Results

March 18, 2020

1 Visualize results of experiments

```
In [12]: import numpy as np
         import matplotlib.pyplot as plt
         from sklearn.manifold import MDS,TSNE
         from sklearn.decomposition import PCA
         import matplotlib.pyplot as plt
         from matplotlib.colors import ListedColormap
```

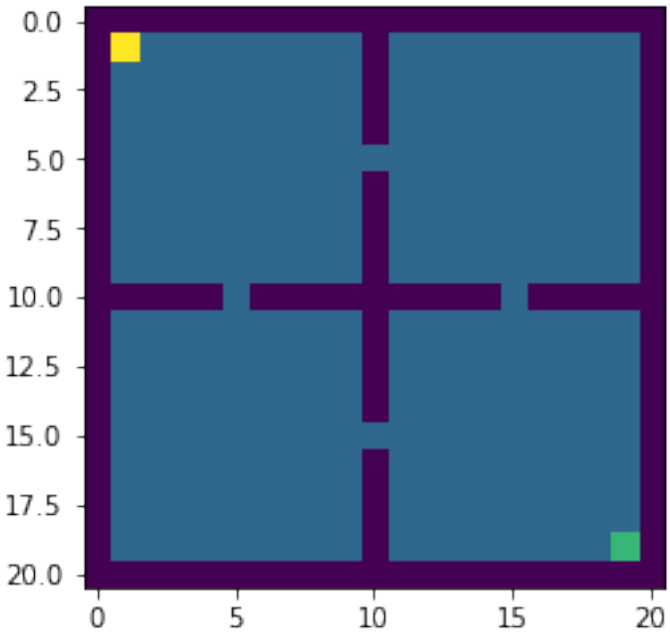
```
In [13]: import torch
         from models.VAE import VAE
         from environments.FourRooms import FourRooms
```

Creating an environment with 9 cells in each room. Each cell is representing a random number from mnist dataset

```
In [14]: room_size = 9
         env = FourRooms(room_size,'mnist')
```

1.1 State Representation

```
In [15]: env.render()
         plt.show()
```



1.2 Loading saved data and visualize results

The running time for our project is ~1 day. Therefore for the sake of visualization we have uploaded the saved weights and data

VAE * Input: mnist image with size 28 X 28 * Output: embedding representation with size 32 X 1 * Upload the trained VAE

```
In [16]: in_channels = 1
         embedding_size = 32
         in_height = 28
         in_width = 28
         vae = VAE(in_channels,embedding_size,in_height,in_width)
         vae.load_state_dict(torch.load('../weights/VAE/VAE_rooms_mnist.pt'))
```

```
Out[16]: <All keys matched successfully>
```

Calulate the state embedding representation using the trained VAE encoder

```
In [17]: n_states = env.n_states
         VAE_reps = np.zeros([n_states,embedding_size])
         VAE_labels = []
         for i,(state,obs) in enumerate(env.state_dict.items()):
             obs = torch.tensor(obs).permute(2,0,1) #(H,W,C)->(C,H,W)
             obs = obs.unsqueeze(0)
             with torch.no_grad():
                 mu, logvar = vae.encoder(obs)
```

```
            state_embedding = torch.cat([mu, logvar],1)
            state_embedding = state_embedding.squeeze()
            state_embedding = state_embedding.cpu().numpy()
        VAE_reps[i,:] = state_embedding
        # different label for each room
        if state[0] < room_size + 1 and state[1] < room_size + 1:
            label = 0
        elif state[0] > room_size + 1 and state[1] < room_size + 1:
            label = 1
        elif state[0] < room_size + 1 and state[1] > room_size + 1:
            label = 2
        elif state[0] > room_size + 1 and state[1] > room_size + 1:
            label = 3
        else:
            label = 4
        VAE_labels.append(label)
```

