
        return state, reward, done, info

    def _get_reward(self, state: np.ndarray, action: np.ndarray,
previous_state: np.ndarray) -> Tuple[float, dict]:
        """
          Parameters:
          - state (np.ndarray): The current state of the environment.
          - action (np.ndarray): The action taken from the current
state.
          - previous_state (np.ndarray): The state of the environment
in the previous time step.

          Returns:
          - reward: The calculated reward
          - info: A dictionary containing additional information about
the reward calculation, including whether the goal was achieved
(success flag).
        """
        object_pos = state[2:4]
        dist_to_goal = np.linalg.norm(object_pos - self._goal_pos[:2])
        success = dist_to_goal < self._dist_threshold
        #### TODO: Q6 design the reward given state, action, and
previous state
        # we initially want the robot to get close to the pink object
-- compute the distance between end-effector and pink object
        robot_pos = state[:2]
        dist_to_block = np.linalg.norm(robot_pos - object_pos)
        if not self.robot_at_block:
          # compute the distance between the robot and the block and
use the distance as the negative reward
          # dist_to_block = np.linalg.norm(robot_pos - object_pos)
          # reward = -dist_to_block
          reward = -5 * dist_to_block # without high negative reward
here, the robot strays far from the block

          # check if the robot's distance to the block is within a
threshold
          if dist_to_block < (self._dist_threshold + self.robot_radius
+ self.block_radius):
            self.robot_at_block = True
            # give some intermediate reward
            reward += 2
        else:
          # ensure that the robot is close to the object and use the
distance to goal as the reward
          reward = -0.5 * dist_to_block - dist_to_goal

        if success:
          # give high reward if the block reaches the goal
          reward += 20

        ####
        info = dict(success=success)
        return reward, info

    def _get_obs(self):
        """
          Returns:
          - np.ndarray: The current state observation, i.e., the x and
y positions of the robot's end-effector.
        """
        gripper_pos = self.robot.arm.get_ee_pose()[0][:2]
        object_pos, object_quat =
self.robot.pb_client.get_body_state(self._box_id)[:2]
        state = np.concatenate([gripper_pos, object_pos[:2]])
        return state

    def _apply_action(self, action: np.ndarray) -> bool:
        """
          Parameters:
          - action (np.ndarray): The action to be executed.

          Returns:
          - bool: Indicates whether a collision occurred as a result
of applying the action.
        """
        if not isinstance(action, np.ndarray):
            action = np.array(action).flatten()
        if action.size != 2:
            raise ValueError('Action should be [d_x, d_y].')
        # we set dz=0
        action = np.append(action, 0)
        pos, quat, rot_mat, euler = self.robot.arm.get_ee_pose()
        pos += action[:3] * self._ee_pos_scale
        pos[2] = self._ref_ee_pos[2]
        # if the new position is out of the bounds, then we don't
apply the action
        if not np.logical_and(np.all(pos[:2] >= self._xy_bounds[:,
0]),
                              np.all(pos[:2] <= self._xy_bounds[:,
1])):
            return False
        # move the end-effector to the new position
        jnt_pos = self.robot.arm.compute_ik(pos, ori=self._ref_ee_ori)
        for step in range(self._action_repeat):
            self.robot.arm.set_jpos(jnt_pos)
            self.robot.pb_client.stepSimulation()

        return False

    def render(self, mode, **kwargs):
        """
          Renders the current state of the environment for
visualization.

          Parameters:
          - mode (str): The mode for rendering. 'human' for on-screen
rendering and potentially other modes
            for off-screen rendering or returning data arrays for
further processing.

          Returns:
          - np.ndarray: An image array representing the current visual
state of the environment, if applicable based on the rendering mode.
        """
        robot_base = self.robot.arm.robot_base_pos
        self.robot.cam.setup_camera(focus_pt=robot_base,
                                    dist=2,
                                    yaw=85,
                                    pitch=-20,
                                    roll=0)
        rgb, _ = self.robot.cam.get_images(get_rgb=True,
                                           get_depth=False)
        return rgb

    def seed(self, seed):
      return np.random.seed(seed)




