LAB 12

Today's Lab has the following objectives:

1. Build a simple Graphical User Interface (GUI) that is easy to use with minimal instructions or understanding of the underlying technology.
2. Assess usability of user interfaces.
3. Design GUI enhancements to increase usability.

Background:

IoT – Internet-of-Things – ubiquitous networking and cheap computing and communication devices is ushering in rapid deployment of the Internet-of-Things. Here, we connect things (objects) in the physical world to the Internet, giving us a common infrastructure to sense, monitor, and control physical objects. This allows us to reach out from our computers and mobile devices to interact with the world. As an example, today we will look at controlling electrical outlets over the IP network.

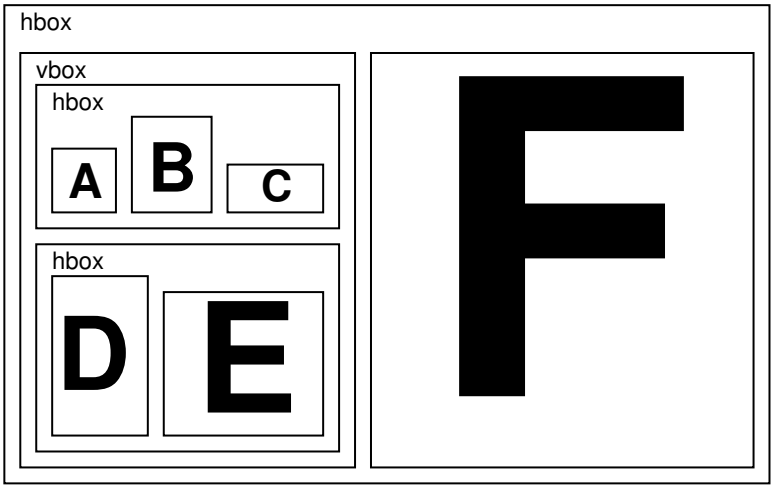
Sockets – as we saw in class and in lab last week, we can create a virtual communication channel between processes running on different machines by identifying the machines and the port on each machine. Headers in TCP/IP packets specify the sending and receiving (IP-address, port) pairs so that hardware and software can deliver the payload contents to the appropriate process on the machine. From a software standpoint, the way we connect the process to a port is by creating a socket. The socket registers the associated port and provides a stream the process can output data to or read data from. A key part of setting up network communication for a process is to create a socket associated with a particular port.

Concatenate (cat) – cat is the unix command-line tool for combining (concatenating) the output from several files and sending them somewhere. Often this somewhere is the terminal. So, one way to read a file on your computer screen is to simply cat the file. The output of cat can be sent to another unix program using the pipe construct that we saw in Lab 9.

Netcat (nc) – nc is a unix command-line tool that can send and receive data over the network. The "cat" part is by analogy with the cat routine above. Instead of sending data to the console, it can send its data over a network connection. As such, it takes arguments for the IP address of the destination host (when sending) and the port on the destination host. It can also listen on a port, in which case it specifies the port that it should receive data from. Rather than reading from files, it typically takes its input from (and produces its output to) another program using the pipe construct.

GUI: callback – a common idiom in GUI programming is to provide a *callback* routine that should be invoked whenever there is user input. This is an answer to the question: what should happen when a button is pressed? The callback routine tells the GUI which function to call. The function packages up the operations that should be performed then the GUI element receives input. Sometimes the callback routine will have an argument so the GUI can tell the function what input the user provided. You will see your first example of a button with callback in the Prelab.

GUI: Graphical composition – A common idiom when controlling the geometric placement of scalable graphical entities is to organize them into a hierarchy of boxes. That is, at the lowest level, we have some graphical item, like a letter, a paragraph of text, an image, or a button. Each of those entities has its own box size (number of vertical and horizontal pixels). The question is how do we layout these things next to each other? In the simplest form, we might put them one after another like text characters on a line. But, as we deal with images and buttons, we often want to be more deliberately about what's placed above/below other things. Starting with every primitive graphical item having some box size, we can then create larger boxes by putting other boxes over-under (vertical or vbox composition) or side-by-side (horizonal or hbox composition). The resulting box from a vbox or hbox composition is, itself, a box that can be used in another vbox or hbox composition. So, the following allows me to put A B and C side by side and over D and E then beside F.