1.2.1 Visualize VAE Representation

```
In [18]: colors = ['green','blue','red','purple','orange']
```

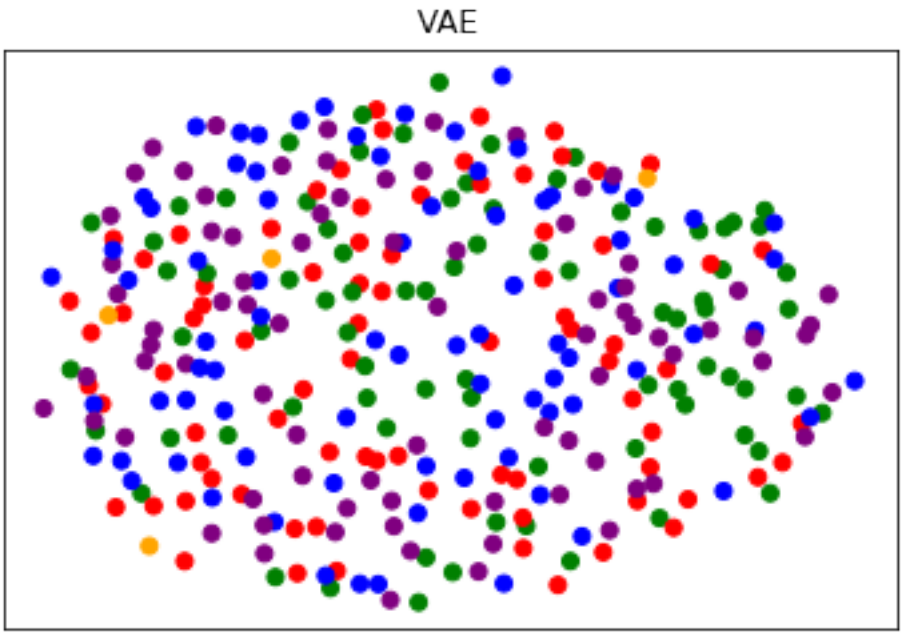
Loading the saved representation results when we used random projection and SR representation in addition to their corresponding labels

```
In [19]: emb_reps = np.load('../results/MFEC_SR/random_TD_mnist_200epochs_3knn_emb_reps.npy')
         SR_reps = np.load('../results/MFEC_SR/random_TD_mnist_200epochs_3knn_SR_reps.npy')
         labels = np.load('../results/MFEC_SR/random_TD_mnist_200epochs_3knn_labels.npy')
```

We have represented multidimensional scaling of VAE, random and SR representation

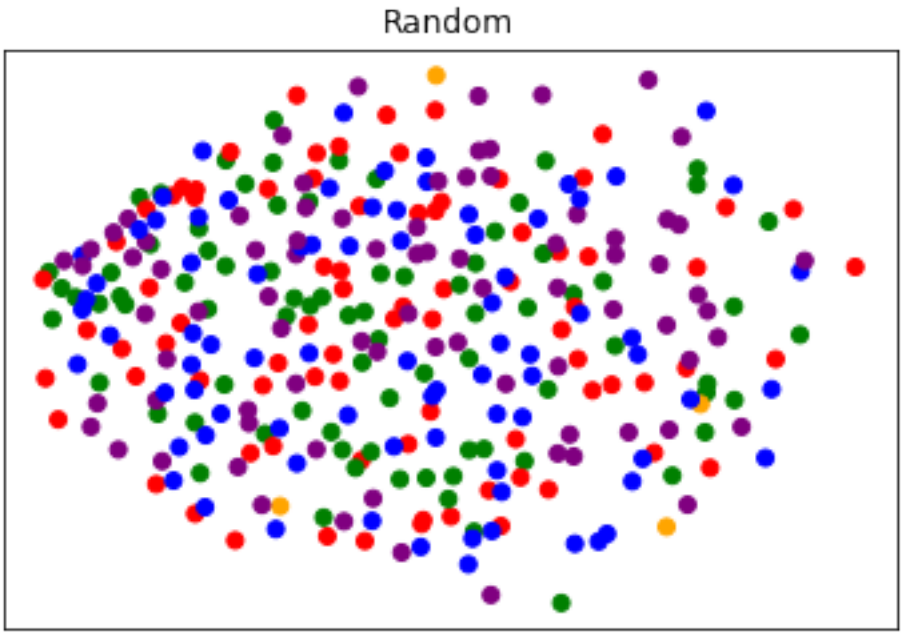
```
In [20]: mds_vae = MDS(n_components=2)
         mds_vae_2d = mds_vae.fit_transform(VAE_reps)
```

```
In [22]: plt.scatter(mds_vae_2d[:,0],mds_vae_2d[:,1],c=labels,cmap=ListedColormap(colors))
         plt.title("VAE")
         plt.tick_params(
             axis='both',
             which='both',
             bottom=False,
             top=False,
             left=False,
             labelbottom=False,
             labelleft=False)
         plt.ticklabel_format(style='plain',useOffset=False)
         plt.savefig("figures/mds_VAE.png",bbox_inches = 'tight',pad_inches = 0.1,dpi=100)
         plt.show()
```



