

B. Select one of the driving policies (DQN or others) baseline code:

## Highway-env using PPO

**introduction** A virtual environment is a tool that allows you to construct isolated Python environments. A part of it has been included into the standard library as the `venv` module since Python 3.3. The `venv` module does not include all of the functionality of this package.

Useful links: The links that build abstractions on top of `virtualenv`:

- **virtualenvwrapper** - a useful set of scripts for creating and deleting virtual environments
- **pew** - provides a set of commands to manage multiple virtual environments
- **tox** - a generic `virtualenv` management and test automation command line tool, driven by a `tox.ini` configuration file.
- **nox** - a tool that automates testing in multiple Python environments, similar to `tox`, driven by a `noxfile.py` configuration file

Basic Installations required:

1. Installations from [python.org](https://python.org)
2. Windows Store Python - note only version 3.7+

## Setup

Package requirements to run the highway env 1.7

```
!apt-get update
```

```
Get:1 https://cloud.r-project.org/bin/linux/ubuntu bionic-cran40/ InRelease [3,626 B]
Ign:2 https://developer.download.nvidia.com/compute/machine-learning/repos/ubuntu1804/x86_64 InRelease
Get:3 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64 InRelease [1,581 B]
Hit:4 https://developer.download.nvidia.com/compute/machine-learning/repos/ubuntu1804/x86_64 Release
Get:5 http://security.ubuntu.com/ubuntu bionic-security InRelease [88.7 kB]
Get:6 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64 Packages [1,038 kB]
Hit:7 http://archive.ubuntu.com/ubuntu bionic InRelease
Hit:8 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu bionic InRelease
Get:9 http://archive.ubuntu.com/ubuntu bionic-updates InRelease [88.7 kB]
Hit:10 http://ppa.launchpad.net/cran/libgit2/ubuntu bionic InRelease
Hit:11 http://ppa.launchpad.net/deadsnakes/ppa/ubuntu bionic InRelease
Get:12 http://archive.ubuntu.com/ubuntu bionic-backports InRelease [83.3 kB]
Get:13 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 Packages [1,563 kB]
Get:14 http://archive.ubuntu.com/ubuntu bionic-updates/restricted amd64 Packages [1,303 kB]
Get:15 http://security.ubuntu.com/ubuntu bionic-security/restricted amd64 Packages [1,262 kB]
Get:16 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu bionic InRelease [21.3 kB]
Get:17 http://security.ubuntu.com/ubuntu bionic-security/main amd64 Packages [3,071 kB]
Get:18 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 Packages [3,497 kB]
Get:19 http://archive.ubuntu.com/ubuntu bionic-updates/universe amd64 Packages [2,338 kB]
Get:20 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu bionic/main amd64 Packages [38.5 kB]
Fetched 14.4 MB in 6s (2,489 kB/s)
Reading package lists... Done
```

```
!pip install gym==0.26
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting gym==0.26
  Downloading gym-0.26.0.tar.gz (710 kB)
    |████████████████████████████████████████| 710 kB 21.3 MB/s
Installing build dependencies ... done
Getting requirements to build wheel ... done
Preparing wheel metadata ... done
Requirement already satisfied: gym-notices>=0.0.4 in /usr/local/lib/python3.7/dist-packages (from gym==0.26) (0.0.8)
Requirement already satisfied: cloudpickle>=1.2.0 in /usr/local/lib/python3.7/dist-packages (from gym==0.26) (1.5.0)
Requirement already satisfied: importlib-metadata>=4.8.0 in /usr/local/lib/python3.7/dist-packages (from gym==0.26) (4.13.0)
Requirement already satisfied: numpy>=1.18.0 in /usr/local/lib/python3.7/dist-packages (from gym==0.26) (1.21.6)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata>=4.8.0->gym==0.26) (3.10.0)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata>=4.8.0->gym==0.26) (3.10.0)
Building wheels for collected packages: gym
  Building wheel for gym (PEP 517) ... done
  Created wheel for gym: filename=gym-0.26.0-py3-none-any.whl size=826302 sha256=6347d0bc9aa222fb1526d017af016d7c3518532a803f97654474f9e
  Stored in directory: /root/.cache/pip/wheels/39/f9/03/534b6090f62aef42cfa9bdf20009b7f2e5ba7557ed511a055
Successfully built gym
Installing collected packages: gym
  Attempting uninstall: gym
    Found existing installation: gym 0.25.2
    Uninstalling gym-0.25.2:
```

