prefix_identification_noELBO

September 24, 2019

In [109]:
```
import numpy as np
from scipy.spatial.distance import euclidean
import scipy
import torch

import dtw
import dtwalign
from fastdtw import fastdtw

from sklearn.manifold import TSNE
import pandas as pd

from src.speech_classification.audio_processing import AudioPreprocessorFbank, Speech
from src.siamese_net_sound_similarity.slstm_train import SiameseSpeechCommandsDataCo
from src.siamese_net_sound_similarity.train import SiameseLSTMNet


import matplotlib.pyplot as plt
import matplotlib
import seaborn as sns
sns.set()

%matplotlib inline
```

0.1 Load data

In [110]:
```
wanted_words = ['bed', 'bird', 'cat', 'dog', 'down', 'eight', 'five', 'four', 'go',
                'marvin',
                'nine', 'no', 'off', 'on', 'one', 'right', 'seven', 'sheila', 'six',
                'up', 'wow', 'yes', 'zero']

wanted_words_combined = wanted_words

model_settings = {
    'dct_coefficient_count': 26,
    'label_count': len(wanted_words_combined) + 2,
    'hidden_reccurent_cells_count': 128,
```

```
    'winlen': 0.04,
    'winstep': 0.02
}
```

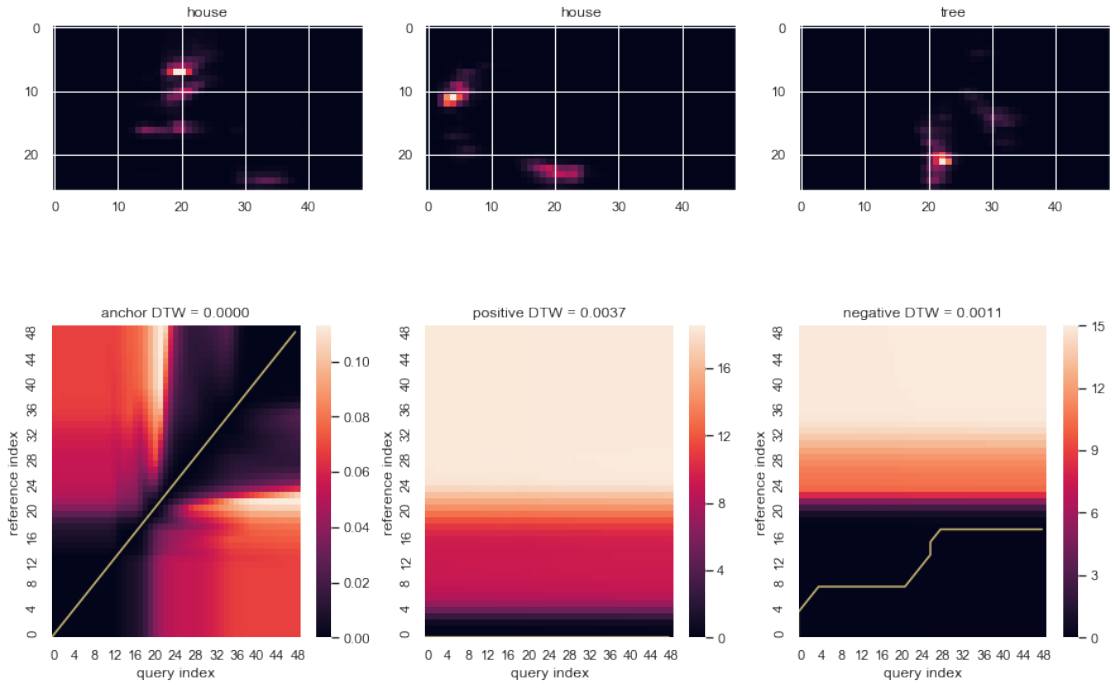
In [111]:
```
preproc = AudioPreprocessorFbank(nfilt=model_settings['dct_coefficient_count'], winle
                                 winstep=model_settings['winstep'])

data_iter = SiameseSpeechCommandsDataCollector(preproc,
                                               data_dir=r'C:\Study\Speech_command_classifica
                                               wanted_words=wanted_words_combined,
                                               testing_percentage=10,
                                               validation_percentage=10
                                               )

index_to_word = {v:k for k,v in data_iter.word_to_index.items()}
```

In [112]:
```
n_mini_batch_size = 1
data = data_iter.get_data(n_mini_batch_size, 0, 'training')
labels = data['y']

duplicates = data_iter.get_duplicates(labels, 0, 'training')
assert np.any(labels == duplicates['y'])

non_duplicates = data_iter.get_nonduplicates(labels, 0, 'training')
assert np.any(labels != non_duplicates['y'])
```

In [113]:
```
i = np.random.randint(data['y'].shape[0])
sample_idx = i

fig, axes = plt.subplots(2, 3, figsize=(15,10))

# plt.figure()
im = axes[0][0].imshow(data['x'][i].T)
# fig.colorbar(im)
label = index_to_word[data['y'][0]]
axes[0][0].title.set_text(f'{label}')

axes[0][1].imshow(duplicates['x'][i].T)
# plt.colorbar()
label = index_to_word[data['y'][0]]
axes[0][1].title.set_text(f'{label}')


axes[0][2].imshow(non_duplicates['x'][i].T)
# plt.colorbar()
label = index_to_word[non_duplicates['y'][0]]
axes[0][2].title.set_text(f'{label}')
```

```
######################################## DTW

x = data['x'][i]

# self dtw (extpected to be 0)

y = data['x'][i]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][0])
axes[1][0].set_title(f"anchor DTW = {res.normalized_distance:.4f}")


# positive dtw

y = duplicates['x'][sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][1])
axes[1][1].set_title(f"positive DTW = {res.normalized_distance:.4f}")


# negative dtw

y = non_duplicates['x'][sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][2])
axes[1][2].set_title(f"negative DTW = {res.normalized_distance:.4f}")
```

```
Out[113]: Text(0.5,1,'negative DTW = 0.0011')
```



1 Gather Data for analysis

In [172]:
```
n_mini_batch_size = 1000

# gather data


data = data_iter.get_data(n_mini_batch_size, 0, 'training')
labels = data['y']

duplicates = data_iter.get_duplicates(labels, 0, 'training')
assert np.any(labels == duplicates['y'])

non_duplicates = data_iter.get_nonduplicates(labels, 0, 'training')
assert np.any(labels != non_duplicates['y'])
```