1.3 Visualize Random Representations

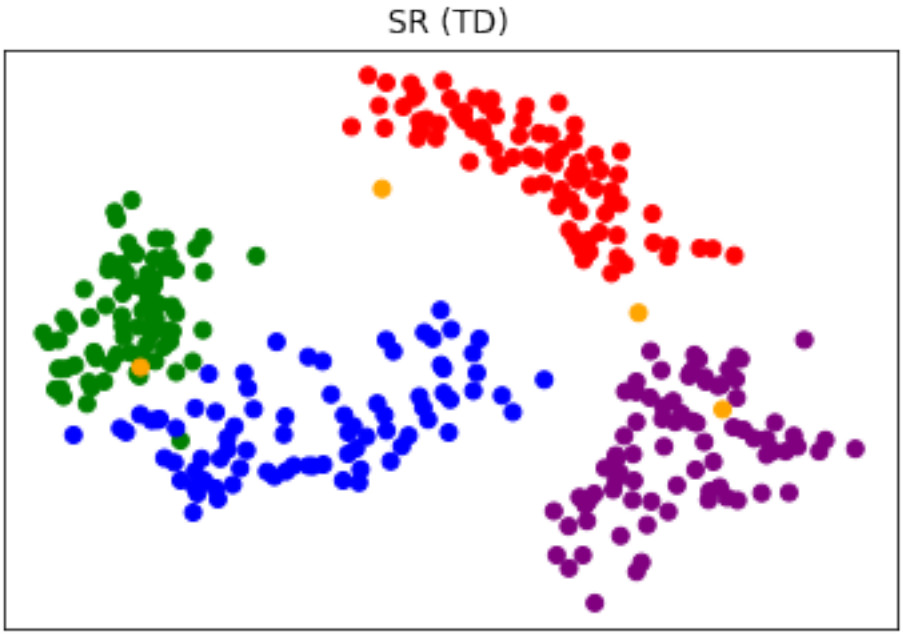
```
In [51]: mds_emb = MDS(n_components=2)
         mds_emb_2d = mds_emb.fit_transform(emb_reps)

In [56]: plt.scatter(mds_emb_2d[:,0],mds_emb_2d[:,1],c=labels,cmap=ListedColormap(colors))
         plt.title("Random")
         plt.tick_params(
             axis='both',
             which='both',
             bottom=False,
             top=False,
             left=False,
             labelbottom=False,
             labelleft=False)
         plt.ticklabel_format(style='plain',useOffset=False)
         plt.savefig("figures/mds_rand.png",bbox_inches = 'tight',pad_inches = 0.1,dpi=100)
         plt.show()
```



1.4 Visualize SR Representation

```
In [ ]: mds_sr = MDS(n_components=2)
        mds_sr_2d = mds_sr.fit_transform(SR_reps)
```

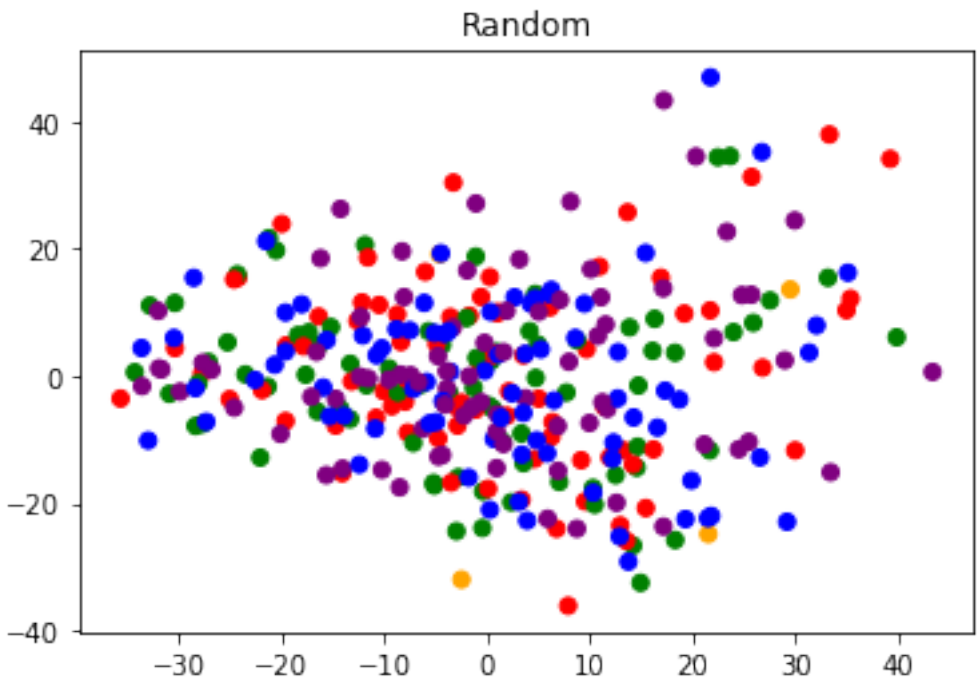
```
In [59]: plt.scatter(mds_sr_2d[:,0],mds_sr_2d[:,1],c=labels,cmap=ListedColormap(colors))
         plt.title("Estimated SR (TD)")
         plt.tick_params(
             axis='both',
             which='both',
             bottom=False,
             top=False,
             left=False,
             labelbottom=False,
             labelleft=False)
         plt.ticklabel_format(style='plain',useOffset=False)
         plt.savefig("figures/mds_SR_TD.png",bbox_inches = 'tight',pad_inches = 0.1,dpi=100)
         plt.show()
```



