Prj03_Filtering

March 4, 2024

0.0.1 EE 421/521 Image Processing - Spring 2021-22

0.1 Project 3 - Two-Dimensional Filtering

Submission deadline: 10 March 2022 In this project, you will implement the following:

1. A 2D convolution
2. High-frequency boost filter
3. Horizontal edge detection filter
4. 135-degree edge detection filter
5. Unsharp-masking filter (long approach)
6. Unsharp-masking filter (direct approach)

Note: This project will be graded for both EE 421 (HW2) and EE 521 (HW2) students.

```
# Bu, kod olarak biçimlendirilmiştir
```

Emirhan Benderli ***********************************

[ ]:
```
# STEP 0 Import the necessary packages

# reading/writing image files
from skimage import io
from skimage import color

# displaying images and plots
import matplotlib.pyplot as plt

# array operations
import numpy as np

# signal processing operations
from scipy import signal
from scipy.linalg import circulant
```

[ ]:
```
# function to round image data to nearest integer, truncate to range [0, 255],␣
 ↪set data type to uint8
```

```
def my_imgTruncate(img):

    img = np.round(img, 0)
    img = np.minimum(img, 255)
    img = np.maximum(img, 0)
    img = img.astype('uint8')

    return img
```

[ ]:

```
# my function to convert to lumincance, round to nearest integer,
# truncate to range [0, 255], and then set data

def my_imgLuminance(imgRGB):

    # make sure it is a color image
    dim_img = imgRGB.shape[2]
    assert dim_img >= 3

    # get the luminance data
    if dim_img == 3:
        imgLum = color.rgb2gray(imgRGB)
    else:
        # ignore the alpha channel
        imgLum = color.rgb2gray(imgRGB[:,:,0:3])

    imgLum = np.round(imgLum * 255, 0)
    imgLum = np.minimum(imgLum, 255)
    imgLum = np.maximum(imgLum, 0)
    imgLum = imgLum.astype('uint8')

    return imgLum

# end of function
```

[ ]:

```
# ===============================
# (1.a) Implement 2D convolution
# ===============================

# ADD YOUR CODE HERE

# calculate 2-D convolution

def my_filter2D(X, H):

    # X: 2D input image
    # H: 2D filter kernel
    # make sure both X and H are 2-D
    assert( X.ndim == 2)
    assert( H.ndim == 2)

    # get the horizontal and vertical size of X and H
    X_size_x = X.shape[1]
    X_size_y = X.shape[0]
    H_size_x = H.shape[1]
    H_size_y = H.shape[0]

    # calculate the horizontal and vertical size of Y (assume "full" convolution)
    Y_size_x = X_size_x + H_size_x - 1
    Y_size_y = X_size_y + H_size_y - 1

    # create an empty output array
    Y = np.zeros((Y_size_y,Y_size_x))

    # (i) go over output locations
    for row_y in range(Y_size_y):
        for col_y in range(Y_size_x):
        # (ii) go over input locations
            for row_x in range(X_size_y):
                for col_x in range(X_size_x):
            # (iii) make sure the kernel is within bounds
                    if (row_y-row_x >= H_size_y or col_y-col_x >= H_size_x ): continue
                    elif( row_y-row_x < 0 or col_y-col_x <0): break
            # (iv) calculate the convolution sum
                    Y[row_y,col_y]+= X[row_x,col_x] * H[row_y-row_x,col_y-col_x]


    return Y

# end of function
```

[ ]:

```
# ==============================
# (1.b) Test your 2-D convolution function
# ==============================

# a sample 2-D input
X = np.array([[2, 1, 2, 3, 0],
              [1, 3, 2, 1, 1],
              [2, 3, 0, 1, 2],
              [0, 1, 3, 2, 1]])

# a sample 2-D filter
```

```
H = np.array([[2, 4, -2],
              [1, 2, -1]])

# call your function to calculate 2D convolution
Y_my = my_filter2D(X, H)

# print your output
print("My convolution: \n", Y_my)

# use SciPy function to calculate 2D convolution
Y_sp = signal.convolve2d(X, H, mode='full', boundary='fill', fillvalue=0)

# print SciPy output and compare it with yours
print("\nSciPy convolution: \n", Y_sp)

# print the error evaluated as sum-squared-difference
print("\nError: ", ((Y_my - Y_sp)*(Y_my - Y_sp)).sum())
```

