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1 EECS 442 PS1: Filtering

Please provide the following information (e.g. Andrew Owens, ahowens):

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Important: 1. after you download the .ipynb file, please name it as **your_uniquename_your_umid.ipynb** before you submit it to canvas. Example: adam_01101100.ipynb. 2. Please convert the your Colab notebook to a PDF file and submit the PDF file to Gradescope. You can follow [this](#) instructions. For your convenience, we have included the PDF conversion script at the end of this notebook.

2 Introduction

We'll provide you with starter code, like this, in a Jupyter notebook for most problem sets. Please fill in the code to complete the assignment, and submit your notebook to Canvas as a .ipynb file. You can, of course, initially write your code offline in an editor like Emacs or Vim -- we'd just like the final output to be in a notebook format to make grading more consistent. You can also host your notebook locally.

Please note that *we won't run your code*. The notebook you submit should already contain all of the results we ask for. In particular, the visualizations of edge responses and blurred images should be computed *before you submit*. Also, please do not include long, unnecessary outputs (a few print statements and visualizations are fine, but pages of debugging messages make grading difficult).

3 First steps

Run the following code to import the modules that you'll need, and to download the images. You are welcome to modify this code (e.g. by importing more modules).

```
[1]: import numpy as np, matplotlib as mpl, matplotlib.pyplot as plt, urllib, os
import scipy.ndimage # For image filtering
import imageio # For loading images
import urllib.request

# Download the images that you'll need
base_url = 'https://web.eecs.umich.edu/~ahowens/eecs442/fa20/psets/ps1/ims'
for name in ['dog-1.jpg', 'dog-2.jpg', 'apple.jpg']:
    with open(name, 'wb') as out:
```

```
url = os.path.join(base_url, name)
out.write(urllib.request.urlopen(url).read())
```

4 Problem 1.2: Pet edge detection (a)

```
[2]: # You can upload images yourself or load them from URLs
im = imageio.imread('dog-1.jpg')
# Convert to grayscale. We'll use floats in [0, 1].
im = im.mean(2)/255.

# Your code here!
##### Solution code #####
def convolve(im, h):
    new_im = np.zeros(im.shape)
    x = im.shape[0]
    y = im.shape[1]
    # print("h = ", h.shape)
    for i in range(x):
        for j in range(y):
            # print("p = (", i, ", ", j, ")\\n")
            res = 0
            if h.shape[0] > 1 & h.shape[1] == 1: # vertical
                for f in range(h.shape[0]):
                    if i+f >= x: # padding
                        res += 0
                    else:
                        res += im[i+f, j] * h[f, 0]
            elif h.shape[1] > 1 & h.shape[0] == 1: # horizontal
                for f in range(h.shape[1]):
                    # print("f = ", f)
                    if j+f >= y: # padding
                        res += 0
                    else:
                        res += im[i, j+f] * h[0, f]
            new_im[i, j] = res

    return new_im

dx = np.array([[ -1, 1]])
# print("dx\\n", dx)
dy = np.array([[ -1], [ 1]])
# print("dy\\n", dy)
##### End solution code #####

# Convolve the image with horizontal and vertical gradient filters
Ix = convolve(im, dx)
```

```

Iy = convolve(im, dy)
edges = Ix**2. + Iy**2.

# Visualize edge maps using matplotlib
plt.figure()
plt.title('Input image')
plt.axis('off')
plt.imshow(im, cmap = 'gray', vmin = 0, vmax = 1)

plt.figure()
plt.axis('off')
plt.title('Ix')
plt.imshow(Ix)

plt.figure()
plt.title('Iy')
plt.axis('off')
plt.imshow(Iy)

plt.figure()
plt.title('Edges')
plt.axis('off')
# Please visualize edge responses using this range of values.
plt.imshow(edges, vmin = 0., vmax = np.percentile(edges, 99))

