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1. Google Colab – Introduction

Google is quite aggressive in AI research. Over many years, Google developed AI framework called **TensorFlow** and a development tool called **Colaboratory**. Today TensorFlow is open-sourced and since 2017, Google made Colaboratory free for public use. Colaboratory is now known as Google Colab or simply **Colab**.

Another attractive feature that Google offers to the developers is the use of GPU. Colab supports GPU and it is totally free. The reasons for making it free for public could be to make its software a standard in the academics for teaching machine learning and data science. It may also have a long term perspective of building a customer base for Google Cloud APIs which are sold per-use basis.

Irrespective of the reasons, the introduction of Colab has eased the learning and development of machine learning applications.

So, let us get started with Colab.

2. Google Colab – What is Google Colab?

If you have used **Jupyter** notebook previously, you would quickly learn to use Google Colab. To be precise, Colab is a free Jupyter notebook environment that runs entirely in the cloud. Most importantly, it does not require a setup and the notebooks that you create can be simultaneously edited by your team members - just the way you edit documents in Google Docs. Colab supports many popular machine learning libraries which can be easily loaded in your notebook.

What Colab Offers You?

As a programmer, you can perform the following using Google Colab.

- Write and execute code in Python
- Document your code that supports mathematical equations
- Create/Upload/Share notebooks
- Import/Save notebooks from/to Google Drive
- Import/Publish notebooks from GitHub
- Import external datasets e.g. from Kaggle
- Integrate PyTorch, TensorFlow, Keras, OpenCV
- Free Cloud service with free GPU

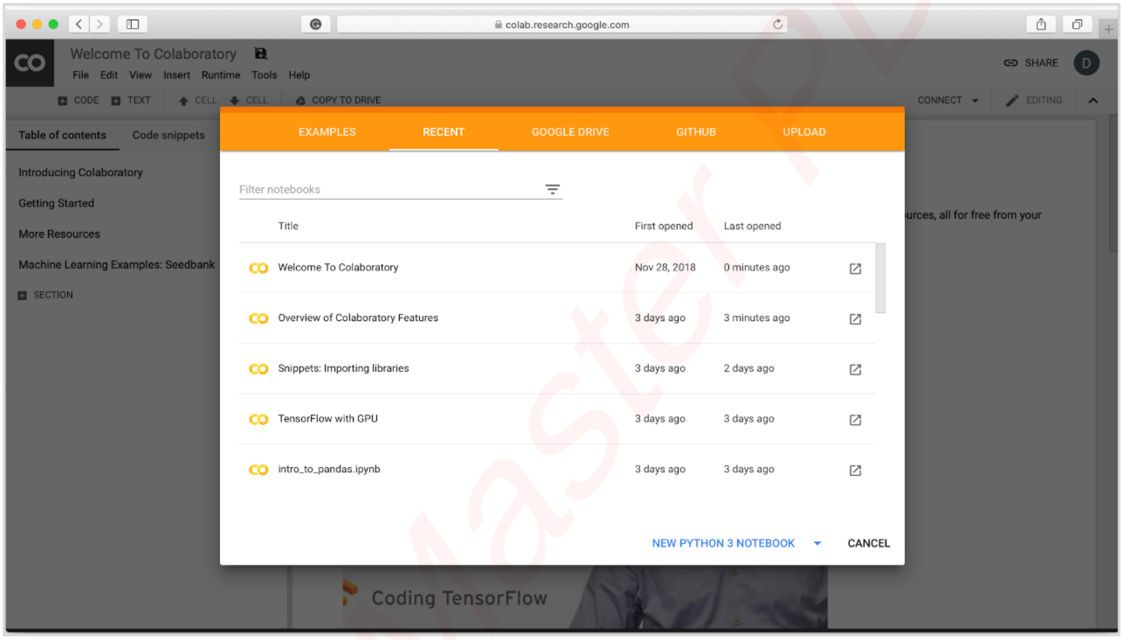
3. Google Colab – Your First Colab Notebook

In this chapter, you will create and execute your first trivial notebook. Follow the steps that have been given wherever needed.

Note: As Colab implicitly uses Google Drive for storing your notebooks, ensure that you are logged in to your Google Drive account before proceeding further.

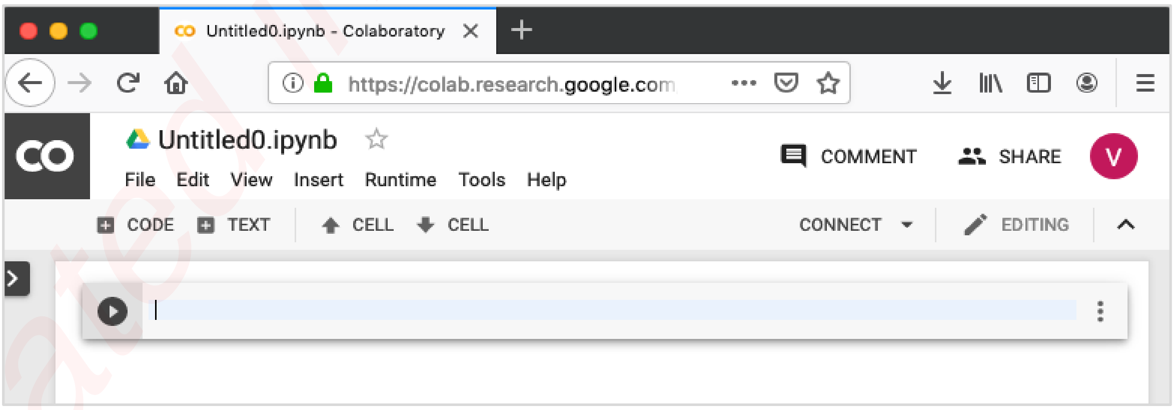
Step 1: Open the following URL in your browser: https://colab.research.google.com

Your browser would display the following screen (assuming that you are logged into your Google Drive):



Title	First opened	Last opened
Welcome To Colaboratory	Nov 28, 2018	0 minutes ago
Overview of Colaboratory Features	3 days ago	3 minutes ago
Snippets: Importing libraries	3 days ago	2 days ago
TensorFlow with GPU	3 days ago	3 days ago
intro_to_pandas.ipynb	3 days ago	3 days ago

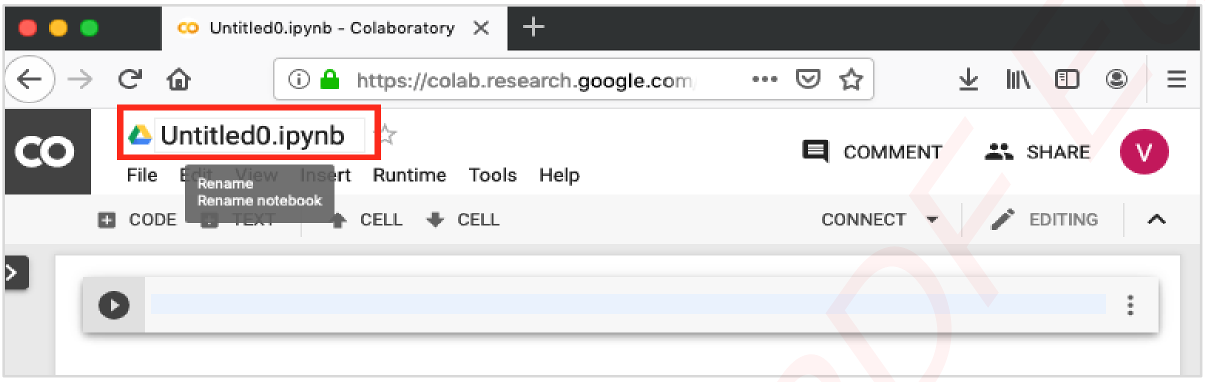
Step 2: Click on the **NEW PYTHON 3 NOTEBOOK** link at the bottom of the screen. A new notebook would open up as shown in the screen below.


Untitled0.ipynb - Colaboratory
https://colab.research.google.com
Untitled0.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE TEXT CELL CELL
CONNECT
EDITING

As you might have noticed, the notebook interface is quite similar to the one provided in Jupyter. There is a code window in which you would enter your Python code.

Setting Notebook Name

By default, the notebook uses the naming convention **UntitledXX.ipynb**. To rename the notebook, click on this name and type in the desired name in the edit box as shown here:


Untitled0.ipynb - Colaboratory
https://colab.research.google.com
Untitled0.ipynb
File Edit View Insert Runtime Tools Help
Rename
Rename notebook
COMMENT
SHARE
CODE TEXT CELL CELL
CONNECT
EDITING

We will call this notebook as **MyFirstColabNotebook**. So type in this name in the edit box and hit ENTER. The notebook will acquire the name that you have given now.

Entering Code

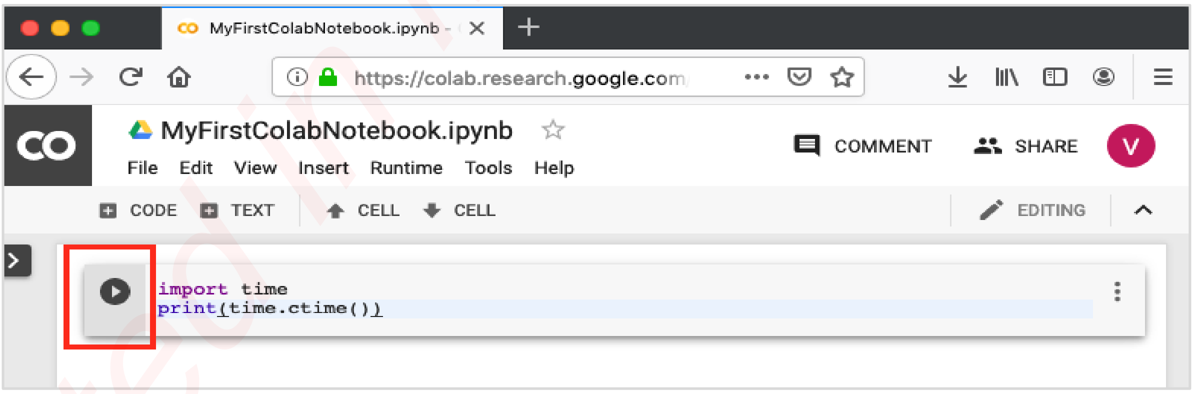
You will now enter a trivial Python code in the code window and execute it.

Enter the following two Python statements in the code window:

```
import time
print(time.ctime())
```

Executing Code

To execute the code, click on the arrow on the left side of the code window.

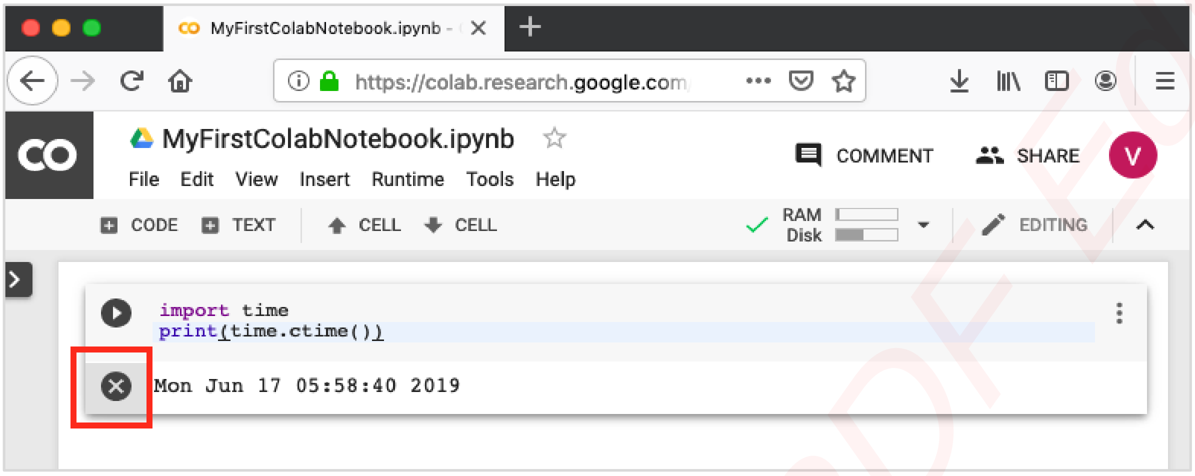

MyFirstColabNotebook.ipynb -
https://colab.research.google.com
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE TEXT CELL CELL
EDITING

```
import time
print(time.ctime())
```

After a while, you will see the output underneath the code window, as shown here:

```
Mon Jun 17 05:58:40 2019
```

You can clear the output anytime by clicking the icon on the left side of the output display.


MyFirstColabNotebook.ipynb
https://colab.research.google.com
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
RAM Disk
EDITING

```
import time
print(time.ctime())
```

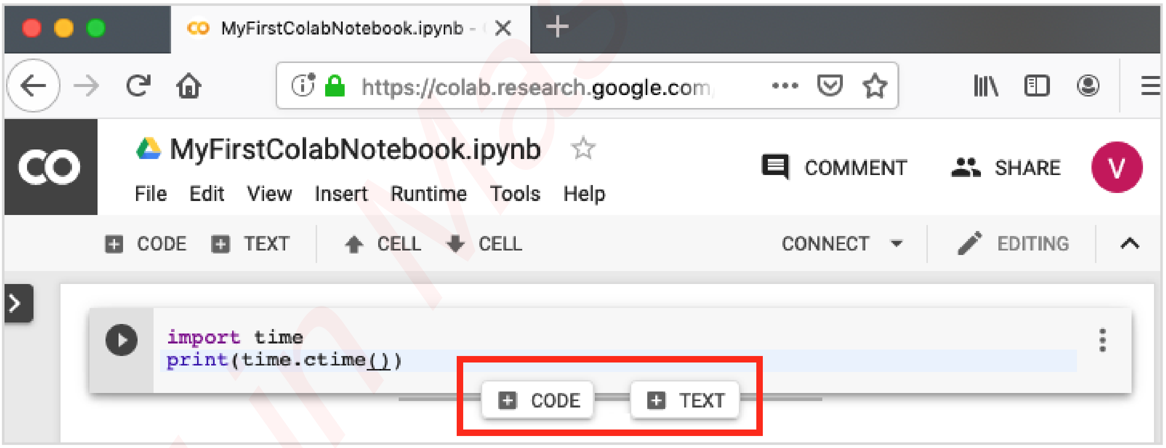
```
Mon Jun 17 05:58:40 2019
```

Adding Code Cells

To add more code to your notebook, select the following **menu** options:

```
Insert / Code Cell
```

Alternatively, just hover the mouse at the bottom center of the Code cell. When the **CODE** and **TEXT** buttons appear, click on the CODE to add a new cell. This is shown in the screenshot below:


MyFirstColabNotebook.ipynb
https://colab.research.google.com
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
CONNECT
EDITING
CODE
TEXT

```
import time
print(time.ctime())
```

A new code cell will be added underneath the current cell. Add the following two statements in the newly created code window:

```
time.sleep(5)
print (time.ctime())
```

Now, if you run this cell, you will see the following output:

```
Mon Jun 17 04:50:27 2019
```