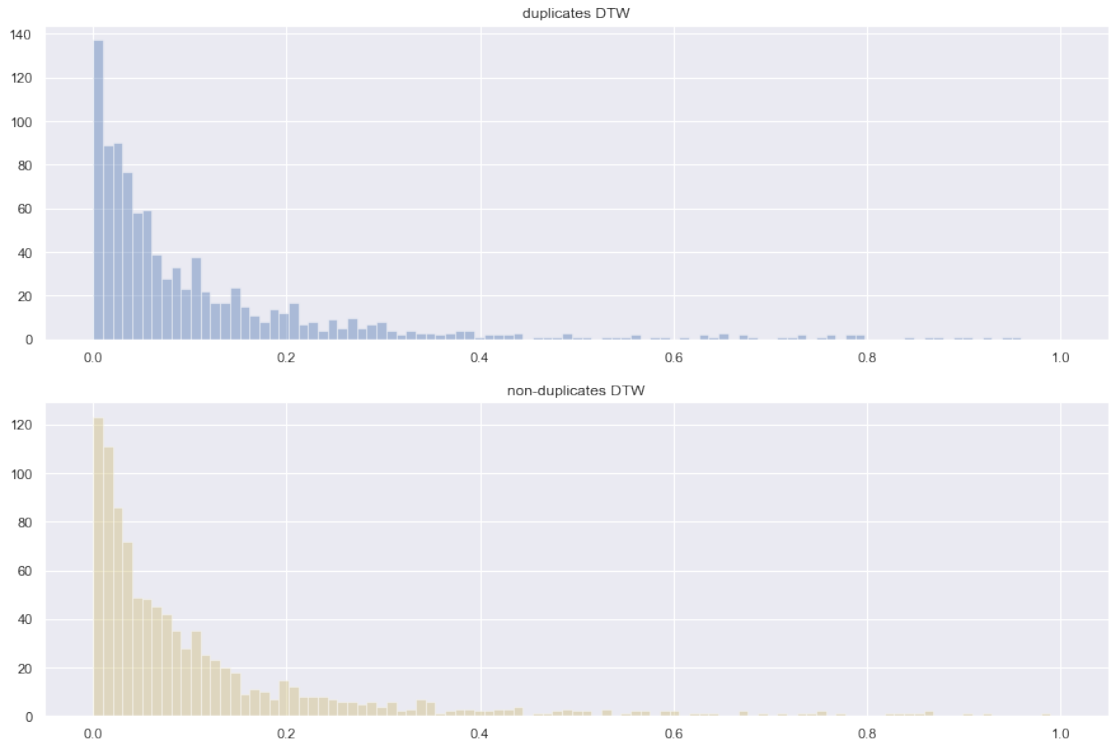
1.1 DTW distribution on raw data

In [173]:
```
# initialize dist_lists

duplicates_dtw = []
non_duplicates_dtw = []

for i in range(n_mini_batch_size):
    print(i, end='\r')
    x = data['x'][i].squeeze()

    y_duplicate = duplicates['x'][i].squeeze()
    duplicates_dtw.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Fals

    y_non_duplicate = non_duplicates['x'][i].squeeze()
    non_duplicates_dtw.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, open_
```

```
999
```

In [174]:
```
bins = np.linspace(0, 1., 100)
fig, axes = plt.subplots(2, 1, figsize=(15,10))

duplicates_dtw_filtered = np.array(duplicates_dtw)[np.where(np.array(duplicates_dtw)
non_duplicates_dtw_filtered = np.array(non_duplicates_dtw)[np.where(np.array(non_dupl


sns.distplot(duplicates_dtw_filtered, bins=bins, ax=axes[0], kde=False)
axes[0].title.set_text('duplicates DTW')
```

```
sns.distplot(non_duplicates_dtw_filtered, bins=bins, color='y', ax=axes[1], kde=Fals
axes[1].title.set_text('non-duplicates DTW')
plt.show()
```



1.1.1 KL Divergence between two DTW distributions:

In [175]:
```
hist_dup, _ = np.histogram(duplicates_dtw, bins=bins)
hist_dup = hist_dup / np.sum(hist_dup)

hist_non_dup, _ = np.histogram(non_duplicates_dtw, bins=bins)
hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
print(f"DKL is: {dkl:.4f}")
```

```
DKL is: 0.1177
```

1.1.2 As it can be seen, DTW calculated on MFCCs signals failed to capture different and similar samples showing no significant difference between duplicates and non-duplicates pairs. Kullback-Leibler divergence just proves this fact that P (distribution of distances between duplicate samples) and Q (non-duplicate ones) have no significant difference.

2 Improving DTW using latent variables from LSTM classifier as a signal

In [229]:
```
# load nn

nn_fname = r'C:/Study/SpeechAcquisitionModel/reports/seamise_net_09_23_2019_03_35_PM/

nn = torch.load(nn_fname)
```

In [230]:
```
nn_input = torch.from_numpy(data['x']).cuda().float()
```

In [231]:
```
z, *_ = nn.single_forward(nn_input)
z = z.detach().cpu().numpy()

duplicates_z, *_ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda().float()
duplicates_z = duplicates_z.detach().cpu().numpy()

non_duplicates_z, *_ = nn.single_forward(torch.from_numpy(non_duplicates['x']).cuda()
non_duplicates_z = non_duplicates_z.detach().cpu().numpy()
```

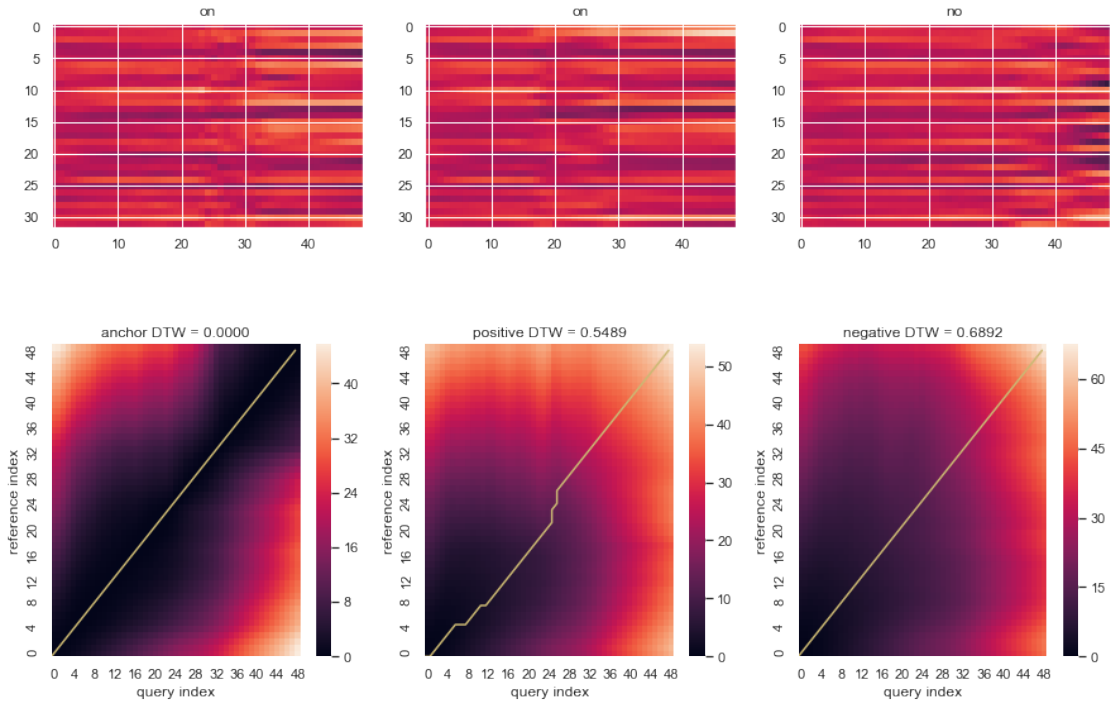
2.1 Embedding and DTW

In [232]:
```
# random latent variables
# z, _, _, _ = nn.single_forward(nn_input)
# z = z.detach().cpu().numpy()

# duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda()
# duplicates_z = duplicates_z.detach().cpu().numpy()

# non_duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(non_duplicates['x']
# non_duplicates_z = non_duplicates_z.detach().cpu().numpy()
```

