In [ ]:

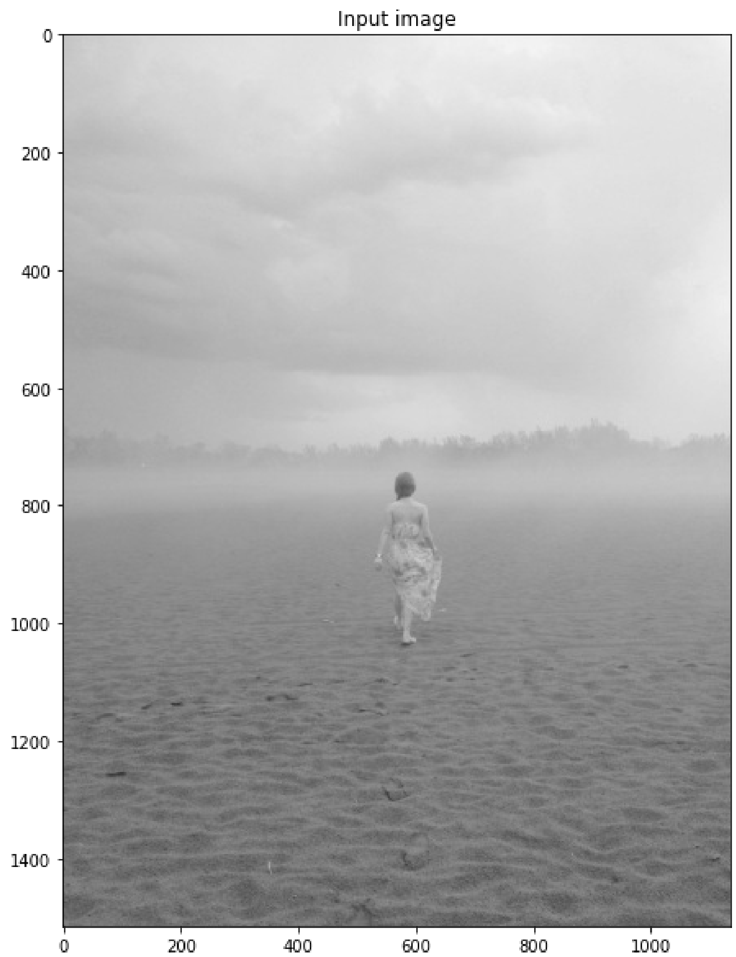
```
%matplotlib inline
from IPython.display import display, Math, Latex

import numpy as np
import matplotlib.pyplot as plt
import requests
from PIL import Image
from io import BytesIO
```

In [ ]:

```
input_url = 'https://i.pinimg.com/originals/fa/95/87/fa9587af615f5670f430308f5ab42235.jpg'

response = requests.get(input_url)
input_img = Image.open(BytesIO(response.content)).convert('L')

#input_url = 'https://www.math.ust.hk/~masyleung/Teaching/CAS/MATLAB/image/images/lenna.jpg'

# display the image
figsize = (10,10)
plt.figure(figsize=figsize)

plt.imshow(input_img, cmap='gray', vmin=0, vmax=255)
plt.title("Input image")
```

Out[ ]:

```
Text(0.5, 1.0, 'Input image')
```



In [ ]:

```
template_url = 'https://www.math.ust.hk/~masyleung/Teaching/CAS/MATLAB/image/images/lenna.jpg'

response = requests.get(template_url)
template_img = Image.open(BytesIO(response.content)).convert('L')

# display the image
```

```python
figsize = (10,10)
plt.figure(figsize=figsize)

plt.imshow(template_img, cmap='gray', vmin=0, vmax=255)
plt.title("Template image")
```