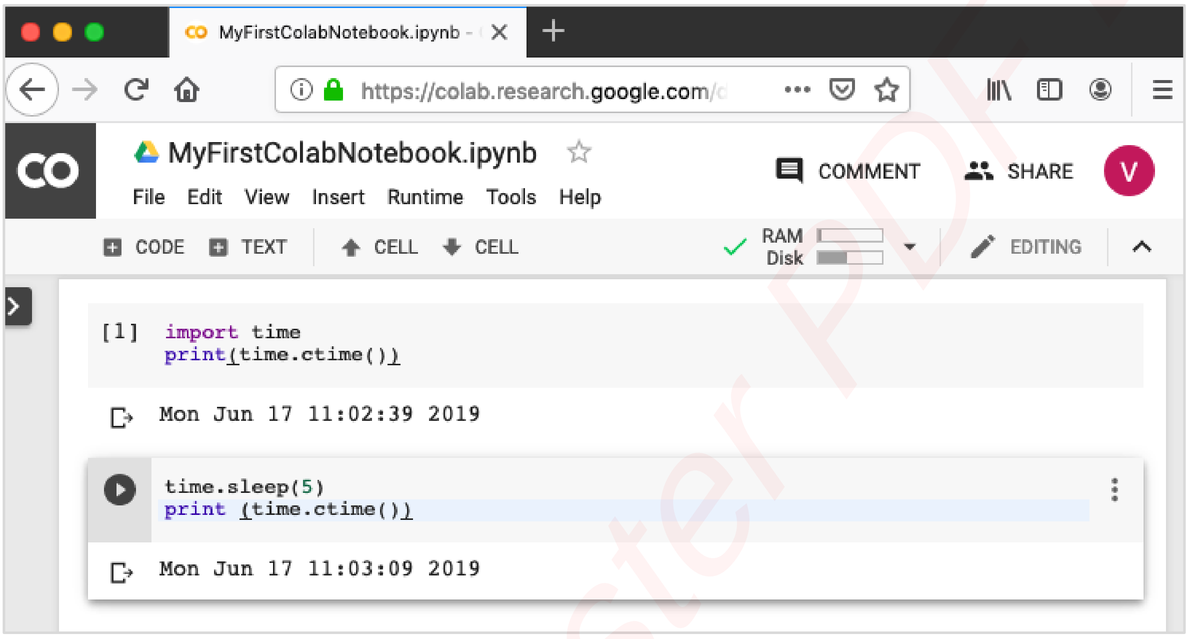
Certainly, the time difference between the two time strings is not 5 seconds. This is obvious as you did take some time to insert the new code. Colab allows you to run all code inside your notebook without an interruption.

Run All

To run the entire code in your notebook without an interruption, execute the following menu options:

```
Runtime / Reset and run all…
```

It will give you the output as shown below:


MyFirstColabNotebook.ipynb
https://colab.research.google.com/
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE TEXT CELL CELL
RAM Disk
EDITING

```
[1] import time
    print(time.ctime())

Mon Jun 17 11:02:39 2019

time.sleep(5)
print (time.ctime())

Mon Jun 17 11:03:09 2019
```

Note that the time difference between the two outputs is now exactly 5 seconds.

The above action can also be initiated by executing the following two menu options:

```
Runtime / Restart runtime…
```

or

```
Runtime / Restart all runtimes…
```

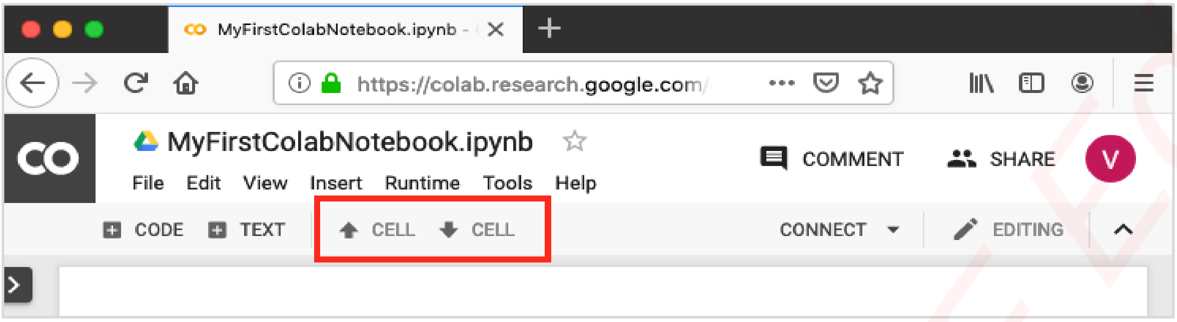
Followed by

```
Runtime / Run all
```

Study the different menu options under the **Runtime** menu to get yourself acquainted with the various options available to you for executing the notebook.

Changing Cell Order

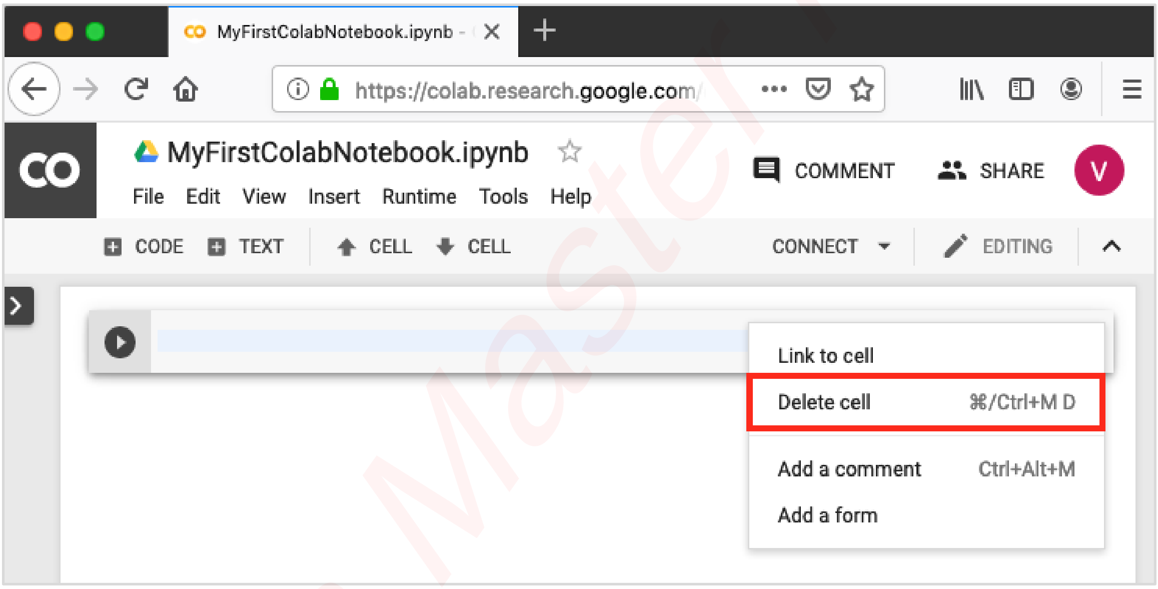
When your notebook contains a large number of code cells, you may come across situations where you would like to change the order of execution of these cells. You can do so by selecting the cell that you want to move and clicking the **UP CELL** or **DOWN CELL** buttons shown in the following screenshot:


MyFirstColabNotebook.ipynb
https://colab.research.google.com/
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
CONNECT EDITING

You may click the buttons multiple times to move the cell for more than a single position.

Deleting Cell

During the development of your project, you may have introduced a few now-unwanted cells in your notebook. You can remove such cells from your project easily with a single click. Click on the vertical-dotted icon at the top right corner of your code cell.


MyFirstColabNotebook.ipynb
https://colab.research.google.com/
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
CONNECT EDITING
Link to cell
Delete cell ⌘/Ctrl+M D
Add a comment Ctrl+Alt+M
Add a form

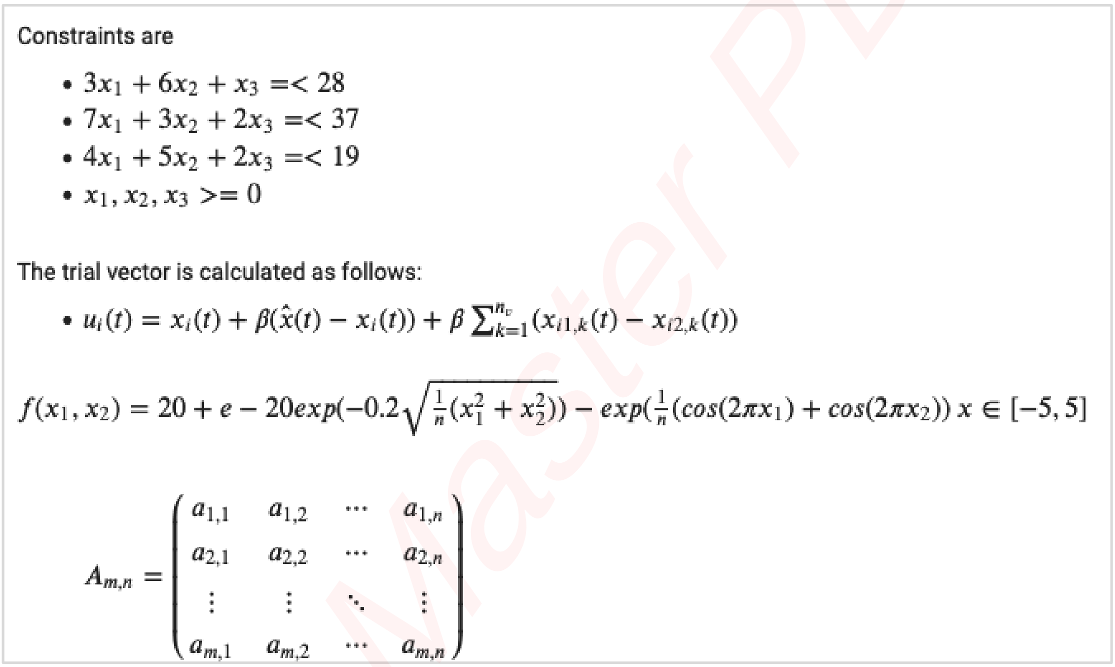
Click on the **Delete cell** option and the current cell will be deleted.

Now, as you have learned how to run a trivial notebook, let us explore the other capabilities of Colab.

4. Google Colab – Documenting Your Code

As the code cell supports full Python syntax, you may use Python **comments** in the code window to describe your code. However, many a time you need more than a simple text based comments to illustrate the ML algorithms. ML heavily uses mathematics and to explain those terms and equations to your readers you need an editor that supports LaTex - a language for mathematical representations. Colab provides **Text Cell**s for this purpose.

A text cell containing few mathematical equations typically used in ML is shown in the screenshot below:



Constraints are

- $3x_1 + 6x_2 + x_3 =< 28$
- $7x_1 + 3x_2 + 2x_3 =< 37$
- $4x_1 + 5x_2 + 2x_3 =< 19$
- $x_1, x_2, x_3 >= 0$

The trial vector is calculated as follows:

- $u_i(t) = x_i(t) + \beta(\hat{x}(t) - x_i(t)) + \beta \sum_{k=1}^{n_v}(x_{i1,k}(t) - x_{i2,k}(t))$

$$f(x_1, x_2) = 20 + e - 20exp(-0.2\sqrt{\frac{1}{n}(x_1^2 + x_2^2)}) - exp(\frac{1}{n}(cos(2\pi x_1) + cos(2\pi x_2)) \; x \in [-5, 5]$$

$$A_{m,n} = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m,1} & a_{m,2} & \cdots & a_{m,n} \end{pmatrix}$$

As we move ahead in this chapter, we will see the code for generating the above output.

Text Cells are formatted using **markdown** - a simple markup language. Let us now see you how to add text cells to your notebook and add to it some text containing mathematical equations.

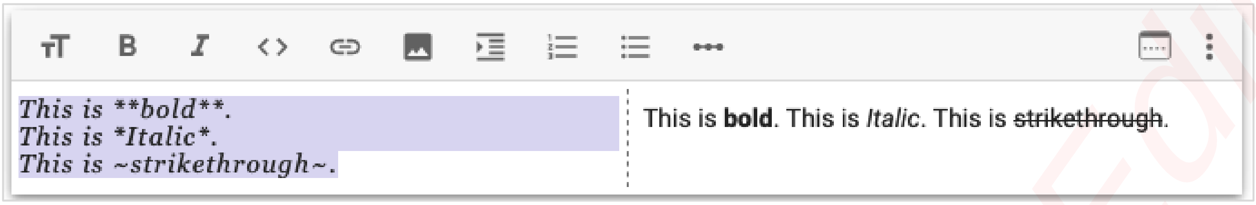
Markdown Examples

Let us look into few examples of markup language syntax to demonstrate its capabilities.

Type in the following text in the Text cell.

```
This is **bold**.
This is *italic*.
This is ~strikethrough~.
```

The output of the above commands is rendered on the right hand side of the **Cell** as shown here.



```
This is **bold**.
This is *Italic*.
This is ~strikethrough~.
```

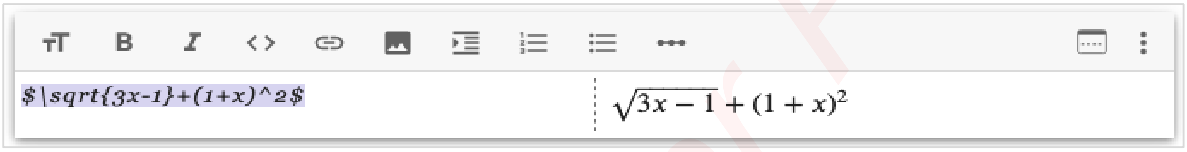
This is **bold**. This is *Italic*. This is ~~strikethrough~~.

Mathematical Equations

Add a **Text Cell** to your notebook and enter the following markdown syntax in the text window:

```
$\sqrt{3x-1}+(1+x)^2$
```

You will see the immediate rendering of the markdown code in the right hand side panel of the text cell. This is shown in the screenshot below:



```
$\sqrt{3x-1}+(1+x)^2$
```

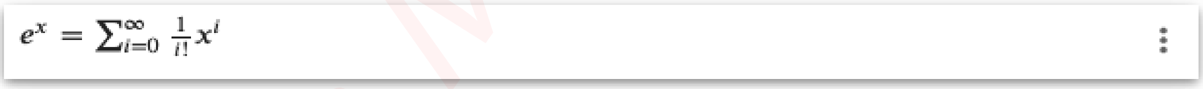
$\sqrt{3x-1}+(1+x)^2$

Hit **Enter** and the markdown code disappears from the text cell and only the rendered output is shown.

Let us try another more complicated equation as shown here:

```
$e^x=\sum_{i=0}^\infty \frac{1}{i!}x^i$
```

The rendered output is shown here for your quick reference.



