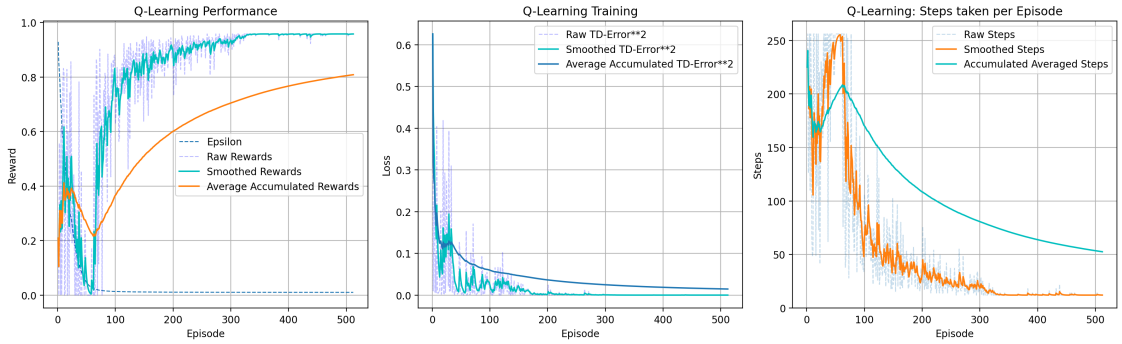
Results

July 31, 2024

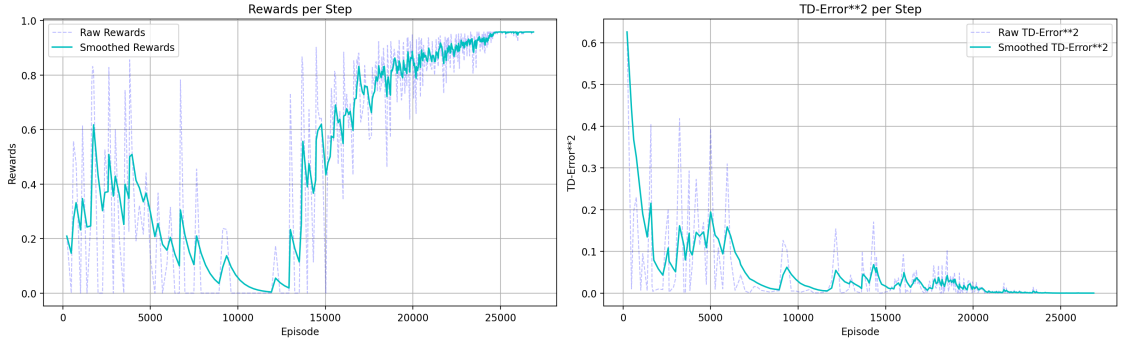
[1]:
```
import json
import pickle

import matplotlib.animation as animation
import matplotlib.pyplot as plt
from IPython.display import HTML

from Utility.Plots import plot_live_data, plot_train_data, plot_steps_taken
from Utility.TabularEpsilonStrategy import EpsilonGreedy

%matplotlib inline
%config InlineBackend.figure_format = 'retina'
```

0.1 Q-Learning

[2]:
```
with open('Q_Learning/QLearning_live_plot.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))
plt.subplot(131)
plot_live_data(data['episode'], data['rewards'], epsilon=data['epsilons'],
               title={'title': "Q-Learning Performance", 'raw': 'Raw Rewards',␣
 ↪'smooth': 'Smoothed Rewards',
                      'acc'  : 'Average Accumulated Rewards', 'xlab':␣
 ↪'Episode', 'ylab': 'Reward'})
plt.subplot(132)
plot_train_data(data['episode'], data['losses'],
                {'title': "Q-Learning Training", 'raw': 'Raw TD-Error**2',␣
 ↪'smooth': 'Smoothed TD-Error**2',
                 'acc'  : 'Average Accumulated TD-Error**2', 'xlab': 'Episode',␣
 ↪'ylab': 'Loss'})
plt.subplot(133)
plot_steps_taken(data['episode'], data['steps_taken'], "Q-Learning")
plt.tight_layout()
plt.savefig('report/figures/QLearning_episode.pdf')
plt.savefig('report/figures/QLearning_episode.png')
plt.show()
```