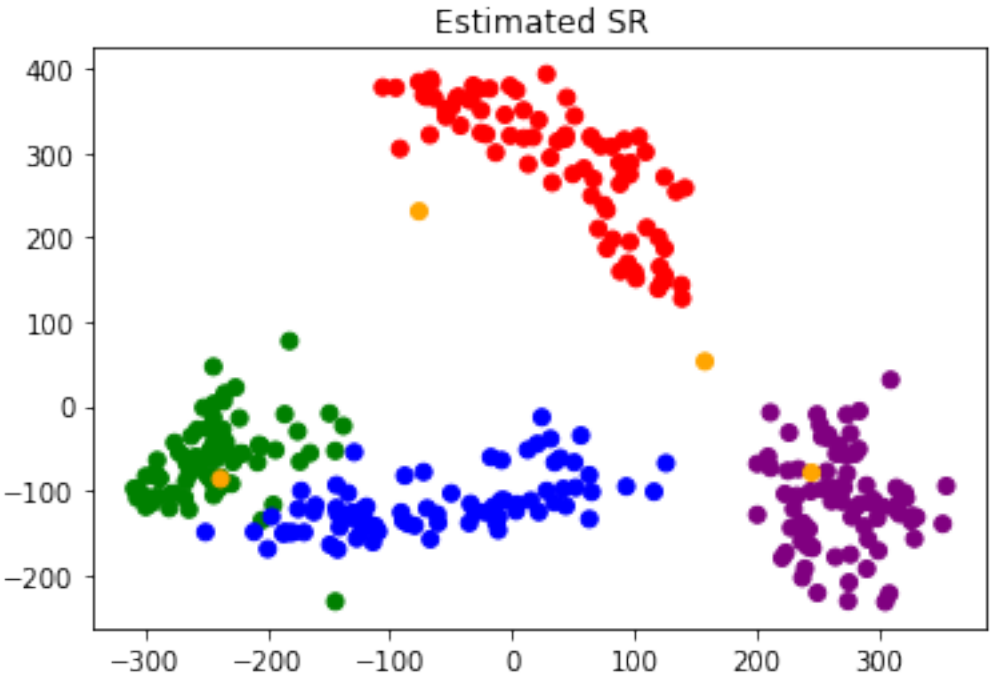
1.5 Principal Component Analysis (PCA)

In addition to MDS, we also used PCA to represent our embedding representation

```
In [61]: pca_emb = PCA(n_components=2)
         pca_emb_2d = pca_emb.fit_transform(emb_reps)
         pca_sr = PCA(n_components=2)
         pca_sr_2d = pca_sr.fit_transform(SR_reps)

In [63]: plt.scatter(pca_emb_2d[:,0],pca_emb_2d[:,1],c=labels,cmap=ListedColormap(colors))
         #plt.title("Embeddings (MDS)")
         plt.title("Random")
         plt.show()
```



In [62]:
```
plt.scatter(pca_sr_2d[:,0],pca_sr_2d[:,1],c=labels,cmap=ListedColormap(colors))
plt.title("Estimated SR")
plt.show()
```



Both MDS and PCA showed how SR has more meaningful temporal abstract information compare to random and VAE embedding representations