In [233]:
```
i = np.random.randint(data['y'].shape[0])
sample_idx = i

fig, axes = plt.subplots(2, 3, figsize=(15,10))

# plt.figure()
im = axes[0][0].imshow(z[i].T, vmin=-1, vmax=1)
# fig.colorbar(im)
label = index_to_word[data['y'][i]]
axes[0][0].title.set_text(f'{label}')
```

```
axes[0][1].imshow(duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[data['y'][i]]
axes[0][1].title.set_text(f'{label}')


axes[0][2].imshow(non_duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[non_duplicates['y'][i]]
axes[0][2].title.set_text(f'{label}')

######################################## DTW

x = z[sample_idx]

# self dtw (extpected to be 0)

y = z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][0])
axes[1][0].set_title(f"anchor DTW = {res.normalized_distance:.4f}")


# positive dtw

y = duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=False)
res.plot_path(ax=axes[1][1])
axes[1][1].set_title(f"positive DTW = {res.normalized_distance:.4f}")


# negative dtw

y = non_duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=False)
res.plot_path(ax=axes[1][2])
axes[1][2].set_title(f"negative DTW = {res.normalized_distance:.4f}")
```

```
Out[233]: Text(0.5,1,'negative DTW = 0.6892')
```



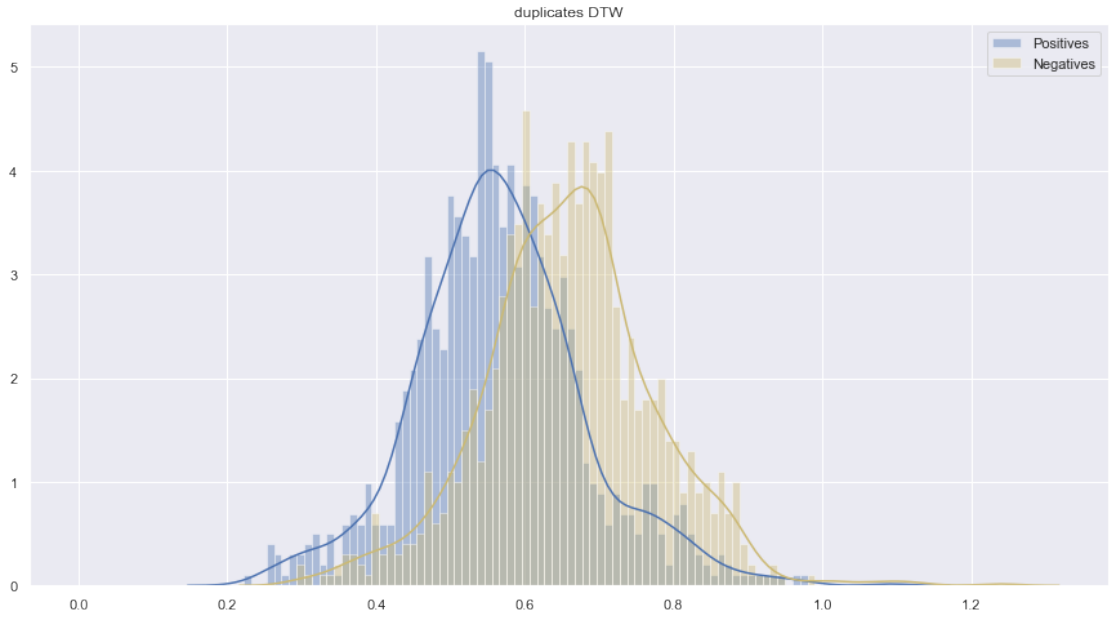
3 1.1 DTW distribution in latent space z (open_end=True)

In [234]:
```
# initialize dist_lists

duplicates_dtw_z = []
non_duplicates_dtw_z = []

for i in range(n_mini_batch_size):
    print(i, end='\r')
    x = z[i].squeeze()

    y_duplicate = duplicates_z[i].squeeze()
    duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Tru

    y_non_duplicate = non_duplicates_z[i].squeeze()
    non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, oper
```

```
999
```

In [235]:
```
bins = np.linspace(0, 1., 100)
fig, axes = plt.subplots(1, 1, figsize=(15,8))

sns.distplot(duplicates_dtw_z, ax=axes, bins=bins, label="Positives")
```

```
axes.title.set_text('duplicates DTW')

sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Negatives')
axes.legend()
# axes[1].title.set_text('non-duplicates DTW')
plt.show()

hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
hist_dup = hist_dup / np.sum(hist_dup)

hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
print(f"DKL is: {dkl:.4f}")
```




```
DKL is: 0.5164
```

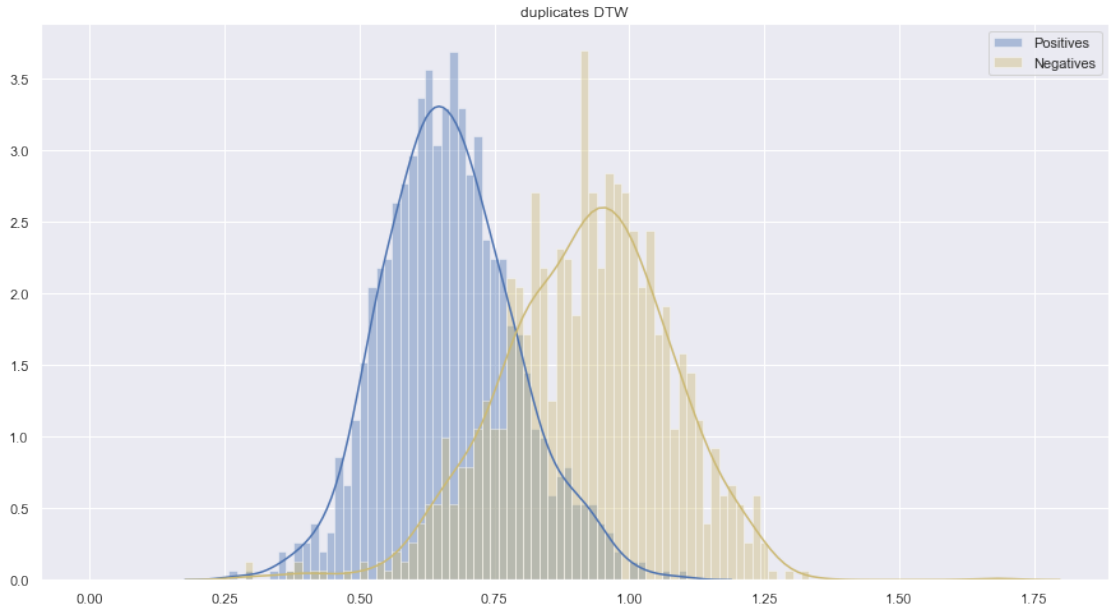
4 1.2 DTW distribution in latent space z (open_end=False)

```
In [236]: # initialize dist_lists

duplicates_dtw_z = []
non_duplicates_dtw_z = []
```

```
        for i in range(n_mini_batch_size):
            print(i, end='\r')
            x = z[i].squeeze()

            y_duplicate = duplicates_z[i].squeeze()
            duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Fal

            y_non_duplicate = non_duplicates_z[i].squeeze()
            non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, oper
```

```
999
```