[3]:
```
with open('Q_Learning/QLearning_train.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))

plt.subplot(121)
plot_live_data(data['steps_done'], data['rewards'], avg=False,
               title={'title': "Rewards per Step", 'raw': 'Raw Rewards',␣
 ↪'smooth': 'Smoothed Rewards',
                      'acc'  : 'Cumulative Average Rewards', 'xlab': 'Episode',␣
 ↪'ylab': 'Rewards'})

plt.subplot(122)
plot_train_data(data['steps_done'], data['td_error_sq'], avg=False,
                title={'title' : "TD-Error**2 per Step", 'raw': 'Raw␣
 ↪TD-Error**2',
                       'smooth': 'Smoothed TD-Error**2', 'acc': 'Cumulative␣
 ↪Average TD-Error**2',
                       'xlab'  : 'Episode', 'ylab': 'TD-Error**2'})
plt.tight_layout()
plt.savefig('report/figures/QLearning_steps.pdf')
plt.savefig('report/figures/QLearning_steps.png')

plt.show()
```



[4]:
```
rewards = data['rewards']
steps_taken = data['steps_taken']
finish_counter = data['finish_counter']
episodes = len(rewards)
print('====== TRAIN SUMMARY ======')
print(f'Episodes       : {episodes}')
print(f"Completion rate: {finish_counter / episodes}")
print(f"Average Reward : {sum(rewards) / episodes:.3f}")
print(f"Average steps  : {sum(steps_taken) / episodes:.3f}")
```

```
====== TRAIN SUMMARY ======
Episodes       : 512
Completion rate: 0.9296875
Average Reward : 0.808
Average steps  : 52.510
```

[5]:
```
from Q_Learning.QLearning import eval as qlearning_eval
from Utility.MiniGrid import MiniGridHash

env = MiniGridHash(render_mode='rgb_array')
with open('Q_Learning/q_learning_table.pkl', 'rb') as f:
    qlearning_table = pickle.load(f)
qlearning_eval(env, qlearning_table, EpsilonGreedy(0, 3), 1000)
```

```
pygame 2.6.0 (SDL 2.28.4, Python 3.10.14)
Hello from the pygame community. https://www.pygame.org/contribute.html
Evaluation…
====== EVALUATION SUMMARY ======
Evaluation episodes: 1000
Completion rate    : 1.0
Average Reward     : 0.958
Average steps      : 12.000
```

[6]:
```
imgs = []
fig = plt.figure(figsize=(5, 5))
strategy = EpsilonGreedy(0, 3)
current_state = env.reset()
plt.axis('off')
im = plt.imshow(env.render(), animated=True)
imgs.append([im])
for step in range(env.maxSteps):
    action = strategy.select_action(current_state, qlearning_table)
    next_state, reward, done, truncated = env.step(action)
    im = plt.imshow(env.render(), animated=True)
```

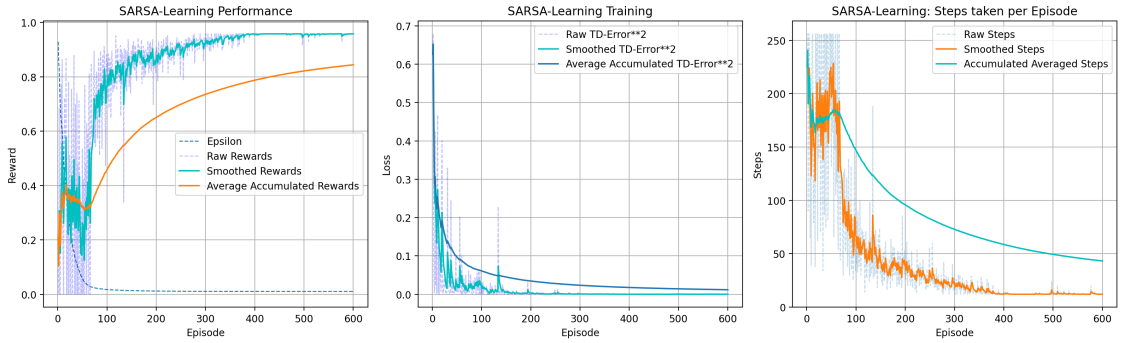
```
    imgs.append([im])
    if done or truncated:
        break
    current_state = next_state
ani = animation.ArtistAnimation(fig, imgs, interval=100, repeat_delay=1000)
ani.save('Q_Learning/q_learning.gif', writer='imagemagickasd')
plt.close()
HTML(ani.to_jshtml())
```

```
MovieWriter imagemagickasd unavailable; using Pillow instead.
```

