ENEE 691 Homework 5.v0

Spring 2023

Please submit your homework as a zip file which should include a pdf file explaining your solutions and your codes/notebook. Due date: 9:00 AM, May 16, 2023.

Introduction

For this homework, you will be working on a near-field microwave microscopy (NFMM) measurement dataset. This is more like CSI project, see Fig. 1. I will give you a set of blurry images and their non-blurry versions. You will train neural networks and then try converting blurry images into legible ones for the samples that were not used during the training.

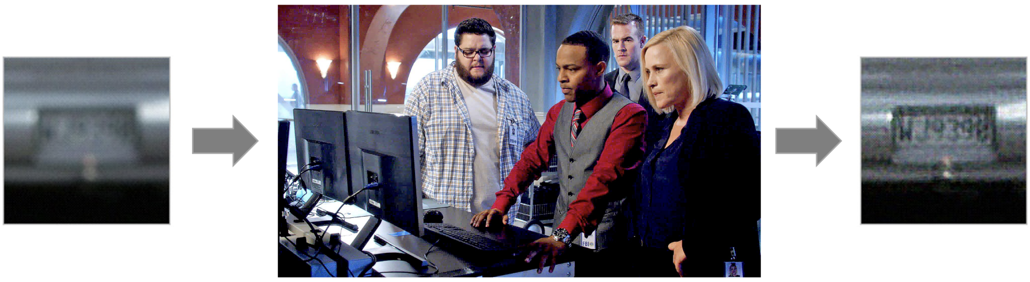

Figure 1: CSI agents convert a blurry image of a plate into a legible one.

Near-field microwave microscopy (NFMM) is a technique that allows for the measurement of electric field distributions in microwave and photonic devices with high spatial resolution. It works by using a probe tip that is brought in close proximity to the device being measured, typically within a few nanometers or less.

When the probe used in NFMM is smaller than the device being studied, as shown in Fig. 2(a), one can measure the electric field distribution along the device successfully, as illustrated in Fig. 2 (b). However, if the probe is wider, see. Fig. 2(c), since the resolution of NFMM is limited by the size of the probe and the distance between the probe and the sample surface, it leads to resolution issues as illustrated in Fig. 2(d).

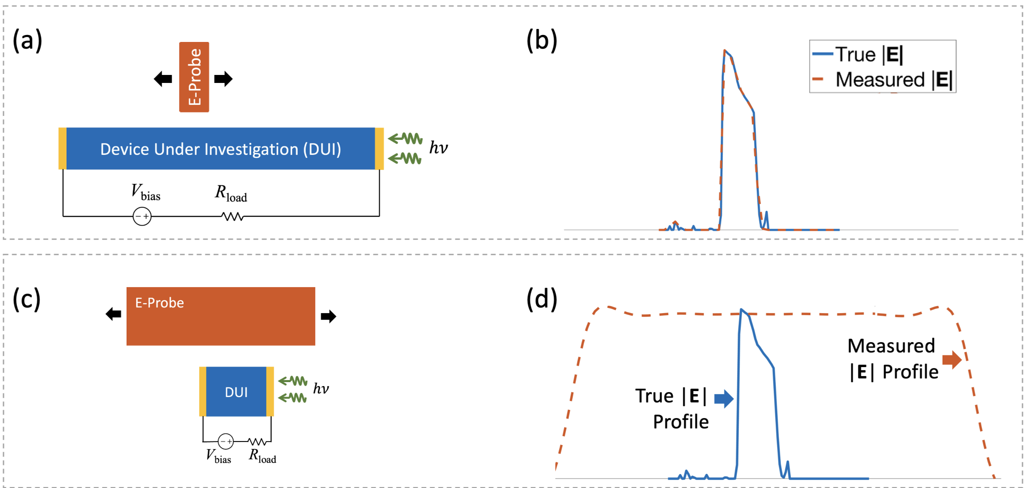

Figure 2: (a) A near electric field measurement setup where the width of the probe is (a) much shorter and (c) longer than the length of the device. (b) and (d) show a typical comparison of true vs. measured field intensity for the setups shown in (a) and (c), respectively.

Assignment

There are two .csv files at `https://github.com/simsekergun/ENEE691/tree/main/homework5`. Please instead of downloading them to your local machine, please load them using pandas, such

```
df_m = pd.read_csv('https://raw.githubusercontent.com/simsekergun/ENEE691/main/homework5/Es_measured_varying_length.csv',header=None)
df_r = pd.read_csv('https://raw.githubusercontent.com/simsekergun/ENEE691/main/homework5/Es_real_varying_length.csv',header=None)
```

Es_measured_varying_length.csv includes the measured field intensities (red dashed lines in Fig. 2(d)). There are 2330 unique devices. For each device, we measure the electric field 200 unique locations, which are uniformly placed along the measurement platform.

Es_real_varying_length.csv includes the true field intensities (blue dashed lines in Fig. 2(d)) calculated at 400 unique locations along the device under investigation.

Note that "Es_measured_varying_length.csv" is the input of your neural network and the other file is the output. Please use 20% of the entire dataset for testing and 80% for training.

TASK-1 (30 points)
Use linear regression to convert blurry e-field measurements into non-blurry ones. Calculate the mean squared error (MSE). Plot a few samples of conversion results comparing the truth vs. predicted. They should look something like this:

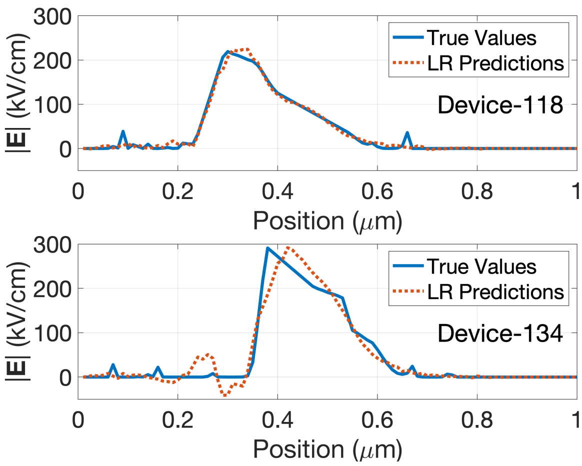

Figure 3: Electric field profiles: truth (blue solid curves) vs. prediction (red dashed curves) obtained with the FCNN for four randomly selected photodetectors.

TASK-2 (30 points)
Repeat task-1 using a fully-connected neural network. Note that you are free to choose your network architecture (in terms of number of layers and neurons) and other hyperparameters such as the optimizer.

TASK-3 (40 points)
Repeat task-1 using an LSTM. Note that this would require a many-to-many LSTM. You can always use the notebooks that we used in our lectures as a staring point.

Task-4 (Extra 20 points)
When you compare the MSE of three different neural nets, do you see a small or large difference? Which one is the most accurate? How about when you look at the field profiles? Do you anything special about FCNN implementation?
What would happen if we were using, let's say 200 measurements instead of almost 1700 measurements? If you don't have a clue, you can try by training your NNs with datasets with different lengths. The final answer is actually quite surprising.