```

[2]: <matplotlib.image.AxesImage at 0x7f32914044d0>

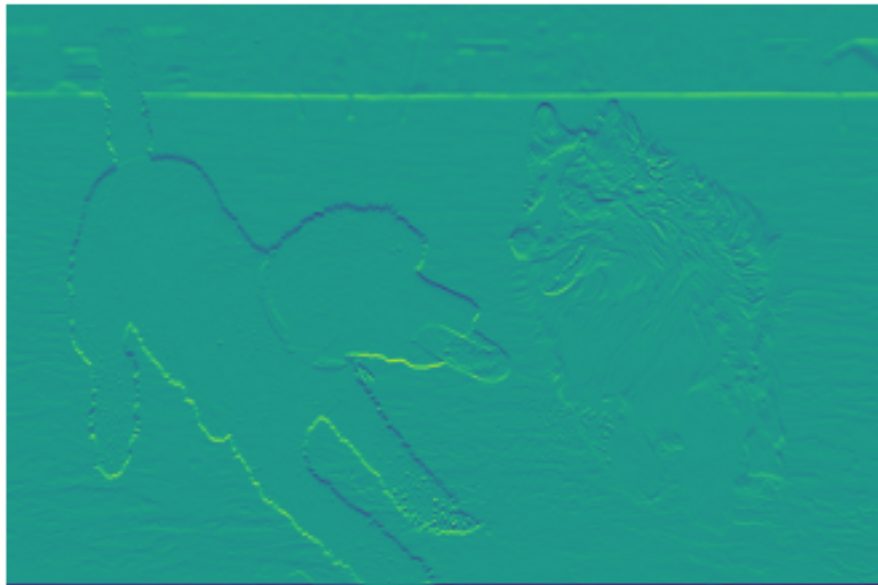
Input image

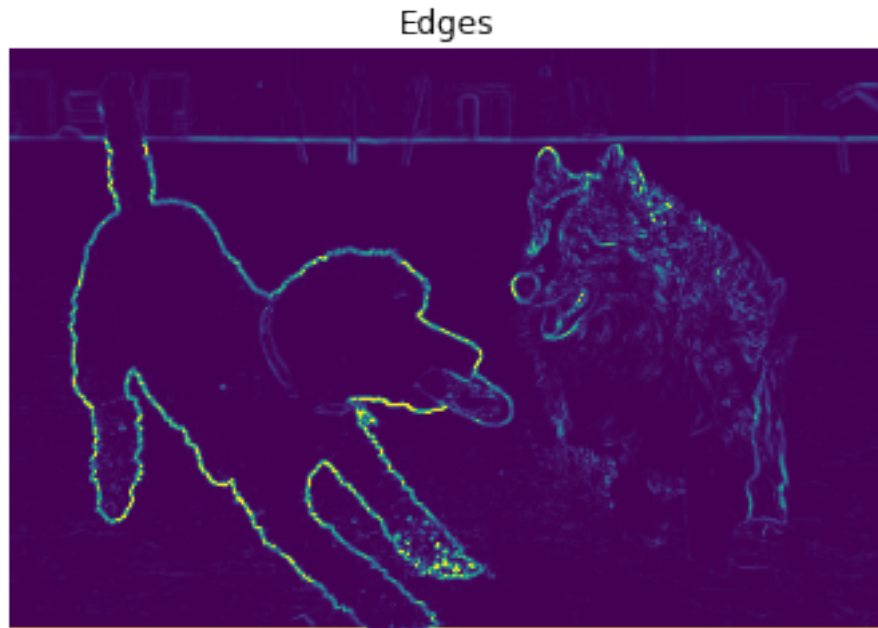


lx



ly





5 Problem 1.2: Pet edge detection (c)

Please visualize the images and edges with matplotlib, using code similar to what we provided in (a).

```
[3]: im = imageio.imread('dog-2.jpg').mean(2)/255.

# Your code here!
##### Solution code #####
import math
dx = np.array([[ -1, 1]])
dy = np.array([[ -1], [ 1]])
Ix = convolve(im, dx)
Iy = convolve(im, dy)
edges = Ix**2. + Iy**2.
plt.figure()
plt.title('Edges without blurring')
plt.axis('off')
plt.imshow(edges, vmin = 0., vmax = np.percentile(edges, 99))

def gaussian_filter(sigma, shape):
    new_im = np.zeros(shape)
    offset = shape[0]//2
    for x in range(shape[0]):
        for y in range(shape[1]):
            x_off = x - offset
```

```

        y_off = offset - y
        new_im[x, y] = (1/float(2*math.pi*(sigma**2))) * (math.
→e**(-(((x_off**2)+(y_off**2))/float(2*(sigma**2)))))
    return new_im

G = gaussian_filter(sigma=2, shape=(11,11))
# print("G\n", G)
# plt.figure()
# plt.title('Gaussian Filter')
# plt.axis('off')
# plt.imshow(G)

val = 1/(11**2)
box_filter = np.full((11,11), val)
Ib = scipy.ndimage.convolve(im, box_filter, mode='constant', cval=0.0)
plt.figure()
plt.title('Box Filtered')
plt.axis('off')
plt.imshow(Ib)

Ix = convolve(Ib, dx)
Iy = convolve(Ib, dy)
edges_b = Ix**2. + Iy**2.
plt.figure()
plt.title('Edges after Box filter blurring')
plt.axis('off')
plt.imshow(edges_b, vmin = 0., vmax = np.percentile(edges_b, 99))

Ig = scipy.ndimage.convolve(im, G, mode='constant', cval=0.0)
plt.figure()
plt.title('Gaussian Filtered')
plt.axis('off')
plt.imshow(Ig)

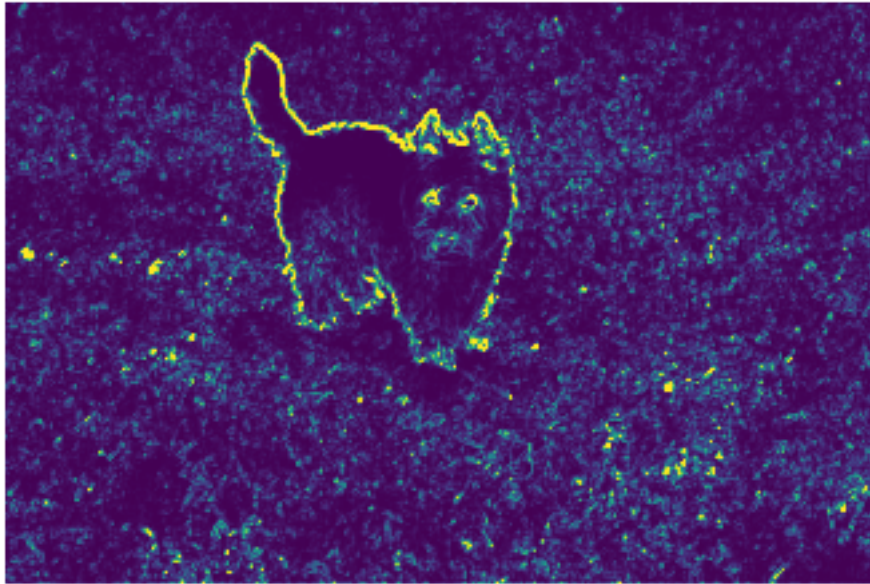
Ix = convolve(Ig, dx)
Iy = convolve(Ig, dy)
edges_g = Ix**2. + Iy**2.
plt.figure()
plt.title('Edges after Gaussian blurring')
plt.axis('off')
plt.imshow(edges_g, vmin = 0., vmax = np.percentile(edges_g, 99))

##### End solution code #####

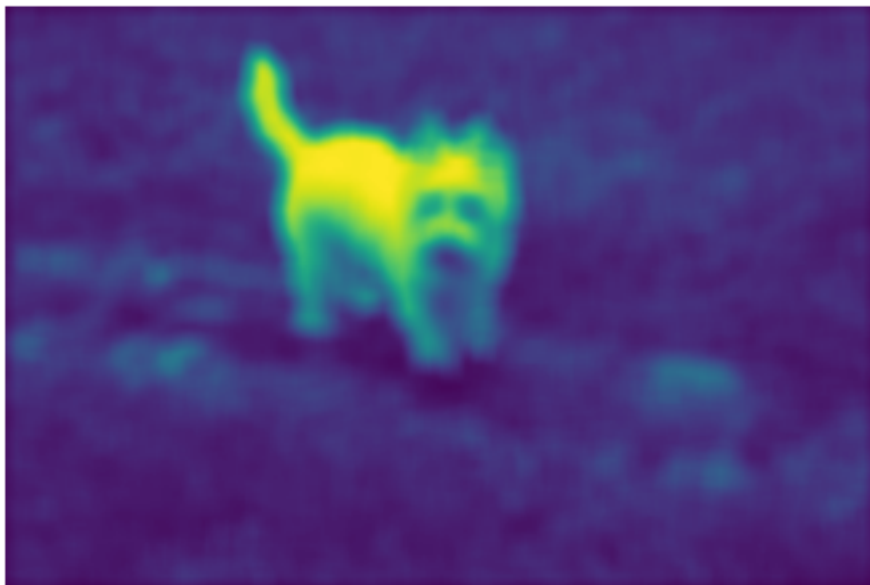
```