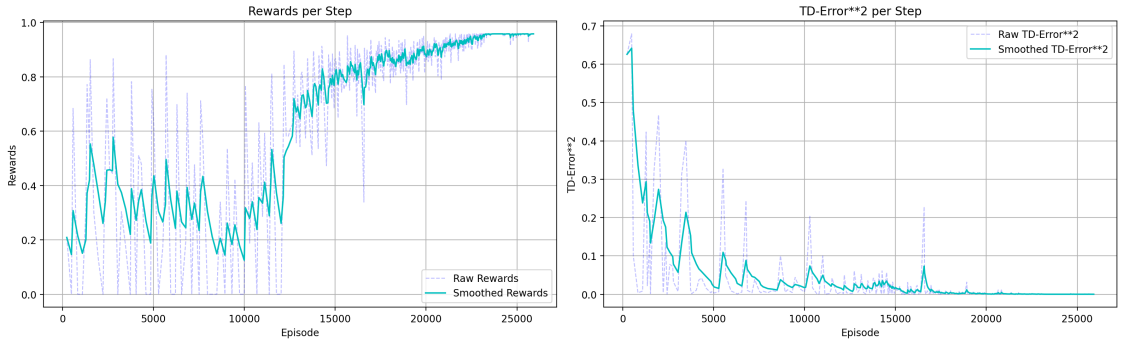
[6]: <IPython.core.display.HTML object>

0.2 SARSA

[7]:
```
with open('SARSA/SARSA_live_plot.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))
plt.subplot(131)
plot_live_data(data['episode'], data['rewards'], epsilon=data['epsilons'],
               title={'title': "SARSA-Learning Performance", 'raw': 'Raw␣
 ↪Rewards', 'smooth': 'Smoothed Rewards',
                      'acc'  : 'Average Accumulated Rewards', 'xlab':␣
 ↪'Episode', 'ylab': 'Reward'})
plt.subplot(132)
plot_train_data(data['episode'], data['losses'],
                {'title': "SARSA-Learning Training", 'raw': 'Raw TD-Error**2',␣
 ↪'smooth': 'Smoothed TD-Error**2',
                 'acc'  : 'Average Accumulated TD-Error**2', 'xlab': 'Episode',␣
 ↪'ylab': 'Loss'})
plt.subplot(133)
plot_steps_taken(data['episode'], data['steps_taken'], "SARSA-Learning")
plt.tight_layout()
plt.savefig('report/figures/SARSALearning_episode.pdf')
plt.savefig('report/figures/SARSALearning_episode.png')
plt.show()
```



[8]:
```
with open('SARSA/SARSA_train.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))

plt.subplot(121)
plot_live_data(data['steps_done'], data['rewards'], avg=False,
               title={'title': "Rewards per Step", 'raw': 'Raw Rewards',␣
 ↪'smooth': 'Smoothed Rewards',
                      'acc'  : 'Cumulative Average Rewards', 'xlab': 'Episode',␣
 ↪'ylab': 'Rewards'})

plt.subplot(122)
plot_train_data(data['steps_done'], data['td_error_sq'], avg=False,
                title={'title' : "TD-Error**2 per Step", 'raw': 'Raw␣
 ↪TD-Error**2',
                       'smooth': 'Smoothed TD-Error**2', 'acc': 'Cumulative␣
 ↪Average TD-Error**2',
                       'xlab'  : 'Episode', 'ylab': 'TD-Error**2'})
plt.tight_layout()
plt.savefig('report/figures/SARSALearning_steps.pdf')
plt.savefig('report/figures/SARSALearning_steps.png')
plt.show()
```



[9]:
```
rewards = data['rewards']
steps_taken = data['steps_taken']
finish_counter = data['finish_counter']
episodes = len(rewards)
print('====== TRAIN SUMMARY ======')
print(f'Episodes       : {episodes}')
print(f"Completion rate: {finish_counter / episodes}")
```

```
print(f"Average Reward : {sum(rewards) / episodes:.3f}")
print(f"Average steps  : {sum(steps_taken) / episodes:.3f}")
```

```
====== TRAIN SUMMARY ======
Episodes       : 600
Completion rate: 0.9566666666666667
Average Reward : 0.844
Average steps  : 43.185
```

