Python's Runtime Environment

The Python Imaging Library (PIL)

The Python Imaging Library, which is known as PIL or PILLOW, is the main library we use in python for dealing with image files. This library is not included with python - it's what's known as a third party library, which means you have to download and install it yourself. In the Coursera system, this has all been done for you. Lets do a little exploring of pillow in the jupyter notebooks.

In [1]:

```
# You'll recall that we import a library using the `import` keyword.
import PIL
```

In [5]:

```
# Documentation is a big help in learning a library. There exist standards that make this process easier.
# For example, most libraries let you check their version using the version attribute.
PIL.__version__
```

Out[5]:

```
'5.4.1'
```

In [6]:

```
# Let's figure out how to open an image with `Pillow`. Python provides some built-in functions to help us
# understand the functions and objects which are available in libraries. For instance, the help function,
# when called on any object, returns the object’s built-in documentation. Lets try it with our new library
# module, PIL.
help(PIL)
```

```
Help on package PIL:

NAME
    PIL - Pillow (Fork of the Python Imaging Library)

DESCRIPTION
    Pillow is the friendly PIL fork by Alex Clark and Contributors.
        https://github.com/python-pillow/Pillow/

    Pillow is forked from PIL 1.1.7.

    PIL is the Python Imaging Library by Fredrik Lundh and Contribut
ors.
    Copyright (c) 1999 by Secret Labs AB.

    Use PIL.__version__ for this Pillow version.
    PIL.VERSION is the old PIL version and will be removed in the fu
ture.

    ;-)

PACKAGE CONTENTS
    BdfFontFile
    BlpImagePlugin
    BmpImagePlugin
    BufrStubImagePlugin
    ContainerIO
    CurImagePlugin
    DcxImagePlugin
    DdsImagePlugin
    EpsImagePlugin
    ExifTags
    FitsStubImagePlugin
    FliImagePlugin
    FontFile
    FpxImagePlugin
    FtexImagePlugin
    GbrImagePlugin
    GdImageFile
    GifImagePlugin
    GimpGradientFile
    GimpPaletteFile
    GribStubImagePlugin
    Hdf5StubImagePlugin
    IcnsImagePlugin
    IcoImagePlugin
    ImImagePlugin
    Image
    ImageChops
    ImageCms
    ImageColor
    ImageDraw
    ImageDraw2
    ImageEnhance
    ImageFile
    ImageFilter
    ImageFont
    ImageGrab
    ImageMath
    ImageMode
    ImageMorph
    ImageOps
    ImagePalette
    ImagePath
    ImageQt
    ImageSequence
    ImageShow
    ImageStat
    ImageTk
    ImageTransform
    ImageWin
    ImtImagePlugin
    IptcImagePlugin
    Jpeg2KImagePlugin
    JpegImagePlugin
    JpegPresets
    McIdasImagePlugin
    MicImagePlugin
    MpegImagePlugin
    MpoImagePlugin
    MspImagePlugin
    OleFileIO
    PSDraw
    PaletteFile
    PalmImagePlugin
    PcdImagePlugin
    PcfFontFile
    PcxImagePlugin
    PdfImagePlugin
    PdfParser
    PixarImagePlugin
    PngImagePlugin
    PpmImagePlugin
    PsdImagePlugin
    PyAccess
    SgiImagePlugin
    SpiderImagePlugin
    SunImagePlugin
    TarIO
    TgaImagePlugin
    TiffImagePlugin
    TiffTags
    WalImageFile
    WebPImagePlugin
    WmfImagePlugin
    XVThumbImagePlugin
    XbmImagePlugin
    XpmImagePlugin
    _binary
    _imaging
    _imagingft
    _imagingmath
    _imagingmorph
    _imagingtk
    _tkinter_finder
    _util
    _version
    features

DATA
    PILLOW_VERSION = '5.4.1'
    VERSION = '1.1.7'
```

```
VERSION
    5.4.1

FILE
    /opt/conda/lib/python3.7/site-packages/PIL/__init__.py
```

In [7]:

```
# This shows us that there are a host of classes available to us in the module, as well as version information
# and even the file, called __init__.py, which has the source code for the module itself. We could look up
# the source code for this in the Jupyter console if we wanted to. These documentation standards make it easy
# to poke around an unexplored library.
#
# Python also has a function called dir() which will list the contents of an object. This is especially useful
# with modules where you might want to see what classes you might interact with. Lets list the details of
# the PIL module
dir(PIL)
```

Out[7]:

```
['PILLOW_VERSION',
 'VERSION',
 '__builtins__',
 '__cached__',
 '__doc__',
 '__file__',
 '__loader__',
 '__name__',
 '__package__',
 '__path__',
 '__spec__',
 '__version__',
 '_plugins']
```