[3]: <matplotlib.image.AxesImage at 0x7f3290545fd0>

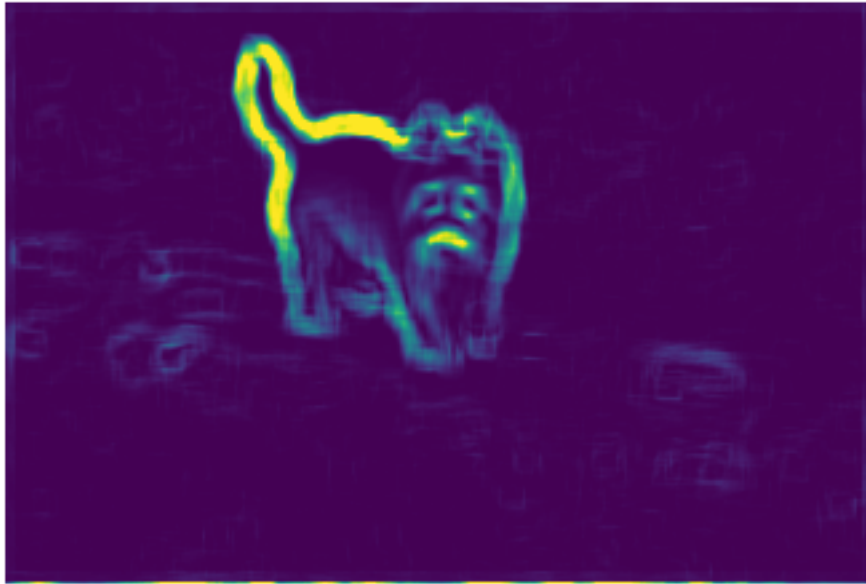
Edges without blurring



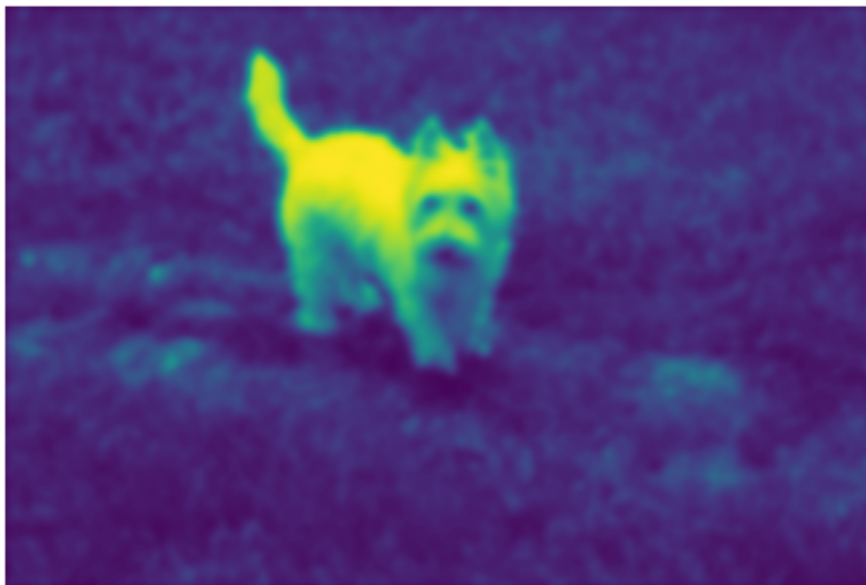
Box Filtered



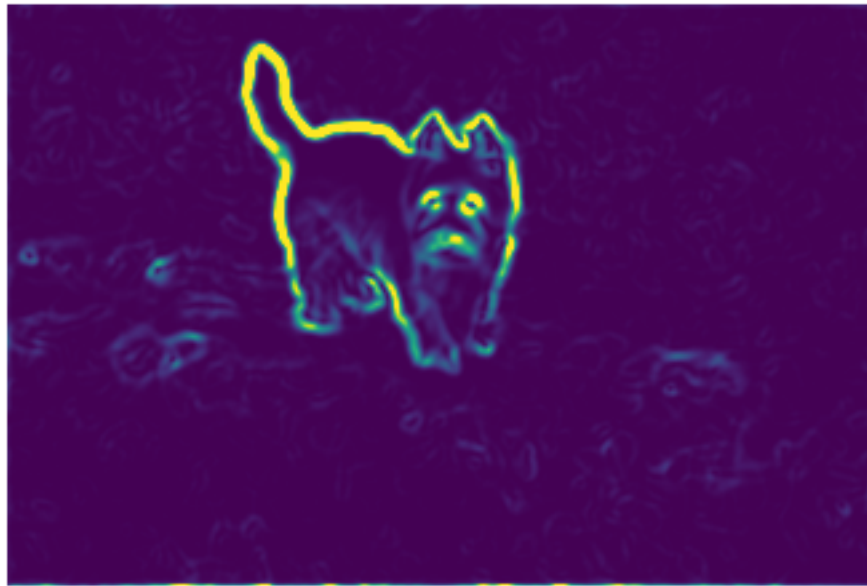
Edges after Box filter blurring



Gaussian Filtered



Edges after Gaussian blurring



6 Problem 1.2: Pet edge detection (d)

Please use the visualization code to display the filter you construct.

```
[4]: # Your code here!
##### Solution code #####
Gx = scipy.ndimage.convolve(gaussian_filter(sigma=2, shape=(11,11)), dx,
    ↪mode='constant', cval=0.0)