0.2.1 Evaluation

[10]:
```
from SARSA.SARSA import eval as sarsa_eval
from Utility.MiniGrid import MiniGridHash

env = MiniGridHash(render_mode='rgb_array')
with open('SARSA/sarsa_learning_table.pkl', 'rb') as f:
    sarsa_table = pickle.load(f)
sarsa_eval(env, qlearning_table, EpsilonGreedy(0, 3), 1000)
```

```
Evaluation…
====== EVALUATION SUMMARY ======
Evaluation episodes: 1000
Completion rate    : 1.0
Average Reward     : 0.958
Average steps      : 12.000
```

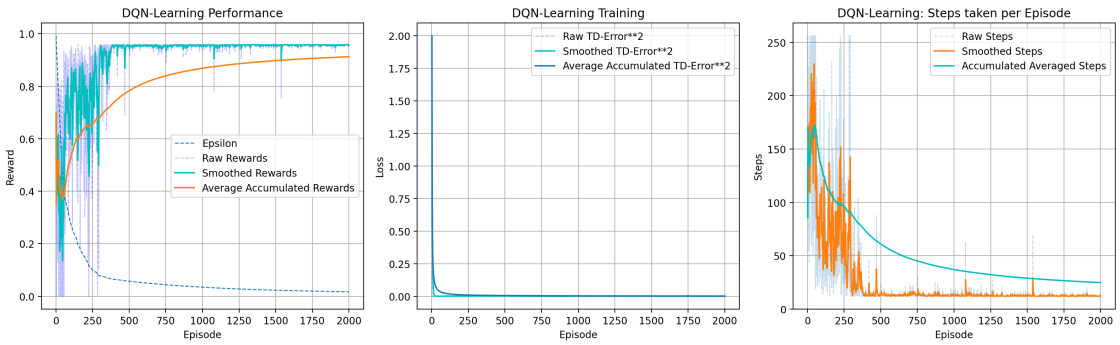
[11]:
```
imgs = []
fig = plt.figure(figsize=(5, 5))
strategy = EpsilonGreedy(0, 3)
current_state = env.reset()
plt.axis('off')
im = plt.imshow(env.render(), animated=True)
imgs.append([im])
for step in range(env.maxSteps):
    action = strategy.select_action(current_state, sarsa_table)
    next_state, reward, done, truncated = env.step(action)
    im = plt.imshow(env.render(), animated=True)
    imgs.append([im])
    if done or truncated:
        break
    current_state = next_state
ani = animation.ArtistAnimation(fig, imgs, interval=100, repeat_delay=1000)
ani.save('SARSA/sarsa.gif', writer='imagemagick')
plt.close()
HTML(ani.to_jshtml())
```

```
MovieWriter imagemagick unavailable; using Pillow instead.
```