In [237]:
```
bins = np.linspace(0, 1.5, 100)
fig, axes = plt.subplots(1, 1, figsize=(15,8))

sns.distplot(duplicates_dtw_z, ax=axes, bins=bins, label="Positives")
axes.title.set_text('duplicates DTW')

sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Negatives')
axes.legend()
# axes[1].title.set_text('non-duplicates DTW')
plt.show()

hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
hist_dup = hist_dup / np.sum(hist_dup)

hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
print(f"DKL is: {dkl:.4f}")
```



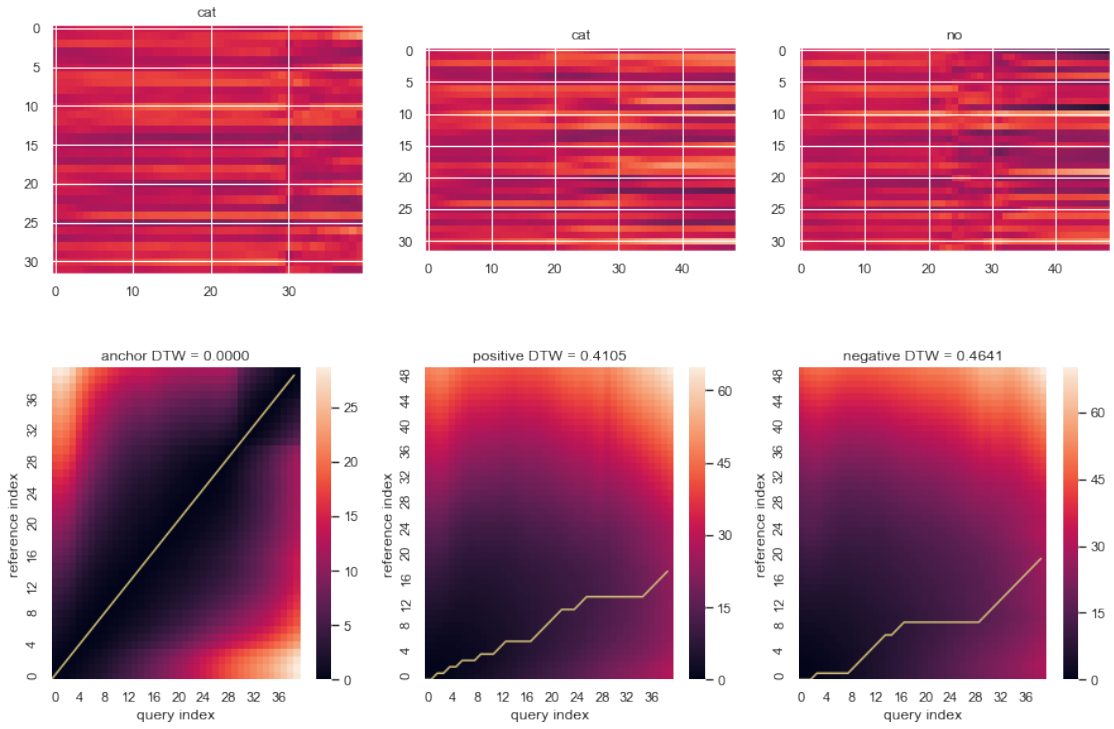

```
DKL is: 1.7515
```

5 2. DTW (prefix case n << m) n = 40

```
In [238]: PREFIX_LEN = 40

In [239]: nn_input = torch.from_numpy(data['x'][:, :PREFIX_LEN, :]).cuda().float()

In [240]: z, *_ = nn.single_forward(nn_input)
          z = z.detach().cpu().numpy()

          duplicates_z, *_ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda().float()
          duplicates_z = duplicates_z.detach().cpu().numpy()

          non_duplicates_z, *_ = nn.single_forward(torch.from_numpy(non_duplicates['x']).cuda()
          non_duplicates_z = non_duplicates_z.detach().cpu().numpy()

In [241]: # random latent variables
          # z, _, _, _ = nn.single_forward(nn_input)
          # z = z.detach().cpu().numpy()

          # duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda()
          # duplicates_z = duplicates_z.detach().cpu().numpy()

          # non_duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(non_duplicates['x']
          # non_duplicates_z = non_duplicates_z.detach().cpu().numpy()
```

In [242]:
```
i = np.random.randint(data['y'].shape[0])
sample_idx = i

fig, axes = plt.subplots(2, 3, figsize=(15,10))

# plt.figure()
im = axes[0][0].imshow(z[i].T, vmin=-1, vmax=1)
# fig.colorbar(im)
label = index_to_word[data['y'][i]]
axes[0][0].title.set_text(f'{label}')

axes[0][1].imshow(duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[data['y'][i]]
axes[0][1].title.set_text(f'{label}')


axes[0][2].imshow(non_duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[non_duplicates['y'][i]]
axes[0][2].title.set_text(f'{label}')

######################################### DTW

x = z[sample_idx]

# self dtw (extpected to be 0)

y = z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][0])
axes[1][0].set_title(f"anchor DTW = {res.normalized_distance:.4f}")


# positive dtw

y = duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][1])
axes[1][1].set_title(f"positive DTW = {res.normalized_distance:.4f}")


# negative dtw

y = non_duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][2])
axes[1][2].set_title(f"negative DTW = {res.normalized_distance:.4f}")
```

Out[242]: Text(0.5,1,'negative DTW = 0.4641')



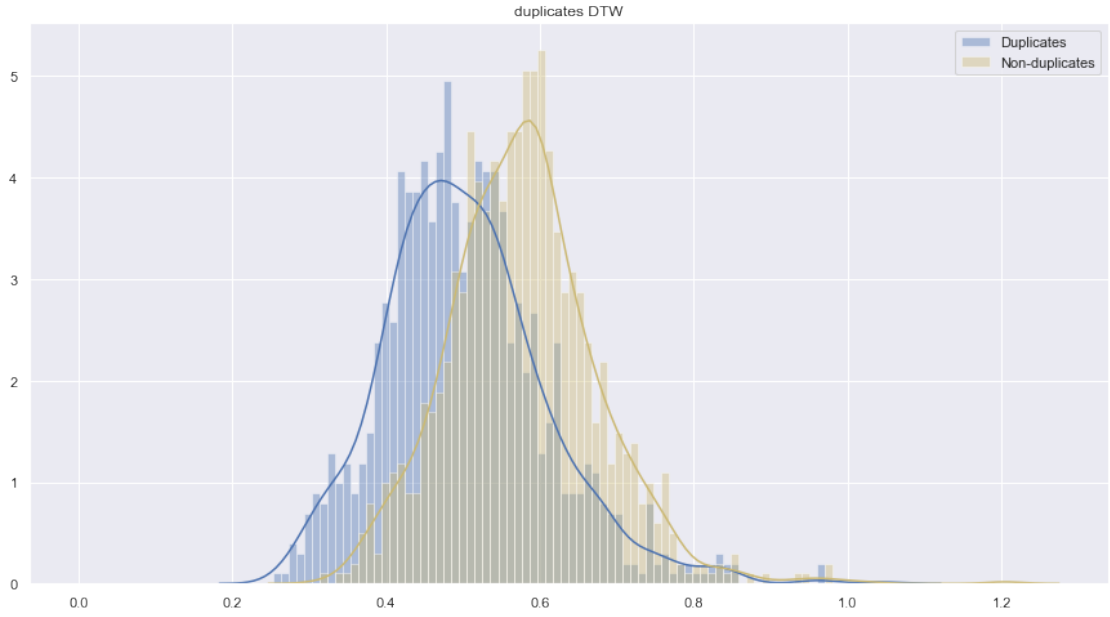
6 2.1 DTW distribution in latent space z (open_end=True)