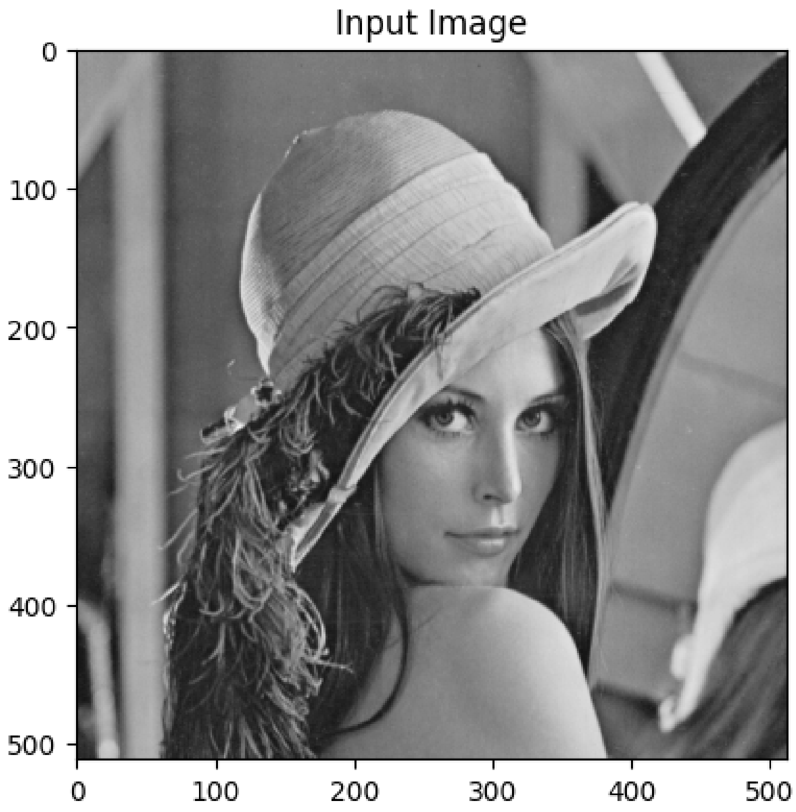
```
My convolution:
 [[ 4. 10.  4. 12.  8. -6.  0.]
 [ 4. 15. 16. 10.  6. -1. -2.]
 [ 5. 19. 15. -2.  9.  7. -5.]
 [ 2.  9. 14. 12.  8.  3. -4.]
 [ 0.  1.  5.  7.  2.  0. -1.]]

SciPy convolution:
 [[ 4 10  4 12  8 -6  0]
 [ 4 15 16 10  6 -1 -2]
 [ 5 19 15 -2  9  7 -5]
 [ 2  9 14 12  8  3 -4]
 [ 0  1  5  7  2  0 -1]]

Error:  0.0
```

[ ]:

```
# STEP 2 Pick an image for filtering
from google.colab import drive
drive.mount('/content/drive',force_remount = True)

# set image folder
image_folder = r'/content/drive/MyDrive/Colab Notebooks/421_Images'

# read input image
image_file = r'/lena.png'
image_path = image_folder + image_file
imgRGB = io.imread(image_path)

height = imgRGB.shape[0]
```

```
width = imgRGB.shape[1]
bands = imgRGB.shape[2]
datatype = imgRGB.dtype

print("Image width is {} and image height is {}.".format(width, height))
print("Number of color bands is {}.".format(bands))
print("Image data type is {}.\n".format(datatype))

# calculate the luminance image
img_input = my_imgLuminance(imgRGB)

# display luminance image
plt.imshow(img_input, cmap='gray', vmin=0, vmax=255)
plt.title('Input Image')
#plt.xticks([]), plt.yticks([])
plt.show()
```

```
Mounted at /content/drive
Image width is 512 and image height is 512.
Number of color bands is 3.
Image data type is uint8.
```