Out[ ]:

```
Text(0.5, 1.0, 'Template image')
```

In [ ]:

```python
def hist_match(source, template):
    """
    Adjust the pixel values of a grayscale image such that its histogram
    matches that of a target image

    Arguments:
    -----------
        source: np.ndarray
            Image to transform; the histogram is computed over the flattened
            array
        template: np.ndarray
            Template image; can have different dimensions to source
    Returns:
    -----------
        matched: np.ndarray
            The transformed output image
    """

    oldshape = source.shape
    source = source.ravel()
    template = template.ravel()

    # get the set of unique pixel values and their corresponding indices and
    # counts
    s_values, bin_idx, s_counts = np.unique(source, return_inverse=True,
                                            return_counts=True)
    t_values, t_counts = np.unique(template, return_counts=True)

    # take the cumsum of the counts and normalize by the number of pixels to
    # get the empirical cumulative distribution functions for the source and
    # template images (maps pixel value --> quantile)
```

```
    s_quantiles = np.cumsum(s_counts).astype(np.float64)
    s_quantiles /= s_quantiles[-1]
    t_quantiles = np.cumsum(t_counts).astype(np.float64)
    t_quantiles /= t_quantiles[-1]

    # interpolate linearly to find the pixel values in the template image
    # that correspond most closely to the quantiles in the source image
    interp_t_values = np.interp(s_quantiles, t_quantiles, t_values)

    return interp_t_values[bin_idx].reshape(oldshape)
```

In [ ]:

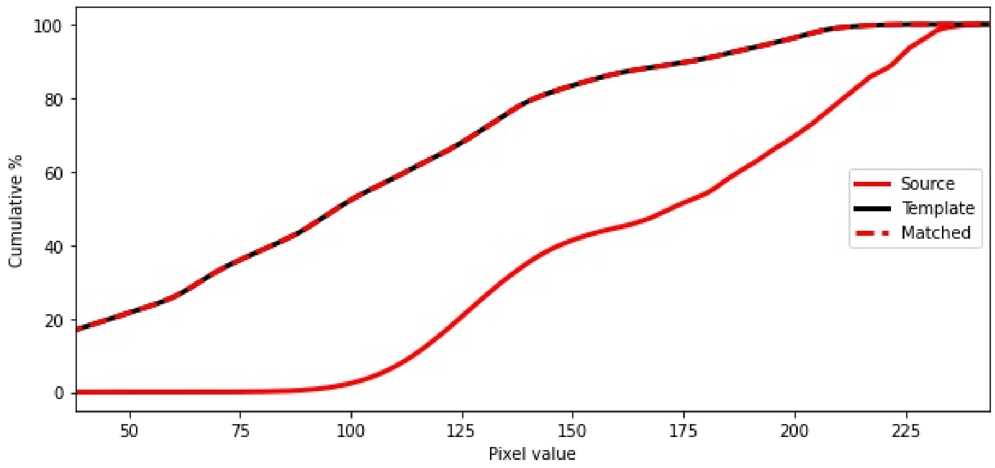
```
source = np.asarray(input_img)
template = np.asarray(template_img)

matched = hist_match(source, template)
```

In [ ]:

```
def ecdf(x):
    """convenience function for computing the empirical CDF"""
    vals, counts = np.unique(x, return_counts=True)
    ecdf = np.cumsum(counts).astype(np.float64)
    ecdf /= ecdf[-1]
    return vals, ecdf

x1, y1 = ecdf(source.ravel())
x2, y2 = ecdf(template.ravel())
x3, y3 = ecdf(matched.ravel())

figsize = (10,10)
fig = plt.figure(figsize=figsize)

#plt.figure(figsize=figsize)
gs = plt.GridSpec(2, 3)
ax1 = fig.add_subplot(gs[0, 0])
ax2 = fig.add_subplot(gs[0, 1], sharex=ax1, sharey=ax1)
ax3 = fig.add_subplot(gs[0, 2], sharex=ax1, sharey=ax1)
ax4 = fig.add_subplot(gs[1, :])
for aa in (ax1, ax2, ax3):
    aa.set_axis_off()

ax1.imshow(source, cmap=plt.cm.gray)
ax1.set_title('Source')
ax2.imshow(template, cmap=plt.cm.gray)
ax2.set_title('Template')
ax3.imshow(matched, cmap=plt.cm.gray)
ax3.set_title('Matched')

ax4.plot(x1, y1 * 100, '-r', lw=3, label='Source')
ax4.plot(x2, y2 * 100, '-k', lw=3, label='Template')
ax4.plot(x3, y3 * 100, '--r', lw=3, label='Matched')
ax4.set_xlim(x1[0], x1[-1])
ax4.set_xlabel('Pixel value')
ax4.set_ylabel('Cumulative %')
ax4.legend(loc=5)
```

Out[ ]:

```
<matplotlib.legend.Legend at 0x7fd37f4af690>
```



Cumulative %
100
80
60
40
20
0
50
75
100
125
150
175
200
225
Pixel value
Source
Template
Matched