In [243]:
```
# initialize dist_lists

duplicates_dtw_z = []
non_duplicates_dtw_z = []

for i in range(n_mini_batch_size):
    print(i, end='\r')
    x = z[i].squeeze()

    y_duplicate = duplicates_z[i].squeeze()
    duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Tru

    y_non_duplicate = non_duplicates_z[i].squeeze()
    non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, oper
```

999

In [244]:
```
bins = np.linspace(0, 1., 100)
fig, axes = plt.subplots(1, 1, figsize=(15,8))
```

```
sns.distplot(duplicates_dtw_z, bins=bins, ax=axes, label="Duplicates")
axes.title.set_text('duplicates DTW')

sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Non-duplicat
axes.legend()
# axes[1].title.set_text('non-duplicates DTW')
plt.show()

hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
hist_dup = hist_dup / np.sum(hist_dup)

hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
print(f"DKL is: {dkl:.4f}")
```




```
DKL is: 0.5891
```

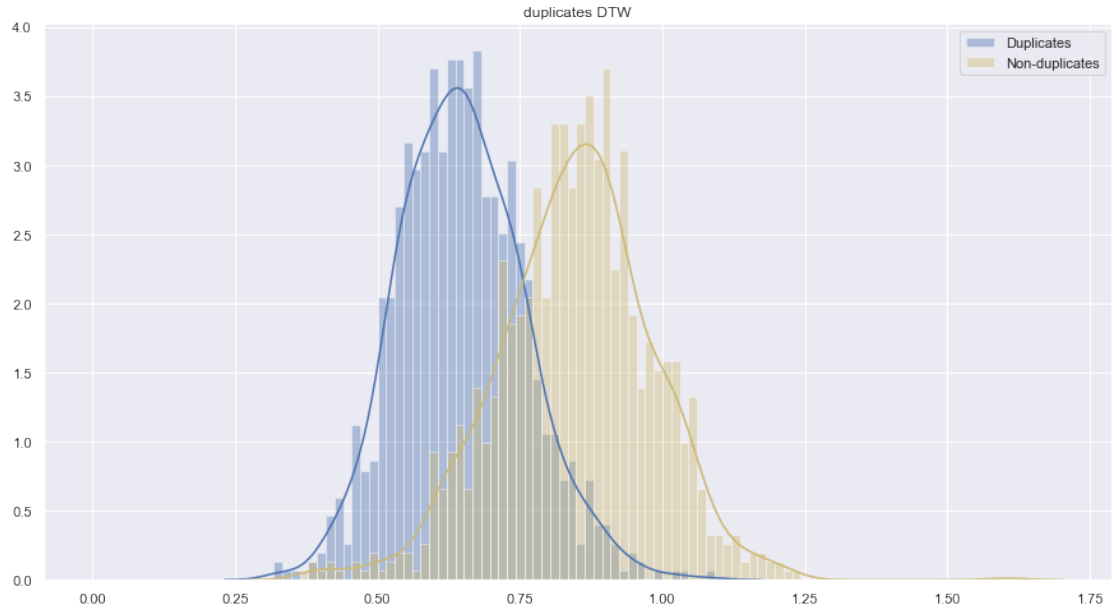
7 2.2 DTW distribution in latent space z (open_end=False)

```
In [245]: # initialize dist_lists

          duplicates_dtw_z = []
```

```
        non_duplicates_dtw_z = []

        for i in range(n_mini_batch_size):
            print(i, end='\r')
            x = z[i].squeeze()

            y_duplicate = duplicates_z[i].squeeze()
            duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Fa

            y_non_duplicate = non_duplicates_z[i].squeeze()
            non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, ope
```

```
999
```

```
In [246]: bins = np.linspace(0, 1.5, 100)
          fig, axes = plt.subplots(1, 1, figsize=(15,8))

          sns.distplot(duplicates_dtw_z, bins=bins, ax=axes, label="Duplicates")
          axes.title.set_text('duplicates DTW')

          sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Non-duplicat
          axes.legend()
          # axes[1].title.set_text('non-duplicates DTW')
          plt.show()

          hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
          hist_dup = hist_dup / np.sum(hist_dup)

          hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
          hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

          dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
          print(f"DKL is: {dkl:.4f}")
```




```
DKL is: 1.2739
```

8 3. DTW (prefix case n << m) n = 30

```
In [247]: PREFIX_LEN = 30
```

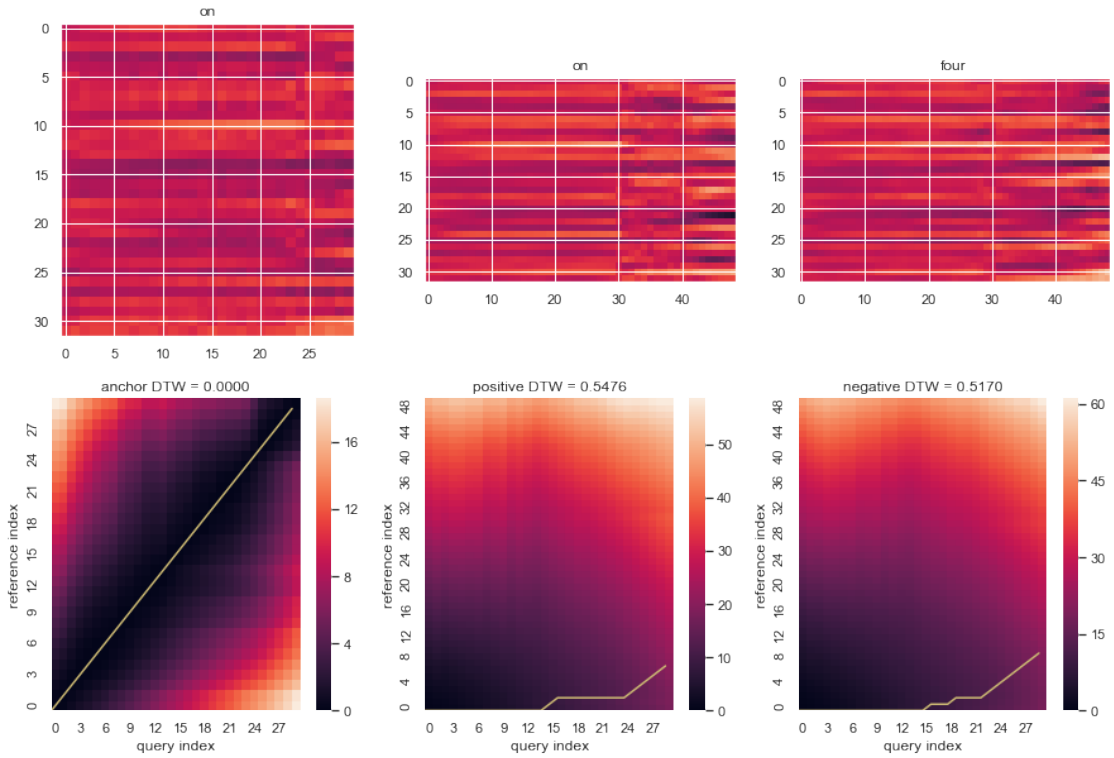
```
In [248]: nn_input = torch.from_numpy(data['x'][:, :PREFIX_LEN, :]).cuda().float()
```

```
In [249]: z, *_ = nn.single_forward(nn_input)
          z = z.detach().cpu().numpy()

          duplicates_z, *_ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda().float()
          duplicates_z = duplicates_z.detach().cpu().numpy()

          non_duplicates_z, *_ = nn.single_forward(torch.from_numpy(non_duplicates['x']).cuda()
          non_duplicates_z = non_duplicates_z.detach().cpu().numpy()
```

```
In [250]: # random latent variables
          # z, _, _, _ = nn.single_forward(nn_input)
          # z = z.detach().cpu().numpy()

          # duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda()
          # duplicates_z = duplicates_z.detach().cpu().numpy()

          # non_duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(non_duplicates['x']
          # non_duplicates_z = non_duplicates_z.detach().cpu().numpy()
```