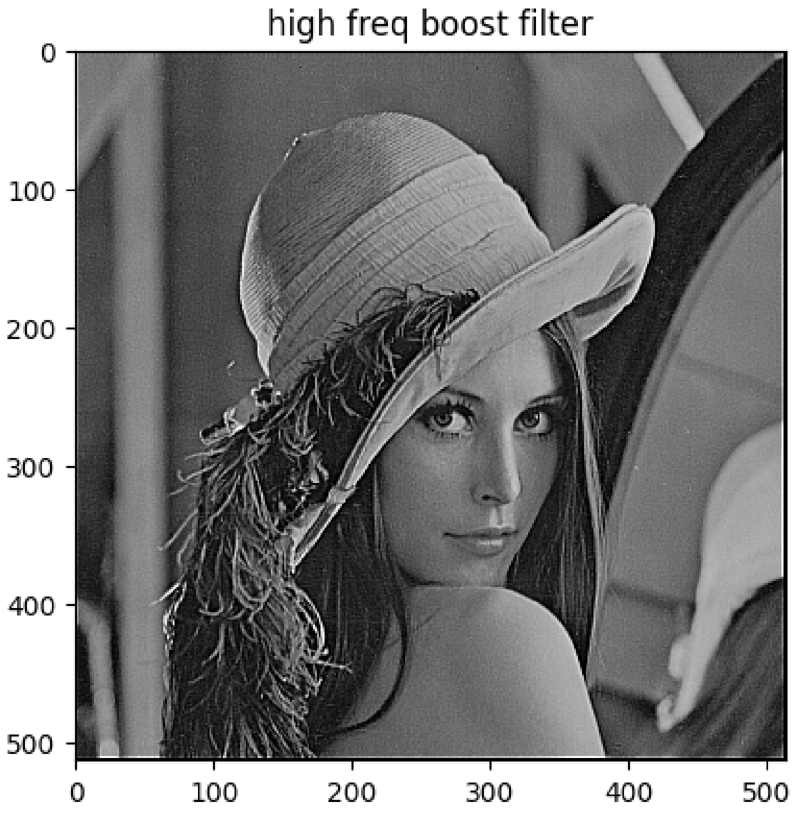


[ ]:

```
# ======================================================
# (2.1) Define a high-frequency boost filter and apply it on input image
# ======================================================

# ADD YOUR CODE HERE

# (i) define a high-frequency boost filter
hfbf = np.multiply([[-1,-1,-1],[-1,10,-1],[-1,-1,-1]], 0.4)
# (ii) apply the high-frequency boost filter on the input image
# use the signal.convolve2d() function for filtering
high_freq_img = signal.convolve2d(img_input,hfbf ,mode='full' ,boundary='fill', fillvalue=0)
# (iii) display the output image
plt.imshow(high_freq_img, cmap='gray', vmin=0, vmax=255)
plt.title("high freq boost filter")
```