[11]: <IPython.core.display.HTML object>

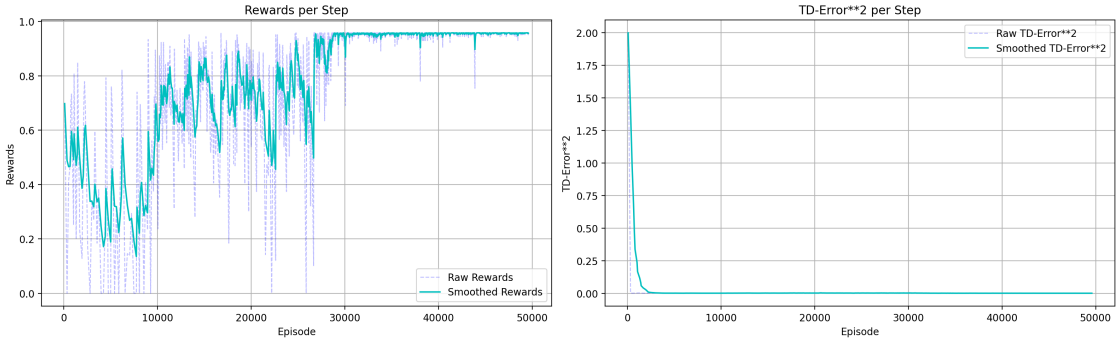
0.3 DQN

[12]:
```
with open('DQN/DQN_live_plot.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))
plt.subplot(131)
plot_live_data(data['episode'], data['rewards'], epsilon=data['epsilons'],
               title={'title': "DQN-Learning Performance", 'raw': 'Raw␣
 ↪Rewards', 'smooth': 'Smoothed Rewards',
                      'acc'  : 'Average Accumulated Rewards', 'xlab':␣
 ↪'Episode', 'ylab': 'Reward'})
plt.subplot(132)
plot_train_data(data['episode'], data['losses'],
                {'title': "DQN-Learning Training", 'raw': 'Raw TD-Error**2',␣
 ↪'smooth': 'Smoothed TD-Error**2',
                 'acc'  : 'Average Accumulated TD-Error**2', 'xlab': 'Episode',␣
 ↪'ylab': 'Loss'})
plt.subplot(133)
plot_steps_taken(data['episode'], data['steps_taken'], "DQN-Learning")
plt.tight_layout()
plt.savefig('report/figures/DQNLearning_episode.pdf')
plt.savefig('report/figures/DQNLearning_episode.png')
plt.show()
```



[13]:
```
with open('DQN/DQN_train.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))

plt.subplot(121)
plot_live_data(data['steps_done'], data['rewards'], avg=False,
```

```
                title={'title': "Rewards per Step", 'raw': 'Raw Rewards',␣
 ↪'smooth': 'Smoothed Rewards',
                       'acc'  : 'Cumulative Average Rewards', 'xlab': 'Episode',␣
 ↪'ylab': 'Rewards'})

plt.subplot(122)
plot_train_data(data['steps_done'], data['td_error_sq'], avg=False,
                title={'title' : "TD-Error**2 per Step", 'raw': 'Raw␣
 ↪TD-Error**2',
                       'smooth': 'Smoothed TD-Error**2', 'acc': 'Cumulative␣
 ↪Average TD-Error**2',
                       'xlab'  : 'Episode', 'ylab': 'TD-Error**2'})
plt.tight_layout()
plt.savefig('report/figures/DQNLearning_steps.pdf')
plt.savefig('report/figures/DQNLearning_steps.png')
plt.show()
```



[14]:
```
rewards = data['rewards']
steps_taken = data['steps_taken']
finish_counter = data['finish_counter']
episodes = len(rewards)
print('====== TRAIN SUMMARY ======')
print(f'Episodes       : {episodes}')
print(f"Completion rate: {finish_counter / episodes}")
print(f"Average Reward : {sum(rewards) / episodes:.3f}")
print(f"Average steps  : {sum(steps_taken) / episodes:.3f}")
```

```
====== TRAIN SUMMARY ======
Episodes       : 2000
Completion rate: 0.992
Average Reward : 0.912
Average steps  : 24.794
```

0.4 Evaluation

[15]:
```
from DQN.DQN import eval as dqn_eval
from DQN.DQN import DQN
from Utility.DQNEpsilonStrategy import EpsilonGreedy as DQNEpsilonGreedy
from Utility.MiniGrid import MiniGridRaw
import torch
from torchinfo import summary

env_dqn = MiniGridRaw(render_mode='rgb_array')
policy_net = DQN(env_dqn.numStates, env_dqn.numActions, (64, 32))
```

[16]:
```
a = env_dqn.reset()
print(summary(policy_net, input_data=a, col_names=['input_size', 'output_size',␣
 ↪'num_params', 'trainable']))
```

```
==========================================================================================
==============================================================
Layer (type:depth-idx)                   Input Shape               Output Shape
Param #                     Trainable
==========================================================================================
==============================================================
DQN                                      [1, 49]                   [1, 3]
--                          True
 Sequential: 1-1                         [1, 49]                   [1, 3]
--                          True
      Linear: 2-1                        [1, 49]                   [1, 64]
3,200                       True
      ReLU: 2-2                          [1, 64]                   [1, 64]
--                          --
      Linear: 2-3                        [1, 64]                   [1, 32]
2,080                       True
      ReLU: 2-4                          [1, 32]                   [1, 32]
--                          --
      Linear: 2-5                        [1, 32]                   [1, 3]
99                          True
==========================================================================================
==============================================================
Total params: 5,379
Trainable params: 5,379
Non-trainable params: 0
Total mult-adds (M): 0.01
==========================================================================================
==============================================================
Input size (MB): 0.00
Forward/backward pass size (MB): 0.00
Params size (MB): 0.02
Estimated Total Size (MB): 0.02
```

```
================================================================================
================================================================
```