1.6 Train results

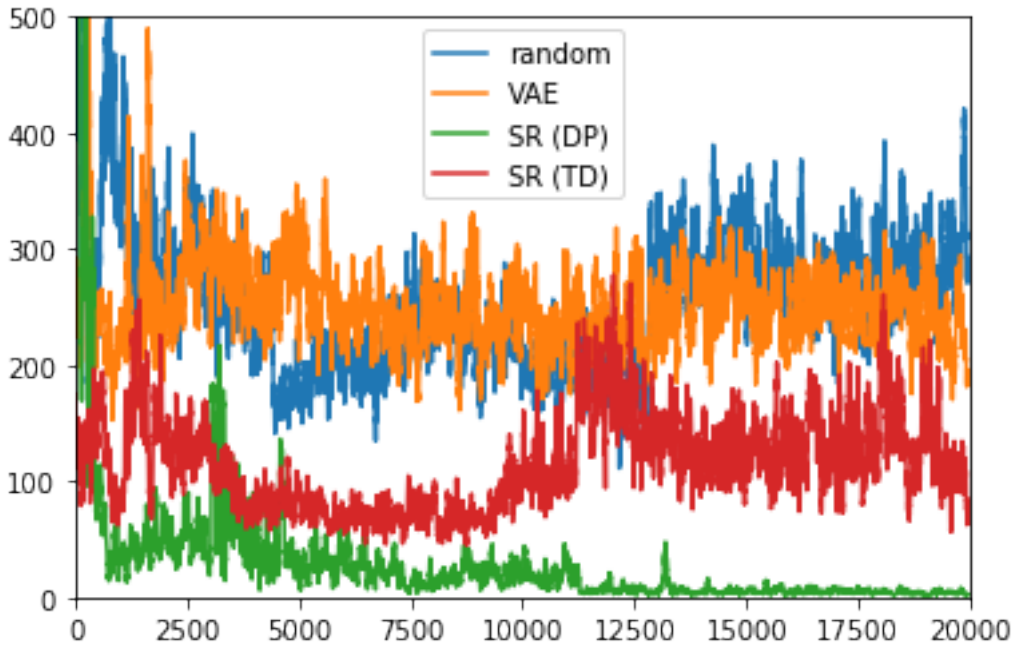
We uploaded the saved data for random, VAE and SR representation

1.6.1 Forced KNN

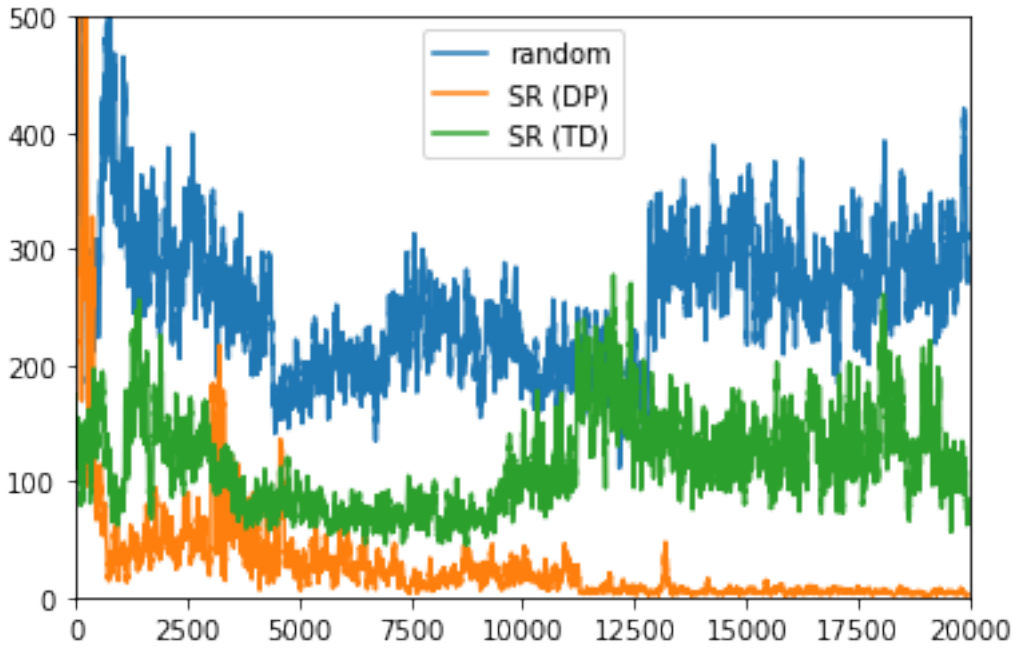
```
In [23]: rand_knn = np.load('../results/MFEC/MFEC_rand_rooms_mnist_knn.npy')
         VAE_knn = np.load('../results/MFEC/MFEC_VAE_rooms_mnist_knn.npy')
         SR_DP_knn = np.load('../results/MFEC_SR/MFEC_SR_rand_DP_rooms_mnist_knn.npy')
         SR_TD_knn = np.load('../results/MFEC_SR/MFEC_SR_rand_TD_rooms_mnist_200epochs_knn.npy')
```

```
In [68]: window = 50
         smoothed_rand_knn = np.convolve(rand_knn[:,2], np.ones((window,))/window, mode='valid')
         smoothed_VAE_knn = np.convolve(VAE_knn[:,2], np.ones((window,))/window, mode='valid')
         smoothed_SR_DP_knn = np.convolve(SR_DP_knn[:,2], np.ones((window,))/window, mode='valid
         smoothed_SR_TD_knn = np.convolve(SR_TD_knn[:,2], np.ones((window,))/window, mode='valid
```

```
In [71]: plt.plot(smoothed_rand_knn)
         plt.plot(smoothed_VAE_knn)
         plt.plot(smoothed_SR_DP_knn)
         plt.plot(smoothed_SR_TD_knn)
         plt.xlim([0,20000])
         plt.ylim([0,500])
         plt.legend(["random","VAE", "SR (DP)", "SR (TD)"])
         plt.show()
```



```
In [72]: plt.plot(smoothed_rand_knn)
         plt.plot(smoothed_SR_DP_knn)
         plt.plot(smoothed_SR_TD_knn)
         plt.xlim([0,20000])
         plt.ylim([0,500])
         plt.legend(["random", "SR (DP)", "SR (TD)"])
         plt.show()
```