im_blur = scipy.ndimage.convolve(im, G, mode='constant', cval=0.0)
##### End solution code #####
plt.figure()
plt.title('Gx')
plt.imshow(Gx)

plt.figure()
plt.title('Edges two filters')
Ix = scipy.ndimage.convolve(im_blur, dx)
plt.imshow(Ix)

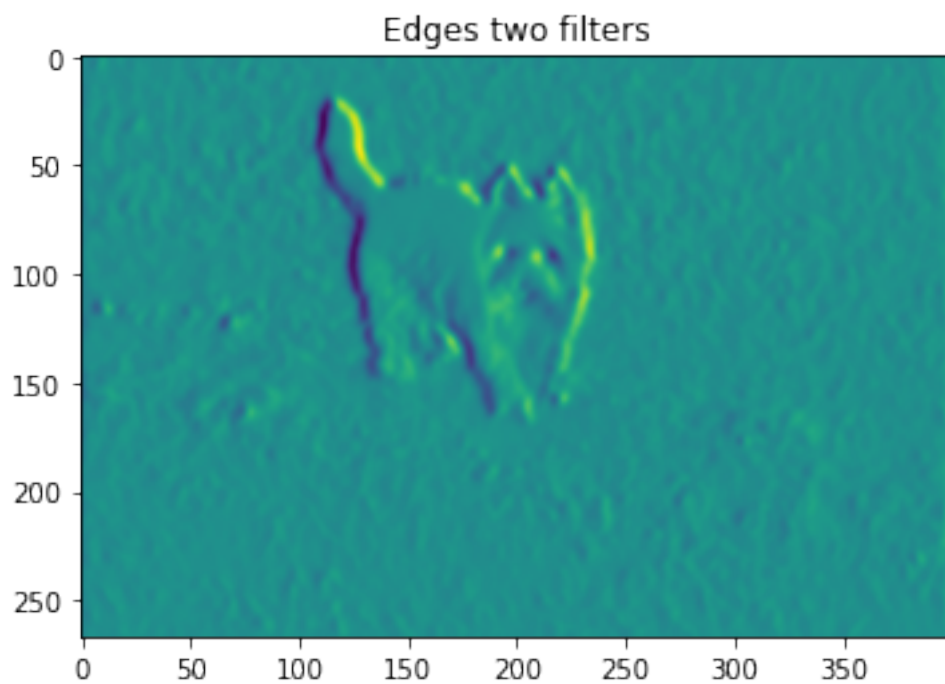
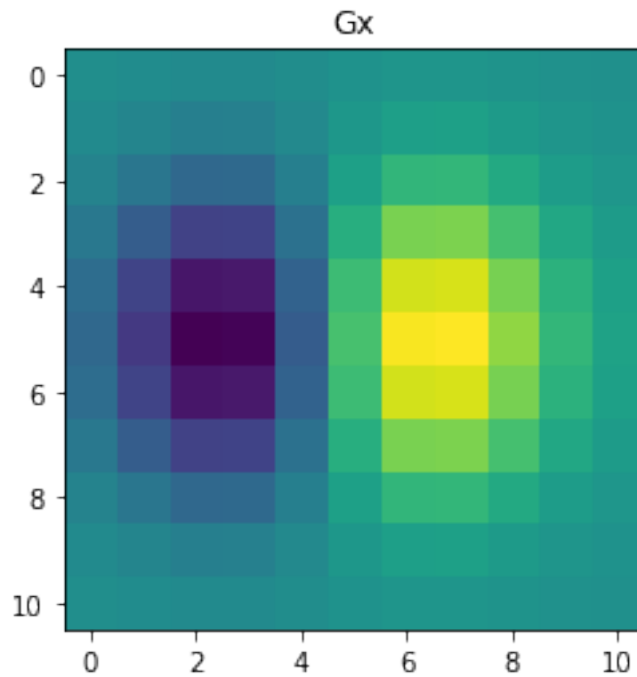
plt.figure()
plt.title('Edges one filter')
plt.imshow(scipy.ndimage.convolve(im, Gx))

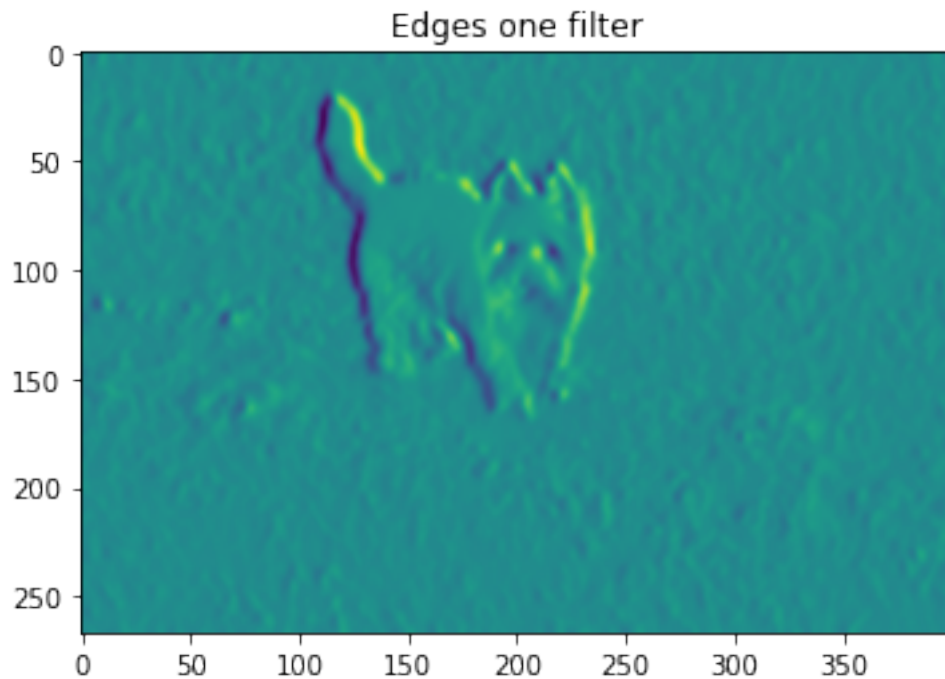
print(np.abs(np.sum(im_blur - im)))
```

```
print(np.abs(scipy.ndimage.convolve(im_blur, dx)[15:-15,15:-15] - scipy.ndimage.  
→convolve(im, Gx)[15:-15,15:-15]).mean())
```