In [251]:
```
i = np.random.randint(data['y'].shape[0])
sample_idx = i

fig, axes = plt.subplots(2, 3, figsize=(15,10))

# plt.figure()
im = axes[0][0].imshow(z[i].T, vmin=-1, vmax=1)
# fig.colorbar(im)
label = index_to_word[data['y'][i]]
axes[0][0].title.set_text(f'{label}')

axes[0][1].imshow(duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[data['y'][i]]
axes[0][1].title.set_text(f'{label}')


axes[0][2].imshow(non_duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[non_duplicates['y'][i]]
axes[0][2].title.set_text(f'{label}')

######################################### DTW

x = z[sample_idx]

# self dtw (extpected to be 0)

y = z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][0])
axes[1][0].set_title(f"anchor DTW = {res.normalized_distance:.4f}")


# positive dtw

y = duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][1])
axes[1][1].set_title(f"positive DTW = {res.normalized_distance:.4f}")


# negative dtw

y = non_duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][2])
axes[1][2].set_title(f"negative DTW = {res.normalized_distance:.4f}")
```

Out[251]: Text(0.5,1,'negative DTW = 0.5170')

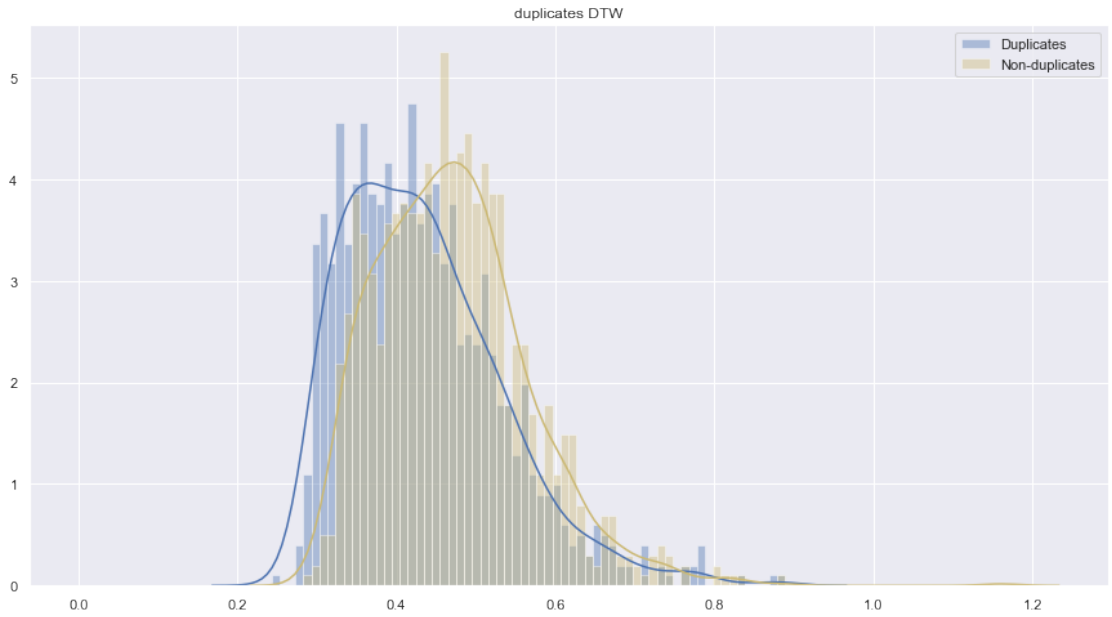


9 3.1 DTW distribution in latent space z (open_end=True)

In [252]:
```
# initialize dist_lists

duplicates_dtw_z = []
non_duplicates_dtw_z = []

for i in range(n_mini_batch_size):
    print(i, end='\r')
    x = z[i].squeeze()

    y_duplicate = duplicates_z[i].squeeze()
    duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Tru

    y_non_duplicate = non_duplicates_z[i].squeeze()
    non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, oper
```

```
999
```

In [253]:
```
bins = np.linspace(0, 1., 100)
fig, axes = plt.subplots(1, 1, figsize=(15,8))

sns.distplot(duplicates_dtw_z, bins=bins, ax=axes, label="Duplicates")
axes.title.set_text('duplicates DTW')

sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Non-duplicat
axes.legend()
# axes[1].title.set_text('non-duplicates DTW')
plt.show()

hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
hist_dup = hist_dup / np.sum(hist_dup)

hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
print(f"DKL is: {dkl:.4f}")
```




```
DKL is: 0.2957
```

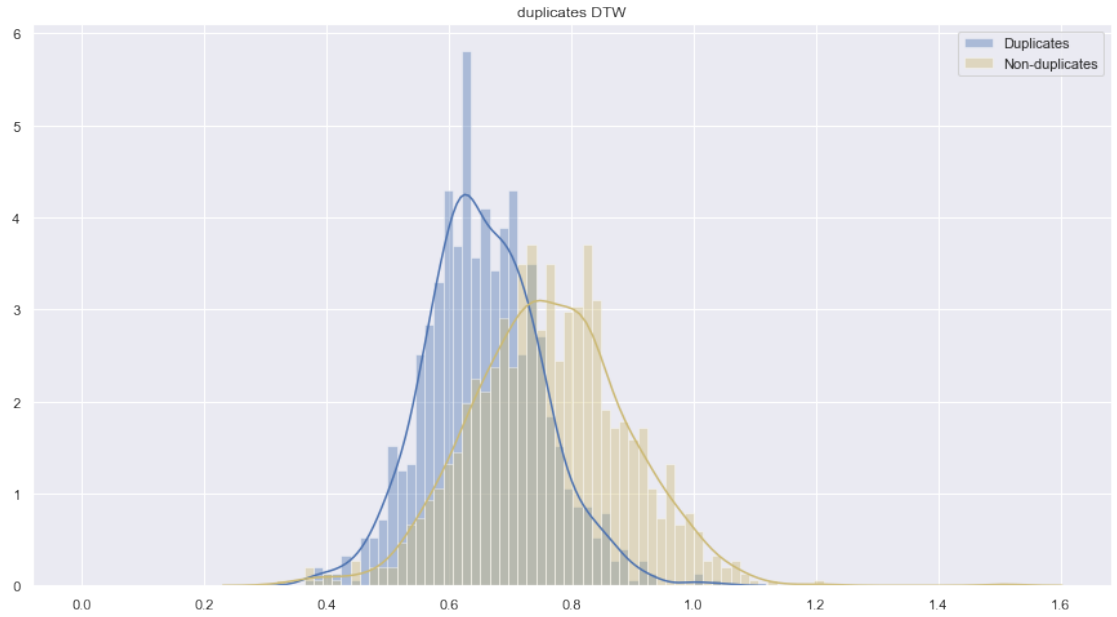
10 3.2 DTW distribution in latent space z (open_end=False)