$e^x=\sum_{i=0}^\infty \frac{1}{i!}x^i$

Code for Sample Equations

Here is the code for the sample equations shown in an earlier screenshot:

```
Constraints are
   - $3x_1  +  6x_2 + x_3 =< 28$
   - $7x_1  +  3x_2 + 2x_3  =< 37$
   - $4x_1  +  5x_2 + 2x_3 =< 19$
   - $x_1,x_2,x_3 >=0 $

The trial vector is calculated as follows:
- $u_i(t) = x_i(t) + \beta(\hat{x}(t) − x_i(t)) + \beta \sum_{k = 1}^{n
        _v}(x_{i1,k}(t) − x_{i2,k}(t))$
```

```
$f(x_1, x_2) = 20 + e - 20exp(-0.2 \sqrt {\frac {1}{n} (x_1^2 + x_2^2)}) - exp
(\frac {1}{n}(cos(2\pi x_1) + cos(2\pi x_2))$

$x ∈ [-5, 5]$


>$A_{m,n} =

 \begin{pmatrix}

  a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\

  a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\

  \vdots  & \vdots  & \ddots & \vdots  \\

  a_{m,1} & a_{m,2} & \cdots & a_{m,n}

 \end{pmatrix}$
```

Describing full markup syntax is beyond the scope of this tutorial. In the next chapter, we will see how to save your work.

5. Google Colab – Saving Your Work

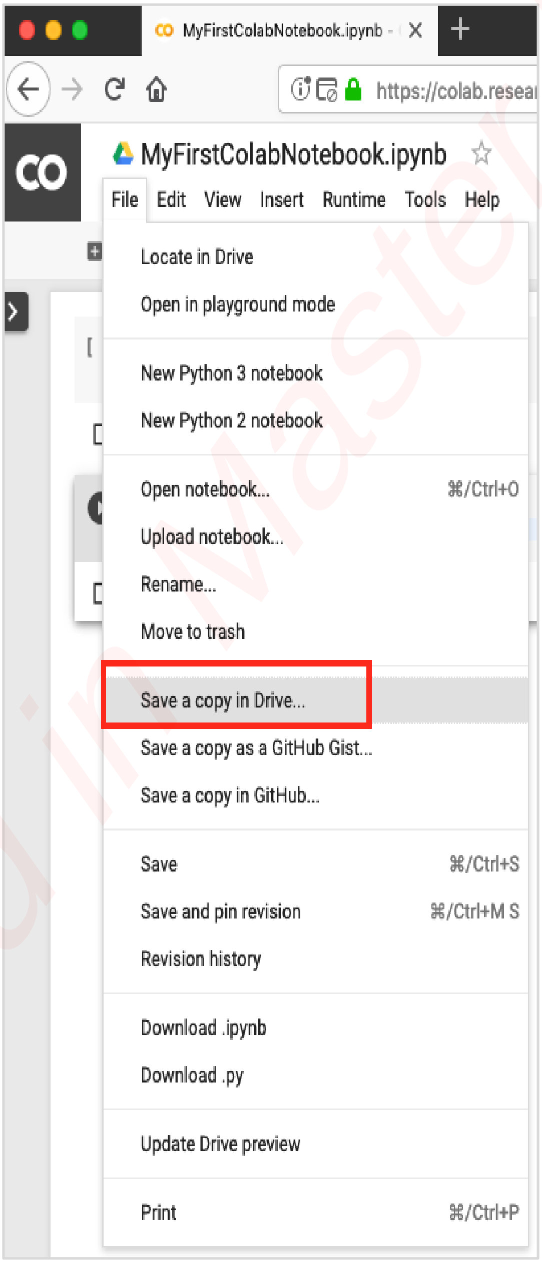
Colab allows you to save your work to Google Drive or even directly to your GitHub repository.

Saving to Google Drive

Colab allows you to save your work to your Google Drive. To save your notebook, select the following menu options:

```
File / Save a copy in Drive…
```

You will see the following screen:



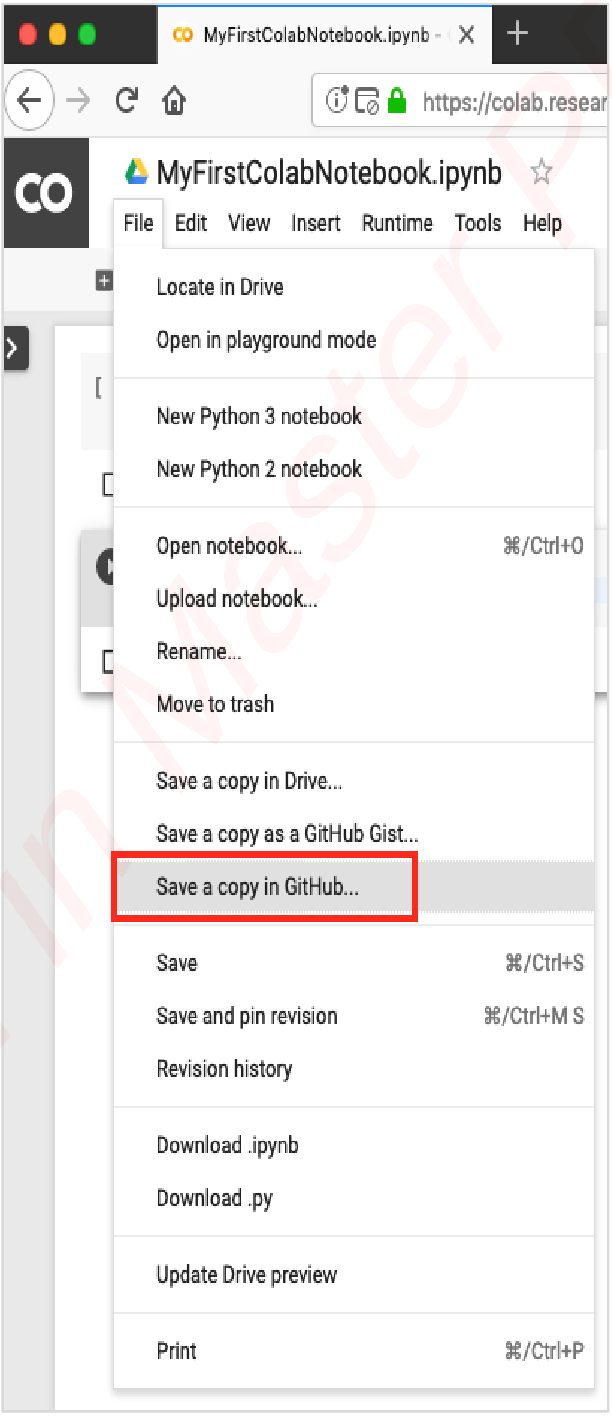
The action will create a copy of your notebook and save it to your drive. Later on you may rename the copy to your choice of name.

Saving to GitHub

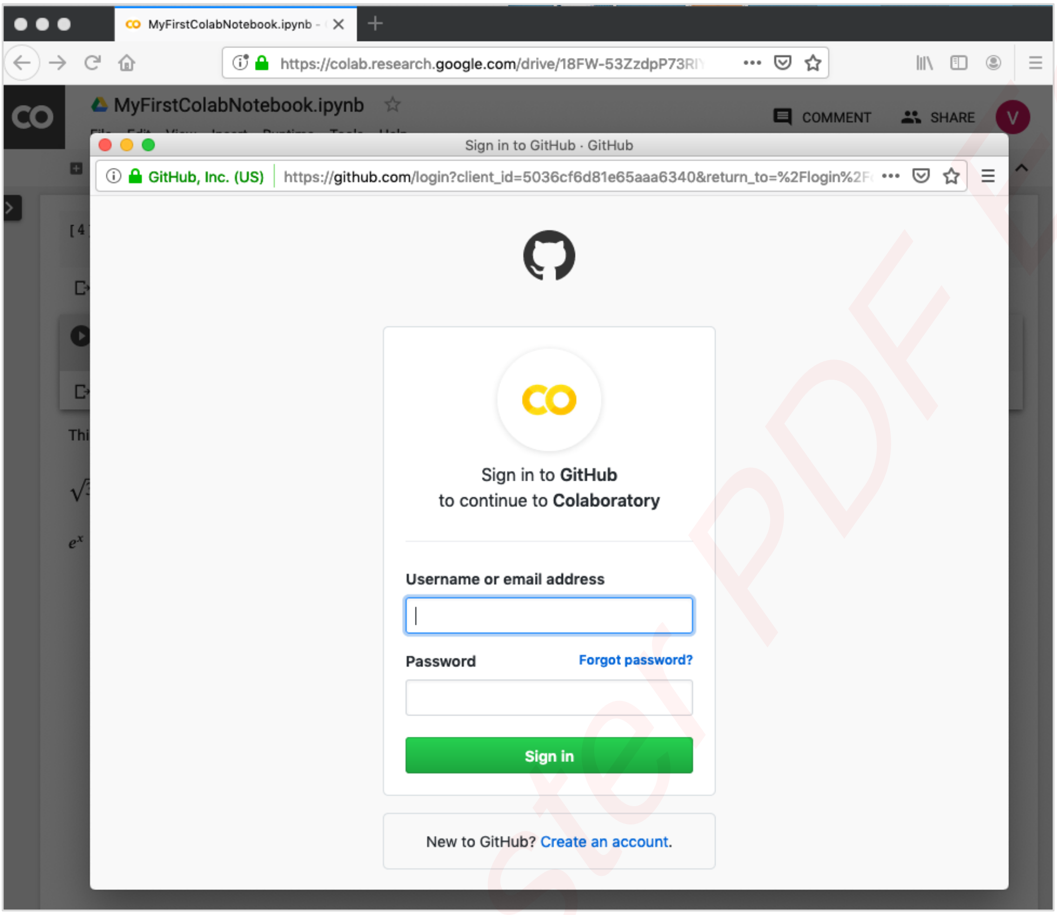
You may also save your work to your GitHub repository by selecting the following menu options:

```
File / Save a copy in GitHub...
```

The menu selection is shown in the following screenshot for your quick reference:



You will have to wait until you see the login screen to GitHub.



Sign in to GitHub · GitHub

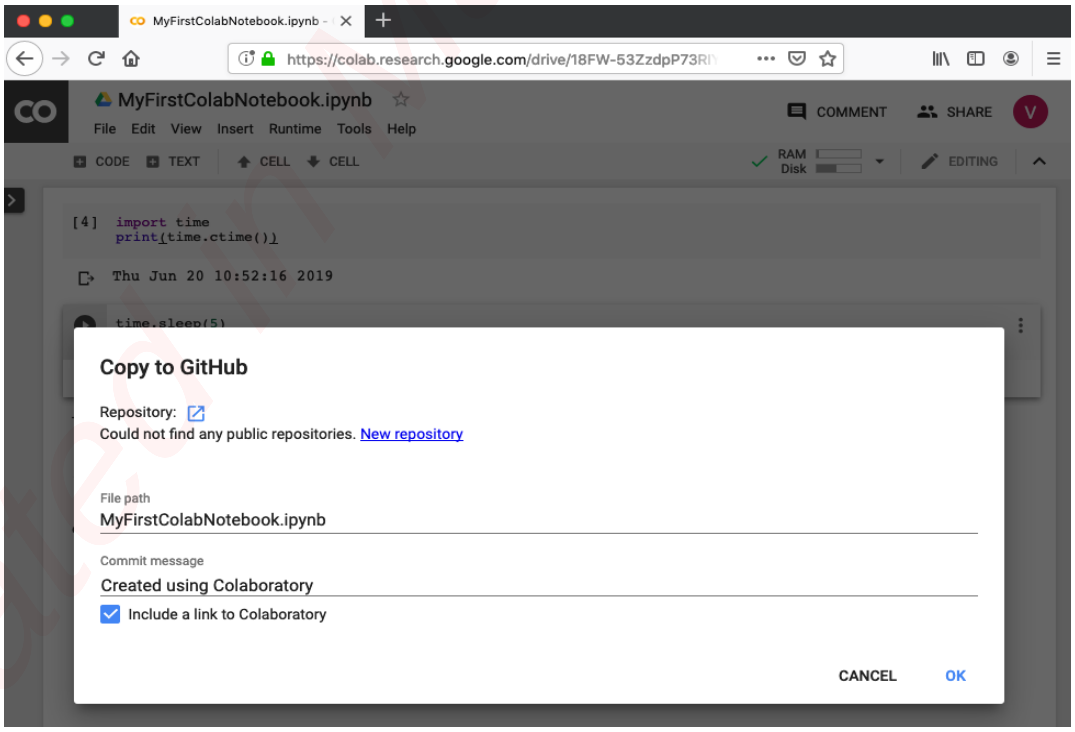
https://github.com/login?client_id=5036cf6d81e65aaa6340&return_to=%2Flogin%2F

Sign in to GitHub
to continue to Colaboratory

Username or email address

Password

Now, enter your credentials. If you do not have a repository, create a new one and save your project as shown in the screenshot below:



```
[4]  import time
     print(time.ctime())

Thu Jun 20 10:52:16 2019
```

Copy to GitHub

Repository:
Could not find any public repositories. New repository

File path
MyFirstColabNotebook.ipynb

Commit message
Created using Colaboratory

☑ Include a link to Colaboratory

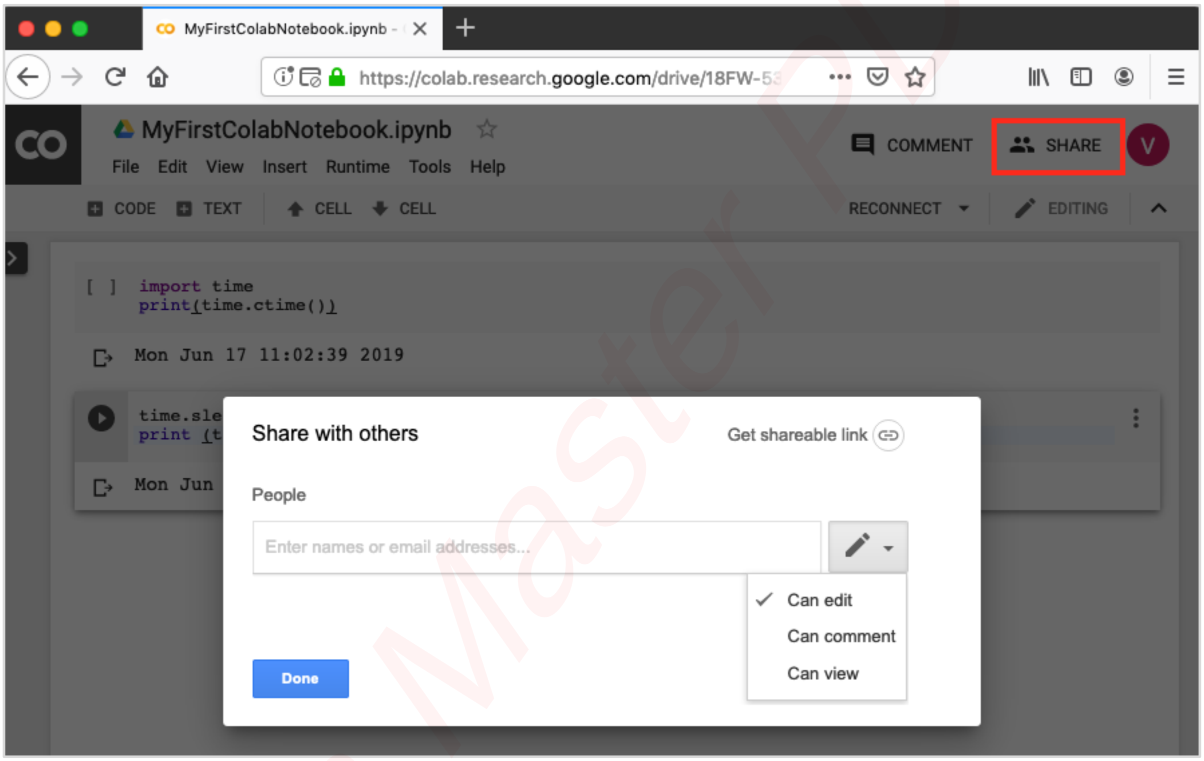
In the next chapter, we will learn how to share your work with others.