358.1441084535949

0.001808628166990084





7 Problem 1.2 Pet edge detection (e)

Please visualize the results using matplotlib.

```
[5]: im = imageio.imread('apple.jpg').mean(2)/255.

# Your code here!
##### Solution code #####
def oriented_grad(Ix, Iy, theta):
    result = (math.cos(theta) * Ix) + (math.sin(theta) * Iy)
    #result = np.zeros(Ix.shape)
    #for x in range(Ix.shape[0]):
    #    for y in range(Ix.shape[1]):
    #        result[x,y] = math.cos(theta) * Ix[x,y] + math.sin(theta) * Iy[x,y]
    return result

im_blur = scipy.ndimage.convolve(im, gaussian_filter(sigma=2, shape=(11,11)),
    ↪mode='constant', cval=0.0)
dx = np.array([[ -1, 1]])
dy = np.array([[ -1, 1]])
Ix = convolve(im_blur, dx)
Iy = convolve(im_blur, dy)
```

```
grad1 = oriented_grad(Ix, Iy, 0.25*math.pi)
grad2 = oriented_grad(Ix, Iy, 0.5*math.pi)
grad3 = oriented_grad(Ix, Iy, 0.75*math.pi)
```

```
plt.figure()
plt.title("Original Image")
plt.axis("off")
plt.imshow(im)
```

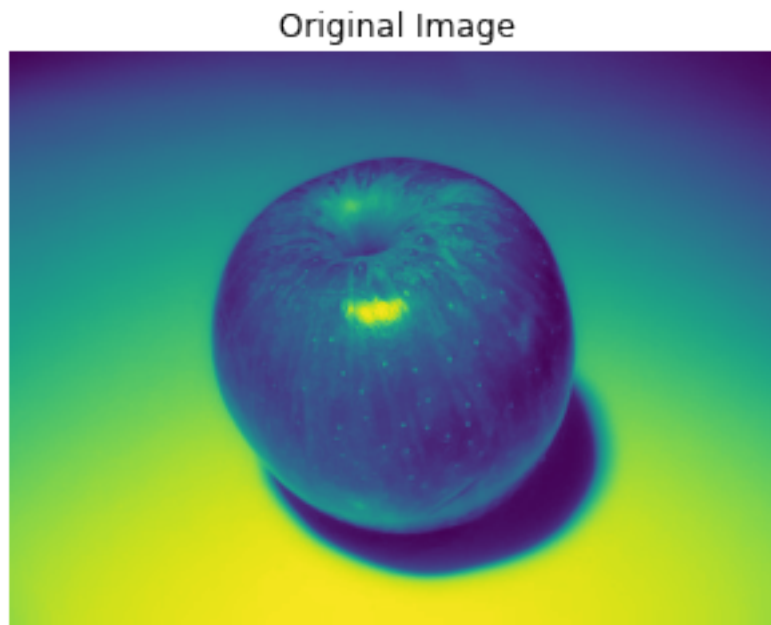
```
plt.figure()
plt.title("theta = 0.25pi")
plt.axis("off")
plt.imshow(grad1)
```

```
plt.figure()
plt.title("theta = 0.5pi")
plt.axis("off")
plt.imshow(grad2)
```

```
plt.figure()
plt.title("theta = 0.75pi")
plt.axis("off")
plt.imshow(grad3)
```

```
##### End solution code #####
```

[5]: <matplotlib.image.AxesImage at 0x7f3290253c90>



$\theta = 0.25\pi$



$\theta = 0.5\pi$



theta = 0.75pi



8 Convert Notebook to PDF

```
[6]: # generate pdf
# %%capture
!git clone https://gist.github.com/bc5f1add34fef7c7f9fb83d3783311e2.git
!cp bc5f1add34fef7c7f9fb83d3783311e2/colab_pdf.py colab_pdf.py
from colab_pdf import colab_pdf
# change the name to your ipynb file name shown on the top left of Colab window
# Important: make sure that your file name does not contain spaces!
colab_pdf('cktran_09859713.ipynb')
```

```
Cloning into 'bc5f1add34fef7c7f9fb83d3783311e2'...
remote: Enumerating objects: 10, done.
remote: Total 10 (delta 0), reused 0 (delta 0), pack-reused 10
Unpacking objects: 100% (10/10), done.
Mounted at /content/drive/
Get:1 http://security.ubuntu.com/ubuntu bionic-security InRelease [88.7 kB]
Ign:2 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64
InRelease
Ign:3 https://developer.download.nvidia.com/compute/machine-
learning/repos/ubuntu1804/x86_64 InRelease
Get:4 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu bionic InRelease
[15.9 kB]
Hit:5 http://archive.ubuntu.com/ubuntu bionic InRelease
Get:6 https://cloud.r-project.org/bin/linux/ubuntu bionic-cran40/ InRelease
```

```

[3,626 B]
Get:7 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64
Release [696 B]
Hit:8 https://developer.download.nvidia.com/compute/machine-
learning/repos/ubuntu1804/x86_64 Release
Get:9 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64
Release.gpg [836 B]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates InRelease [88.7 kB]
Get:11 http://security.ubuntu.com/ubuntu bionic-security/main amd64 Packages
[2,324 kB]
Hit:12 http://ppa.launchpad.net/cran/libgit2/ubuntu bionic InRelease
Get:13 http://archive.ubuntu.com/ubuntu bionic-backports InRelease [74.6 kB]
Get:14 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 Packages
[1,428 kB]
Get:15 http://ppa.launchpad.net/deadsnakes/ppa/ubuntu bionic InRelease [15.9 kB]
Get:16 http://security.ubuntu.com/ubuntu bionic-security/restricted amd64
Packages [567 kB]
Hit:17 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu bionic InRelease
Get:19
https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64
Packages [717 kB]
Get:20 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu bionic/main Sources
[1,799 kB]
Get:21 http://archive.ubuntu.com/ubuntu bionic-updates/universe amd64 Packages
[2,202 kB]
Get:22 http://archive.ubuntu.com/ubuntu bionic-updates/restricted amd64 Packages
[600 kB]
Get:23 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 Packages
[2,760 kB]
Get:24 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu bionic/main amd64
Packages [921 kB]
Get:25 http://ppa.launchpad.net/deadsnakes/ppa/ubuntu bionic/main amd64 Packages
[40.8 kB]
Fetched 13.6 MB in 4s (3,818 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
79 packages can be upgraded. Run 'apt list --upgradable' to see them.
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynchronet1 libtexlua52 libtexlua52 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5