[17]:
```
policy_net.load_state_dict(torch.load('DQN/dqn.pth'))
dqn_eval(env_dqn, policy_net, DQNEpsilonGreedy(0, 3), 1000)
```

```
Evaluation…
====== EVALUATION SUMMARY ======
Evaluation episodes: 1000
Completion rate    : 1.0
Average Reward     : 0.958
Average steps      : 12.000
```

[18]:
```
imgs = []
fig = plt.figure(figsize=(5, 5))
strategy_dqn = DQNEpsilonGreedy(0, 3)
current_state = env_dqn.reset()
plt.axis('off')
imgs.append([plt.imshow(env_dqn.render(), animated=True)])
for step in range(env.maxSteps):
    action = strategy_dqn.select_action(current_state, policy_net)
    next_state, reward, done, truncated = env_dqn.step(action)
    imgs.append([plt.imshow(env_dqn.render(), animated=True)])
    if done or truncated:
        break
    current_state = next_state
ani = animation.ArtistAnimation(fig, imgs, interval=100, repeat_delay=1000)
ani.save('DQN/dqn.gif', writer='imagemagick')
plt.close()
HTML(ani.to_jshtml())
```

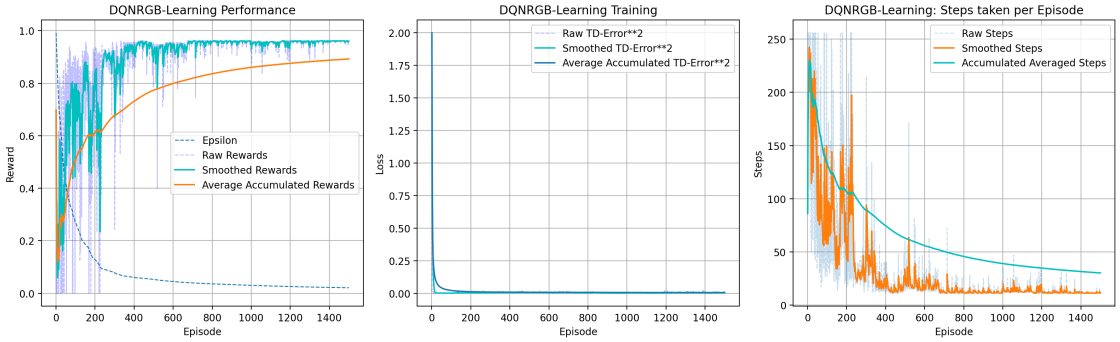
```
MovieWriter imagemagick unavailable; using Pillow instead.
```