6. Google Colab – Sharing Notebook

To share the notebook that you have created with other co-developers, you may share the copy that you have made in your Google Drive.

To publish the notebook to general audience, you may share it from your GitHub repository.

There is one more way to share your work and that is by clicking on the **SHARE** link at the top right hand corner of your Colab notebook. This will open the share box as shown here:


MyFirstColabNotebook.ipynb -
https://colab.research.google.com/drive/18FW-5
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE TEXT CELL CELL
RECONNECT
EDITING
Share with others
Get shareable link
People
Enter names or email addresses...
Can edit
Can comment
Can view
Done

```
import time
print(time.ctime())
```

```
Mon Jun 17 11:02:39 2019
```

You may enter the email IDs of people with whom you would like to share the current document. You can set the kind of access by selecting from the three options shown in the above screen.

Click on the **Get shareable link** option to get the URL of your notebook. You will find options for whom to share as follows:

- Specified group of people
- Colleagues in your organization
- Anyone with the link
- All public on the web

Now. you know how to create/execute/save/share a notebook. In the Code cell, we used Python so far. The code cell can also be used for invoking system commands. This is explained next.

7. Google Colab – Invoking System Commands

Jupyter includes shortcuts for many common system operations. Colab Code cell supports this feature.

Simple Commands

Enter the following code in the Code cell that uses the system command **echo**.

```
message = 'A Great Tutorial on Colab by Tutorialspoint!'
greeting = !echo -e '$message\n$message'
greeting
```

Now, if you run the cell, you will see the following output:

```
['A Great Tutorial on Colab by Tutorialspoint!',
 'A Great Tutorial on Colab by Tutorialspoint!']
```

Getting Remote Data

Let us look into another example that loads the dataset from a remote server. Type in the following command in your Code cell:

```
!wget http://mlr.cs.umass.edu/ml/machine-learning-databases/adult/adult.data -P
"/content/drive/My Drive/app"
```

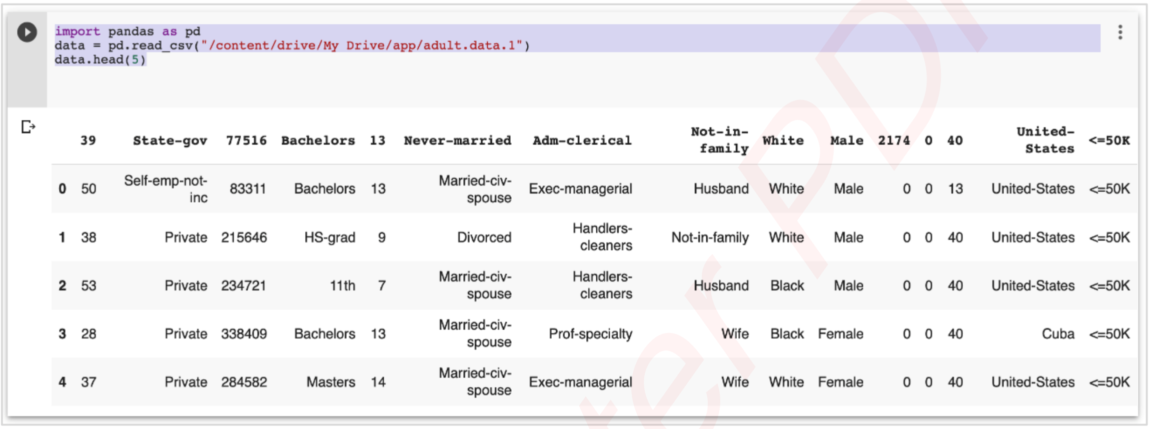
If you run the code, you would see the following output:

```
--2019-06-20 10:09:53--  http://mlr.cs.umass.edu/ml/machine-learning-
databases/adult/adult.data
Resolving mlr.cs.umass.edu (mlr.cs.umass.edu)... 128.119.246.96
Connecting to mlr.cs.umass.edu (mlr.cs.umass.edu)|128.119.246.96|:80...
connected.
HTTP request sent, awaiting response... 200 OK
Length: 3974305 (3.8M) [text/plain]
Saving to: ‘/content/drive/My Drive/app/adult.data.1’


adult.data.1        100%[===================>]   3.79M  1.74MB/s    in 2.2s


2019-06-20 10:09:56 (1.74 MB/s) - ‘/content/drive/My Drive/app/adult.data.1’
saved [3974305/3974305]
```

As the message says, the **adult.data.1** file is now added to your drive. You can verify this by examining the folder contents of your drive. Alternatively, type in the following code in a new Code cell:

```
import pandas as pd
data = pd.read_csv("/content/drive/My Drive/app/adult.data.1")
data.head(5)
```

Run the code now and you will see the following output:



```
import pandas as pd
data = pd.read_csv("/content/drive/My Drive/app/adult.data.1")
data.head(5)
```

	39	State-gov	77516	Bachelors	13	Never-married	Adm-clerical	Not-in-family	White	Male	2174	0	40	United-States	<=50K
0	50	Self-emp-not-inc	83311	Bachelors	13	Married-civ-spouse	Exec-managerial	Husband	White	Male	0	0	13	United-States	<=50K
1	38	Private	215646	HS-grad	9	Divorced	Handlers-cleaners	Not-in-family	White	Male	0	0	40	United-States	<=50K
2	53	Private	234721	11th	7	Married-civ-spouse	Handlers-cleaners	Husband	Black	Male	0	0	40	United-States	<=50K
3	28	Private	338409	Bachelors	13	Married-civ-spouse	Prof-specialty	Wife	Black	Female	0	0	40	Cuba	<=50K
4	37	Private	284582	Masters	14	Married-civ-spouse	Exec-managerial	Wife	White	Female	0	0	40	United-States	<=50K

Likewise, most of the system commands can be invoked in your code cell by prepending the command with an Exclamation Mark (!). Let us look into another example before giving out the complete list of commands that you can invoke.

Cloning Git Repository

You can clone the entire GitHub repository into Colab using the **git** command. For example, to clone the keras tutorial, type the following command in the Code cell:

```
!git clone https://github.com/wxs/keras-mnist-tutorial.git
```

After a successful run of the command, you would see the following output:

```
Cloning into 'keras-mnist-tutorial'...
remote: Enumerating objects: 26, done.
remote: Total 26 (delta 0), reused 0 (delta 0), pack-reused 26
Unpacking objects: 100% (26/26), done.
```

Once the repo is cloned, locate a Jupyter project (e.g. MINST in keras.ipyab) in it, right-click on the file name and select **Open With / Colaboratory** menu option to open the project in Colab.

System Aliases

To get a list of shortcuts for common operations, execute the following command:

```
!ls /bin
```

You will see the list in the output window as shown below:

```
bash*           journalctl*     sync*
bunzip2*        kill*           systemctl*
bzcat*          kmod*           systemd@
bzcmp@          less*           systemd-ask-password*
bzdiff*         lessecho*       systemd-escape*
bzegrep@        lessfile@       systemd-hwdb*
bzexe*          lesskey*        systemd-inhibit*
bzfgrep@        lesspipe*       systemd-machine-id-setup*
bzgrep*         ln*             systemd-notify*
bzip2*          login*          systemd-sysusers*
bzip2recover*   loginctl*       systemd-tmpfiles*
bzless@         ls*             systemd-tty-ask-password-agent*
bzmore*         lsblk*          tar*
cat*            lsmod@          tempfile*
chgrp*          mkdir*          touch*
chmod*          mknod*          true*
chown*          mktemp*         udevadm*
cp*             more*           ulockmgr_server*
dash*           mount*          umount*
date*           mountpoint*     uname*
dd*             mv*             uncompress*
df*             networkctl*     vdir*
dir*            nisdomainname@  wdctl*
dmesg*          pidof@          which*
dnsdomainname@  ps*             ypdomainname@
domainname@     pwd*            zcat*
echo*           rbash@          zcmp*
egrep*          readlink*       zdiff*
false*          rm*             zegrep*
fgrep*          rmdir*          zfgrep*
findmnt*        run-parts*      zforce*
fusermount*     sed*            zgrep*
```

```
grep*           sh@             zless*
gunzip*         sh.distrib@     zmore*
gzexe*          sleep*          znew*
gzip*           stty*
hostname*       su*
```

Execute any of these commands as we have done for **echo** and **wget**. In the next chapter, we shall see how to execute your previously created Python code.

8. Google Colab – Executing External Python Files

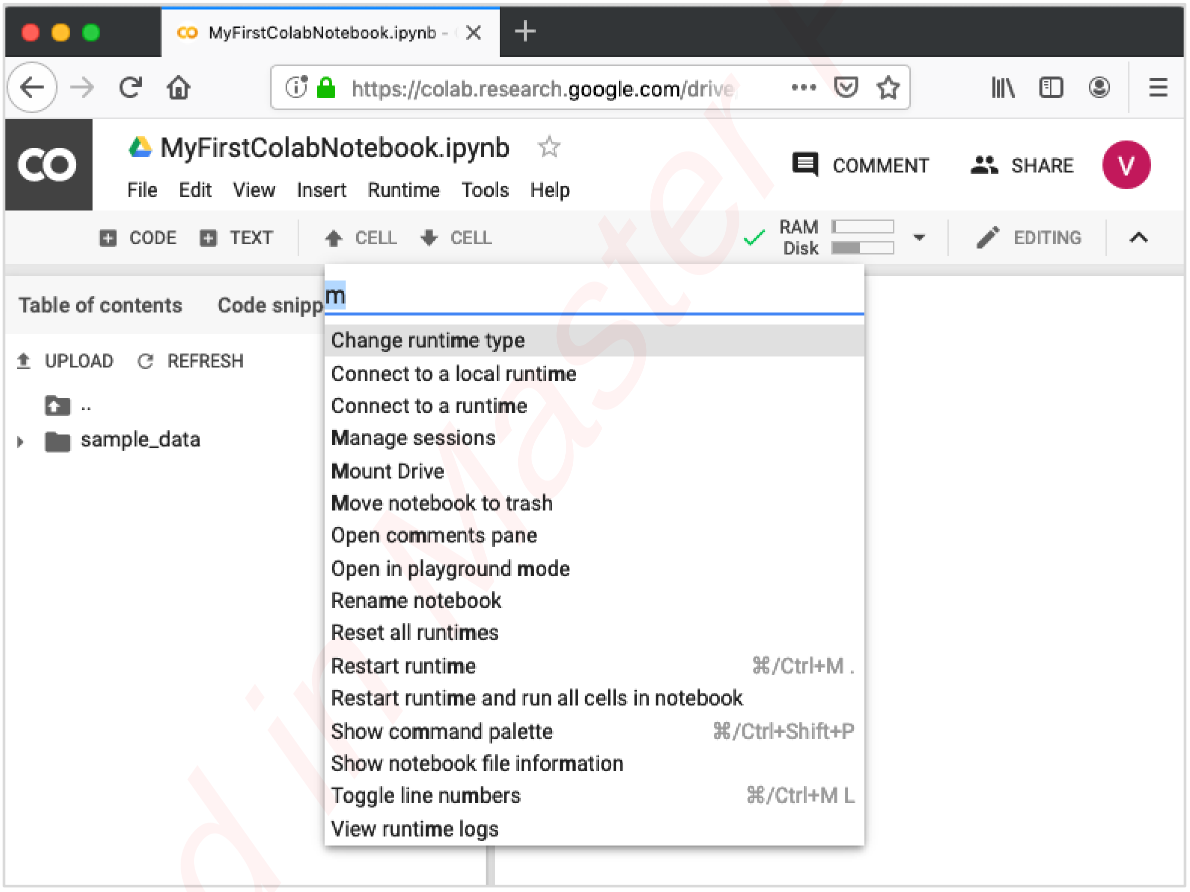
Suppose, you already have some Python code developed that is stored in your Google Drive. Now, you will like to load this code in Colab for further modifications. In this chapter, we will see how to load and run the code stored in your Google Drive.