Successfully uninstalled gym-0.25.2  
 Successfully installed gym-0.26.0

```
!pip install gym==0.21.0
!pip install highway-env==1.5
!pip install sb3-contrib==1.5.0
!pip install importlib-metadata==4.8.1

Successfully installed gym-0.21.0
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting highway-env==1.5
  Downloading highway_env-1.5-py3-none-any.whl (103 kB)
    |#####| 103 kB 12.4 MB/s
Requirement already satisfied: matplotlib in /usr/local/lib/python3.7/dist-packages (from highway-env==1.5) (3.2.2)
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages (from highway-env==1.5) (1.21.6)
Requirement already satisfied: pandas in /usr/local/lib/python3.7/dist-packages (from highway-env==1.5) (1.3.5)
Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-packages (from highway-env==1.5) (1.7.3)
Collecting pygame
  Downloading pygame-2.1.2-cp37-cp37m-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (21.8 MB)
    |#####| 21.8 MB 1.3 MB/s
Requirement already satisfied: gym in /usr/local/lib/python3.7/dist-packages (from highway-env==1.5) (0.21.0)
Requirement already satisfied: importlib-metadata>=4.8.1 in /usr/local/lib/python3.7/dist-packages (from gym->highway-env==1.5) (4.13.0)
Requirement already satisfied: cloudpickle>=1.2.0 in /usr/local/lib/python3.7/dist-packages (from gym->highway-env==1.5) (1.5.0)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata>=4.8.1->gym->highway-env==1.5) (0.5.0)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata>=4.8.1->gym->highway-env==1.5) (3.7.4)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env==1.5) (1.4.4)
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env==1.5) (2.8.1)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env==1.5) (0.11.0)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env==1.5) (2.4.7)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.7/dist-packages (from python-dateutil>=2.1->matplotlib->highway-env==1.5) (1.16.0)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (from pandas->highway-env==1.5) (2022.6)
Installing collected packages: pygame, highway-env
Successfully installed highway-env-1.5 pygame-2.1.2
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting sb3-contrib==1.5.0
  Downloading sb3_contrib-1.5.0-py3-none-any.whl (62 kB)
    |#####| 62 kB 1.1 MB/s
Collecting stable-baselines3>=1.5.0
  Downloading stable_baselines3-1.6.2-py3-none-any.whl (170 kB)
    |#####| 170 kB 37.5 MB/s
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (1.21.6)
Requirement already satisfied: torch>=1.11 in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (1.12.0)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (3.2.2)
Requirement already satisfied: importlib-metadata~>4.13 in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (4.13.0)
Requirement already satisfied: gym==0.21 in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (0.21.0)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (1.5.0)
Requirement already satisfied: pandas in /usr/local/lib/python3.7/dist-packages (from stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (1.3.5)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata~>4.13->stable-baselines3>=1.5.0) (0.5.0)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata~>4.13->stable-baselines3>=1.5.0) (3.7.4)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3>=1.5.0) (2.4.7)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3>=1.5.0) (1.4.4)
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3>=1.5.0) (2.8.1)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (0.11.0)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.7/dist-packages (from python-dateutil>=2.1->matplotlib->stable-baselines3>=1.5.0) (1.16.0)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (from pandas->stable-baselines3>=1.5.0->sb3-contrib==1.5.0) (2022.6)
Installing collected packages: stable-baselines3, sb3-contrib
Successfully installed sb3-contrib-1.5.0 stable-baselines3-1.6.2
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting importlib-metadata==4.8.1
  Downloading importlib_metadata-4.8.1-py3-none-any.whl (17 kB)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata==4.8.1) (3.7.4)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata==4.8.1) (0.5.0)
Installing collected packages: importlib-metadata
Attempting uninstall: importlib-metadata
Found existing installation: importlib-metadata 4.13.0
Uninstalling importlib-metadata-4.13.0:
```

In this task, the ego-vehicle is driving on a multilane highway populated with other vehicles. The agent's objective is to reach a high speed while voiding collisions with neighbouring vehicles. Driving on the right side of the road is also rewarded.