[ ]:

```
Text(0.5, 1.0, 'high freq boost filter')
```

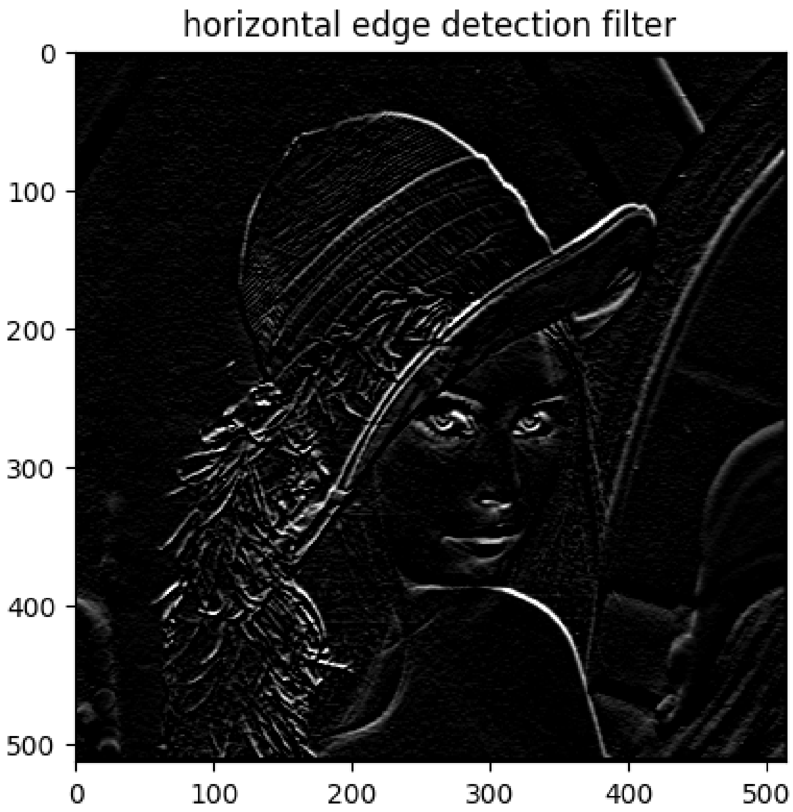


[ ]:

```
# ==========================================================
# (2.2) Define a horizontal edge detection filter and apply it on input image
# ==========================================================

# ADD YOUR CODE HERE
hedf = [[1,2,1],[0,0,0],[-1,-2,-1]]

# (ii) apply the horizontal edge detection filter on the input image
# use the signal.convolve2d() function for filtering
hori_img = signal.convolve2d(img_input, hedf, mode='full', boundary='fill',␣
 ↪fillvalue=0)

# (iii) display the output image
plt.imshow(hori_img, cmap='gray',vmin=0, vmax=255)
plt.title("horizontal edge detection filter")
```

[ ]:

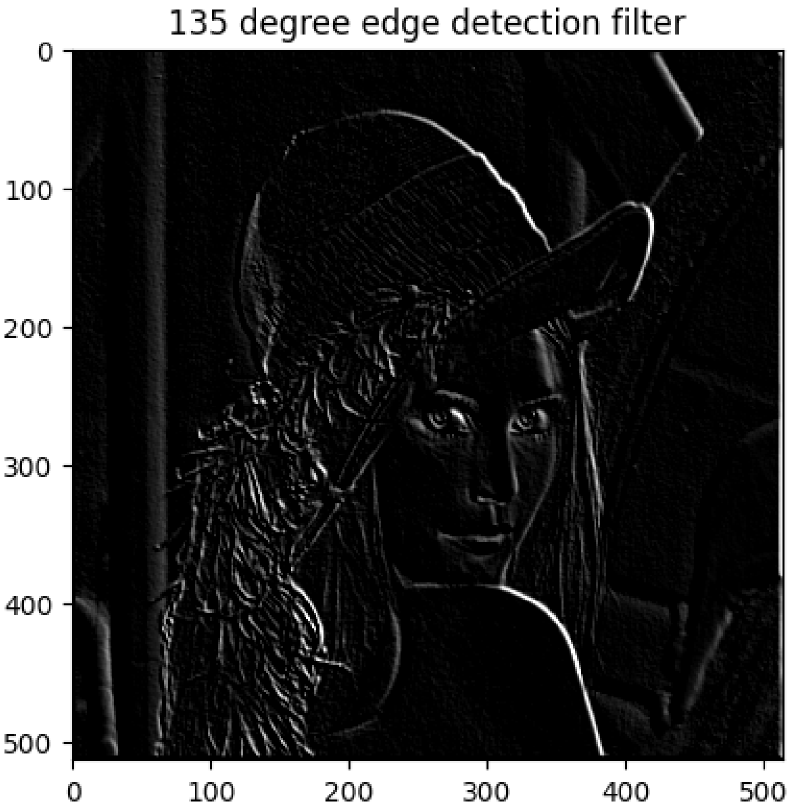
```
Text(0.5, 1.0, 'horizontal edge detection filter')
```