Mounting Drive

First, you need to mount your Google Drive in Colab. Select the following menu options:

```
Tools / Command palette
```

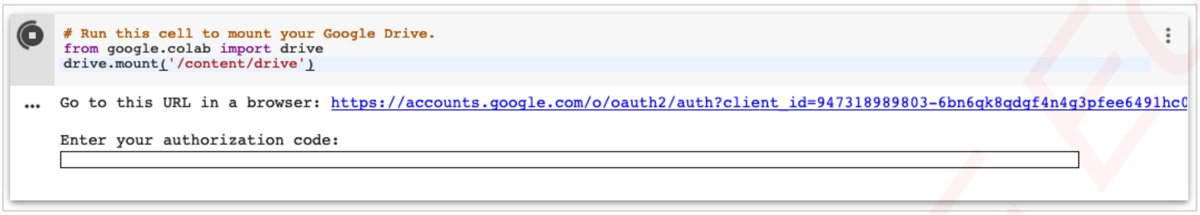
You will see the list of commands as shown in this screenshot:


MyFirstColabNotebook.ipynb
https://colab.research.google.com/drive
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE
TEXT
CELL
CELL
RAM
Disk
EDITING
Table of contents
Code snipp
UPLOAD
REFRESH
sample_data
m
Change runtime type
Connect to a local runtime
Connect to a runtime
Manage sessions
Mount Drive
Move notebook to trash
Open comments pane
Open in playground mode
Rename notebook
Reset all runtimes
Restart runtime ⌘/Ctrl+M .
Restart runtime and run all cells in notebook
Show command palette ⌘/Ctrl+Shift+P
Show notebook file information
Toggle line numbers ⌘/Ctrl+M L
View runtime logs

Type a few letters like "m" in the search box to locate the mount command. Select **Mount Drive** command from the list. The following code would be inserted in your Code cell.

```
# Run this cell to mount your Google Drive.
from google.colab import drive
drive.mount('/content/drive')
```

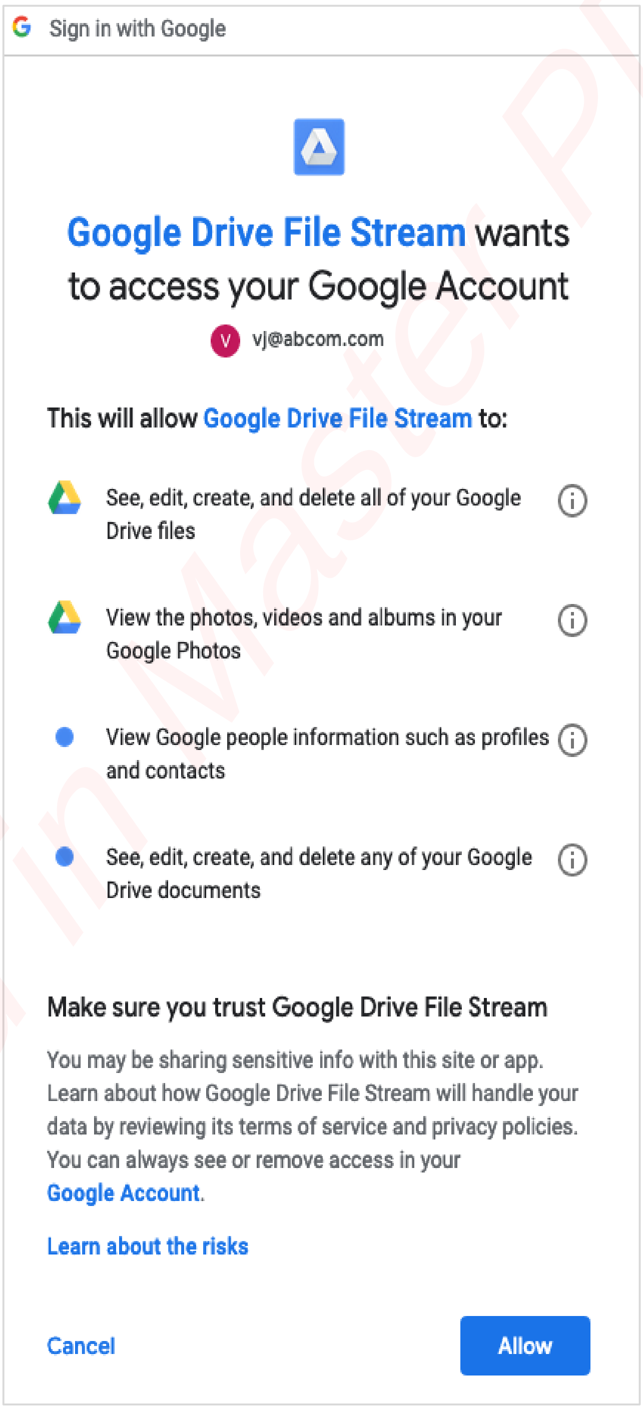
If you run this code, you will be asked to enter the authentication code. The corresponding screen looks as shown below:



```
# Run this cell to mount your Google Drive.
from google.colab import drive
drive.mount('/content/drive')
```

```
... Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3pfee6491hc0

    Enter your authorization code:
```

Open the above URL in your browser. You will be asked to login to your Google account. Now, you will see the following screen:



Sign in with Google

Google Drive File Stream wants to access your Google Account

vj@abcom.com

This will allow **Google Drive File Stream** to:

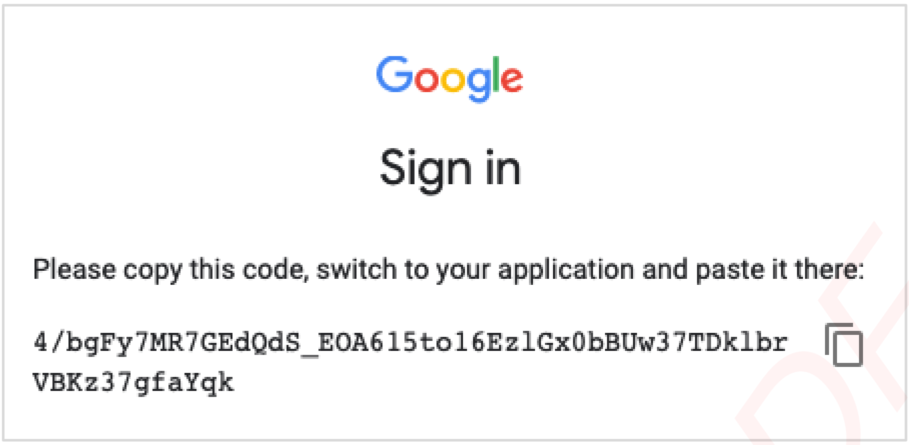
- See, edit, create, and delete all of your Google Drive files
- View the photos, videos and albums in your Google Photos
- View Google people information such as profiles and contacts
- See, edit, create, and delete any of your Google Drive documents

Make sure you trust Google Drive File Stream

You may be sharing sensitive info with this site or app. Learn about how Google Drive File Stream will handle your data by reviewing its terms of service and privacy policies. You can always see or remove access in your **Google Account**.

Learn about the risks

If you grant the permissions, you will receive your code as follows:

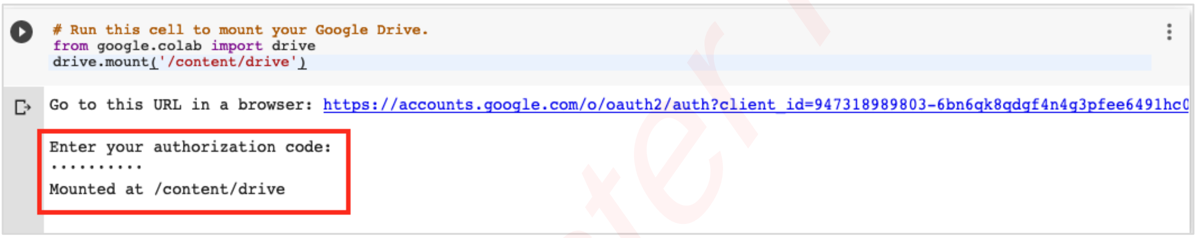


Sign in

Please copy this code, switch to your application and paste it there:

```
4/bgFy7MR7GEdQdS_EOA615to16EzlGx0bBUw37TDklbr
VBKz37gfaYqk
```

Cut-n-paste this code in the Code cell and hit ENTER. After a while, the drive will be mounted as seen in the screenshot below:



```
# Run this cell to mount your Google Drive.
from google.colab import drive
drive.mount('/content/drive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3pfee6491hc0

Enter your authorization code:
··········
Mounted at /content/drive
```

Now, you are ready to use the contents of your drive in Colab.

Listing Drive Contents

You can list the contents of the drive using the **ls** command as follows:

```
!ls "/content/drive/My Drive/Colab Notebooks"
```

This command will list the contents of your Colab Notebooks folder. The sample output of my drive contents are shown here:

```
Greeting.ipynb
hello.py
LogisticRegressionCensusData.ipynb
LogisticRegressionDigitalOcean.ipynb
MyFirstColabNotebook.ipynb
SamplePlot.ipynb
```

Running Python Code

Now, let us say that you want to run a Python file called **hello.py** stored in your Google Drive. Type the following command in the Code cell:

```
!python3 "/content/drive/My Drive/Colab Notebooks/hello.py"
```

The contents of hello.py are given here for your reference:

```
print("Welcome to TutorialsPoint!")
```

You will now see the following output:

```
Welcome to TutorialsPoint!
```

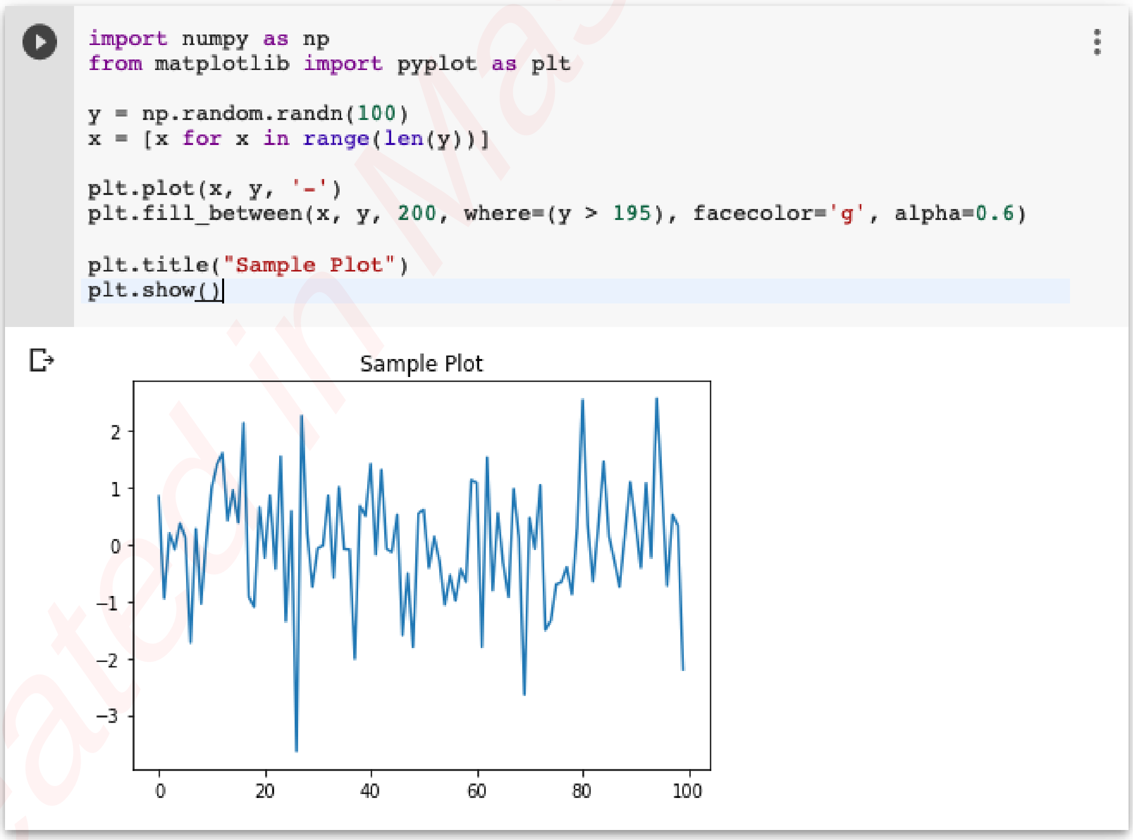
Besides the text output, Colab also supports the graphical outputs. We will see this in the next chapter.

9. Google Colab – Graphical Outputs

Colab also supports rich outputs such as charts. Type in the following code in the Code cell.

```
import numpy as np

from matplotlib import pyplot as plt


y = np.random.randn(100)

x = [x for x in range(len(y))]


plt.plot(x, y, '-')

plt.fill_between(x, y, 200, where=(y > 195), facecolor='g', alpha=0.6)


plt.title("Sample Plot")

plt.show()
```

Now, if you run the code, you will see the following output:



```
import numpy as np
from matplotlib import pyplot as plt

y = np.random.randn(100)
x = [x for x in range(len(y))]

plt.plot(x, y, '-')
plt.fill_between(x, y, 200, where=(y > 195), facecolor='g', alpha=0.6)

plt.title("Sample Plot")
plt.show()
```

Note that the graphical output is shown in the output section of the Code cell. Likewise, you will be able to create and display several types of charts throughout your program code.

Now, as you have got familiar with the basics of Colab, let us move on to the features in Colab that makes your Python code development easier.

10. Google Colab – Code Editing Help

The present day developers rely heavily on context-sensitive help to the language and library syntaxes. That is why the IDEs are widely used. The Colab notebook editor provides this facility.

In this chapter, let us see how to ask for context-sensitive help while writing Python code in Colab. Follow the steps that have been given wherever needed.

Function List

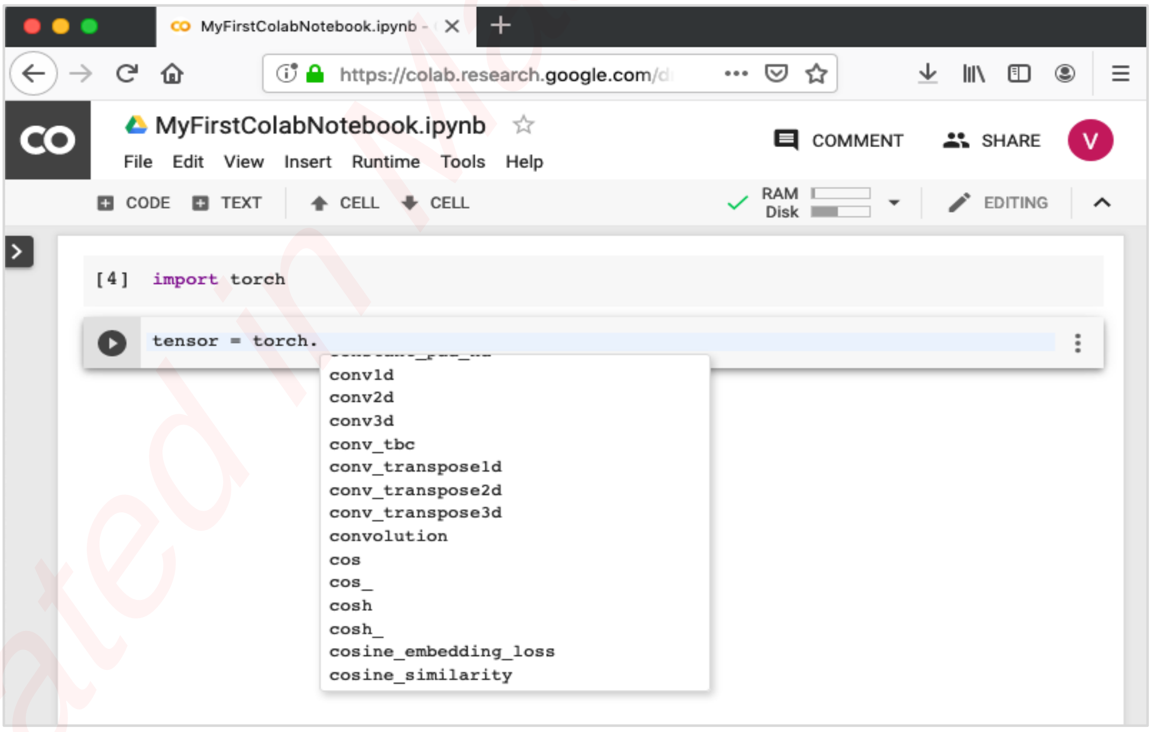
Step 1: Open a new notebook and type in the following code in the Code cell:

```
import torch
```

Step 2: Run the code by clicking on the **Run** icon in the left panel of the Code cell. Add another Code cell and type in the following code:

```
Tensor = torch.
```

At this point, suppose you have forgotten what are the various functions available in **torch** module. You can ask for the context-sensitive help on function names by hitting the **TAB** key. Note the presence of the **DOT** after the **torch** keyword. Without this DOT, you will not see the context help. Your screen would look like as shown in the screenshot here:


MyFirstColabNotebook.ipynb
https://colab.research.google.com/
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE
TEXT
CELL
CELL
RAM
Disk
EDITING

```
[4] import torch

tensor = torch.
```

```
conv1d
conv2d
conv3d
conv_tbc
conv_transpose1d
conv_transpose2d
conv_transpose3d
convolution
cos
cos_
cosh
cosh_
cosine_embedding_loss
cosine_similarity
```

Now, select the desired function from the list and proceed with your coding.