Python – Python is a dynamically-typed, interpreted, high-level programming language. After C and MATLAB (and Java from CIS110), hopefully you're getting more and more comfortable with picking up and modifying code in different languages. There are many languages in use today, and new ones will continue to be invented that make specific things easier to do. So, you will find it useful to continue to pickup new languages throughout your career. We use Python for this lab because it is free and open-source and has some convenient and lightweight interface to GUI toolkits that will allow us to build useful interfaces with small amounts of new code. You will find similar GUI toolkits in most languages (including Java and MATLAB).

User Interface (UI) Assessment Rubric – in class we discussed many desirable properties of good user interfaces. For the purpose of this lab, we'll focus on a specific, somewhat simplified rubric for assessing the UIs we use or generate. This has 4 components:

1. User time -- How much time does it take for the user to accomplish the desired task? Saving the user time is generally good. This can be measured with a stop-watch. You may want to define a particular benchmark task that you can time. Steve Jobs used to motivate his designers by noting how many users they had and how often each user performed an operation and then computing number of lifetimes that could be saved if specific operations could be completed some number of seconds faster.
2. Cognitive load – How hard does the user have to think in order to perform the task? There is probably some correlation here to user time, but they can diverge depending on the UI. If the user needs to perform computations in their head or remember detailed facts correctly, that can lead to a high cognitive load. Here you can note what things a user needs to know and may need to figure out on their own.
3. Error prone – How likely is it that the user can make an error in interacting with the UI? A good UI will prevent users form making errors. In a more elaborate rubric we might break out how bad errors can be, how easy it is for users to understand what went wrong and how to recover, and how easy it is to recover form errors if they are possible. Here you might note what errors the user could make and perhaps identify what fraction of potential inputs from users would lead to errors.
4. Self describing – How much is the interface clear and usable without instruction? In general, we would be concerned with several things like: how long it takes to learn an interface, how often one needs to refer back to instructions, how easy it is to determine the right way to use the interface. The ultimately goal might be to have something that was immediately usable with no instruction and provided enough guidance so that anyone could learn how to use it quickly just by using the UI. Since our task is simple, we'll try to rate it in terms of how close it comes to this ultimate, self-describing goal. Here you can note how the UI might fall short of being self describing for a wide-range of audiences.

Prelab:

PreLab – Section 1: GUI Tools

- Collect the software you need to build and run the GUIs on your laptop.
- (Make sure your laptop is plugged into the power source throughout the installation process)

1. Installing python-gtk on your Mac.
    a. First let's check if you have brew installed on your Mac. To do this run
    `$ brew --version`
    If you get an output that shows versions of Homebrew that is installed on your Mac, then go to step d.
    Note, we show $ here to indicate the prompt form your terminal on the mac. It is not something you type.
    b. To install brew run this command:
    `$ ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/master/install)" < /dev/null 2> /dev/null`
    When prompted, type in your password. This command takes about 5 mins with good internet speed.
    c. Run `$ brew --version` again to see if the terminal outputs the version. Once you have successfully installed brew, move to the next step. If you get errors, please ask a TA for help or post on Piazza.
    d. Run this command on the terminal to see if you have PyGTK installed –
    `$ brew list | grep gtk`
    If your system has pygtk installed you will see the terminal output this:
    ```
    gtk+
    pygtk
    ```
    e. If you don't see this, follow the next few instructions to install it. If it is already installed, please continue to step (2)
    Run the following commands:
    `$ brew install pygtk`
    `$ brew install pygobject3 gtk+3`
    [see: https://pygobject.readthedocs.io/en/latest/getting_started.html#macosx-getting-started]
    This installation takes a couple of minutes. Run `$ brew list | grep gtk` again to see if you see gtk+ and pygtk installed.
2. To install PyGTK on Linux (Debian based Linux), use
    `$ sudo apt-get python-gtk2`
3. To install python-gtk on Windows,
    a. Follow the instructions to install MSYS2 and python-gtk on the site below:
    https://pygobject.readthedocs.io/en/latest/getting_started.html
    b. Whenever you need to use a terminal, run the following command in PowerShell:
    `C:\msys64\mingw64.exe`
    c. This will start a new terminal window, which starts in the path
    `C:\msys64\home\<username>`