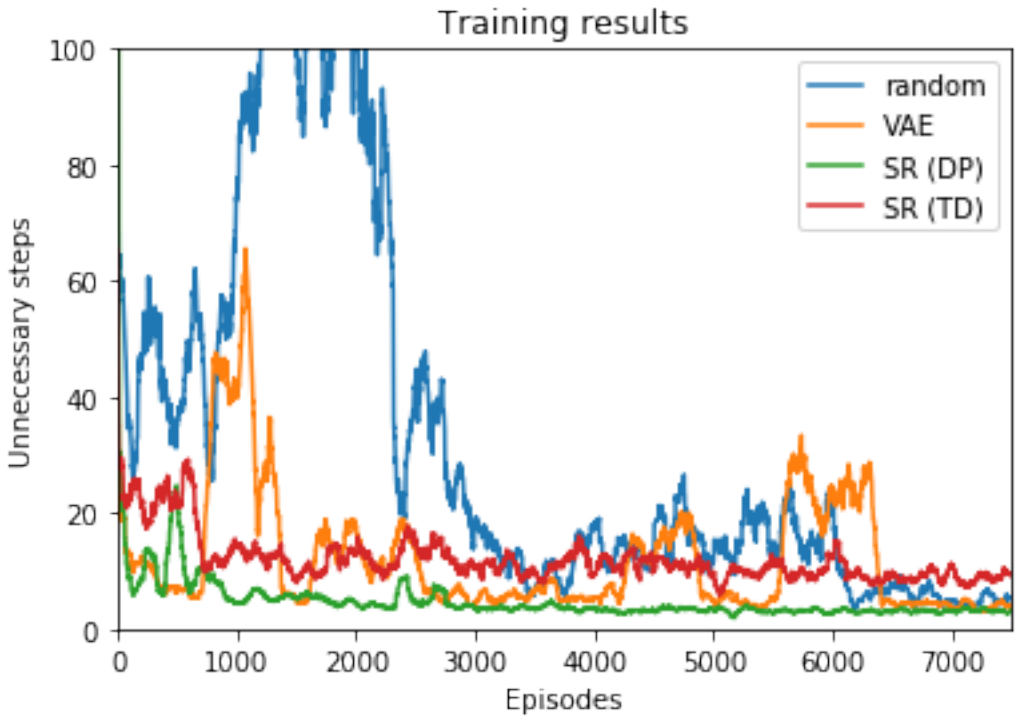
1.6.2 Forced KNN, 3 neighbors

```
In [73]: rand_3knn = np.load('../results/MFEC/MFEC_rand_rooms_mnist_3knn.npy')
         VAE_3knn = np.load('../results/MFEC/MFEC_VAE_rooms_mnist_3knn.npy')
         SR_DP_3knn = np.load('../results/MFEC_SR/MFEC_SR_rand_DP_rooms_mnist_3knn.npy')
         SR_TD_3knn = np.load('../results/MFEC_SR/MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn.npy
```

```
In [74]: window = 100
         smoothed_rand_3knn = np.convolve(rand_3knn[:,2], np.ones((window,))/window, mode='valid
         smoothed_VAE_3knn = np.convolve(VAE_3knn[:,2], np.ones((window,))/window, mode='valid')
         smoothed_SR_DP_3knn = np.convolve(SR_DP_3knn[:,2], np.ones((window,))/window, mode='val
         smoothed_SR_TD_3knn = np.convolve(SR_TD_3knn[:,2], np.ones((window,))/window, mode='val
```

```
In [75]: plt.plot(smoothed_rand_3knn)
         plt.plot(smoothed_VAE_3knn)
```

```
plt.plot(smoothed_SR_DP_3knn)
plt.plot(smoothed_SR_TD_3knn)
plt.title("Training results")
plt.xlabel("Episodes")
plt.ylabel("Unnecessary steps")
plt.xlim([0,7500])
plt.ylim([0,100])
plt.legend(["random","VAE","SR (DP)", "SR (TD)"])
plt.savefig("figures/train_curves.png",bbox_inches = 'tight',pad_inches = 0,dpi=100)
plt.show()
```