[ ]:

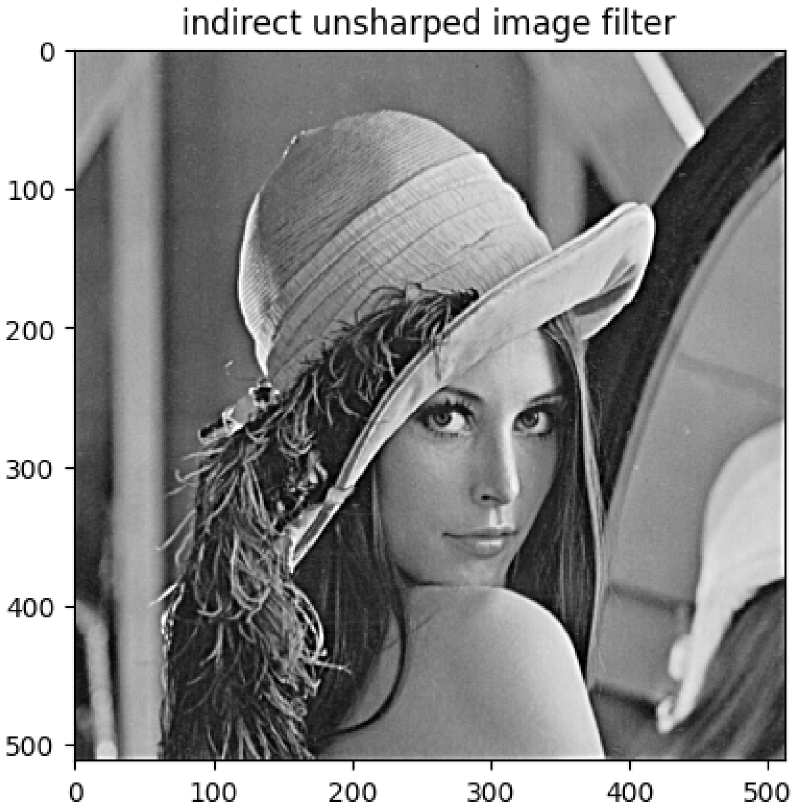
```
# ==========================================================
# (2.3) Apply a 135-degree edge detection filter on input image
# ==========================================================
# ADD YOUR CODE HERE

# (i) define a 135-degree edge detection filter
degH = [[ 0, 1, 1],[-1, 0, 1],[-1,-1, 0]]
# (ii) apply the 135-degree edge detection filter on the input image
# use the signal.convolve2d() function for filtering
deg_img = signal.convolve2d(img_input, degH, mode='full', boundary='fill',␣
 ↪fillvalue=0)

# (iii) display the output image
plt.imshow(deg_img, cmap='gray', vmin=0, vmax=255)
plt.title("135 degree edge detection filter")
```

```
[ ]: Text(0.5, 1.0, '135 degree edge detection filter')
```



```
[ ]: # ==========================================================================
     # (3.1) Implement unsharp masking (long approach)
     # ==========================================================================

     # ADD YOUR CODE HERE
```

```python
# (i) define a Gaussian filter
# h
def gaussianFilter(M):
    sigma= 0.425*M
    size= np.round(2.55 * M, 0)
    size= size.astype(int)
    if (size%2==0):
        size -=1
    my_filter = signal.windows.gaussian(size, sigma, sym=True)
    return my_filter

M= 5
h= gaussianFilter(M)
h= h/np.sum(h)
h= np.outer(h,h)

# (ii) apply the Gaussian filter to obtain a blurred image
# use the signal.convolve2d() function for filtering
# x * h
gauss_filter_img= signal.convolve2d(img_input, h, mode='same', boundary='fill', fillvalue=0)

# (iii) calculate the sharpening image
# x - x * h
sharpening_img= img_input-gauss_filter_img
# (iv) calculate the output image using the blurred image and sharpening image
# x + x - x * h
unsharp_img= img_input + sharpening_img
# (v) display the output image
plt.imshow(unsharp_img, cmap='gray', vmin=0, vmax=255)
plt.title("indirect unsharped image filter")
plt.show()
```