module_name = __name__

env_name = 'URPusher-v1'
if env_name in registry:
    del registry[env_name]
register(
    id=env_name,
    entry_point=f'{module_name}:URRobotPusherGym',
)
```

Q6 [40 pts]: Can you design a reward function so that the robot can push the box to the goal position? Write down the reward function $r(s_t, a_t)$ mathematically. Same as before, train the policy and plot the return curve and the success rate curve. If the reward function is good, you will see that the success rate will be at least above 0.8 for a continued period of time. **HINTS**: If you use the negative of the distance between the object and the goal location as the reward function, does it work? What if you add another term to encourage the gripper to be close to the object? If the policy still does not learn, what other reward shaping terms are helpful for the training? The information you can use include the state before and after the robot executes the action, the action that the robot takes, the radius of the object is 0.05m, the radius of the end-effector stick is about $0.02 \sim 0.03$m.

A:

$$r(s_t, a_t) = ???$$

$$r(s_t, a_t) = \left(\begin{array}{ll} -5 \times \| s_t - s_b \|_2, & \text{if not self.robot\_at\_block and } \| s_t - s_b \|_2 \geq (d_{threshold} + r_r + b_r) \\ -5 \times \| s_t - s_b \|_2 + 2, & \text{if not self.robot\_at\_block and } \| s_t - s_o \|_2 < (d_{threshold} + r_r + b_r) \\ -0.5 \times \| s_t - s_o \|_2 - \| s_t - s_g \|_2, & \text{if self.robot\_at\_block and } \| s_t - s_g \|_2 \geq d_{threshold} \\ +20, & \text{if } \| d_t - d_g \|_2 < d_{threshold} \end{array} \right)$$

Where, \ s_t is robot position, s_b is the block position, s_g is the goal position and self.robot_at_block is set to true when $\| s_t - s_b \|_2 < d_{threshold}$ is true for the first time, \ r_r and b_r indicate the robot radius and block radius.

```
#### Q6 (expected running time on T4 GPU: 25:00 min)
# you can reduce the number of steps for debugging purpose
# but for the submission, you should run the experiment for at least
350000 steps!
push_save_dir = train_ppo(push_exp=True, max_steps=350000)
# push_save_dir = train_ppo(push_exp=True, max_steps=50000)

[INFO][2024-03-15 01:29:36]: Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
INFO:EasyRL:Alogrithm type:<class
'easyrl.configs.ppo_config.PPOConfig'>
[INFO][2024-03-15 01:29:36]: Creating 1 environments.
INFO:EasyRL:Creating 1 environments.
[INFO][2024-03-15 01:29:36]: Load in OpenGL!
INFO:AIRobot:Load in OpenGL!

====================================
      Device:cuda
      Total number of steps:350000
====================================

[ERROR][2024-03-15 01:29:38]: Not a valid git repo:
/usr/local/lib/python3.10/dist-packages
ERROR:EasyRL:Not a valid git repo: /usr/local/lib/python3.10/dist-
```

```
packages
[INFO][2024-03-15 01:29:38]: Exploration steps: 0
INFO:EasyRL:Exploration steps: 0
[INFO][2024-03-15 01:29:38]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000000000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000000000.pt.
[INFO][2024-03-15 01:29:38]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:30:10]: Exploration steps: 10000
INFO:EasyRL:Exploration steps: 10000
[INFO][2024-03-15 01:30:10]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000010000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000010000.pt.
[INFO][2024-03-15 01:30:10]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:30:42]: Exploration steps: 20000
INFO:EasyRL:Exploration steps: 20000
[INFO][2024-03-15 01:30:42]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000020000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000020000.pt.
[INFO][2024-03-15 01:30:42]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:31:11]: Exploration steps: 30000
INFO:EasyRL:Exploration steps: 30000
[INFO][2024-03-15 01:31:11]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000030000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000030000.pt.
[INFO][2024-03-15 01:31:11]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:31:39]: Exploration steps: 40000
INFO:EasyRL:Exploration steps: 40000
[INFO][2024-03-15 01:31:39]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000040000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000040000.pt.
[INFO][2024-03-15 01:31:39]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
```

```
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:32:07]: Exploration steps: 50000
INFO:EasyRL:Exploration steps: 50000
[INFO][2024-03-15 01:32:07]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000050000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000050000.pt.
[INFO][2024-03-15 01:32:07]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:32:34]: Exploration steps: 60000
INFO:EasyRL:Exploration steps: 60000
[INFO][2024-03-15 01:32:34]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000060000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000060000.pt.
[INFO][2024-03-15 01:32:34]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:33:02]: Exploration steps: 70000
INFO:EasyRL:Exploration steps: 70000
[INFO][2024-03-15 01:33:02]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000070000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000070000.pt.
[INFO][2024-03-15 01:33:02]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:33:29]: Exploration steps: 80000
INFO:EasyRL:Exploration steps: 80000
[INFO][2024-03-15 01:33:29]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000080000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000080000.pt.
[INFO][2024-03-15 01:33:29]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:33:55]: Exploration steps: 90000
INFO:EasyRL:Exploration steps: 90000
[INFO][2024-03-15 01:33:55]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000090000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000090000.pt.
[INFO][2024-03-15 01:33:55]: Saving checkpoint:
```