[18]:
```
<IPython.core.display.HTML object>
```

0.5 DQN RGB Technique

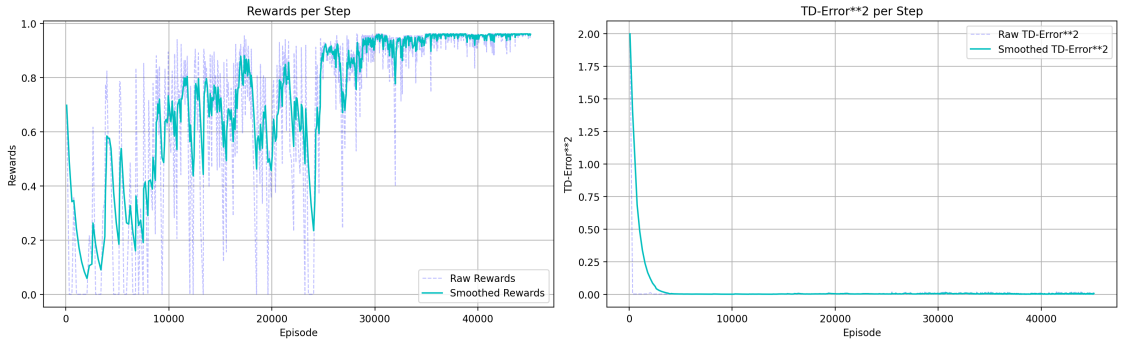
[19]:
```
with open('DQN/DQNIMAGE_live_plot.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))
plt.subplot(131)
plot_live_data(data['episode'], data['rewards'], epsilon=data['epsilons'],
               title={'title': "DQNRGB-Learning Performance", 'raw': 'Raw␣
 ↪Rewards', 'smooth': 'Smoothed Rewards',
                      'acc'  : 'Average Accumulated Rewards', 'xlab':␣
 ↪'Episode', 'ylab': 'Reward'})
plt.subplot(132)
```

```
plot_train_data(data['episode'], data['losses'],
                {'title': "DQNRGB-Learning Training", 'raw': 'Raw TD-Error**2',␣
 ↪'smooth': 'Smoothed TD-Error**2',
                 'acc'  : 'Average Accumulated TD-Error**2', 'xlab': 'Episode',␣
 ↪'ylab': 'Loss'})
plt.subplot(133)
plot_steps_taken(data['episode'], data['steps_taken'], "DQNRGB-Learning")
plt.tight_layout()
plt.savefig('report/figures/DQNRGBLearning_episode.pdf')
plt.savefig('report/figures/DQNRGBLearning_episode.png')
plt.show()
```



[20]:
```
with open('DQN/DQNIMAGE_train.json', 'r') as f:
    data = json.load(f)

plt.figure(figsize=(16, 5))

plt.subplot(121)
plot_live_data(data['steps_done'], data['rewards'], avg=False,
               title={'title': "Rewards per Step", 'raw': 'Raw Rewards',␣
 ↪'smooth': 'Smoothed Rewards',
                      'acc'  : 'Cumulative Average Rewards', 'xlab': 'Episode',␣
 ↪'ylab': 'Rewards'})

plt.subplot(122)
plot_train_data(data['steps_done'], data['td_error_sq'], avg=False,
                title={'title' : "TD-Error**2 per Step", 'raw': 'Raw␣
 ↪TD-Error**2',
                       'smooth': 'Smoothed TD-Error**2', 'acc': 'Cumulative␣
 ↪Average TD-Error**2',
                       'xlab'  : 'Episode', 'ylab': 'TD-Error**2'})
plt.tight_layout()
plt.savefig('report/figures/DQNRGBLearning_steps.pdf')
plt.savefig('report/figures/DQNRGBLearning_steps.png')
```

```
plt.show()
```



[21]:
```
rewards = data['rewards']
steps_taken = data['steps_taken']
finish_counter = data['finish_counter']
episodes = len(rewards)
print('====== TRAIN SUMMARY ======')
print(f'Episodes       : {episodes}')
print(f"Completion rate: {finish_counter / episodes}")
print(f"Average Reward : {sum(rewards) / episodes:.3f}")
print(f"Average steps  : {sum(steps_taken) / episodes:.3f}")
```

```
====== TRAIN SUMMARY ======
Episodes       : 1500
Completion rate: 0.98
Average Reward : 0.892
Average steps  : 30.068
```

0.6 Evaluation

[22]:
```
from DQN.DQNIMAGE import eval as dqn_image_eval
from DQN.DQNIMAGE import CNN_DQN, FrameStack
from Utility.DQNEpsilonStrategy import EpsilonGreedy as DQNEpsilonGreedy
from Utility.MiniGrid import MiniGridImage, get_device
import torch

device = get_device()

env_dqn_img = MiniGridImage(render_mode='rgb_array')
policy_net_img = CNN_DQN(56, 56, 3).to(device)
```

[23]:
```
summary(policy_net_img, input_size=(1,4,56,56), device=device,␣
↪col_names=['input_size', 'kernel_size','output_size', 'num_params',␣
↪'trainable'])
```