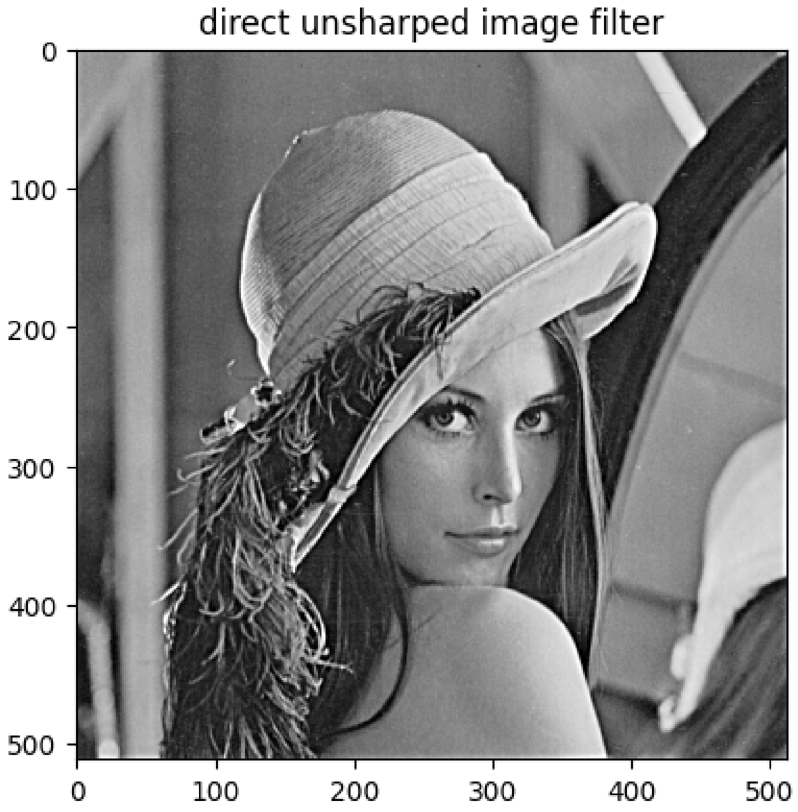


[ ]:

```
# ===========================================================================
# (3.2) Implement unsharp masking (direct approach)
# ===========================================================================

# ADD YOUR CODE HERE

# (i) define convolution mask
# x + x - x * h = x * I + x * I - x * h = x * (I + I - h) = x * D
#
# 3 x 3 identity filter I = [[0, 0, 0],
#                             [0, 1, 0]]
#                             [0, 0, 0]]
#
# Direct unsharp masking filter: D = 2I - h
size= h.shape[0]
I= np.zeros((size,size))
I[int((size-1)/2), int((size-1)/2)]= 1
conv_mask= (2*I)-h

# (ii) calculate the output image
# use the signal.convolve2d() function for filtering
```

```
unsharp_img2 = signal.convolve2d(img_input, conv_mask, mode='same',␣
 ↪boundary='fill', fillvalue=0)

# (iii) display the output image
plt.imshow(unsharp_img2, cmap='gray', vmin=0, vmax=255)
plt.title("direct unsharped image filter")
```

```
[ ]: Text(0.5, 1.0, 'direct unsharped image filter')
```



STEP 4 Comments on the results

ADD YOUR COMMENTS HERE

(a) Comment on the filtering results in 2.1, 2.2 and 2.3. Do the results look as expected? 2.1 is more detailed(sharper). 2.2 shows horizantal boundary with brighter color while 2.3 showing 135 degree boundary with brighter colors.