In [254]:
```
# initialize dist_lists
```

```
        duplicates_dtw_z = []
        non_duplicates_dtw_z = []

        for i in range(n_mini_batch_size):
            print(i, end='\r')
            x = z[i].squeeze()

            y_duplicate = duplicates_z[i].squeeze()
            duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Fa

            y_non_duplicate = non_duplicates_z[i].squeeze()
            non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, ope
```

```
999
```

In [255]:
```
        bins = np.linspace(0, 1.5, 100)
        fig, axes = plt.subplots(1, 1, figsize=(15,8))

        sns.distplot(duplicates_dtw_z, bins=bins, ax=axes, label="Duplicates")
        axes.title.set_text('duplicates DTW')

        sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Non-duplicat
        axes.legend()
        # axes[1].title.set_text('non-duplicates DTW')
        plt.show()

        hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
        hist_dup = hist_dup / np.sum(hist_dup)

        hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
        hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

        dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
        print(f"DKL is: {dkl:.4f}")
```



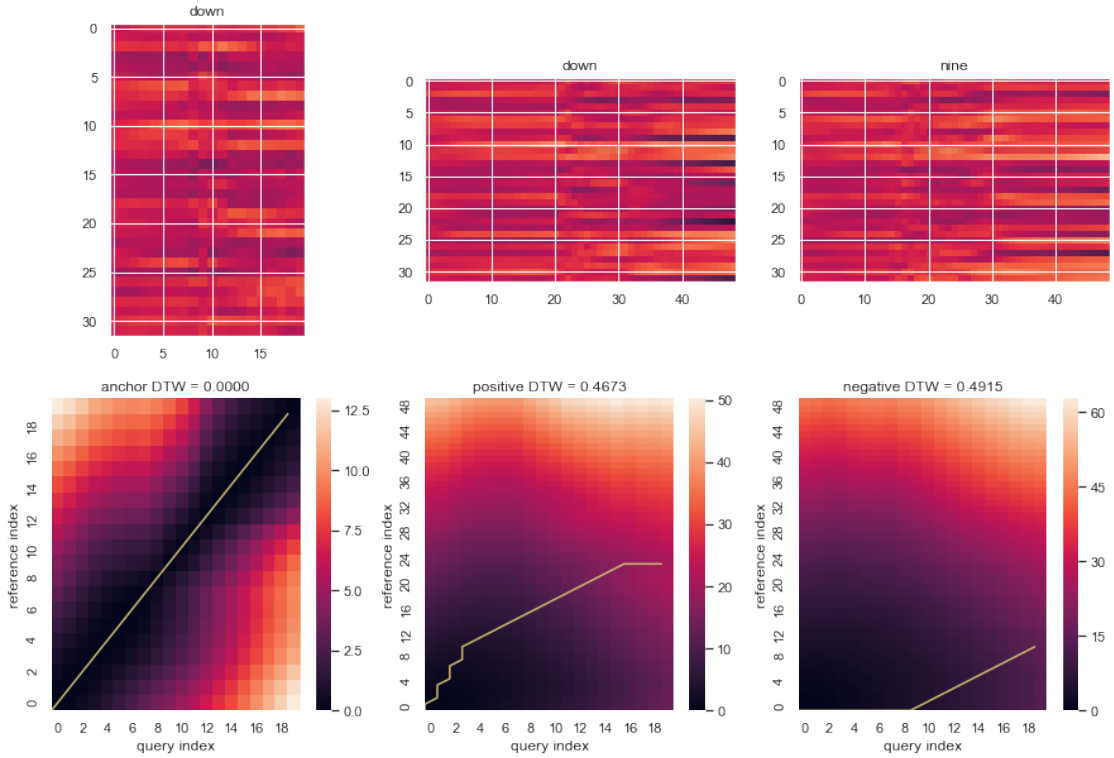

```
DKL is: 0.5455
```

11 4. DTW (prefix case n << m) n = 20

```
In [256]: PREFIX_LEN = 20

In [257]: nn_input = torch.from_numpy(data['x'][:, :PREFIX_LEN, :]).cuda().float()

In [258]: z, *_ = nn.single_forward(nn_input)
          z = z.detach().cpu().numpy()

          duplicates_z, *_ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda().float()
          duplicates_z = duplicates_z.detach().cpu().numpy()

          non_duplicates_z, *_ = nn.single_forward(torch.from_numpy(non_duplicates['x']).cuda()
          non_duplicates_z = non_duplicates_z.detach().cpu().numpy()

In [259]: # random latent variables
          # z, _, _, _ = nn.single_forward(nn_input)
          # z = z.detach().cpu().numpy()

          # duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(duplicates['x']).cuda()
          # duplicates_z = duplicates_z.detach().cpu().numpy()

          # non_duplicates_z, _, _, _ = nn.single_forward(torch.from_numpy(non_duplicates['x']
          # non_duplicates_z = non_duplicates_z.detach().cpu().numpy()
```

In [260]:
```
i = np.random.randint(data['y'].shape[0])
sample_idx = i

fig, axes = plt.subplots(2, 3, figsize=(15,10))

# plt.figure()
im = axes[0][0].imshow(z[i].T, vmin=-1, vmax=1)
# fig.colorbar(im)
label = index_to_word[data['y'][i]]
axes[0][0].title.set_text(f'{label}')

axes[0][1].imshow(duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[data['y'][i]]
axes[0][1].title.set_text(f'{label}')


axes[0][2].imshow(non_duplicates_z[i].T, vmin=-1, vmax=1)
# plt.colorbar()
label = index_to_word[non_duplicates['y'][i]]
axes[0][2].title.set_text(f'{label}')

######################################### DTW

x = z[sample_idx]

# self dtw (extpected to be 0)

y = z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][0])
axes[1][0].set_title(f"anchor DTW = {res.normalized_distance:.4f}")


# positive dtw

y = duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][1])
axes[1][1].set_title(f"positive DTW = {res.normalized_distance:.4f}")


# negative dtw

y = non_duplicates_z[sample_idx]
res = dtwalign.dtw(x, y, dist=euclidean, open_end=True)
res.plot_path(ax=axes[1][2])
axes[1][2].set_title(f"negative DTW = {res.normalized_distance:.4f}")
```

Out[260]: Text(0.5,1,'negative DTW = 0.4915')

