ECS795P Deep Learning and Computer Vision, 2022

Course Work 1: Image Super-resolution Using Deep Learning

Introduction

Aim: To obtain practical knowledge and hands-on understanding of the concepts of image super-resolution, deep learning using convolutional neural networks (CNN) and peak signal-to-noise ratio (PSNR).

Start: Download **CW1_ECS795P.zip** from the course website at http://www.eecs.qmul.ac.uk/~sgg/_ECS795P_/.

Tasks: three subtasks are involved:

1. Coding: to add your code blocks in the required sections; (40% of this CW)
2. Report: to complete the questions in report; (30% of this CW)
3. Online assessment: to answer one question and to conduct one exercise, which are randomly selected from below. It will be carried out during the lab demo session in WK10; (30% of this CW)

Platform: Python + PyTorch

1. Understanding image super-resolution

Objective: To become familiar with the image super-resolution problem setting.

Questions:

1. What is the concept of image resolution?
   The concept of image resolution specifies the details an image holds. Resolution refers to the quality of an image in which the greater the resolution more clear is the image. The resolution of a digital image is typically defined in PPI(Pixels Per Inch). The more pixels per inch (PPI) there are, the more detail there is in the image or display. When the resolution of an image changes it means number of pixels in an inch of image are there.
   Let's take an example, supposedly two images one of 600 PPI and another of 72 PPI resolution. The image with 600 PPI will look crisp with finer details rather than the one with 72 PPI. The reason for this variation in detail is because the image with 600 PPI has more number of 600 pixels in one inch while image of 72 PPI has only 72 pixels in one inch. Therefore, the more number of pixels in one inch better is the image quality.

2. What is the gray-scale or single-channel image super-resolution?
   A grey-scale image is one in which the value of each pixel is a single sample representing only an amount of light; it carries only intensity information. Super-resolution imaging (SR) refers to a group of techniques that improve (increase)

an imaging system's resolution. The diffraction limit of systems is transcend in optical SR, whereas the resolution of digital imaging sensors is improved in geometrical SR. Super-resolution can also be referred to increasing the resolution of an imaging system.

3. What is the Ground Truth image?
   Ground truth means image that is known to be much more accurate than image from the system tested.

4. How to measure the quality of the output high-resolution images?
   The quality might be measured in comparison to an ideal image (Ground Truth image).

Exercises:

1. To read the image named *butterfly_GT.bmp*
2. To show the image resolution of this image
3. To convert the image from the RGB colour space into the gray-scale space (Tip: use *imageio* package to read image)
4. To downsample the current image by 3 times
5. To upsample the current image by 3 times with interpolation algorithm

2. Understanding deep learning by convolutional neural network

Objective: To understand the principles of deep convolutional neural network.

Questions:

1. What are the parameters of a CNN?
   For every layer in the Convolution neural network, there are two types of parameters – weights and biases. The total number of parameters is just the sum of all weights and biases. Let's define, = Number of weights of the Conv Layer. = Number of biases of the Conv Layer.
   Calculation: Number of parameters in a CONV layer would be : ((m * n * d)+1)* k), added 1 because of the bias term for each filter. The same expression can be written as follows: ((shape of width of the filter * shape of height of the filter * number of filters in the previous layer+1)*number of filters).
   Depending on the work it does in a CNN layer, we have learnable parameters and training parameters.
   Learnable parameters: The learnable parameters are weights that are learned during training. They are weight matrices that change during the back-propagation process and contribute to the predictive power of the model.
   Trainable parameters: Trainable parameters are the number of neurons in your network that are affected by backpropagation. W and b, for example, are trainable in each neuron for the Wx + b operation because they are changed by optimizers after backpropagation was used for gradient computation.

2. What is the target of CNN model training?
   The CNN model training goal is to find the significant property of the data in order to solve the task.

3. What is the difference between the training and testing stage of a CNN?
   Training stage: During the training stage our goal is to learn the weights that make the network extract meaningful features from the input.
   Testing Stage: In the testing phase we feed the network new inputs and we test its ability to extract good features.
   In conclusion, it can be said that for training stage, we fit the model using training samples and in testing we check the performance of the model against the testing set.

Exercises:

1. To load the pre-trained model named *model.pth*
2. To set and show the weights of the first convolutional layer
   - To set the channel number of the input
   - To set the filter number
   - To set the filter size
   - To set the padding

- To show the weight of the 1st filter in command window
- To show the bias of the 10th filter in command window

3. To set and show the weights of the second convolutional layer
    - To set the channel number of the input
    - To set the filter number
    - To set the filter size
    - To set the padding
    - To show the weight of the 5th filter in command window
    - To show the bias of the 6th filter in command window
4. To set show the weights of the third convolutional layer
    - To set the channel number of the input
    - To set the filter number
    - To set the filter size
    - To set the padding
    - To show the weight of the 1st filter in command window
    - To show the bias of the 1st filter in command window
5. To perform 2-d convolutional operation on a 2-d matrix with a given filter (Tip: *conv2d* and *relu* are PyTorch build-in functions)

3. Image super-resolution using deep convolutional network

Objective: To perform image super-resolution with deep convolutional neural network and evaluate the performance.

Questions:

1. How to use a trained SRCNN to perform image super-resolution (testing stage)?
   Harm "ideal" image, pass the result to a model and compare the refurbished image with the "ideal".

2. What are the input and the output of the SRCNN?
   - Input - low-resolution image
   - Output - high-resolution one

3. How to conduct qualitative and quantitative comparison between two different SR networks?
   qualitative - PSNR and SSIM
   quantitative - PSNR (???), speed

4. What is the typical numerical measure metric for quantitative analysis?
   PSNR - peak signal-to-noise ratio PSNR = 20lg(MAX) - 10lg(MSE) MAX - the maximum possible pixel value of the image MSE - the difference between the estimator and what is estimated.

5. What is the maximum power of imaging signal (i.e., pixel) and noise signal?
   e.g., image of uint8 type?

Exercises:

1. To get and show the Ground Truth image
2. To get and show the low-resolution image (downsampled)
3. To feed the input image into the SRCNN
4. To get and show the output high-resolution image by SRCNN
5. To compute the PSNR of the high-resolution image against the Ground Truth image (Tip: use the python module: *skimage.metrics.peak_signal_noise_ratio*)
6. To get the high-resolution image by interpolation algorithm (baseline result)
7. To compute the PSNR of the baseline result against the Ground Truth
8. To compare the results of the two methods (baseline and SRCNN) in terms of PSNR