(b) Comment on the filtering results of 3.1 and 3.2. Do they look the same and appear as enhanced? They are looking sharper and the same, because both techniques are basicly do the same thing. Difference between them is indirect approach being longer to apply.

```
[ ]: !sudo apt-get install texlive-xetex texlive-fonts-recommended␣
      ↪texlive-plain-generic
```

[53]:

```
!jupyter nbconvert --to pdf '/content/drive/My Drive/Colab Notebooks/
  ↪Prj03_Filtering.ipynb'
```

```
[NbConvertApp] WARNING | pattern '/content/drive/My Drive/Colab
Notebooks/Prj03_Filtering.ipynb' matched no files
This application is used to convert notebook files (*.ipynb)
        to various other formats.

        WARNING: THE COMMANDLINE INTERFACE MAY CHANGE IN FUTURE RELEASES.

Options
=======
The options below are convenience aliases to configurable class-options,
as listed in the "Equivalent to" description-line of the aliases.
To see all configurable class-options for some <cmd>, use:
    <cmd> --help-all

--debug
    set log level to logging.DEBUG (maximize logging output)
    Equivalent to: [--Application.log_level=10]
--show-config
    Show the application's configuration (human-readable format)
    Equivalent to: [--Application.show_config=True]
--show-config-json
    Show the application's configuration (json format)
    Equivalent to: [--Application.show_config_json=True]
--generate-config
    generate default config file
    Equivalent to: [--JupyterApp.generate_config=True]
-y
    Answer yes to any questions instead of prompting.
    Equivalent to: [--JupyterApp.answer_yes=True]
--execute
    Execute the notebook prior to export.
    Equivalent to: [--ExecutePreprocessor.enabled=True]
--allow-errors
    Continue notebook execution even if one of the cells throws an error and
include the error message in the cell output (the default behaviour is to abort
conversion). This flag is only relevant if '--execute' was specified, too.
    Equivalent to: [--ExecutePreprocessor.allow_errors=True]
--stdin
    read a single notebook file from stdin. Write the resulting notebook with
default basename 'notebook.*'
    Equivalent to: [--NbConvertApp.from_stdin=True]
--stdout
    Write notebook output to stdout instead of files.
    Equivalent to: [--NbConvertApp.writer_class=StdoutWriter]
```

```
--inplace
    Run nbconvert in place, overwriting the existing notebook (only
            relevant when converting to notebook format)
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=]
--clear-output
    Clear output of current file and save in place,
            overwriting the existing notebook.
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=
--ClearOutputPreprocessor.enabled=True]
--no-prompt
    Exclude input and output prompts from converted document.
    Equivalent to: [--TemplateExporter.exclude_input_prompt=True
--TemplateExporter.exclude_output_prompt=True]
--no-input
    Exclude input cells and output prompts from converted document.
            This mode is ideal for generating code-free reports.
    Equivalent to: [--TemplateExporter.exclude_output_prompt=True
--TemplateExporter.exclude_input=True
--TemplateExporter.exclude_input_prompt=True]
--allow-chromium-download
    Whether to allow downloading chromium if no suitable version is found on the
system.
    Equivalent to: [--WebPDFExporter.allow_chromium_download=True]
--disable-chromium-sandbox
    Disable chromium security sandbox when converting to PDF..
    Equivalent to: [--WebPDFExporter.disable_sandbox=True]
--show-input
    Shows code input. This flag is only useful for dejavu users.
    Equivalent to: [--TemplateExporter.exclude_input=False]
--embed-images
    Embed the images as base64 dataurls in the output. This flag is only useful
for the HTML/WebPDF/Slides exports.
    Equivalent to: [--HTMLExporter.embed_images=True]
--sanitize-html
    Whether the HTML in Markdown cells and cell outputs should be sanitized..
    Equivalent to: [--HTMLExporter.sanitize_html=True]
--log-level=<Enum>
    Set the log level by value or name.
    Choices: any of [0, 10, 20, 30, 40, 50, 'DEBUG', 'INFO', 'WARN', 'ERROR',
'CRITICAL']
    Default: 30
    Equivalent to: [--Application.log_level]
--config=<Unicode>
    Full path of a config file.
    Default: ''
    Equivalent to: [--JupyterApp.config_file]
```

```
--to=<Unicode>
    The export format to be used, either one of the built-in formats