```
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:34:23]: Exploration steps: 100000
INFO:EasyRL:Exploration steps: 100000
[INFO][2024-03-15 01:34:23]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000100000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000100000.pt.
[INFO][2024-03-15 01:34:23]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:34:50]: Exploration steps: 110000
INFO:EasyRL:Exploration steps: 110000
[INFO][2024-03-15 01:34:50]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000110000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000110000.pt.
[INFO][2024-03-15 01:35:16]: Exploration steps: 120000
INFO:EasyRL:Exploration steps: 120000
[INFO][2024-03-15 01:35:16]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000120000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000120000.pt.
[INFO][2024-03-15 01:35:43]: Exploration steps: 130000
INFO:EasyRL:Exploration steps: 130000
[INFO][2024-03-15 01:35:43]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000130000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000130000.pt.
[INFO][2024-03-15 01:36:09]: Exploration steps: 140000
INFO:EasyRL:Exploration steps: 140000
[INFO][2024-03-15 01:36:09]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000140000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000140000.pt.
[INFO][2024-03-15 01:36:09]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:36:35]: Exploration steps: 150000
INFO:EasyRL:Exploration steps: 150000
[INFO][2024-03-15 01:36:35]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000150000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000150000.pt.
[INFO][2024-03-15 01:37:01]: Exploration steps: 160000
INFO:EasyRL:Exploration steps: 160000
```

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[INFO][2024-03-15 01:37:01]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000160000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000160000.pt.
[INFO][2024-03-15 01:37:01]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:37:26]: Exploration steps: 170000
INFO:EasyRL:Exploration steps: 170000
[INFO][2024-03-15 01:37:26]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000170000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000170000.pt.
[INFO][2024-03-15 01:37:52]: Exploration steps: 180000
INFO:EasyRL:Exploration steps: 180000
[INFO][2024-03-15 01:37:52]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000180000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000180000.pt.
[INFO][2024-03-15 01:38:17]: Exploration steps: 190000
INFO:EasyRL:Exploration steps: 190000
[INFO][2024-03-15 01:38:17]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000190000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000190000.pt.
[INFO][2024-03-15 01:38:17]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:38:43]: Exploration steps: 200000
INFO:EasyRL:Exploration steps: 200000
[INFO][2024-03-15 01:38:43]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000200000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000200000.pt.
[INFO][2024-03-15 01:39:09]: Exploration steps: 210000
INFO:EasyRL:Exploration steps: 210000
[INFO][2024-03-15 01:39:09]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000210000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000210000.pt.
[INFO][2024-03-15 01:39:09]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:39:35]: Exploration steps: 220000
INFO:EasyRL:Exploration steps: 220000
[INFO][2024-03-15 01:39:35]: Saving checkpoint:
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/content/data/push/seed_0/model/ckpt_000000220000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000220000.pt.
[INFO][2024-03-15 01:40:01]: Exploration steps: 230000
INFO:EasyRL:Exploration steps: 230000
[INFO][2024-03-15 01:40:01]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000230000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000230000.pt.
[INFO][2024-03-15 01:40:01]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:40:26]: Exploration steps: 240000
INFO:EasyRL:Exploration steps: 240000
[INFO][2024-03-15 01:40:26]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000240000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000240000.pt.
[INFO][2024-03-15 01:40:26]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:40:52]: Exploration steps: 250000
INFO:EasyRL:Exploration steps: 250000
[INFO][2024-03-15 01:40:52]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000250000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000250000.pt.
[INFO][2024-03-15 01:40:52]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:41:17]: Exploration steps: 260000
INFO:EasyRL:Exploration steps: 260000
[INFO][2024-03-15 01:41:17]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000260000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000260000.pt.
[INFO][2024-03-15 01:41:17]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:41:43]: Exploration steps: 270000
INFO:EasyRL:Exploration steps: 270000
[INFO][2024-03-15 01:41:43]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000270000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000270000.pt.
```

