Assignment 1 Code Outputs

Reproduction

1. Install the requirements

```
python3 -m pip install -Ur requirements.txt
```

2. Run all the tasks

```
python3 run_tasks.py
```

Task 1

Convert an image from RGB to YCbCr `4:2:0` and recover it.

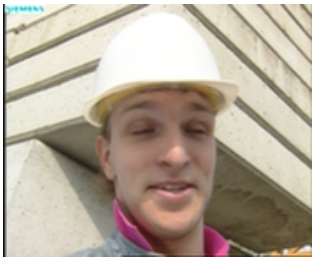
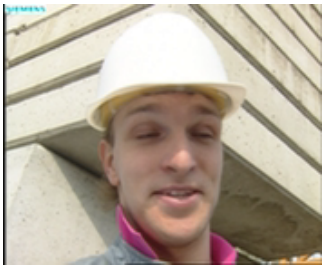
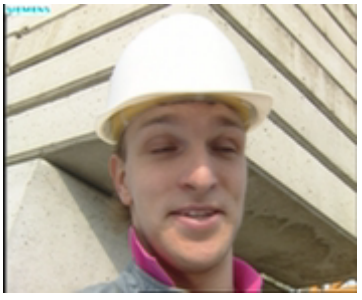
Assume that the copied image is equivalent to the original image.

Visual Comparison

Display images.

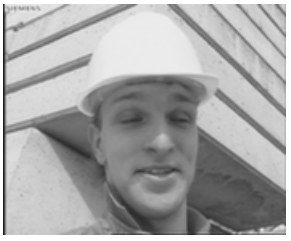
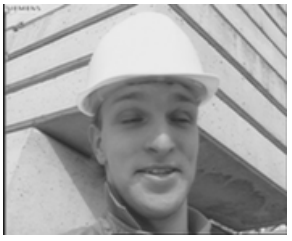
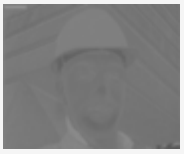
I added transformed images from YCbCr to RGB using `utils/YUVDisplay.exe`.

There are the images in the RGB color space below.

Copied Image	Transformed Image (Mine)	Transformed Image (YUVDisplay.exe)
		

There are the images in the YCbCr color space re-mapped to the grayscale colorspace below.

	Before sub-sampling	After sub-sampling	After up-sampling

On Y plane			
On Cb plane			
On Cr plane			

Statistical Comparison

Compare between the copied and transformed images in the RGB color space.

There are the metric results computed between the copied and transformed images below.