            ['asciidoc', 'custom', 'html', 'latex', 'markdown', 'notebook',
'pdf', 'python', 'rst', 'script', 'slides', 'webpdf']
            or a dotted object name that represents the import path for an
            ``Exporter`` class
    Default: ''
    Equivalent to: [--NbConvertApp.export_format]
--template=<Unicode>
    Name of the template to use
    Default: ''
    Equivalent to: [--TemplateExporter.template_name]
--template-file=<Unicode>
    Name of the template file to use
    Default: None
    Equivalent to: [--TemplateExporter.template_file]
--theme=<Unicode>
    Template specific theme(e.g. the name of a JupyterLab CSS theme distributed
    as prebuilt extension for the lab template)
    Default: 'light'
    Equivalent to: [--HTMLExporter.theme]
--sanitize_html=<Bool>
    Whether the HTML in Markdown cells and cell outputs should be sanitized.This
    should be set to True by nbviewer or similar tools.
    Default: False
    Equivalent to: [--HTMLExporter.sanitize_html]
--writer=<DottedObjectName>
    Writer class used to write the
                                        results of the conversion
    Default: 'FilesWriter'
    Equivalent to: [--NbConvertApp.writer_class]
--post=<DottedOrNone>
    PostProcessor class used to write the
                                        results of the conversion
    Default: ''
    Equivalent to: [--NbConvertApp.postprocessor_class]
--output=<Unicode>
    overwrite base name use for output files.
                can only be used when converting one notebook at a time.
    Default: ''
    Equivalent to: [--NbConvertApp.output_base]
--output-dir=<Unicode>
    Directory to write output(s) to. Defaults
                                  to output to the directory of each notebook.
To recover
                                  previous default behaviour (outputting to the
current
                                  working directory) use . as the flag value.
    Default: ''
    Equivalent to: [--FilesWriter.build_directory]
--reveal-prefix=<Unicode>
    The URL prefix for reveal.js (version 3.x).
            This defaults to the reveal CDN, but can be any url pointing to a
copy
            of reveal.js.
            For speaker notes to work, this must be a relative path to a local
            copy of reveal.js: e.g., "reveal.js".
            If a relative path is given, it must be a subdirectory of the
            current directory (from which the server is run).
            See the usage documentation
            (https://nbconvert.readthedocs.io/en/latest/usage.html#reveal-js-
html-slideshow)
            for more details.
    Default: ''
    Equivalent to: [--SlidesExporter.reveal_url_prefix]
--nbformat=<Enum>
    The nbformat version to write.
            Use this to downgrade notebooks.
    Choices: any of [1, 2, 3, 4]
    Default: 4
    Equivalent to: [--NotebookExporter.nbformat_version]

Examples
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    The simplest way to use nbconvert is

            > jupyter nbconvert mynotebook.ipynb --to html

            Options include ['asciidoc', 'custom', 'html', 'latex', 'markdown',
'notebook', 'pdf', 'python', 'rst', 'script', 'slides', 'webpdf'].

            > jupyter nbconvert --to latex mynotebook.ipynb

            Both HTML and LaTeX support multiple output templates. LaTeX
includes
            'base', 'article' and 'report'.  HTML includes 'basic', 'lab' and
            'classic'. You can specify the flavor of the format used.

            > jupyter nbconvert --to html --template lab mynotebook.ipynb

            You can also pipe the output to stdout, rather than a file

            > jupyter nbconvert mynotebook.ipynb --stdout

            PDF is generated via latex
            > jupyter nbconvert mynotebook.ipynb --to pdf

            You can get (and serve) a Reveal.js-powered slideshow

            > jupyter nbconvert myslides.ipynb --to slides --post serve

            Multiple notebooks can be given at the command line in a couple of
            different ways:

            > jupyter nbconvert notebook*.ipynb
            > jupyter nbconvert notebook1.ipynb notebook2.ipynb

            or you can specify the notebooks list in a config file, containing::

                c.NbConvertApp.notebooks = ["my_notebook.ipynb"]

            > jupyter nbconvert --config mycfg.py

To see all available configurables, use `--help-all`.
```

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