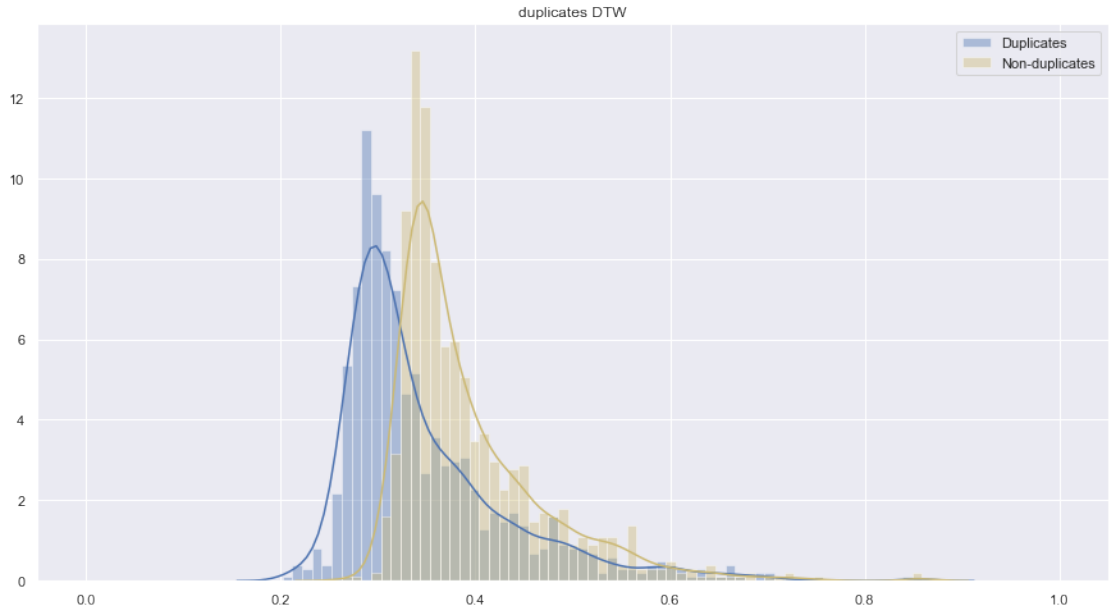


12 4.1 DTW distribution in latent space z (open_end=True)

In [261]:
```
# initialize dist_lists

duplicates_dtw_z = []
non_duplicates_dtw_z = []

for i in range(n_mini_batch_size):
    print(i, end='\r')
    x = z[i].squeeze()

    y_duplicate = duplicates_z[i].squeeze()
    duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Tru

    y_non_duplicate = non_duplicates_z[i].squeeze()
    non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, oper
```

```
999
```

In [262]:
```
bins = np.linspace(0, 1., 100)
fig, axes = plt.subplots(1, 1, figsize=(15,8))

sns.distplot(duplicates_dtw_z, bins=bins, ax=axes, label="Duplicates")
axes.title.set_text('duplicates DTW')

sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Non-duplicat
axes.legend()
# axes[1].title.set_text('non-duplicates DTW')
plt.show()

hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
hist_dup = hist_dup / np.sum(hist_dup)

hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
print(f"DKL is: {dkl:.4f}")
```




```
DKL is: 2.1786
```

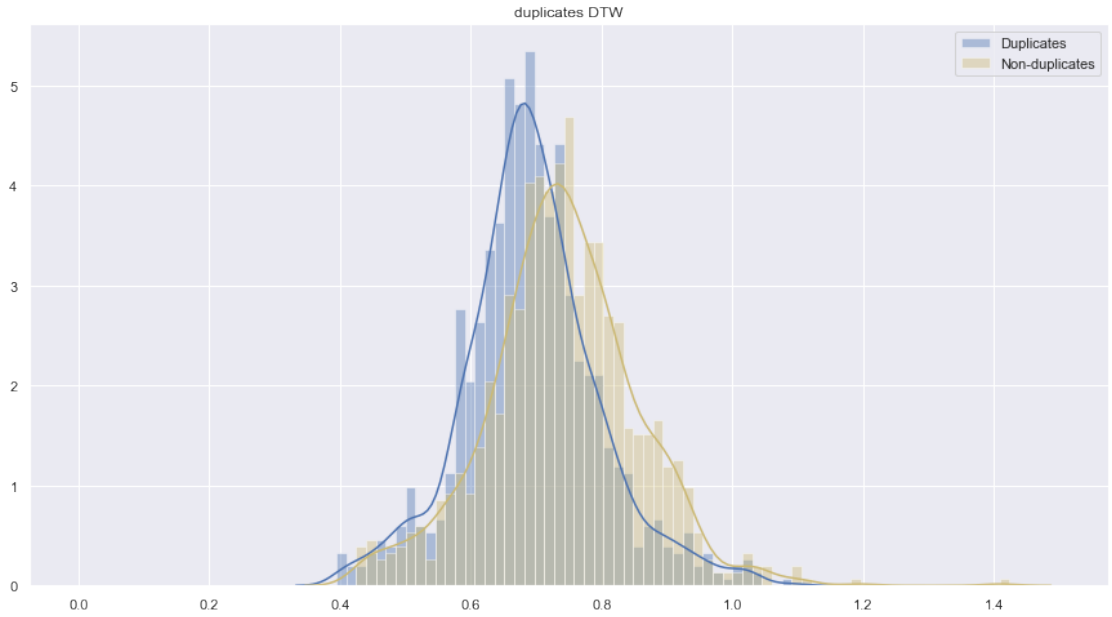
13 4.2 DTW distribution in latent space z (open_end=False)

In [263]:
```
# initialize dist_lists
```

```
        duplicates_dtw_z = []
        non_duplicates_dtw_z = []

        for i in range(n_mini_batch_size):
            print(i, end='\r')
            x = z[i].squeeze()

            y_duplicate = duplicates_z[i].squeeze()
            duplicates_dtw_z.append(dtwalign.dtw(x, y_duplicate, dist=euclidean, open_end=Fa

            y_non_duplicate = non_duplicates_z[i].squeeze()
            non_duplicates_dtw_z.append(dtwalign.dtw(x, y_non_duplicate, dist=euclidean, ope
```

```
999
```

In [264]:
```
        bins = np.linspace(0, 1.5, 100)
        fig, axes = plt.subplots(1, 1, figsize=(15,8))

        sns.distplot(duplicates_dtw_z, bins=bins, ax=axes, label="Duplicates")
        axes.title.set_text('duplicates DTW')

        sns.distplot(non_duplicates_dtw_z, bins=bins, color='y', ax=axes, label='Non-duplicat
        axes.legend()
        # axes[1].title.set_text('non-duplicates DTW')
        plt.show()

        hist_dup, _ = np.histogram(duplicates_dtw_z, bins=bins)
        hist_dup = hist_dup / np.sum(hist_dup)

        hist_non_dup, _ = np.histogram(non_duplicates_dtw_z, bins=bins)
        hist_non_dup = hist_non_dup / np.sum(hist_non_dup)

        dkl = scipy.special.kl_div(hist_dup+1e-5, hist_non_dup+1e-5).sum()
        print(f"DKL is: {dkl:.4f}")
```


duplicates DTW
Duplicates
Non-duplicates
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

DKL is: 0.1969