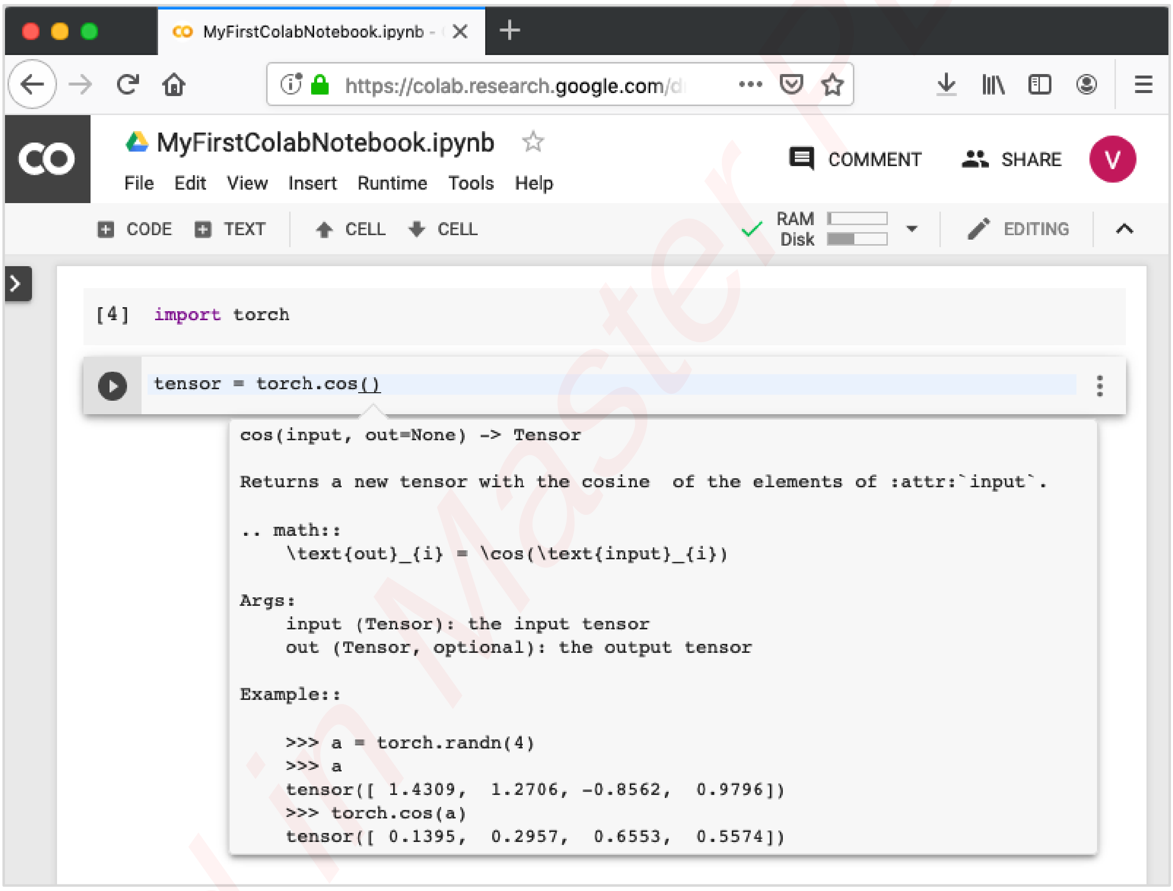
Function Documentation

Colab gives you the documentation on any **function** or **class** as a context-sensitive help.

Type the following code in your code window:

```
Tensor = torch.cos(
```

Now, hit **TAB** and you will see the documentation on **cos** in the popup window as shown in the screenshot here. Note that you need to type in **open parenthesis** before hitting TAB.


MyFirstColabNotebook.ipynb
https://colab.research.google.com/d
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE
TEXT
CELL
CELL
RAM
Disk
EDITING

```
[4] import torch

tensor = torch.cos()
```

```
cos(input, out=None) -> Tensor

Returns a new tensor with the cosine  of the elements of :attr:`input`.

.. math::
    \text{out}_{i} = \cos(\text{input}_{i})

Args:
    input (Tensor): the input tensor
    out (Tensor, optional): the output tensor

Example::

    >>> a = torch.randn(4)
    >>> a
    tensor([ 1.4309,  1.2706, -0.8562,  0.9796])
    >>> torch.cos(a)
    tensor([ 0.1395,  0.2957,  0.6553,  0.5574])
```

In the next chapter, we will see **Magics** in Colab that lets us to do more powerful things than what we did with system aliases.

11. Google Colab – Magics

Magics is a set of system commands that provide a mini extensive command language.

Magics are of two types:

- Line magics
- Cell magics

The line magics as the name indicates that it consists of a single line of command, while the cell magic covers the entire body of the code cell.

In case of line magics, the command is prepended with a single % character and in the case of cell magics, it is prepended with two % characters (%%).

Let us look into some examples of both to illustrate these.

Line Magics

Type the following code in your code cell:

```
%ldir
```

You will see the contents of your local directory, something like this -

```
drwxr-xr-x 3 root  4096 Jun 20 10:05 drive/

drwxr-xr-x 1 root  4096 May 31 16:17 sample_data/
```

Try the following command:

```
%history
```

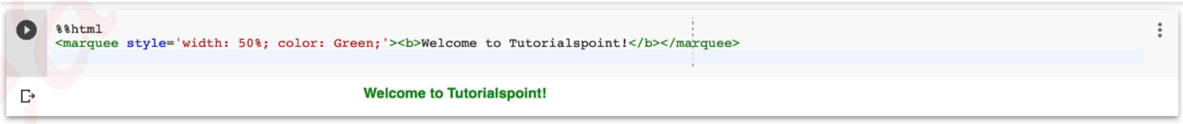
This presents the complete history of commands that you have previously executed.

Cell Magics

Type in the following code in your code cell:

```
%%html

<marquee style='width: 50%; color: Green;'><b>Welcome to
Tutorialspoint!</b></marquee>
```

Now, if you run the code and you will see the scrolling welcome message on the screen as shown here:



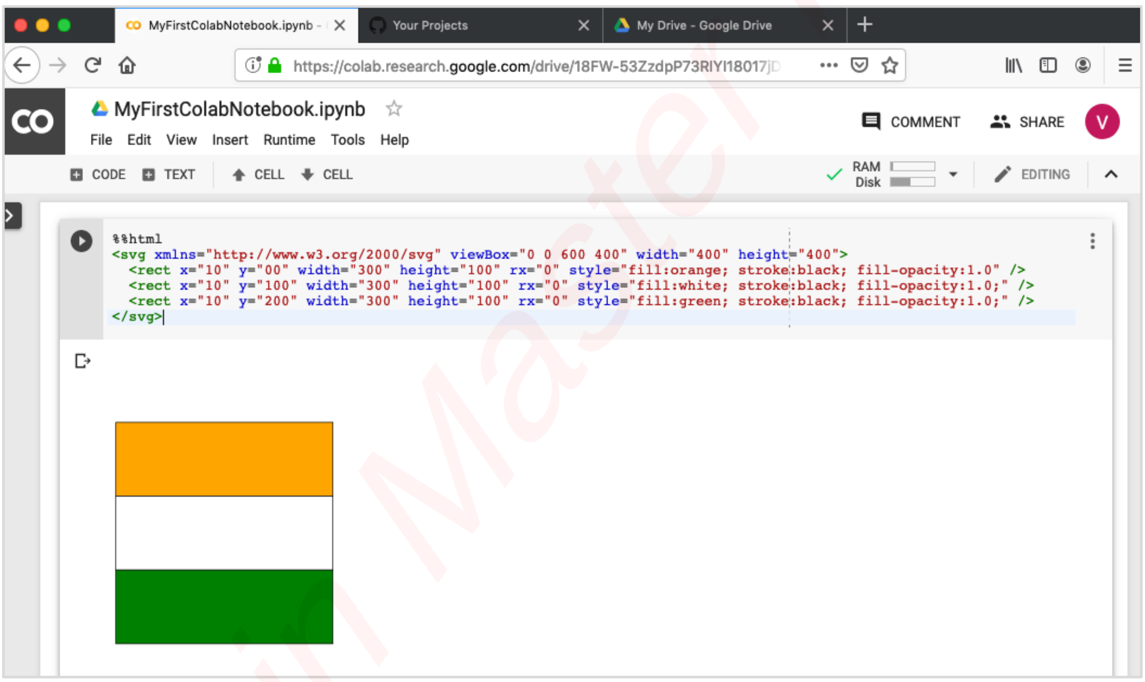
```
%%html
<marquee style='width: 50%; color: Green;'><b>Welcome to Tutorialspoint!</b></marquee>
```

Welcome to Tutorialspoint!

The following code will add SVG to your document.

```
%%html

<svg xmlns="http://www.w3.org/2000/svg" viewBox="0 0 600 400" width="400"
height="400">

  <rect x="10" y="00" width="300" height="100" rx="0" style="fill:orange;
stroke:black; fill-opacity:1.0" />

  <rect x="10" y="100" width="300" height="100" rx="0" style="fill:white;
stroke:black; fill-opacity:1.0;" />

  <rect x="10" y="200" width="300" height="100" rx="0" style="fill:green;
stroke:black; fill-opacity:1.0;" />

</svg>
```

If you run the code, you would see the following output:


MyFirstColabNotebook.ipynb
Your Projects
My Drive - Google Drive
https://colab.research.google.com/drive/18FW-53ZzdpP73RlYl18017jD
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE
TEXT
CELL
CELL
RAM
Disk
EDITING

```
%%html
<svg xmlns="http://www.w3.org/2000/svg" viewBox="0 0 600 400" width="400" height="400">
  <rect x="10" y="00" width="300" height="100" rx="0" style="fill:orange; stroke:black; fill-opacity:1.0" />
  <rect x="10" y="100" width="300" height="100" rx="0" style="fill:white; stroke:black; fill-opacity:1.0;" />
  <rect x="10" y="200" width="300" height="100" rx="0" style="fill:green; stroke:black; fill-opacity:1.0;" />
</svg>
```

Magics List

To get a complete list of supported magics, execute the following command:

```
%lsmagic
```

You will see the following output:

```
Available line magics:

%alias  %alias_magic  %autocall  %automagic  %autosave  %bookmark  %cat  %cd
%clear  %colors  %config  %connect_info  %cp  %debug  %dhist  %dirs
%doctest_mode  %ed  %edit  %env  %gui  %hist  %history  %killbgscripts  %ldir
       %less  %lf  %lk  %ll  %load  %load_ext  %loadpy  %logoff  %logon
```

```
%logstart  %logstate  %logstop  %ls  %lsmagic  %lx  %macro  %magic  %man
%matplotlib  %mkdir  %more  %mv  %notebook  %page  %pastebin  %pdb  %pdef
%pdoc  %pfile  %pinfo  %pinfo2  %pip  %popd  %pprint  %precision  %profile
%prun  %psearch  %psource  %pushd  %pwd  %pycat  %pylab  %qtconsole  %quickref
%recall  %rehashx  %reload_ext  %rep  %rerun  %reset  %reset_selective  %rm
%rmdir  %run  %save  %sc  %set_env  %shell  %store  %sx  %system  %tb
%tensorflow_version  %time  %timeit  %unalias  %unload_ext  %who  %who_ls
%whos  %xdel  %xmode


Available cell magics:

%%!  %%HTML  %%SVG  %%bash  %%bigquery  %%capture  %%debug  %%file  %%html
%%javascript  %%js  %%latex  %%perl  %%prun  %%pypy  %%python  %%python2
%%python3  %%ruby  %%script  %%sh  %%shell  %%svg  %%sx  %%system  %%time
%%timeit  %%writefile


Automagic is ON, % prefix IS NOT needed for line magics.
```

Next, you will learn another powerful feature in Colab to set the program variables at runtime.

12. Google Colab – Adding Forms

Colab provides a very useful utility called Forms that allows you to accept inputs from the user at runtime. Let us now move on to see how to add forms to your notebook.

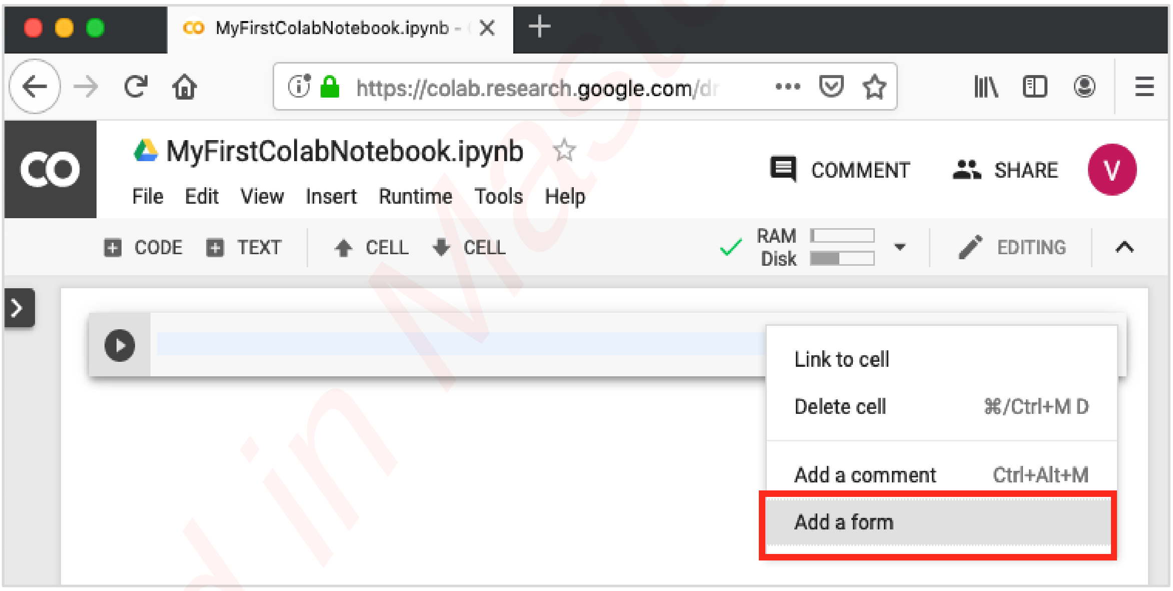
Adding Form

In an earlier lesson, you used the following code to create a time delay:

```
import time
print(time.ctime())
time.sleep(5)
print (time.ctime())
```

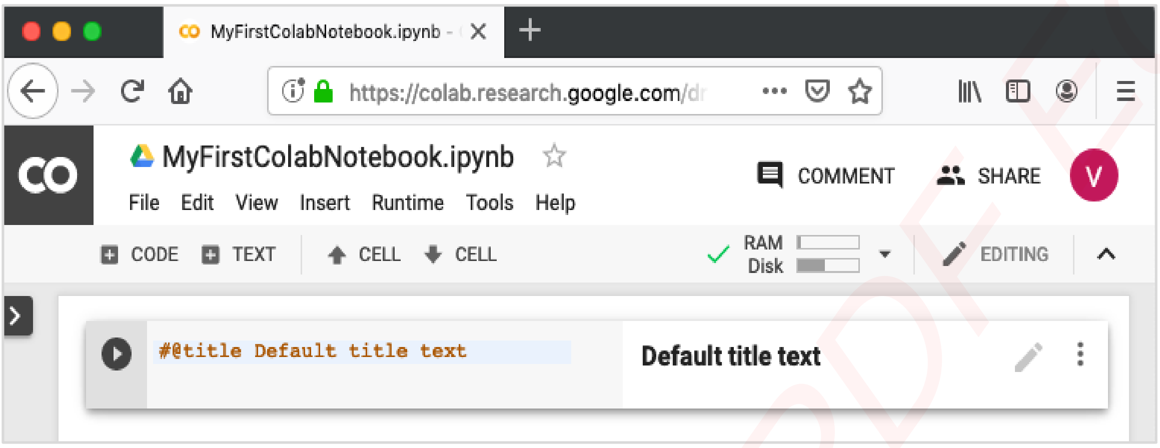
Suppose, you want a user set time delay instead of a fixed delay of 5 seconds. For this, you can add a Form to the Code cell to accept the sleep time.