In [8]:

```python
# At the top of the list, there is something called Image. This sounds like it could be interesting, so lets
# import it directly, and run the help command on it.
from PIL import Image
help(Image)
```

```
Help on module PIL.Image in PIL:

NAME
    PIL.Image

DESCRIPTION
    # The Python Imaging Library.
    # $Id$
    #
    # the Image class wrapper
    #
    # partial release history:
    # 1995-09-09 fl   Created
    # 1996-03-11 fl   PIL release 0.0 (proof of concept)
    # 1996-04-30 fl   PIL release 0.1b1
    # 1999-07-28 fl   PIL release 1.0 final
    # 2000-06-07 fl   PIL release 1.1
    # 2000-10-20 fl   PIL release 1.1.1
    # 2001-05-07 fl   PIL release 1.1.2
    # 2002-03-15 fl   PIL release 1.1.3
    # 2003-05-10 fl   PIL release 1.1.4
    # 2005-03-28 fl   PIL release 1.1.5
    # 2006-12-02 fl   PIL release 1.1.6
    # 2009-11-15 fl   PIL release 1.1.7
    #
    # Copyright (c) 1997-2009 by Secret Labs AB.  All rights reserve
d.
    # Copyright (c) 1995-2009 by Fredrik Lundh.
    #
    # See the README file for information on usage and redistributio
n.
    #

CLASSES
    builtins.Exception(builtins.BaseException)
        DecompressionBombError
    builtins.RuntimeWarning(builtins.Warning)
        DecompressionBombWarning
    builtins.object
        Image
        ImagePointHandler
        ImageTransformHandler

    class DecompressionBombError(builtins.Exception)
     |  Common base class for all non-exit exceptions.
     |
     |  Method resolution order:
     |      DecompressionBombError
     |      builtins.Exception
     |      builtins.BaseException
     |      builtins.object
     |
     |  Data descriptors defined here:
     |
     |  __weakref__
     |      list of weak references to the object (if defined)
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from builtins.Exception:
     |
     |  __init__(self, /, *args, **kwargs)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |
     |  ------------------------------------------------------------
----------
     |  Static methods inherited from builtins.Exception:
     |
     |  __new__(*args, **kwargs) from builtins.type
     |      Create and return a new object.  See help(type) for accu
rate signature.
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from builtins.BaseException:
     |
     |  __delattr__(self, name, /)
     |      Implement delattr(self, name).
     |
     |  __getattribute__(self, name, /)
     |      Return getattr(self, name).
     |
     |  __reduce__(...)
     |      Helper for pickle.
     |
     |  __repr__(self, /)
     |      Return repr(self).
     |
     |  __setattr__(self, name, value, /)
     |      Implement setattr(self, name, value).
     |
     |  __setstate__(...)
     |
     |  __str__(self, /)
     |      Return str(self).
     |
     |  with_traceback(...)
     |      Exception.with_traceback(tb) --
     |      set self.__traceback__ to tb and return self.
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from builtins.BaseException:
     |
     |  __cause__
     |      exception cause
     |
     |  __context__
     |      exception context
     |
     |  __dict__
     |
     |  __suppress_context__
     |
     |  __traceback__
     |
     |  args

    class DecompressionBombWarning(builtins.RuntimeWarning)
     |  Base class for warnings about dubious runtime behavior.
     |
     |  Method resolution order:
     |      DecompressionBombWarning
     |      builtins.RuntimeWarning
     |      builtins.Warning
     |      builtins.Exception
     |      builtins.BaseException
     |      builtins.object
     |  
     |  Data descriptors defined here:
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
     |  
     |  ------------------------------------------------------------
----------
     |  Methods inherited from builtins.RuntimeWarning:
     |  
     |  __init__(self, /, *args, **kwargs)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |  
     |  ------------------------------------------------------------
----------
     |  Static methods inherited from builtins.RuntimeWarning:
     |  
     |  __new__(*args, **kwargs) from builtins.type
     |      Create and return a new object.  See help(type) for accu
rate signature.
     |  
     |  ------------------------------------------------------------
----------
     |  Methods inherited from builtins.BaseException:
     |  
     |  __delattr__(self, name, /)
     |      Implement delattr(self, name).
     |  
     |  __getattribute__(self, name, /)
     |      Return getattr(self, name).
     |  
     |  __reduce__(...)
     |      Helper for pickle.
     |  
     |  __repr__(self, /)
     |      Return repr(self).
     |  
     |  __setattr__(self, name, value, /)
     |      Implement setattr(self, name, value).
     |  
     |  __setstate__(...)
     |  
     |  __str__(self, /)
     |      Return str(self).
     |  
     |  with_traceback(...)
     |      Exception.with_traceback(tb) --
     |      set self.__traceback__ to tb and return self.