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.48102', '0.00000'],
 ['MSE', '0.73883', '0.00000'],
 ['NRMSE', '0.00483', '0.00000'],
 ['PSNR', '49.44534', 'inf'],
 ['SSIM', '0.99853', '1.00000']]
```

Details

The process workflow is as follows.

Task 2

Convert the multiple images from RGB to YCbCr `4:2:0` color space and pack them into a file in planar format.

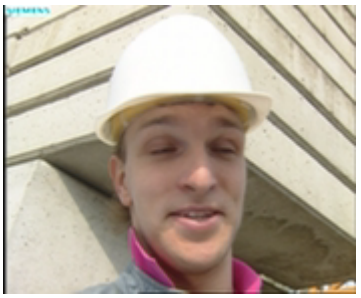
Visual Comparison

Display images.

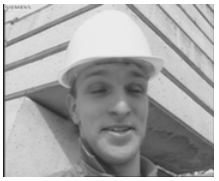
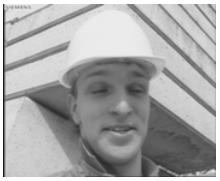
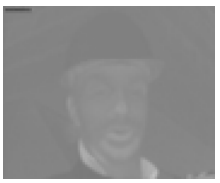
I added the up-sampled images and re-exported ones using `utils/YUVDisplay.exe` for comparison purposes since they have the same size as the original ones.

The images with sequence number `0` are displayed below.

There are the images in the RGB color space below.

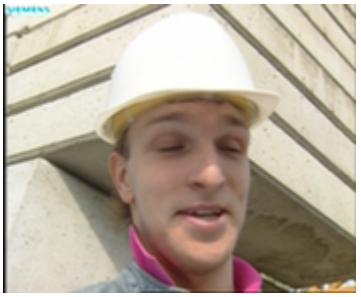
Original Image	Transformed Image (YUVDisplay.exe)
	

There are images in the YCbCr color space re-mapped to the grayscale color space below.

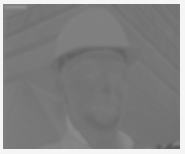
	Without sub-sampling	With sub-sampling	With up-sampling
On Y plane			
On Cb plane			
On Cr plane			

The images with sequence number 1 are displayed below.			

There are the images in the RGB color space below.

Original Image	Transformed Image (YUVDisplay.exe)
	

There are images in the YCbCr color space re-mapped to the grayscale color space below.

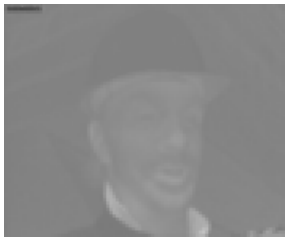
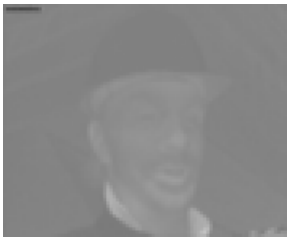
	Without sub-sampling	With sub-sampling	With up-sampling
On Y plane			
On Cb plane			
On Cr plane			
The images with sequence number 2 are displayed below.			

There are the images in the RGB color space below.

Original Image	Transformed Image (YUVDisplay.exe)

There are images in the YCbCr color space re-mapped to the grayscale color space below.

	Without sub-sampling	With sub-sampling	With up-sampling
On Y plane			
On Cb plane			
On Cr plane			

Statistical Comparison

Compare between the images without sub-sampling and with sub-sampling in the YCbCr color space.

There are the metric results computed between the copied and transformed images below.

The image pair with sequence number `0` :

On the Y plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.00000', '0.00000'],
 ['MSE', '0.00000', '0.00000'],
 ['NRMSE', '0.00000', '0.00000'],
 ['PSNR', 'inf', 'inf'],
 ['SSIM', '1.00000', '1.00000']]
```

On the Cb plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.01610', '0.00000'],
 ['MSE', '0.04553', '0.00000'],
 ['NRMSE', '0.00179', '0.00000'],
 ['PSNR', '61.54750', 'inf'],
 ['SSIM', '0.99981', '1.00000']]
```

On the Cr plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.02233', '0.00000'],
 ['MSE', '0.22230', '0.00000'],
 ['NRMSE', '0.00350', '0.00000'],
 ['PSNR', '54.66139', 'inf'],
 ['SSIM', '0.99976', '1.00000']]
```

The image pair with sequence number `1` :

On the Y plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.00000', '0.00000'],
 ['MSE', '0.00000', '0.00000'],
 ['NRMSE', '0.00000', '0.00000'],
 ['PSNR', 'inf', 'inf'],
 ['SSIM', '1.00000', '1.00000']]
```

On the Cb plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.01172', '0.00000'],
 ['MSE', '0.04076', '0.00000'],
 ['NRMSE', '0.00169', '0.00000'],
 ['PSNR', '62.02855', 'inf'],
 ['SSIM', '0.99988', '1.00000']]
```

On the Cr plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.02225', '0.00000'],
```

```
 ['MSE', '0.21607', '0.00000'],
 ['NRMSE', '0.00345', '0.00000'],
 ['PSNR', '54.78492', 'inf'],
 ['SSIM', '0.99980', '1.00000']]
```

The image pair with sequence number `2` :

On the Y plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.00000', '0.00000'],
 ['MSE', '0.00000', '0.00000'],
 ['NRMSE', '0.00000', '0.00000'],
 ['PSNR', 'inf', 'inf'],
 ['SSIM', '1.00000', '1.00000']]
```

On the Cb plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.01417', '0.00000'],
 ['MSE', '0.04257', '0.00000'],
 ['NRMSE', '0.00173', '0.00000'],
 ['PSNR', '61.83934', 'inf'],
 ['SSIM', '0.99984', '1.00000']]
```

On the Cr plane:

```
[['<Metrics>', '<Score>', '<Goal>'],
 ['MAE', '0.02095', '0.00000'],
 ['MSE', '0.21784', '0.00000'],
 ['NRMSE', '0.00346', '0.00000'],
 ['PSNR', '54.74938', 'inf'],
 ['SSIM', '0.99982', '1.00000']]
```

Details

The process workflow is as follows.

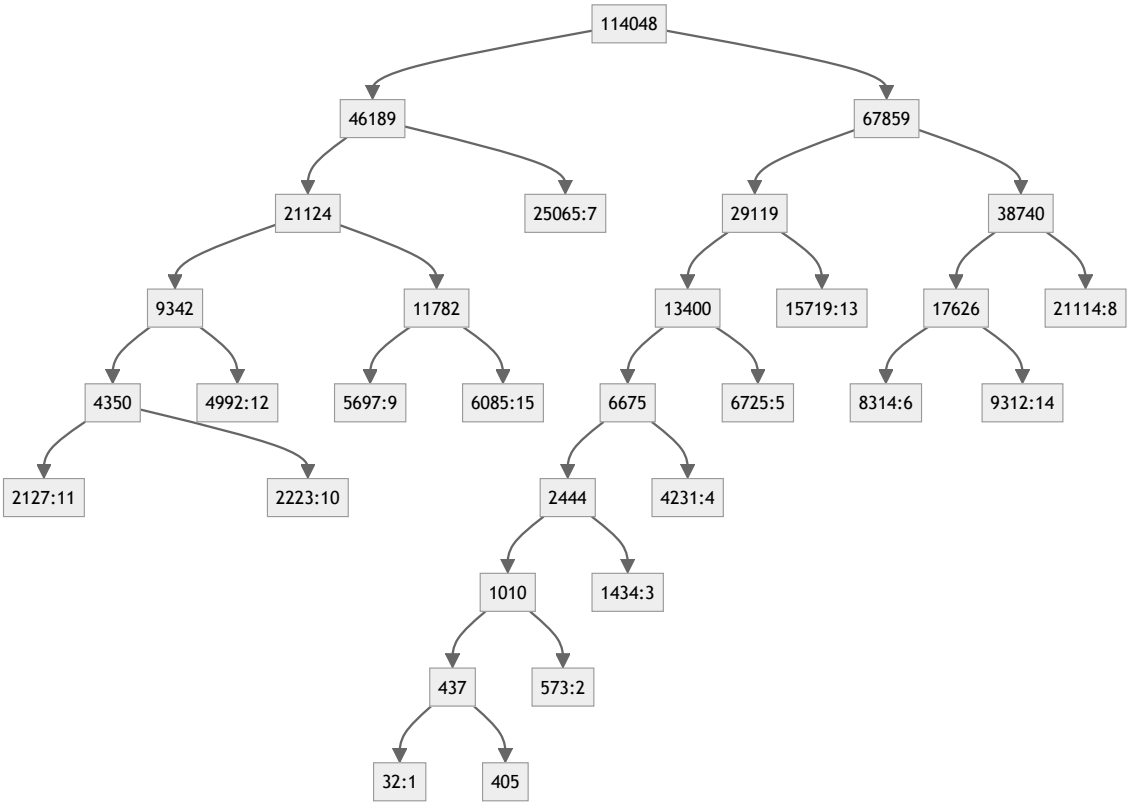
Task 3

Quantize and encode YCbCr `4:2:0` images and recover them.

Taking quantization levels as symbols, here are the Huffman tree and code table used:

```
{0: '10000001',
 1: '10000000',
```

```
2: '1000001',
3: '100001',
4: '10001',
5: '1001',
6: '1100',
7: '01',
8: '111',
9: '0010',
10: '00001',
11: '00000',
12: '0001',
13: '101',
14: '1101',
15: '0011'}
```



Comparison between the images without and with quantization

The quantized versions are visually different from the original RGB images.

The transformed image `0` on different Y, Cb and Cr planes in the grayscale colorspace:

	Before quantization	After quantization & de-quantization

On Y plane		
On Cb plane		
On Cr plane