```

```

rubygems-integration tlutils tex-common tex-gyre texlive-base
texlive-binaries texlive-latex-base texlive-latex-extra
texlive-latex-recommended texlive-pictures texlive-plain-generic tipa
Suggested packages:
  fonts-noto apache2 | lighttpd | httpd poppler-utils ghostscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri
  ruby-dev bundler debhelper gv | postscript-viewer perl-tk xpdf-reader
  | pdf-viewer texlive-fonts-recommended-doc texlive-latex-base-doc
  python-pygments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc
  texlive-latex-recommended-doc texlive-pstricks dot2tex prerex ruby-tcltk
  | libtcltk-ruby texlive-pictures-doc vprerex
The following NEW packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynchronet1 libtexlua52 libtexluajit2 libzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration tlutils tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-generic-recommended
  texlive-latex-base texlive-latex-extra texlive-latex-recommended
  texlive-pictures texlive-plain-generic texlive-xetex tipa
0 upgraded, 47 newly installed, 0 to remove and 79 not upgraded.
Need to get 146 MB of archives.
After this operation, 460 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-droid-fallback
all 1:6.0.1r16-1.1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lato all 2.0-2
[2,698 kB]
Get:3 http://archive.ubuntu.com/ubuntu bionic/main amd64 poppler-data all
0.4.8-2 [1,479 kB]
Get:4 http://archive.ubuntu.com/ubuntu bionic/main amd64 tex-common all 6.09
[33.0 kB]
Get:5 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lmodern all
2.004.5-3 [4,551 kB]
Get:6 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-noto-mono all
20171026-2 [75.5 kB]
Get:7 http://archive.ubuntu.com/ubuntu bionic/universe amd64 fonts-texgyre all
20160520-1 [8,761 kB]
Get:8 http://archive.ubuntu.com/ubuntu bionic/main amd64 javascript-common all
11 [6,066 B]
Get:9 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsfilters1
amd64 1.20.2-0ubuntu3.1 [108 kB]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsimage2
amd64 2.2.7-1ubuntu2.8 [18.6 kB]
Get:11 http://archive.ubuntu.com/ubuntu bionic/main amd64 libijs-0.35 amd64