Double-click (or enter) to edit

```
import gym
import torch as th
from stable_baselines3 import PPO
from torch.distributions import Categorical
import torch
```

```
import torch.nn as nn
import numpy as np
from torch.nn import functional as F
from stable_baselines3.common.env_util import make_vec_env
from stable_baselines3.common.torch_layers import BaseFeaturesExtractor
from stable_baselines3.common.vec_env import SubprocVecEnv
import highway_env
```

---

## Installing and visualizing the environment and agent

---

```
# Install environment and agent
!pip install highway-env
# TODO: we use the bleeding edge version because the current stable version does not support the latest gym>=0.21 versions. Revert back to st
!pip install git+https://github.com/DLR-RM/stable-baselines3

# Environment
import gym
import highway_env

# Agent
from stable_baselines3 import DQN

# Visualization utils
%load_ext tensorboard
import sys
from tqdm.notebook import trange
!pip install tensorboardx gym pyvirtualdisplay
!apt-get install -y xvfb python-opengl ffmpeg
!git clone https://github.com/eleurent/highway-env.git 2> /dev/null
sys.path.insert(0, '/content/highway-env/scripts/')
from utils import record_videos, show_videos
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: highway-env in /usr/local/lib/python3.7/dist-packages (1.5)
Requirement already satisfied: gym in /usr/local/lib/python3.7/dist-packages (from highway-env) (0.21.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages (from highway-env) (1.21.6)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.7/dist-packages (from highway-env) (3.2.2)
Requirement already satisfied: pandas in /usr/local/lib/python3.7/dist-packages (from highway-env) (1.3.5)
Requirement already satisfied: pygame in /usr/local/lib/python3.7/dist-packages (from highway-env) (2.1.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-packages (from highway-env) (1.7.3)
Requirement already satisfied: importlib-metadata>=4.8.1 in /usr/local/lib/python3.7/dist-packages (from gym->highway-env) (4.8.1)
Requirement already satisfied: cloudpickle>=1.2.0 in /usr/local/lib/python3.7/dist-packages (from gym->highway-env) (1.5.0)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata>=4.8.1->gym->highway-env)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata>=4.8.1->gym->highway-env)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env) (0.11.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env) (1.4.4)
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env) (2.8.2)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->highway-env)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.7/dist-packages (from python-dateutil>=2.1->matplotlib->highway-env)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (from pandas->highway-env) (2022.6)
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting git+https://github.com/DLR-RM/stable-baselines3
  Cloning https://github.com/DLR-RM/stable-baselines3 to /tmp/pip-req-build-s2pecl3v
  Running command git clone -q https://github.com/DLR-RM/stable-baselines3 /tmp/pip-req-build-s2pecl3v
Requirement already satisfied: gym==0.21 in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4) (0.21.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4) (1.21.6)
Requirement already satisfied: torch>=1.11 in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4) (1.12.1+cu113)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4) (1.5.0)
Requirement already satisfied: pandas in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4) (1.3.5)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4) (3.2.2)
Collecting importlib-metadata~4.13
  Downloading importlib_metadata-4.13.0-py3-none-any.whl (23 kB)
Requirement already satisfied: typing_extensions<5,=>4.0 in /usr/local/lib/python3.7/dist-packages (from stable-baselines3==1.7.0a4)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata~4.13->stable-baselines3==1.7.0a4)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3==1.7.0a4)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3==1.7.0a4)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3==1.7.0a4)
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->stable-baselines3==1.7.0a4)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.7/dist-packages (from python-dateutil>=2.1->matplotlib->stable-baselines3==1.7.0a4)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (from pandas->stable-baselines3==1.7.0a4) (2022.6)
Building wheels for collected packages: stable-baselines3
  Building wheel for stable-baselines3 (setup.py) ... done
  Created wheel for stable-baselines3: filename=stable_baselines3-1.7.0a4-py3-none-any.whl size=168926 sha256=0f1977845dabf7bb441bcbf
  Stored in directory: /tmp/pip-ephem-wheel-cache-j972ng2r/wheels/2b/88/65/5d0cb266b061107af8c518096240bea8578e9843716f79e4da
Successfully built stable-baselines3
Installing collected packages: importlib-metadata, stable-baselines3
  Attempting uninstall: importlib-metadata
    Found existing installation: importlib-metadata 4.8.1
    Uninstalling importlib-metadata-4.8.1:
```

```
Successfully uninstalled importlib-metadata-4.8.1
Attempting uninstall: stable-baselines3
Found existing installation: stable-baselines3 1.6.2
Uninstalling stable-baselines3-1.6.2:
Successfully uninstalled stable-baselines3-1.6.2
Successfully installed importlib-metadata-4.13.0 stable-baselines3-1.7.0a4
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting tensorboardx
  Downloading tensorboardx-2.5.1-py2.py3-none-any.whl (125 kB)
```