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from builtins.BaseException:
     |  
     |  __cause__
     |      exception cause
     |
     |  __context__
     |      exception context
     |
     |  __dict__
     |
     |  __suppress_context__
     |
     |  __traceback__
     |
     |  args

    class Image(builtins.object)
     |  This class represents an image object.  To create
     |  :py:class:`~PIL.Image.Image` objects, use the appropriate fa
ctory
     |  functions.  There's hardly ever any reason to call the Image
constructor
     |  directly.
     |
     |  * :py:func:`~PIL.Image.open`
     |  * :py:func:`~PIL.Image.new`
     |  * :py:func:`~PIL.Image.frombytes`
     |
     |  Methods defined here:
     |
     |  __copy__ = copy(self)
     |
     |  __del__(self)
     |
     |  __enter__(self)
     |      # Context manager support
     |
     |  __eq__(self, other)
     |      Return self==value.
     |
     |  __exit__(self, *args)
     |
     |  __getstate__(self)
     |
     |  __init__(self)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |
     |  __ne__(self, other)
     |      Return self!=value.
     |
     |  __repr__(self)
     |      Return repr(self).
     |
     |  __setstate__(self, state)
     |
     |  alpha_composite(self, im, dest=(0, 0), source=(0, 0))
     |      'In-place' analog of Image.alpha_composite. Composites a
n image
     |      onto this image.
     |
     |      :param im: image to composite over this one
     |      :param dest: Optional 2 tuple (left, top) specifying the
```

```
upper
     |        left corner in this (destination) image.
     |      :param source: Optional 2 (left, top) tuple for the uppe
r left
     |        corner in the overlay source image, or 4 tuple (left,
top, right,
     |        bottom) for the bounds of the source rectangle
     |
     |      Performance Note: Not currently implemented in-place in
the core layer.
     |
     |  close(self)
     |      Closes the file pointer, if possible.
     |
     |      This operation will destroy the image core and release i
ts memory.
     |      The image data will be unusable afterward.
     |
     |      This function is only required to close images that have
not
     |      had their file read and closed by the
     |      :py:meth:`~PIL.Image.Image.load` method. See
     |      :ref:`file-handling` for more information.
     |
     |  convert(self, mode=None, matrix=None, dither=None, palette=
0, colors=256)
     |      Returns a converted copy of this image. For the "P" mod
e, this
     |      method translates pixels through the palette.  If mode i
s
     |      omitted, a mode is chosen so that all information in the
image
     |      and the palette can be represented without a palette.
     |
     |      The current version supports all possible conversions be
tween
     |      "L", "RGB" and "CMYK." The **matrix** argument only supp
orts "L"
     |      and "RGB".
     |
     |      When translating a color image to greyscale (mode "L"),
     |      the library uses the ITU-R 601-2 luma transform::
     |
     |          L = R * 299/1000 + G * 587/1000 + B * 114/1000
     |
     |      The default method of converting a greyscale ("L") or "R
GB"
     |      image into a bilevel (mode "1") image uses Floyd-Steinbe
rg
     |      dither to approximate the original image luminosity leve
ls. If
     |      dither is NONE, all values larger than 128 are set to 25
5 (white),
     |      all other values to 0 (black). To use other thresholds,
use the
     |      :py:meth:`~PIL.Image.Image.point` method.
     |
     |      When converting from "RGBA" to "P" without a **matrix**
argument,
     |      this passes the operation to :py:meth:`~PIL.Image.Image.
quantize`,
     |      and **dither** and **palette** are ignored.
     |
     |      :param mode: The requested mode. See: :ref:`concept-mode
s`.
     |      :param matrix: An optional conversion matrix.  If given,
this
     |         should be 4- or 12-tuple containing floating point va
lues.
     |      :param dither: Dithering method, used when converting fr
om
     |         mode "RGB" to "P" or from "RGB" or "L" to "1".
     |         Available methods are NONE or FLOYDSTEINBERG (defaul
t).
     |         Note that this is not used when **matrix** is supplie
d.
     |      :param palette: Palette to use when converting from mode
"RGB"
     |         to "P".  Available palettes are WEB or ADAPTIVE.
     |      :param colors: Number of colors to use for the ADAPTIVE
palette.
     |         Defaults to 256.
     |      :rtype: :py:class:`~PIL.Image.Image`
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  copy(self)
     |      Copies this image. Use this method if you wish to paste
things
     |      into an image, but still retain the original.
     |
     |      :rtype: :py:class:`~PIL.Image.Image`
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  crop(self, box=None)
     |      Returns a rectangular region from this image. The box is
a
     |      4-tuple defining the left, upper, right, and lower pixel