```


0.35-13 [15.5 kB]
 Get:12 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 libjbig2dec0 amd64
 0.13-6 [55.9 kB]
 Get:13 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libgs9-common
 all 9.26~dfsg+0-0ubuntu0.18.04.14 [5,092 kB]
 Get:14 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libgs9 amd64
 9.26~dfsg+0-0ubuntu0.18.04.14 [2,265 kB]
 Get:15 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 libjs-jquery all
 3.2.1-1 [152 kB]
 Get:16 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libkpathsea6
 amd64 2017.20170613.44572-8ubuntu0.1 [54.9 kB]
 Get:17 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 libpotrace0 amd64
 1.14-2 [17.4 kB]
 Get:18 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libptexenc1
 amd64 2017.20170613.44572-8ubuntu0.1 [34.5 kB]
 Get:19 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 rubygems-integration
 all 1.11 [4,994 B]
 Get:20 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 ruby2.5 amd64
 2.5.1-1ubuntu1.10 [48.6 kB]
 Get:21 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 ruby amd64 1:2.5.1
 [5,712 B]
 Get:22 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 rake all
 12.3.1-1ubuntu0.1 [44.9 kB]
 Get:23 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 ruby-did-you-mean all
 1.2.0-2 [9,700 B]
 Get:24 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 ruby-minitest all
 5.10.3-1 [38.6 kB]
 Get:25 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 ruby-net-telnet all
 0.1.1-2 [12.6 kB]
 Get:26 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 ruby-power-assert all
 0.3.0-1 [7,952 B]
 Get:27 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 ruby-test-unit all
 3.2.5-1 [61.1 kB]
 Get:28 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libruby2.5
 amd64 2.5.1-1ubuntu1.10 [3,071 kB]
 Get:29 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libsyntax1
 amd64 2017.20170613.44572-8ubuntu0.1 [41.4 kB]
 Get:30 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libtexlua52
 amd64 2017.20170613.44572-8ubuntu0.1 [91.2 kB]
 Get:31 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libtexluajit2
 amd64 2017.20170613.44572-8ubuntu0.1 [230 kB]
 Get:32 <http://archive.ubuntu.com/ubuntu> bionic-updates/main amd64 libzip-0-13
 amd64 0.13.62-3.1ubuntu0.18.04.1 [26.0 kB]
 Get:33 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 lmodern all 2.004.5-3
 [9,631 kB]
 Get:34 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 preview-latex-style
 all 11.91-1ubuntu1 [185 kB]
 Get:35 <http://archive.ubuntu.com/ubuntu> bionic/main amd64 tiutils amd64 1.41-2

```

[56.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tex-gyre all
20160520-1 [4,998 kB]
Get:37 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 texlive-
binaries amd64 2017.20170613.44572-8ubuntu0.1 [8,179 kB]
Get:38 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-base all
2017.20180305-1 [18.7 MB]
Get:39 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-fonts-
recommended all 2017.20180305-1 [5,262 kB]
Get:40 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-plain-
generic all 2017.20180305-2 [23.6 MB]
Get:41 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-generic-
recommended all 2017.20180305-1 [15.9 kB]
Get:42 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-base all
2017.20180305-1 [951 kB]
Get:43 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-
recommended all 2017.20180305-1 [14.9 MB]
Get:44 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-pictures
all 2017.20180305-1 [4,026 kB]
Get:45 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-latex-
extra all 2017.20180305-2 [10.6 MB]
Get:46 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:47 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-xetex all
2017.20180305-1 [10.7 MB]
Fetched 146 MB in 6s (25.9 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages ...
Selecting previously unselected package fonts-droid-fallback.
(Reading database ... 148492 files and directories currently installed.)
Preparing to unpack .../00-fonts-droid-fallback_1%3a6.0.1r16-1.1_all.deb ...
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1) ...
Selecting previously unselected package fonts-lato.
Preparing to unpack .../01-fonts-lato_2.0-2_all.deb ...
Unpacking fonts-lato (2.0-2) ...
Selecting previously unselected package poppler-data.
Preparing to unpack .../02-poppler-data_0.4.8-2_all.deb ...
Unpacking poppler-data (0.4.8-2) ...
Selecting previously unselected package tex-common.
Preparing to unpack .../03-tex-common_6.09_all.deb ...
Unpacking tex-common (6.09) ...
Selecting previously unselected package fonts-lmodern.
Preparing to unpack .../04-fonts-lmodern_2.004.5-3_all.deb ...
Unpacking fonts-lmodern (2.004.5-3) ...
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack .../05-fonts-noto-mono_20171026-2_all.deb ...
Unpacking fonts-noto-mono (20171026-2) ...
Selecting previously unselected package fonts-texgyre.

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Preparing to unpack .../06-fonts-texgyre_20160520-1_all.deb ...
Unpacking fonts-texgyre (20160520-1) ...
Selecting previously unselected package javascript-common.
Preparing to unpack .../07-javascript-common_11_all.deb ...
Unpacking javascript-common (11) ...
Selecting previously unselected package libcupsfilters1:amd64.
Preparing to unpack .../08-libcupsfilters1_1.20.2-0ubuntu3.1_amd64.deb ...
Unpacking libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) ...
Selecting previously unselected package libcupsimage2:amd64.
Preparing to unpack .../09-libcupsimage2_2.2.7-1ubuntu2.8_amd64.deb ...
Unpacking libcupsimage2:amd64 (2.2.7-1ubuntu2.8) ...
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack .../10-libijs-0.35_0.35-13_amd64.deb ...
Unpacking libijs-0.35:amd64 (0.35-13) ...
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack .../11-libjbig2dec0_0.13-6_amd64.deb ...
Unpacking libjbig2dec0:amd64 (0.13-6) ...
Selecting previously unselected package libgs9-common.
Preparing to unpack .../12-libgs9-common_9.26~dfsg+0-0ubuntu0.18.04.14_all.deb
...
Unpacking libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.14) ...
Selecting previously unselected package libgs9:amd64.
Preparing to unpack .../13-libgs9_9.26~dfsg+0-0ubuntu0.18.04.14_amd64.deb ...
Unpacking libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.14) ...
Selecting previously unselected package libjs-jquery.
Preparing to unpack .../14-libjs-jquery_3.2.1-1_all.deb ...
Unpacking libjs-jquery (3.2.1-1) ...
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack .../15-libkpathsea6_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libpotrace0.
Preparing to unpack .../16-libpotrace0_1.14-2_amd64.deb ...
Unpacking libpotrace0 (1.14-2) ...
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack .../17-libptexenc1_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package rubygems-integration.
Preparing to unpack .../18-rubygems-integration_1.11_all.deb ...
Unpacking rubygems-integration (1.11) ...
Selecting previously unselected package ruby2.5.
Preparing to unpack .../19-ruby2.5_2.5.1-1ubuntu1.10_amd64.deb ...
Unpacking ruby2.5 (2.5.1-1ubuntu1.10) ...
Selecting previously unselected package ruby.
Preparing to unpack .../20-ruby_1%3a2.5.1_amd64.deb ...
Unpacking ruby (1:2.5.1) ...
Selecting previously unselected package rake.

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Preparing to unpack .../21-rake_12.3.1-1ubuntu0.1_all.deb ...
Unpacking rake (12.3.1-1ubuntu0.1) ...
Selecting previously unselected package ruby-did-you-mean.
Preparing to unpack .../22-ruby-did-you-mean_1.2.0-2_all.deb ...
Unpacking ruby-did-you-mean (1.2.0-2) ...
Selecting previously unselected package ruby-minitest.
Preparing to unpack .../23-ruby-minitest_5.10.3-1_all.deb ...
Unpacking ruby-minitest (5.10.3-1) ...
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack .../24-ruby-net-telnet_0.1.1-2_all.deb ...
Unpacking ruby-net-telnet (0.1.1-2) ...
Selecting previously unselected package ruby-power-assert.
Preparing to unpack .../25-ruby-power-assert_0.3.0-1_all.deb ...
Unpacking ruby-power-assert (0.3.0-1) ...
Selecting previously unselected package ruby-test-unit.