d. You should make sure files into this location to see them in the terminal.

PreLab – Section 1: Visual access to biglab [fallback]

This is only necessary if you are unable to get Pythong GTK running on your laptop.

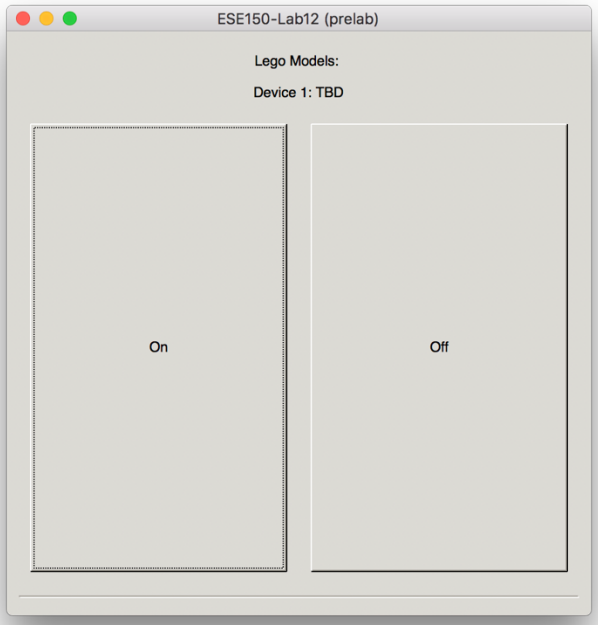
- Collect the software you need to run visuals tools on biglap and see them on your laptop.

1. If you have X windows running on your machine, you should be ready to go
    a. Use ssh -X -Y PENNKEY@enaic.seas.upenn.edu
    b. Then ssh -X -Y PENNKEY@biglab.seas.upenn.edu
    c. This is the same thing you did in Lab 9, except we'll target biglab
2. If you are running Linux, you probably have X.
3. If you are running OSX, you can install XQuartz to run X: https://www.xquartz.org
4. If you are running Windows, you can install Xming: https://sourceforge.net/projects/xming/
5. If you do not have X Windows, don't want to use X Windows, or have trouble with installing or operating X, you can use VNC. Follow the separate instructions provided instructions (from ESE570) for installing VNC and using it for Windows, Mac, or Linux.

Prelab – Section 2: Python GTK Buttons

- Build and extend a simple Python GUI.

1. If you did not already create ESE150_Lab12 during the Section 1 install, open a terminal and create it now.
   ```
   $ mkdir ESE150_Lab12
   ```
2. Pickup a starting UI from ~ese150/lab12/prelab_ui.py (or by downloading the support code for the lab from the course syllabus)
3. Copy it to your ESE150_Lab12 directory:
   ```
   $ cd ESE150-Lab12
   $ cp ~ese150/lab12/prelab_ui.py .
   ```
   [more likely the above is an scp from eniac to your laptop.]
   [there is also a ~ese150/lab12/prelab_ui_python3.py to use instead if you are running python3.]
   Run the python script by typing- `$ python prelab_ui.py`
   [or python3 prelab_ui_python3.py]
   You should see a GUI open up showing this :



   Now click on these two text boxes (Which are actually buttons).
   What do you see? From looking at the code, explain what is happening.
4. Modify it to add some functionality.
   a. Open the python script. And read through the code. Make sure you understand it. Also note that the you are only required to add a small section of the code which is commented #YOUR CODE GOES HERE. There will be a total of 3 line of added code.
      i. Here add a button labeled “Do not press this button”.