Training and Testing the environment

```
if __name__ == "__main__":
    train = True
    if train:
        n_cpu = 6
        batch_size = 64
        env = make_vec_env("highway-fast-v0")
        model = PPO("MlpPolicy",
                    env,
                    policy_kwargs=dict(net_arch=[dict(pi=[256, 256], vf=[256, 256])]),
                    n_steps=batch_size * 12 // n_cpu,
                    batch_size=batch_size,
                    n_epochs=10,
                    learning_rate=5e-4,
                    gamma=0.8,
                    verbose=2,
                    tensorboard_log="highway_ppo/")
        # Train the agent
        model.learn(total_timesteps=int(2e4))
        # Save the agent
        model.save("highway_ppo/model")

    model = PPO.load("highway_ppo/model")
    env = gym.make("highway-fast-v0")
```

Using cuda device  
Logging to highway\_ppo/PPO\_1

-----		
rollout/		
ep_len_mean	9.15	
ep_rew_mean	6.79	
time/		
fps	7	
iterations	1	
time_elapsed	16	
total_timesteps	128	
-----		

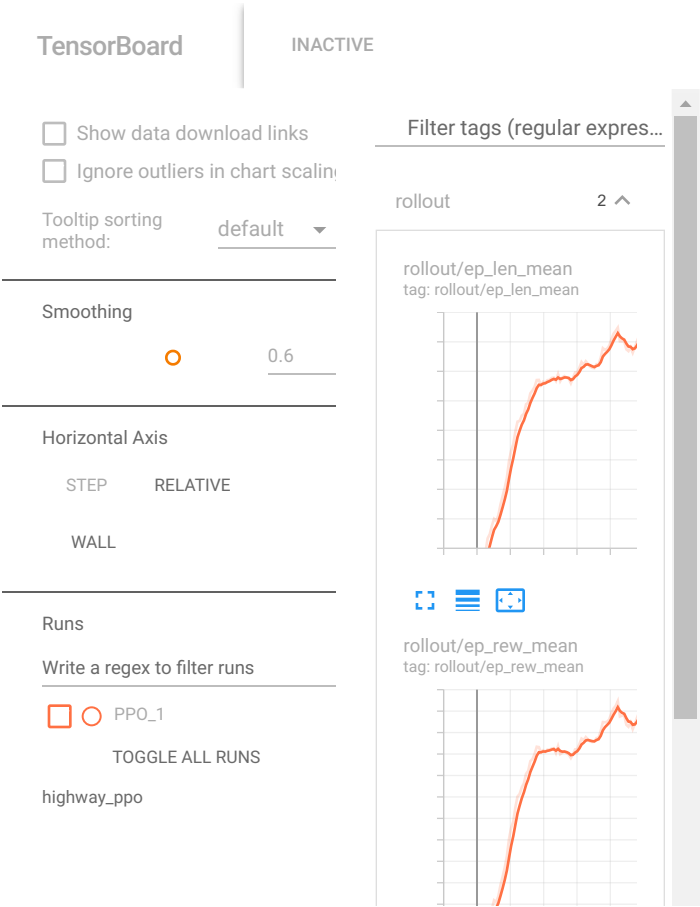
-----		
rollout/		
ep_len_mean	10.2	
ep_rew_mean	7.68	
time/		
fps	10	
iterations	2	
time_elapsed	24	
total_timesteps	256	
train/		
approx_kl	0.0116943605	
clip_fraction	0.121	
clip_range	0.2	
entropy_loss	-1.6	
explained_variance	-0.00301	
learning_rate	0.0005	
loss	0.576	
n_updates	10	
policy_gradient_loss	-0.0125	
value_loss	1.57	
-----		

-----		
rollout/		
ep_len_mean	10	
ep_rew_mean	7.42	
time/		
fps	11	
iterations	3	
time_elapsed	32	
total_timesteps	384	
train/		
-----		

approx_kl	0.010006225
clip_fraction	0.0422
clip_range	0.2
entropy_loss	-1.6
explained_variance	0.0123
learning_rate	0.0005
loss	0.495
n_updates	20
policy_gradient_loss	-0.0115
value_loss	1.15
-----	
rollout/	
ep_len_mean	11.8
ep_rew_mean	8.66

Tensorboard visualizations for training and tests conducted:

```
%tensorboard --logdir "highway_ppo"
```



Simulation visualization

```
env = gym.make("highway-v0")
env = record_videos(env)
for episode in trange(3, desc="Test episodes"):
    obs, done = env.reset(), False
    while not done:
        # Predict
        action, _ = model.predict(obs, deterministic=True)
        # Get reward
```

```
    obs, reward, done, info = env.step(int(action))
    # Render
    env.render()
env.close()
show_videos()
```

Test episodes:

3/3 [01:15<00:00,

100%

26.60s/it]

0:00 / 0:20



0:00 / 0:15