Preparing to unpack .../26-ruby-test-unit_3.2.5-1_all.deb ...
Unpacking ruby-test-unit (3.2.5-1) ...
Selecting previously unselected package libruby2.5:amd64.
Preparing to unpack .../27-libruby2.5_2.5.1-1ubuntu1.10_amd64.deb ...
Unpacking libruby2.5:amd64 (2.5.1-1ubuntu1.10) ...
Selecting previously unselected package libsyntax1:amd64.
Preparing to unpack .../28-libsyntax1_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libsyntax1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libtexlua52:amd64.
Preparing to unpack .../29-libtexlua52_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
.../30-libtexluajit2_2017.20170613.44572-8ubuntu0.1_amd64.deb ...
Unpacking libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libzip-0-13:amd64.
Preparing to unpack .../31-libzip-0-13_0.13.62-3.1ubuntu0.18.04.1_amd64.deb ...
Unpacking libzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) ...
Selecting previously unselected package lmodern.
Preparing to unpack .../32-lmodern_2.004.5-3_all.deb ...
Unpacking lmodern (2.004.5-3) ...
Selecting previously unselected package preview-latex-style.
Preparing to unpack .../33-preview-latex-style_11.91-1ubuntu1_all.deb ...
Unpacking preview-latex-style (11.91-1ubuntu1) ...
Selecting previously unselected package t1utils.
Preparing to unpack .../34-t1utils_1.41-2_amd64.deb ...
Unpacking t1utils (1.41-2) ...
Selecting previously unselected package tex-gyre.
Preparing to unpack .../35-tex-gyre_20160520-1_all.deb ...
Unpacking tex-gyre (20160520-1) ...
Selecting previously unselected package texlive-binaries.

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Preparing to unpack .../36-texlive-
binaries_2017.20170613.44572-8ubuntu0.1_amd64.deb ...
Unpacking texlive-binaries (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package texlive-base.
Preparing to unpack .../37-texlive-base_2017.20180305-1_all.deb ...
Unpacking texlive-base (2017.20180305-1) ...
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack .../38-texlive-fonts-recommended_2017.20180305-1_all.deb ...
Unpacking texlive-fonts-recommended (2017.20180305-1) ...
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack .../39-texlive-plain-generic_2017.20180305-2_all.deb ...
Unpacking texlive-plain-generic (2017.20180305-2) ...
Selecting previously unselected package texlive-generic-recommended.
Preparing to unpack .../40-texlive-generic-recommended_2017.20180305-1_all.deb
...
Unpacking texlive-generic-recommended (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-base.
Preparing to unpack .../41-texlive-latex-base_2017.20180305-1_all.deb ...
Unpacking texlive-latex-base (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack .../42-texlive-latex-recommended_2017.20180305-1_all.deb ...
Unpacking texlive-latex-recommended (2017.20180305-1) ...
Selecting previously unselected package texlive-pictures.
Preparing to unpack .../43-texlive-pictures_2017.20180305-1_all.deb ...
Unpacking texlive-pictures (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack .../44-texlive-latex-extra_2017.20180305-2_all.deb ...
Unpacking texlive-latex-extra (2017.20180305-2) ...
Selecting previously unselected package tipa.
Preparing to unpack .../45-tipa_2%3a1.3-20_all.deb ...
Unpacking tipa (2:1.3-20) ...
Selecting previously unselected package texlive-xetex.
Preparing to unpack .../46-texlive-xetex_2017.20180305-1_all.deb ...
Unpacking texlive-xetex (2017.20180305-1) ...
Setting up libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.14) ...
Setting up libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up libjs-jquery (3.2.1-1) ...
Setting up libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up fonts-droid-fallback (1:6.0.1r16-1.1) ...
Setting up libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up tex-common (6.09) ...
update-language: texlive-base not installed and configured, doing nothing!
Setting up poppler-data (0.4.8-2) ...
Setting up tex-gyre (20160520-1) ...
Setting up preview-latex-style (11.91-1ubuntu1) ...
Setting up fonts-texgyre (20160520-1) ...
Setting up fonts-noto-mono (20171026-2) ...

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Setting up fonts-lato (2.0-2) ...
Setting up libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) ...
Setting up libcupsimage2:amd64 (2.2.7-1ubuntu2.8) ...
Setting up libjbig2dec0:amd64 (0.13-6) ...
Setting up ruby-did-you-mean (1.2.0-2) ...
Setting up t1utils (1.41-2) ...
Setting up ruby-net-telnet (0.1.1-2) ...
Setting up libijs-0.35:amd64 (0.35-13) ...
Setting up rubygems-integration (1.11) ...
Setting up libpotrace0 (1.14-2) ...
Setting up javascript-common (11) ...
Setting up ruby-minitest (5.10.3-1) ...
Setting up libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) ...
Setting up libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.14) ...
Setting up libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up fonts-lmodern (2.004.5-3) ...
Setting up ruby-power-assert (0.3.0-1) ...
Setting up texlive-binaries (2017.20170613.44572-8ubuntu0.1) ...
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up texlive-base (2017.20180305-1) ...
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST...
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN...
mktexlsr: Updating /var/lib/texmf/ls-R...
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4: /var/lib/texmf/dvips/config
/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4: /var/lib/texmf/dvipdfmx
/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4:
/var/lib/texmf/tex/generic/config/pdftexconfig.tex
Setting up texlive-fonts-recommended (2017.20180305-1) ...
Setting up texlive-plain-generic (2017.20180305-2) ...
Setting up texlive-generic-recommended (2017.20180305-1) ...
Setting up texlive-latex-base (2017.20180305-1) ...
Setting up lmodern (2.004.5-3) ...
Setting up texlive-latex-recommended (2017.20180305-1) ...
Setting up texlive-pictures (2017.20180305-1) ...
Setting up tipa (2:1.3-20) ...
Regenerating '/var/lib/texmf/fmtutil.cnf-DEBIAN'... done.
Regenerating '/var/lib/texmf/fmtutil.cnf-TEXLIVEDIST'... done.
update-fmtutil has updated the following file(s):
    /var/lib/texmf/fmtutil.cnf-DEBIAN
    /var/lib/texmf/fmtutil.cnf-TEXLIVEDIST
If you want to activate the changes in the above file(s),

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you should run fmtutil-sys or fmtutil.
Setting up texlive-latex-extra (2017.20180305-2) ...
Setting up texlive-xetex (2017.20180305-1) ...
Setting up ruby2.5 (2.5.1-1ubuntu1.10) ...
Setting up ruby (1:2.5.1) ...
Setting up ruby-test-unit (3.2.5-1) ...
Setting up rake (12.3.1-1ubuntu0.1) ...
Setting up libruby2.5:amd64 (2.5.1-1ubuntu1.10) ...
Processing triggers for mime-support (3.60ubuntu1) ...
Processing triggers for libc-bin (2.27-3ubuntu1.2) ...
/sbin/ldconfig.real: /usr/local/lib/python3.7/dist-
packages/ideep4py/lib/libmkldnn.so.0 is not a symbolic link

Processing triggers for man-db (2.8.3-2ubuntu0.1) ...
Processing triggers for fontconfig (2.12.6-0ubuntu2) ...
Processing triggers for tex-common (6.09) ...
Running updmap-sys. This may take some time... done.
Running mktexlsr /var/lib/texmf ... done.
Building format(s) --all.
    This may take some time... done.
[NbConvertApp] Converting notebook /content/drive/My Drive/Colab
Notebooks/cktran_09859713.ipynb to pdf
[NbConvertApp] Support files will be in cktran_09859713_files/
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
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[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Making directory ./cktran_09859713_files
[NbConvertApp] Writing 74997 bytes to ./notebook.tex
[NbConvertApp] Building PDF
[NbConvertApp] Running xelatex 3 times: [u'xelatex', u'./notebook.tex',
'-quiet']
[NbConvertApp] Running bibtex 1 time: [u'bibtex', u'./notebook']
[NbConvertApp] WARNING | bibtex had problems, most likely because there were no
citations
[NbConvertApp] PDF successfully created
[NbConvertApp] Writing 956959 bytes to /content/drive/My

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Drive/cktran_09859713.pdf

<IPython.core.display.Javascript object>

<IPython.core.display.Javascript object>

[6]: 'File ready to be Downloaded and Saved to Drive'