Open a new notebook. Click on the **Options** (vertically-dotted) menu. A popup menu shows up as seen in the screenshot below:



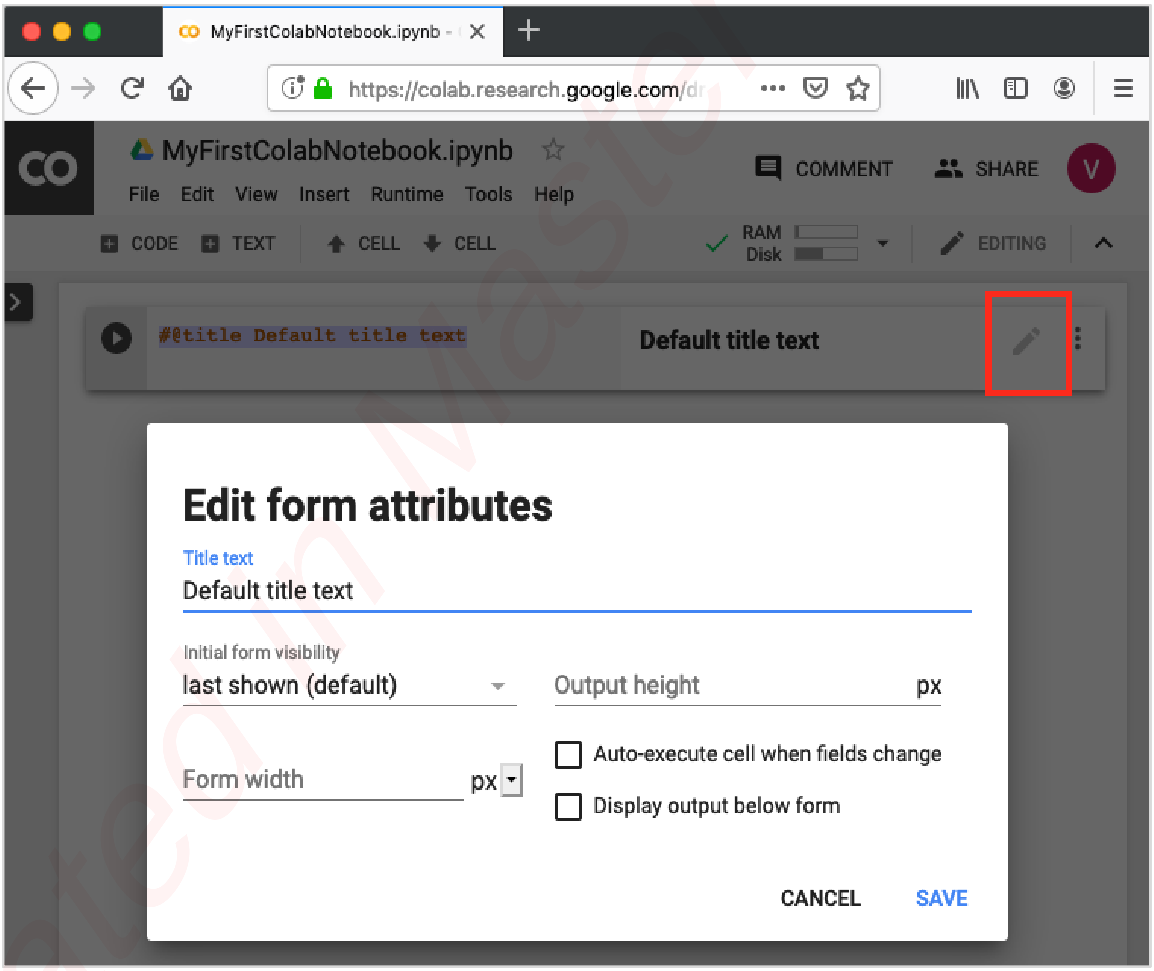
MyFirstColabNotebook.ipynb
https://colab.research.google.com/dr
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE
TEXT
CELL
CELL
RAM
Disk
EDITING
Link to cell
Delete cell ⌘/Ctrl+M D
Add a comment Ctrl+Alt+M
Add a form

Now, select **Add a form** option. It will add the form to your Code cell with a Default title as seen in the screenshot here:


MyFirstColabNotebook.ipynb
https://colab.research.google.com/dr
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
RAM Disk
EDITING
Default title text

```
#@title Default title text
```

To change the title of the form, click on the **Settings** button (pencil icon on the right). It will pop up a settings screen as shown here:


MyFirstColabNotebook.ipynb
https://colab.research.google.com/dr
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
RAM Disk
EDITING
Default title text
CANCEL
SAVE

```
#@title Default title text
```

Edit form attributes

Title text: Default title text

Initial form visibility: last shown (default)

Output height px

Form width px

Auto-execute cell when fields change

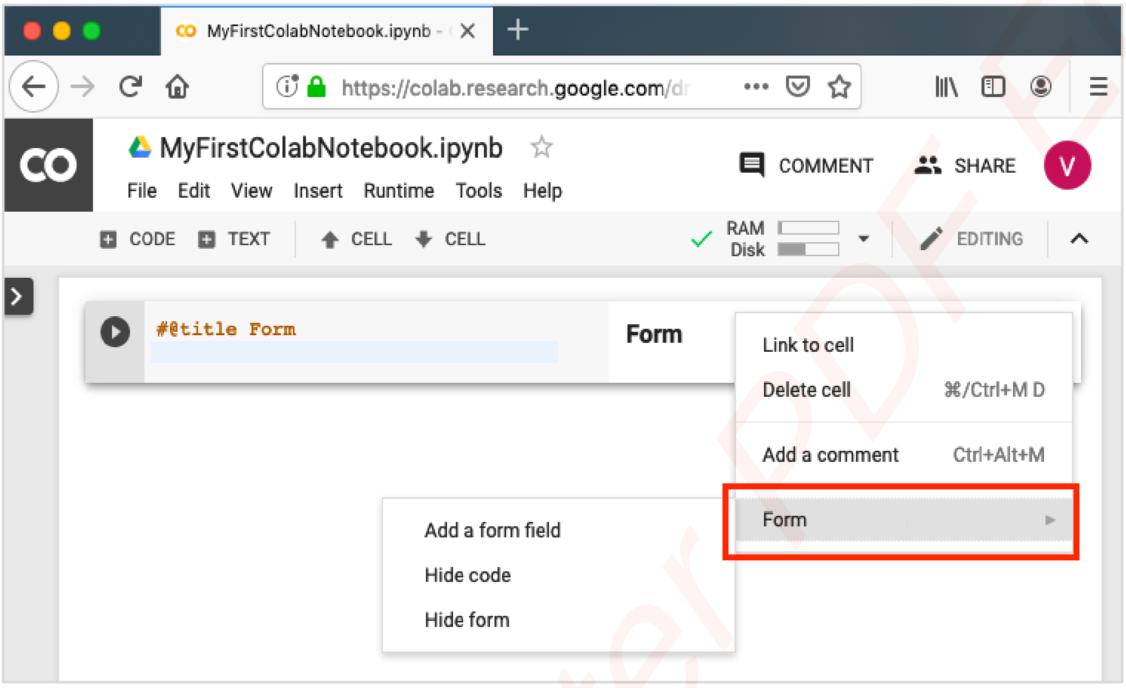
Display output below form

Change the form title to "**Form**" and save the form. You may use some other name of your choice. Notice that it adds the **@title** to your code cell.

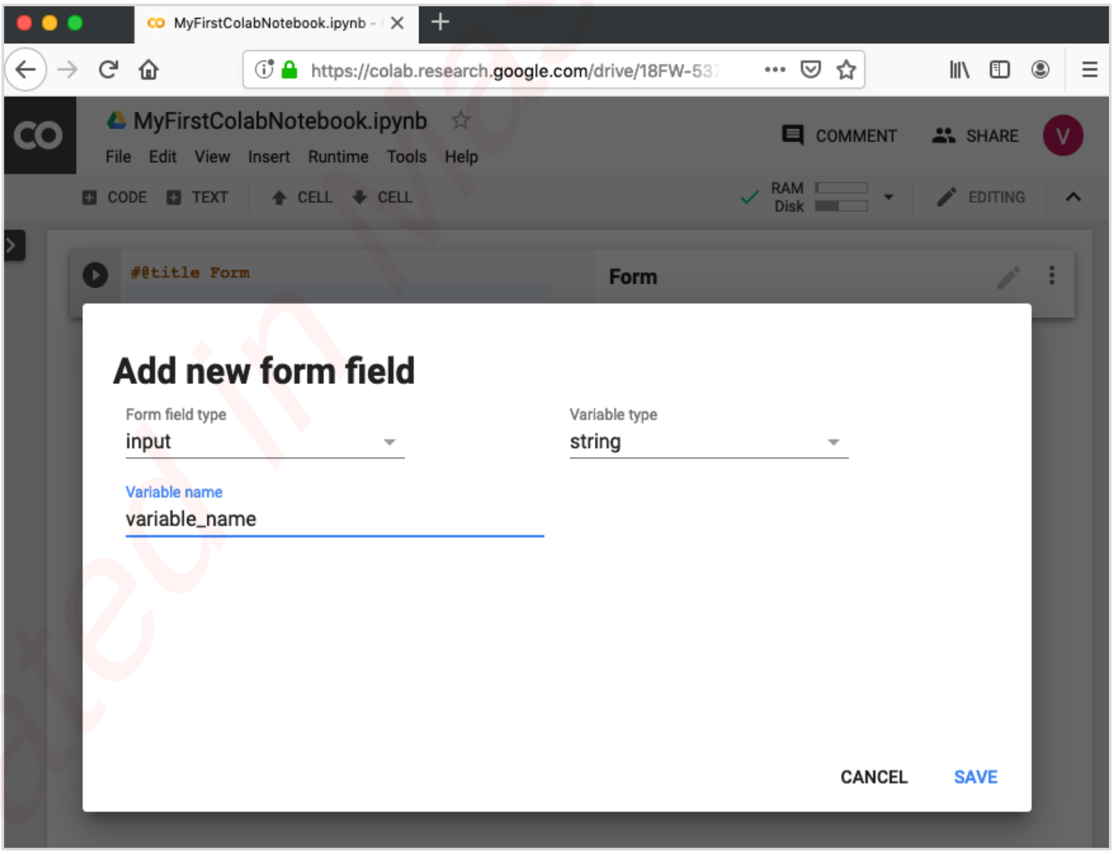
You may explore other options on the above screen at a later time. In the next section, we will learn how add input fields to the form.

Adding Form Fields

To add a form field, click the **Options** menu in the Code cell, click on the **Form** to reveal the submenus. The screen will look as shown below:

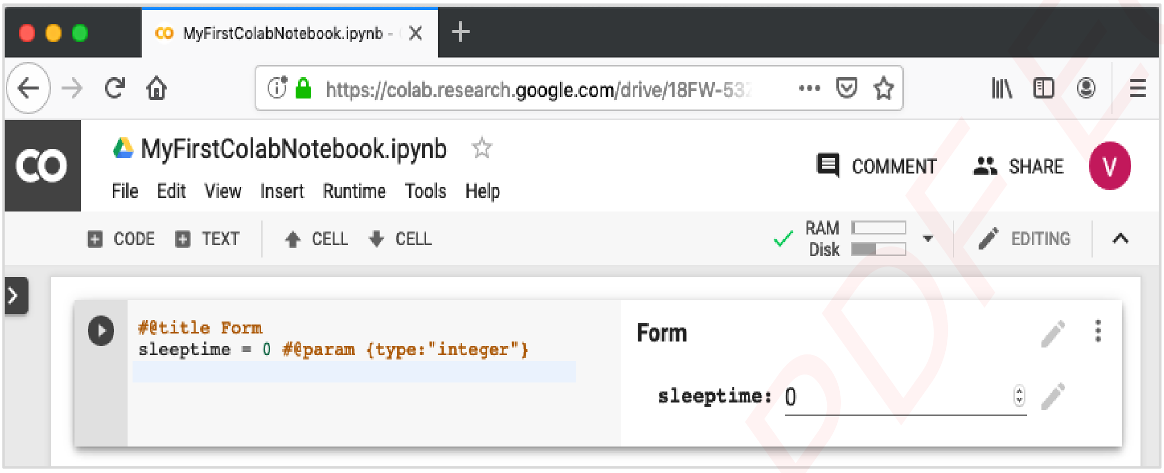


Select **Add a form field** menu option. A dialog pops up as seen here:



Leave the **Form field type** to **input**. Change the **Variable name** to **sleeptime** and set the **Variable type** to **integer**. Save the changes by clicking the **Save** button.

Your screen will now look like the following with the **sleeptime** variable added into the code.


MyFirstColabNotebook.ipynb
https://colab.research.google.com/drive/18FW-53
File Edit View Insert Runtime Tools Help
COMMENT
SHARE
CODE TEXT CELL CELL
RAM Disk
EDITING
Form

```
#@title Form
sleeptime = 0 #@param {type:"integer"}
```

sleeptime: 0

Next, let us see how to test the form by adding some code that uses the **sleeptime** variable.