Average number of extra steps throughout training:

```
In [76]: print("Random:", np.mean(rand_3knn[:7500,2]))
         print("VAE:", np.mean(VAE_3knn[:7500,2]))
         print("SR (DP):", np.mean(SR_DP_3knn[:7500,2]))
         print("SR (TD):", np.mean(SR_TD_3knn[:7500,2]))

Random: 35.217866666666666
VAE: 12.92
SR (DP): 8.163733333333333
SR (TD): 12.6072
```

Average number of extra steps in the last 100 episodes

```
In [77]: print("Random:", np.mean(rand_3knn[7400:7500,2]))
         print("VAE:", np.mean(VAE_3knn[7400:7500,2]))
         print("SR (DP):", np.mean(SR_DP_3knn[7400:7500,2]))
         print("SR (TD):", np.mean(SR_TD_3knn[7400:7500,2]))

Random: 4.3
VAE: 4.46
SR (DP): 3.24
SR (TD): 9.21
```

1.7 Running the code for state embedding representations

(not using the saved data)

```
In [26]: #MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn

         !python train.py \
         --seed 1 \
         --environment_type fourrooms \
         --room_size 9 \
         --fourrooms_state_type mnist \
         --frames_to_stack 1 \
         --n_episodes 20000 \
         --initial_epsilon 1.0 \
         --final_epsilon 0.1 \
         --epsilon_decay 0.9 \
         --gamma 0.99 \
         --Q_train_algo MC \
         --use_Q_max \
         --force_knn \
         --weight_neighbors \
         --delta 0.01 \
         --SR_gamma 0.99 \
         --SR_batch_size 64 \
         --SR_train_frames 1000000 \
         --SR_epochs 200 \
         --SR_train_algo TD \
         --agent MFEC \
         --num_neighbors 3 \
         --embedding_type SR \
         --SR_embedding_type random \
         --embedding_size 32 \
         --in_height 28 \
         --in_width 28 \
         --max_memory 328 \
         --n_hidden 100 \
         --lr 0.0001 \
```

```
        --optimizer 'RMSprop' \
        --SR_filename ../results/MFEC_SR/random_TD_mnist_200epochs_3knn \
        --print_every 20 \
        --out_data_file ../results/MFEC_SR/MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn.npy

/Users/Maryam/anaconda3/lib/python3.6/site-packages/h5py/__init__.py:36: FutureWarning: Conversi
  from ._conv import register_converters as _register_converters
Traceback (most recent call last):
  File "train.py", line 9, in <module>
    from models.DND import *
  File "/Users/Maryam/Courses_UCDavis/Winter2020/EEC289A_RL/project/finalVersion_RL_project/Pred
    from utils.utils import get_optimizer
  File "/Users/Maryam/anaconda3/lib/python3.6/site-packages/utils.py", line 632
    print 'Warning: Unknown file extension. Using fileformat value.'
                                                                    ^
SyntaxError: Missing parentheses in call to 'print'. Did you mean print('Warning: Unknown file e
```

In [ ]:
```
#MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn

        !python train.py \
        --seed 1 \
        --environment_type fourrooms \
        --room_size 9 \
        --fourrooms_state_type mnist \
        --frames_to_stack 1 \
        --n_episodes 20000 \
        --initial_epsilon 1.0 \
        --final_epsilon 0.1 \
        --epsilon_decay 0.9 \
        --gamma 0.99 \
        --Q_train_algo MC \
        --use_Q_max \
        --force_knn \
        --weight_neighbors \
        --delta 0.01 \
        --SR_gamma 0.99 \
        --SR_batch_size 64 \
        --SR_train_frames 1000000 \
        --SR_epochs 200 \
        --SR_train_algo TD \
        --agent MFEC \
        --num_neighbors 3 \
        --embedding_type SR \
        --SR_embedding_type random \
        --embedding_size 32 \
        --in_height 28 \
        --in_width 28 \
```

```
        --max_memory 328 \
        --n_hidden 100 \
        --lr 0.0001 \
        --optimizer 'RMSprop' \
        --SR_filename ../results/MFEC_SR/random_TD_mnist_200epochs_3knn \
        --print_every 20 \
        --out_data_file ../results/MFEC_SR/MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn.npy
```