Use the syntax- button_name = gtk.Button("<string that should be displayed on the button>")

ii. Add a call back function to this button which when pressed it puts up a window that says "Please, do not press this button again." ☺ Please refer to the first section for this. (Use #Syntax - button_name.connect("clicked", <call back function name>, "<Data that is sent to the function>"))
    1. For amusement value on one source of this joke, see: https://www.youtube.com/watch?v=kLC8qPNU6_0
iii. Make this part of the hbox by using pack_start on hbox.
iv. Test and debug UI.

b. Change the layout so the new button is below the previous on-off buttons
    i. Copy prelab_ui.py to prelab_ui_vert.py
    ii. Change the packing command for your added button to pack on vbox_app instead of hbox
        1. This is a small change to only one line of code.
    iii. Test and debug revised UI.

5. Include your final prelab_ui.py, prelab_ui_vert.py and a screenshot of each GUI in your writeup.
6. Show your GUI to your TA for prelab checkoff.

Lab Procedure:

Lab – Section 1: Routes between computers

- Establish primitive network communication with an Internet-controlled power outlet

  We will use a Wemo Insight Smart Plug: https://www.belkin.com/us/p/P-F7C029/

These are controlling a number of lighted LEGO models:

1. Determine the port you should use to control a Wemo Insight power outlet.

   a. See the port assigned in the Partners and Port spreadsheet.
2. Connect to https://meet.google.com/bqf-csqv-mzd to view the lighted models controlled by the outlet.
   a. This meeting may need to be updated/replaced periodically; watch piazza for updates.

Pix below shows the back of the ChromeBook that is providing the video feed for the models:

Here's a side view that shows the collection of Wemo Insight's that you will be controlling:

3. Copy the wemo_on.txt and wemo_off.txt files into your working directory for the lab.
   $ scp eniac.seas.upenn.edu:~ese150/lab12/wemo_*.txt .
4. Turn the outlet on and off using:
   a. $ cat wemo_on.txt | nc 66.92.55.241 assigned-port
      i. The router at 66.92.55.241 will forward the data to port 49153 on an internal IP address for a particular Wemo
   b. $ cat wemo_on.txt | nc 66.92.55.241 assigned-port
      i. The router at 66.92.55.241 will forward the data to port 49153 on an internal IP address for a particular Wemo
   c. Note this is the same command you used in Step 1; you are just sending specific content to a specific port on the Wemo outlet.
   d. Make sure the outlet goes on and off based on what you send it.
5. Look at the wemo_on.txt file (use cat, more, or nano)
   a. Note how the beginning of the file looks like the beginning of the HTTP request you made last week. Identify the part that is similar and include in your report.
   b. Identify what is different between the wemo_on.txt and wemo_off.txt file. Include this in your report.
      i. It may be useful to use the diff command to get you started:
         $ diff wemo_on.txt wemo_off.txt

ii. If you've never used diff before, see how the output of diff relates to the two files you give it. You can also see the man page for diff.
iii. The diff will narrow down what you need to look at to one or more lines, but there is still quite a bit common between the lines. So, look further and identify what part of the lines are the same and different.

c. Based on your identified headers and difference, describe how these network messages are specifying that the outlet should be on or off.

6. Create a unix shell script that contains the unix command line that you used above (Step 5) to turn the device on and a second to turn the device off.
   a. Name based on the lighted structure your outlet is controlling.
   b. Use chmod -x to make the shell scripts executable.
      ```
      $ chmod –x script–name
      ```
   c. Test that you can turn the outlet on and off with your shell scripts.
   d. Include your shell scripts in your writeup.
   e. In your writeup,
      i. Describe how using the shell scripts is easier for you than using the raw unix command line? [assume you're coming back to use it 2 weeks from now.]
      ii. Describe how it is easier to use the shell script than to use the raw nc command for one of your classmates who only knows where to find the shell script and that it controls the lighted structure that goes with the name of the shell script.