Testing Form

Add a new Code cell underneath the form cell. Use the code given below:

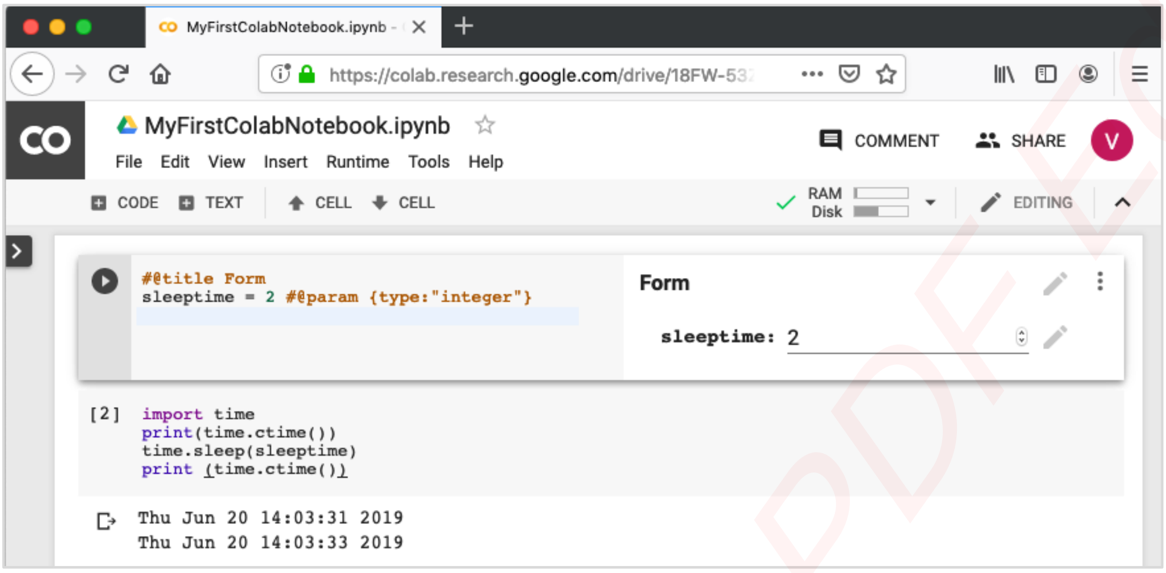
```
import time
print(time.ctime())
time.sleep(sleeptime)
print (time.ctime())
```

You have used this code in the earlier lesson. It prints the current time, waits for a certain amount of time and prints a new timestamp. The amount of time that the program waits is set in the variable called **sleeptime**.

Now, go back to the **Form** Cell and type in a value of 2 for the **sleeptime**. Select the following menu:

```
Runtime / Run all
```

This runs the entire notebook. You can see an output screen as shown below.


MyFirstColabNotebook.ipynb
https://colab.research.google.com/drive/18FW-53
MyFirstColabNotebook.ipynb
File Edit View Insert Runtime Tools Help
COMMENT SHARE
CODE TEXT CELL CELL
RAM Disk
EDITING
Form

```
#@title Form
sleeptime = 2 #@param {type:"integer"}
```

sleeptime: 2

```
[2] import time
    print(time.ctime())
    time.sleep(sleeptime)
    print (time.ctime())
```

```
Thu Jun 20 14:03:31 2019
Thu Jun 20 14:03:33 2019
```

Notice that it has taken your input value of 2 for the **sleeptime**. Try changing this to a different value and **Run all** to see its effect.

Inputting Text

To accept a text input in your form, enter the following code in a new code cell.

```
name = 'Tutorialspoint' #@param {type:"string"}
print(name)
```

Now, if you run the Code cell, whatever the name you set in the form would be printed on the screen. By default, the following output would appear on the screen.

```
Tutorialspoint
```

Note that you may use the menu options as shown for the integer input to create a **Text** input field.

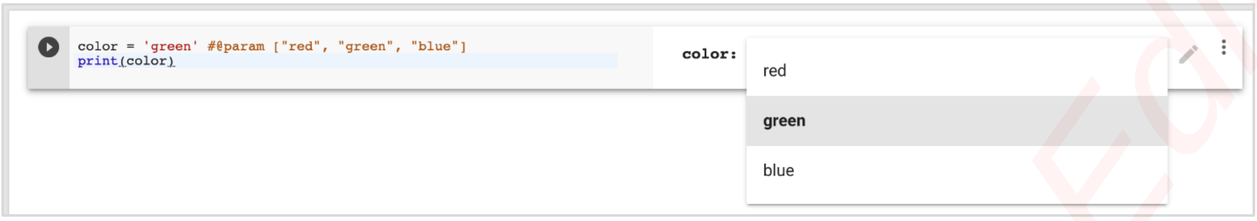
Dropdown List

To add a dropdown list to your form, use the following code:

```
color = 'green' #@param ["red", "green", "blue"]
print(color)
```

This creates a dropdown list with three values - red, green and blue. The default selection is green.

The dropdown list is shown in the screenshot below:



```
color = 'green' #@param ["red", "green", "blue"]
print(color)
```

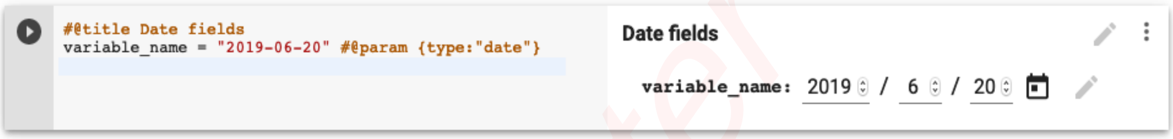
color:

Date Input

Colab Form allows you to accept dates in your code with validations. Use the following code to input date in your code.

```
#@title Date fields

date_input = '2019-06-03' #@param {type:"date"}

print(date_input)
```

The Form screen looks like the following.



```
#@title Date fields
variable_name = "2019-06-20" #@param {type:"date"}
```

Date fields

variable_name: 2019 / 6 / 20

Try inputting a wrong date value and observe the validations.

So far you have learned how to use Colab for creating and executing Jupyter notebooks with your Python code. In the next chapter, we will see how to install popular ML libraries in your notebook so that you can use those in your Python code.

13. Google Colab – Installing ML Libraries

Colab supports most of machine learning libraries available in the market. In this chapter, let us take a quick overview of how to install these libraries in your Colab notebook.

To install a library, you can use either of these options:

```
!pip install
```

or

```
!apt-get install
```

Keras

Keras, written in Python, runs on top of TensorFlow, CNTK, or Theano. It enables easy and fast prototyping of neural network applications. It supports both convolutional networks (CNN) and recurrent networks, and also their combinations. It seamlessly supports GPU.

To install Keras, use the following command:

```
!pip install -q keras
```

PyTorch

PyTorch is ideal for developing deep learning applications. It is an optimized tensor library and is GPU enabled. To install PyTorch, use the following command:

```
!pip3 install torch torchvision
```

MxNet

Apache MxNet is another flexible and efficient library for deep learning. To install MxNet execute the following commands:

```
!apt install libnvrtc8.0

!pip install mxnet-cu80
```

OpenCV

OpenCV is an open source computer vision library for developing machine learning applications. It has more than 2500 optimized algorithms which support several applications such as recognizing faces, identifying objects, tracking moving objects, stitching images, and so on. Giants like Google, Yahoo, Microsoft, Intel, IBM, Sony, Honda, Toyota use this library. This is highly suited for developing real-time vision applications.

To install OpenCV use the following command:

```
!apt-get -qq install -y libsm6 libxext6 && pip install -q -U opencv-python
```

XGBoost

XGBoost is a distributed gradient boosting library that runs on major distributed environments such as Hadoop. It is highly efficient, flexible and portable. It implements ML algorithms under the Gradient Boosting framework.

To install XGBoost, use the following command:

```
!pip install -q xgboost==0.4a30
```

GraphViz

Graphviz is an open source software for graph visualizations. It is used for visualization in networking, bioinformatics, database design, and for that matter in many domains where a visual interface of the data is desired.

To install GraphViz, use the following command:

```
!apt-get -qq install -y graphviz && pip install -q pydot
```

By this time, you have learned to create Jupyter notebooks containing popular machine learning libraries. You are now ready to develop your machine learning models. This requires high processing power. Colab provides free GPU for your notebooks.

In the next chapter, we will learn how to enable GPU for your notebook.

14. Google Colab – Using Free GPU

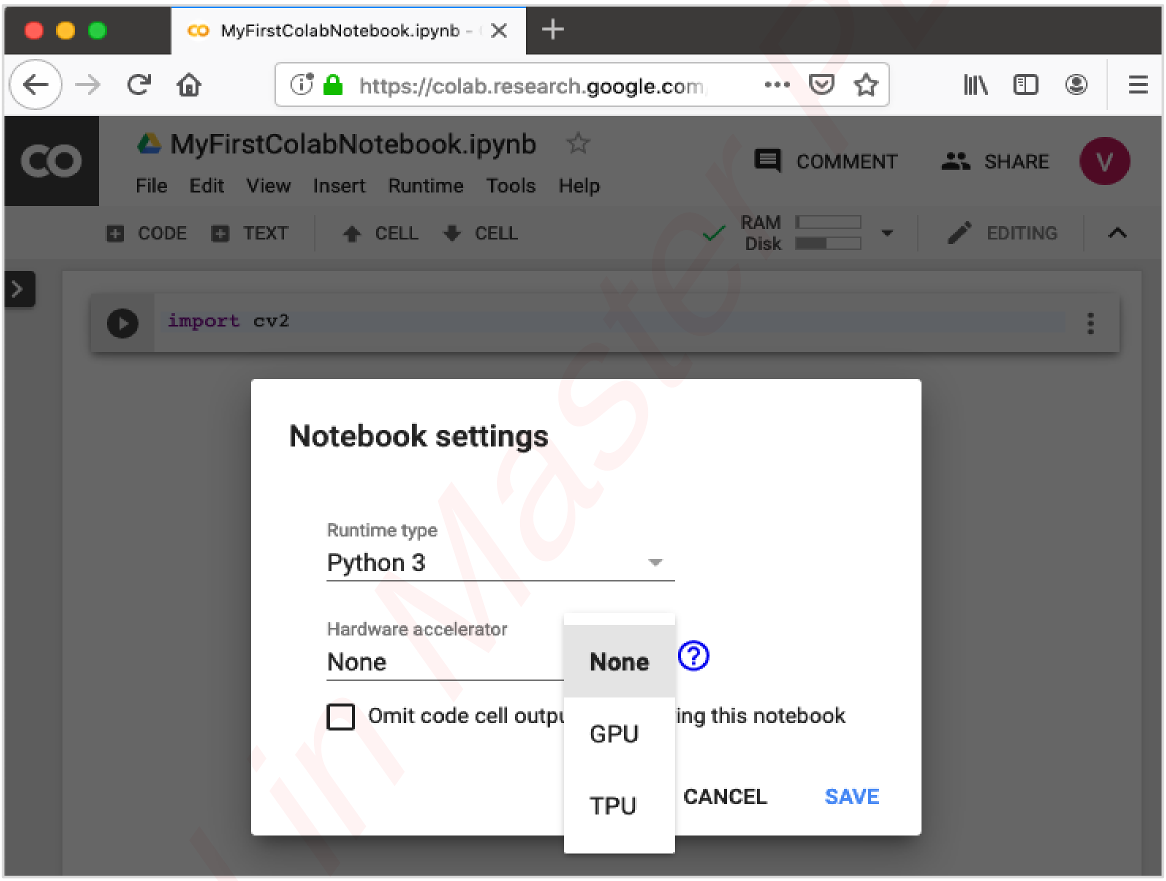
Google provides the use of free GPU for your Colab notebooks.

Enabling GPU

To enable GPU in your notebook, select the following menu options:

```
Runtime / Change runtime type
```

You will see the following screen as the output:



```
import cv2
```

Notebook settings

Runtime type: Python 3

Hardware accelerator: None

☐ Omit code cell output when saving this notebook

Select **GPU** and your notebook would use the free GPU provided in the cloud during processing. To get the feel of GPU processing, try running the sample application from **MNIST** tutorial that you cloned earlier.

```
!python3 "/content/drive/My Drive/app/mnist_cnn.py"
```

Try running the same Python file without the GPU enabled. Did you notice the difference in speed of execution?

Testing for GPU

You can easily check if the GPU is enabled by executing the following code:

```
import tensorflow as tf

tf.test.gpu_device_name()
```

If the GPU is enabled, it will give the following output:

```
'/device:GPU:0'
```

Listing Devices

If you are curious to know the devices used during the execution of your notebook in the cloud, try the following code:

```
from tensorflow.python.client import device_lib

device_lib.list_local_devices()
```

You will see the output as follows:

```
[name: "/device:CPU:0"
 device_type: "CPU"
 memory_limit: 268435456
 locality {
 }
 incarnation: 1734904979049303143, name: "/device:XLA_CPU:0"
 device_type: "XLA_CPU"
 memory_limit: 17179869184
 locality {
 }
 incarnation: 16069148927281628039
 physical_device_desc: "device: XLA_CPU device", name: "/device:XLA_GPU:0"
 device_type: "XLA_GPU"
 memory_limit: 17179869184
 locality {
 }
 incarnation: 16623465188569787091
 physical_device_desc: "device: XLA_GPU device", name: "/device:GPU:0"
 device_type: "GPU"
 memory_limit: 14062547764
 locality {
   bus_id: 1
   links {
   }
 }
 incarnation: 6674128802944374158
 physical_device_desc: "device: 0, name: Tesla T4, pci bus id: 0000:00:04.0,
compute capability: 7.5"]
```

Checking RAM

To see the memory resources available for your process, type the following command:

```
!cat /proc/meminfo
```

You will see the following output:

```
MemTotal:       13335276 kB
MemFree:         7322964 kB
MemAvailable:   10519168 kB
Buffers:           95732 kB
Cached:          2787632 kB
SwapCached:            0 kB
Active:          2433984 kB
Inactive:        3060124 kB
Active(anon):    2101704 kB
Inactive(anon):    22880 kB
Active(file):     332280 kB
Inactive(file):  3037244 kB
Unevictable:           0 kB
Mlocked:               0 kB
SwapTotal:             0 kB
SwapFree:              0 kB
Dirty:               412 kB
Writeback:             0 kB
AnonPages:       2610780 kB
Mapped:           838200 kB
Shmem:             23436 kB
Slab:             183240 kB
SReclaimable:     135324 kB
SUnreclaim:        47916 kB
```

```
KernelStack:        4992 kB
PageTables:        13600 kB
NFS_Unstable:          0 kB
Bounce:                0 kB
WritebackTmp:          0 kB
CommitLimit:     6667636 kB
Committed_AS:    4801380 kB
VmallocTotal:   34359738367 kB
VmallocUsed:           0 kB
VmallocChunk:          0 kB
AnonHugePages:         0 kB
ShmemHugePages:        0 kB
ShmemPmdMapped:        0 kB
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       2048 kB
DirectMap4k:      303092 kB
DirectMap2M:     5988352 kB
DirectMap1G:     9437184 kB
```

You are now all set for the development of machine learning models in Python using Google Colab.

15. Google Colab – Conclusion

Google Colab is a powerful platform for learning and quickly developing machine learning models in Python. It is based on Jupyter notebook and supports collaborative development. The team members can share and concurrently edit the notebooks, even remotely. The notebooks can also be published on GitHub and shared with the general public. Colab supports many popular ML libraries such as PyTorch, TensorFlow, Keras and OpenCV. The restriction as of today is that it does not support R or Scala yet. There is also a limitation to sessions and size. Considering the benefits, these are small sacrifices one needs to make.