1.8 Running the code for train results

(not using the saved data)

In [ ]:
```
# MFEC_rand_rooms_mnist_3knn

!python train.py \
--seed 1 \
--environment_type fourrooms \
--room_size 9 \
--fourrooms_state_type mnist \
--frames_to_stack 1 \
--n_episodes 20000 \
--initial_epsilon 1.0 \
--final_epsilon 0.1 \
--epsilon_decay 0.9 \
--gamma 0.99 \
--Q_train_algo MC \
--use_Q_max \
--force_knn \
--weight_neighbors \
--delta 0.01 \
--agent MFEC \
--num_neighbors 3 \
--embedding_type random \
--embedding_size 32 \
--in_height 28 \
--in_width 28 \
--max_memory 328 \
--print_every 20 \
--out_data_file ../results/MFEC/MFEC_rand_rooms_mnist_3knn.npy
```

In [ ]:
```
# MFEC_VAE_rooms_mnist_3knn

python train.py \
--seed 1 \
--environment_type fourrooms \
--room_size 9 \
--fourrooms_state_type mnist \
--frames_to_stack 1 \
```

```
--n_episodes 20000 \
--initial_epsilon 1.0 \
--final_epsilon 0.1 \
--epsilon_decay 0.9 \
--gamma 0.99 \
--Q_train_algo MC \
--use_Q_max \
--force_knn \
--weight_neighbors \
--delta 0.01 \
--agent MFEC \
--num_neighbors 3 \
--embedding_type VAE \
--vae_batch_size 4 \
--vae_train_frames 100000 \
--vae_epochs 10 \
--embedding_size 32 \
--in_height 28 \
--in_width 28 \
--max_memory 328 \
--optimizer 'RMSprop' \
--lr 1e-5 \
--print_every 20 \
--vae_print_every 100 \
--load_vae_from weights/VAE/VAE_rooms_mnist.pt \
--out_data_file ../results/MFEC/MFEC_VAE_rooms_mnist_3knn.npy
```

In [ ]:
```
# MFEC_SR_rand_DP_rooms_mnist_3knn

!python train.py \
--seed 1 \
--environment_type fourrooms \
--room_size 9 \
--fourrooms_state_type mnist \
--frames_to_stack 1 \
--n_episodes 20000 \
--initial_epsilon 1.0 \
--final_epsilon 0.1 \
--epsilon_decay 0.9 \
--gamma 0.99 \
--Q_train_algo MC \
--use_Q_max \
--force_knn \
--weight_neighbors \
--delta 0.01 \
--SR_gamma 0.99 \
--SR_batch_size 32 \
--SR_train_frames 1000000 \
```

```
        --SR_epochs 10 \
        --SR_train_algo DP \
        --agent MFEC \
        --num_neighbors 3 \
        --embedding_type SR \
        --SR_embedding_type random \
        --embedding_size 32 \
        --in_height 28 \
        --in_width 28 \
        --max_memory 328 \
        --n_hidden 100 \
        --lr 0.000006 \
        --optimizer 'RMSprop' \
        --SR_filename ../results/MFEC_SR/random_DP_mnist_3knn \
        --print_every 20 \
        --out_data_file ../results/MFEC_SR/MFEC_SR_rand_DP_rooms_mnist_3knn.npy
```

```
In [ ]: # MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn

        !python train.py \
        --seed 1 \
        --environment_type fourrooms \
        --room_size 9 \
        --fourrooms_state_type mnist \
        --frames_to_stack 1 \
        --n_episodes 20000 \
        --initial_epsilon 1.0 \
        --final_epsilon 0.1 \
        --epsilon_decay 0.9 \
        --gamma 0.99 \
        --Q_train_algo MC \
        --use_Q_max \
        --force_knn \
        --weight_neighbors \
        --delta 0.01 \
        --SR_gamma 0.99 \
        --SR_batch_size 64 \
        --SR_train_frames 1000000 \
        --SR_epochs 200 \
        --SR_train_algo TD \
        --agent MFEC \
        --num_neighbors 3 \
        --embedding_type SR \
        --SR_embedding_type random \
        --embedding_size 32 \
        --in_height 28 \
        --in_width 28 \
        --max_memory 328 \
```

```
--n_hidden 100 \
--lr 0.0001 \
--optimizer 'RMSprop' \
--SR_filename results/MFEC_SR/random_TD_mnist_200epochs_3knn \
--print_every 20 \
--out_data_file ../results/MFEC_SR/MFEC_SR_rand_TD_rooms_mnist_200epochs_3knn.npy
```