Final Project: Bush Digital Spectroscope
Updated May 17th for Students

We will be building the Bush Digital Spectroscope (BDS) during this period. The Bush Digital Spectroscope will allow researchers to spectral images of various kinds of Electro-Magnetic radiation that our Planet Earth is bathed in every day. We will primarily focus of emission spectra formed by many sources of light, including those from the Sun, clouds, other reflected daylight from everyday objects, discharge tubes of elements like Hydrogen, Helium, Neon, Argon, Mercury, Nitrogen. We will also attempt to obtain spectra of open flames with Sodium Chloride, burning Metal strips and other chemicals prepared in cuvettes.

1. Build Phase - Build and test the spectroscope

Design:

The BDS is fully enclosed in a wooden box which contains a Raspberry Pi computer which will be programmed in Python to obtain spectra of sources above with the light entering through a slit on one end and a diffraction grating on the other end facing a connected digital camera of a Raspberry PI. The entire setup will be completely dark from any extraneous light allowing the dimmest of sources to clearly form a spectrum.

This spectroscope design is compact and operated completely wirelessly. The embedded rPI can be programmed to take hundreds of pictures which can be overlaid to obtain a clear spectrum with remarkable accuracy of frequency measurements with errors not exceeding just a few nano-meters. The BDS will also be able to capture frequencies beyond the visible range into both Ultraviolet and Infrared.

Budget:

This custom design formulated specifically for the Fundamentals of Computing for Researchers (FCSR) class is inexpensive, but also using state-of-the art technologies available today. The Bill of Materials each of the BDS is given below. The materials all together including the computer, diffraction grating, battery, and other equipment did not exceed $200 per BDS.

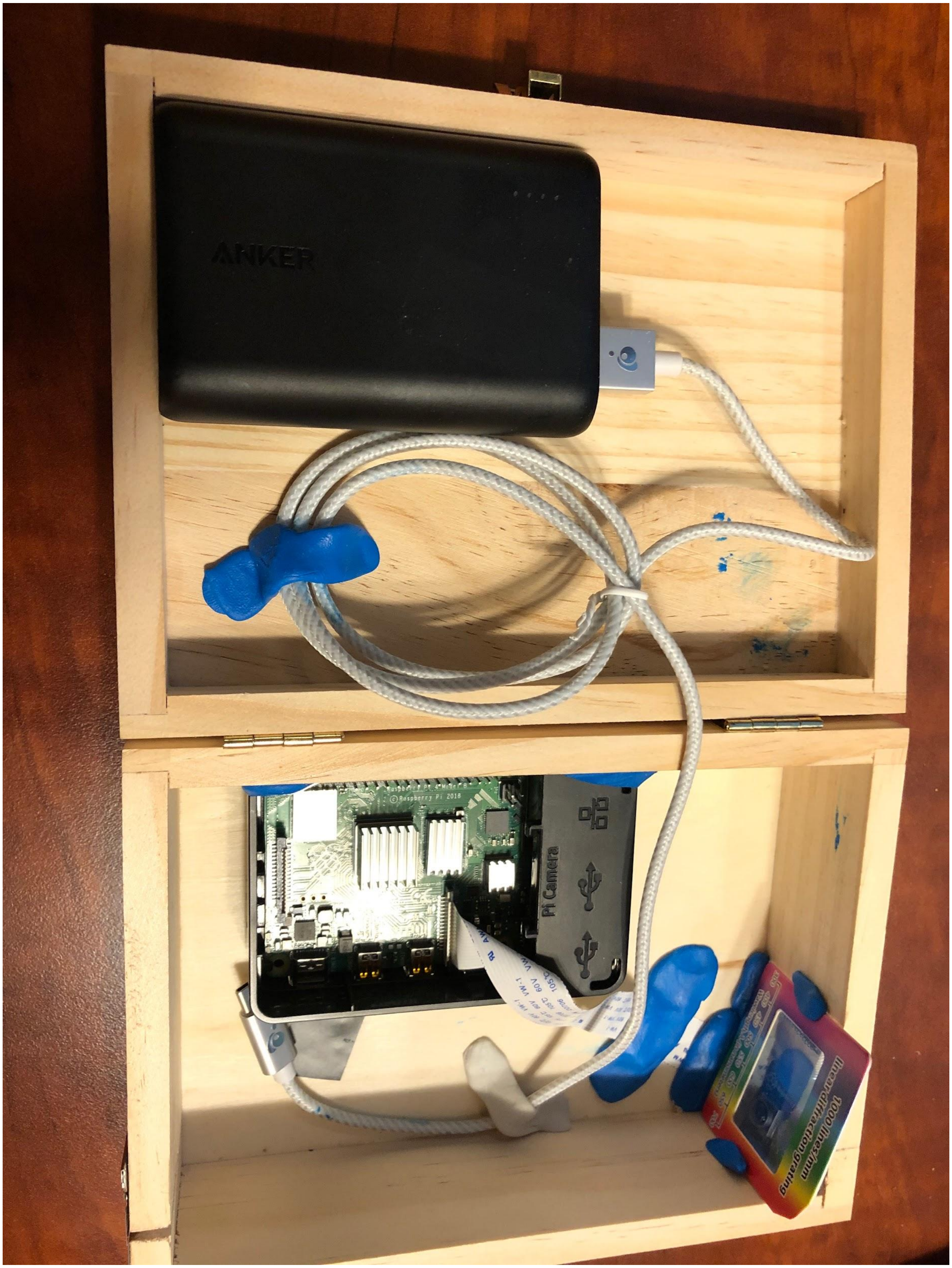
Bill of Materials:

1. Raspberry Pi 4 Computer
2. Visible/IR/UV Camera
3. **1000 lines/mm Diffraction Grating (Chandru will bring on Friday)**
4. **Self-contained Battery power for Computer (Use Blue tape for today. This can be re-done on Friday with Velcro)**
5. Fully enclosed connective cables
6. Construction materials - Velcro, Blue Tack)
7. Adjustable entry slit

Construction:

The students are divided in teams of 2-4 for this project and will build multiple spectroscopes, one per team. Each team noted here will follow the same process for construction with allowances made for creativity within design parameters. Each Raspberry Pi computer will be programmed using Python by the respective teams with specific and distinct purposes based on the assigned tasks. A model BDS was designed and built by the FCSR instructor and will welcome design improvements from each of the teams and they build their own BDS.

Please use a minimal amount of tack to result in a robust construction. See pictures below carefully. Please do not use more tack than necessary, it will become sloppy.
Please do not use the blue tack like Ply Doh - IT IS NOT TO BE USED FOR THAT THAT.


ANKER
Pi Camera
1000 lines/mm
linear diffraction grating


1000 lines/mm
linear diffraction grating
300 400 450 500 550 600 650 700
Wavelength, λ (in nanometers)


Raspberry Pi 4 Model B
© Raspberry Pi 2018
Pi Camera

Now it is your turn to build the BDS !!

Once you have built the BDS, you can connect the cable and test it via the links provided here. See the Spectroscope Project Team table at the bottom of the page. Verify that the bupi# is correct and corresponds to the assigned raspberry pi computer for your project. MAke sure that the Juoyter Notebook opens up on your system.

If you get this far, you can start updating the Jupyter Notebook by adding code from a prior notebook you have created that took images from the camera. You should able to produce images of the Slit appear in your Jupyter Notebook.

Good luck!

2. Software Phase - Develop code for the BDS

We will now develop Python code to use in the BDS. The software consists of several modules - both supplied and custom code.

Supplied functions

a. Identify slit
b. Count pixels
c. Adjust for Diffraction grating angle
d. Adjust for slit position
e. Adjust for exposure
f. Newton's method to determine ideal shutter speed for camera

Functions to develop

g. Determine ideal Shutter Speed
h. Calibrate for known spectral line frequency using Hydrogen
i. Obtain Emission Spectrum for a given source
j. Calculate frequencies of Spectral lines
k. Plot the graph of Emission Spectrum

3. Calibration Phase - Calibrate the BDS

We will now calibrate the BDS using a known spectral line of Hydrogen using a discharge tube or LED laser pointer. We will use the software we developed and obtain the spectral angle and wavelength factor to match the obtained frequency of the spectral line to the known frequency. We can adjust the wavelength factor to obtain a close match.

4. Experimental Phase - Obtain Emission spectral images from the BDS

We will use the calibrated spectrometer to obtain a series of spectral images and calculate the frequency distribution. We will then compare with the standard frequencies for each of the elements from the NIST and other publications.

We can calculate the deviation from the standard and compute the percentage error for each of the frequencies

5. Publication Phase - Calibrate the BDS

Organize and collate the results obtained for publication. We will create a Jupyter notebook of our results and analysis of each spectrum obtained.