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[INFO][2024-03-15 01:41:43]: Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/model_best.pt.
[INFO][2024-03-15 01:42:08]: Exploration steps: 280000
INFO:EasyRL:Exploration steps: 280000
[INFO][2024-03-15 01:42:08]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000280000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000280000.pt.
[INFO][2024-03-15 01:42:33]: Exploration steps: 290000
INFO:EasyRL:Exploration steps: 290000
[INFO][2024-03-15 01:42:33]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000290000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000290000.pt.
[INFO][2024-03-15 01:42:59]: Exploration steps: 300000
INFO:EasyRL:Exploration steps: 300000
[INFO][2024-03-15 01:42:59]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000300000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000300000.pt.
[INFO][2024-03-15 01:43:24]: Exploration steps: 310000
INFO:EasyRL:Exploration steps: 310000
[INFO][2024-03-15 01:43:24]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000310000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000310000.pt.
[INFO][2024-03-15 01:43:50]: Exploration steps: 320000
INFO:EasyRL:Exploration steps: 320000
[INFO][2024-03-15 01:43:50]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000320000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000320000.pt.
[INFO][2024-03-15 01:44:15]: Exploration steps: 330000
INFO:EasyRL:Exploration steps: 330000
[INFO][2024-03-15 01:44:15]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000330000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000330000.pt.
[INFO][2024-03-15 01:44:40]: Exploration steps: 340000
INFO:EasyRL:Exploration steps: 340000
[INFO][2024-03-15 01:44:40]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000340000.pt.
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000340000.pt.
[INFO][2024-03-15 01:45:05]: Exploration steps: 350000
INFO:EasyRL:Exploration steps: 350000
[INFO][2024-03-15 01:45:05]: Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000350000.pt.
```
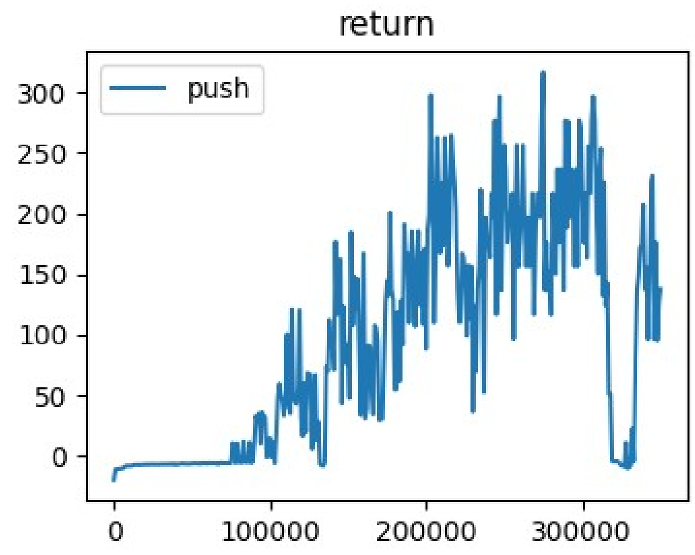
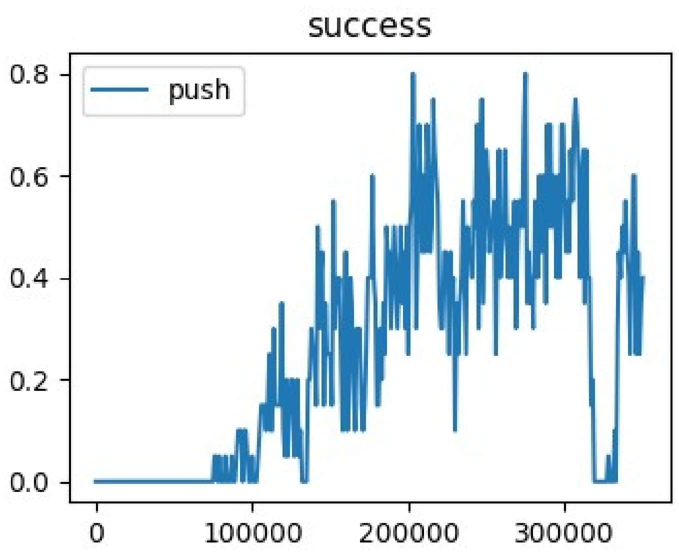

```
INFO:EasyRL:Saving checkpoint:
/content/data/push/seed_0/model/ckpt_000000350000.pt.

{'eval/episode_length/max': 25,
 'eval/episode_length/mean': 25.0,
 'eval/episode_length/median': 25.0,
 'eval/episode_length/min': 25,
 'eval/return/max': 396.60147,
 'eval/return/mean': 396.60147,
 'eval/return/median': 396.60147,
 'eval/return/min': 396.60147,
 'eval/smooth_return/mean': 282.8277044969685,
 'eval/success': 1.0}

steps, returns, success_rate = read_tf_log(push_save_dir)
return_data = dict(
    push=[steps, returns]
)
plot_curves(return_data, 'return')
success_data = dict(
    push=[steps, success_rate]
)
plot_curves(success_data, 'success')
play_video(push_save_dir)

<IPython.core.display.HTML object>
```





Feedback Survey (optional)

Please enter the bonus code you get after filling out the anonymous assignment survey. (10 pts).

Bonus code: plus_ten_reward or policy_gradient?