[23]:
```
==========================================================================
==========================================================================
=====
Layer (type:depth-idx)                   Input Shape               Kernel Shape
Output Shape              Param #                   Trainable
==========================================================================
==========================================================================
=====
CNN_DQN                                  [1, 4, 56, 56]            --
[1, 3]                    --                        True
 Sequential: 1-1                        [1, 4, 56, 56]            --
[1, 512]                  --                        True
      Conv2d: 2-1                       [1, 4, 56, 56]            [3, 3]
[1, 16, 27, 27]           576                       True
      BatchNorm2d: 2-2                  [1, 16, 27, 27]           --
[1, 16, 27, 27]           32                        True
      ReLU: 2-3                         [1, 16, 27, 27]           --
[1, 16, 27, 27]           --                        --
      Conv2d: 2-4                       [1, 16, 27, 27]           [3, 3]
[1, 32, 13, 13]           4,608                     True
      BatchNorm2d: 2-5                  [1, 32, 13, 13]           --
[1, 32, 13, 13]           64                        True
      ReLU: 2-6                         [1, 32, 13, 13]           --
[1, 32, 13, 13]           --                        --
      Conv2d: 2-7                       [1, 32, 13, 13]           [3, 3]
[1, 64, 6, 6]             18,432                    True
      BatchNorm2d: 2-8                  [1, 64, 6, 6]             --
[1, 64, 6, 6]             128                       True
      ReLU: 2-9                         [1, 64, 6, 6]             --
[1, 64, 6, 6]             --                        --
      Conv2d: 2-10                      [1, 64, 6, 6]             [3, 3]
[1, 128, 2, 2]            73,728                    True
      BatchNorm2d: 2-11                 [1, 128, 2, 2]            --
[1, 128, 2, 2]            256                       True
      Flatten: 2-12                     [1, 128, 2, 2]            --
[1, 512]                  --                        --
 Sequential: 1-2                        [1, 512]                  --
[1, 3]                    --                        True
      Linear: 2-13                      [1, 512]                  --
[1, 64]                   32,832                    True
      ReLU: 2-14                        [1, 64]                   --
[1, 64]                   --                        --
      Linear: 2-15                      [1, 64]                   --
[1, 3]                    195                       True
==========================================================================
==========================================================================
=====
```

```
Total params: 130,851
Trainable params: 130,851
Non-trainable params: 0
Total mult-adds (M): 2.19
==========================================================================================
==========================================================================================
=====
Input size (MB): 0.05
Forward/backward pass size (MB): 0.32
Params size (MB): 0.52
Estimated Total Size (MB): 0.89
==========================================================================================
==========================================================================================
=====
```

[24]:
```
policy_net_img.load_state_dict(torch.load('DQN/dqn_image.pth',␣
 ↪map_location=device))
dqn_image_eval(env_dqn_img, policy_net_img, DQNEpsilonGreedy(0, 3), 1000)
```

```
Evaluation…

/Users/lucien/.pyenv/versions/3.10.14/envs/torch/lib/python3.10/site-
packages/gymnasium/core.py:311: UserWarning: WARN: env.get_frame to get
variables from other wrappers is deprecated and will be removed in v1.0, to get
this variable you can do `env.unwrapped.get_frame` for environment variables or
`env.get_wrapper_attr('get_frame')` that will search the reminding wrappers.
  logger.warn(

====== EVALUATION SUMMARY ======
Evaluation episodes: 1000
Completion rate    : 1.0
Average Reward     : 0.961
Average steps      : 11.000
```

[25]:
```
imgs = []
fig = plt.figure(figsize=(5, 5))
frame_stack = FrameStack(56, 56, 4)
strategy_dqn_img = DQNEpsilonGreedy(0, 3)
current_state = env_dqn_img.reset()
current_stack = frame_stack.push(current_state, True)
plt.axis('off')
imgs.append([plt.imshow(env_dqn_img.render(), animated=True)])
for step in range(env_dqn_img.maxSteps):
    action = strategy_dqn_img.select_action(current_stack, policy_net_img)
    next_state, reward, done, truncated = env_dqn_img.step(action.item())
    next_stack = frame_stack.push(next_state, False)
    imgs.append([plt.imshow(env_dqn_img.render(), animated=True)])
```

```
    if done or truncated:
        break
    current_stack = next_stack
ani = animation.ArtistAnimation(fig, imgs, interval=100, repeat_delay=1000)
ani.save('DQN/dqn_img.gif', writer='imagemagick')
plt.close()
HTML(ani.to_jshtml())
```

```
MovieWriter imagemagick unavailable; using Pillow instead.
```

[25]: <IPython.core.display.HTML object>