Lab – Section 2: GUI

- Revise/extend your GUI to control your outlet and other outlets

1. Copy ~ese150/lab12/single_outlet.py (or ~ese150/lab12/single_outlet_python3.py) to your ESE150_Lab12 directory (or grab from the downloaded support code).
2. Review the code and comments
    a. This code includes a basic on/off UI like the prelab.
    b. It also contains code to perform a similar function to the netcat (nc) unix command you used to send messages between computers and to turn on and off your outlet. See sendCommand(…).
    c. Read through the comments in the code to see how it does that.
    d. Note that it takes an IP address in the host argument.
    e. Note that it takes a port number argument.
    f. Note that it takes a string to send in the command argument.
    g. Note that single_outlet.py also contains string variables that hold the same contents as wemo_on.txt and wemo_off.txt that can be used as the command string argument for this sendCommand sendCallback.
3. Revise single_outlet.py GUI to control the Wemo outlet:
    a. As provided, it has two buttons, on and off; they simply pop up windows like the prelab version.
    b. Change the callBacks for these buttons so that pushing a button calls the sendCallback/sendCommand routines with suitable arguments to turn your outlet on or off.
4. Test and debug your GUI.
5. Include your final single_outlet.py in your writeup.
6. Copy single_outlet.py to multi_outlet.py.
7. Revise multi_outlet.py by adding two more buttons so that it can control three lighted structures: yours, and two of the other models you can see.
    a. Label so it is clear which buttons do which things to which models.
    b. Coordinate with the assigned teams for testing.
    c. Test and Debug.
    d. Include multi_outlet.py in your writeup.
8. Copy multi_outlet.py to visual_outlet.py.
9. Copy over the png images from ~ese150/lab12/
10. Revise visual_outlet.py so that the it uses the images to visually denote the lighted structure controlled by the buttons on the GUI.
    a. prelab_image_ui.py (or prelab_image_ui_python3.py) in ~ese150/lab12 is the same as prelab_ui.py except that it uses an image for the “on” button instead of text. Use that as a template to see how to use images on buttons. Again, diff may be helpful in identifying the exact differences between the two files.
    b. You may want to rearrange on and off buttons so they are a vertical rather than horizontal pair.

c. Coordinate with other teams for testing.
d. Test and Debug.
e. Have a TA use your GUI.
    i. Note how easily the TA could use your GUI and/or what problems they had.
    ii. Include that results in your writeup.
    iii. This is the required part of the lab checkoff.
f. Include visual_outlet.py in your writeup.
g. Include a screenshot of visual_outlet.py UI window in your writeup.

11. Use the lab UI rubric to compare 4 UIs and include in report:
    a. Using netcat -- Section 1, Step 4
    b. Using a script – Section 1, Step 6
    c. multi_outlet.py
    d. visual_outlet.py

    You probably want to write this up properly outside of lab time.
    Make sure you take adequate notes on your experience during lab that you can complete this outside of lab.
12. Improve the GUI further.
    a. How would you make the GUI even more usable?
    b. Draw up the revised GUI in PowerPoint and describe the interactions.
        i. Include in your report.
    c. Assess the improved GUI using the UI rubric.
    d. (optional) implement the GUI or a step between the visual_outlet.py GUI and this envisioned GUI.

Postlab:

There is no separate postlab. Remember to complete the UI rubric assessment comparison among all 5 UIs (4 noted in Section 2, Step 11; then Step 12).

HOW TO TURN IN THE LAB

- Each individual student should author their own, independent writeup and submit a PDF document to canvas containing:
    - Recorded data and descriptions/explanations where asked.
    - Code developed.
    - Screenshot of visual_outlet.py UI window.
    - Improved GUI (Section 2, Step 12).
    - UI Assessments.
- Note that this is due Wednesday, April 29th (last day of classes) at 11:59pm.
    - By Penn regulations, in a class with a final (which we have), nothing can be due after classes end.