     |      coordinate. See :ref:`coordinate-system`.
     |
     |      Note: Prior to Pillow 3.4.0, this was a lazy operation.
     |
     |      :param box: The crop rectangle, as a (left, upper, righ
t, lower)-tuple.
     |      :rtype: :py:class:`~PIL.Image.Image`
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  draft(self, mode, size)
     |      Configures the image file loader so it returns a version
of the
     |      image that as closely as possible matches the given mode
and
     |      size.  For example, you can use this method to convert a
color
     |      JPEG to greyscale while loading it, or to extract a 128x
192
     |      version from a PCD file.
     |
     |      Note that this method modifies the :py:class:`~PIL.Imag
e.Image` object
     |      in place.  If the image has already been loaded, this me
thod has no
     |      effect.
     |
     |      Note: This method is not implemented for most images. It
is
     |      currently implemented only for JPEG and PCD images.
     |
     |      :param mode: The requested mode.
     |      :param size: The requested size.
     |
     |  effect_spread(self, distance)
     |      Randomly spread pixels in an image.
     |
     |      :param distance: Distance to spread pixels.
     |
     |  filter(self, filter)
     |      Filters this image using the given filter.  For a list o
f
     |      available filters, see the :py:mod:`~PIL.ImageFilter` mo
dule.
     |
     |      :param filter: Filter kernel.
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  frombytes(self, data, decoder_name='raw', *args)
     |      Loads this image with pixel data from a bytes object.
     |
     |      This method is similar to the :py:func:`~PIL.Image.fromb
ytes` function,
     |      but loads data into this image instead of creating a new
image object.
     |
     |  fromstring(self, *args, **kw)
     |
     |  getbands(self)
     |      Returns a tuple containing the name of each band in this
image.
     |      For example, **getbands** on an RGB image returns ("R",
"G", "B").
     |
     |      :returns: A tuple containing band names.
     |      :rtype: tuple
     |
     |  getbbox(self)
     |      Calculates the bounding box of the non-zero regions in t
he
     |      image.
     |
     |      :returns: The bounding box is returned as a 4-tuple defi
ning the
     |         left, upper, right, and lower pixel coordinate. See
     |         :ref:`coordinate-system`. If the image is completely
empty, this
     |         method returns None.
     |
     |  getchannel(self, channel)
     |      Returns an image containing a single channel of the sour
ce image.
     |
     |      :param channel: What channel to return. Could be index
     |        (0 for "R" channel of "RGB") or channel name
     |        ("A" for alpha channel of "RGBA").
     |      :returns: An image in "L" mode.
     |
     |      .. versionadded:: 4.3.0
     |
     |  getcolors(self, maxcolors=256)
     |      Returns a list of colors used in this image.
     |
     |      :param maxcolors: Maximum number of colors.  If this num
ber is
     |         exceeded, this method returns None.  The default limi
t is
     |         256 colors.
     |      :returns: An unsorted list of (count, pixel) values.
     |
     |  getdata(self, band=None)
     |      Returns the contents of this image as a sequence object
     |      containing pixel values.  The sequence object is flatten
ed, so

     |      that values for line one follow directly after the value
s of

     |      line zero, and so on.
     |
     |      Note that the sequence object returned by this method is
an

     |      internal PIL data type, which only supports certain sequ
ence

     |      operations.  To convert it to an ordinary sequence (e.g.
for

     |      printing), use **list(im.getdata())**.
     |
     |      :param band: What band to return.  The default is to ret
urn

     |         all bands.  To return a single band, pass in the inde
x

     |         value (e.g. 0 to get the "R" band from an "RGB" imag
e).
     |      :returns: A sequence-like object.
     |
     |  getextrema(self)
     |      Gets the the minimum and maximum pixel values for each b
and in

     |      the image.
     |
     |      :returns: For a single-band image, a 2-tuple containing
the

     |         minimum and maximum pixel value.  For a multi-band im
age,

     |         a tuple containing one 2-tuple for each band.
     |
     |  getim(self)
     |      Returns a capsule that points to the internal image memo
ry.

     |
     |      :returns: A capsule object.
     |
     |  getpalette(self)
     |      Returns the image palette as a list.
     |
     |      :returns: A list of color values [r, g, b, ...], or None
if the

     |         image has no palette.
     |
     |  getpixel(self, xy)
     |      Returns the pixel value at a given position.
     |
     |      :param xy: The coordinate, given as (x, y). See
     |         :ref:`coordinate-system`.
     |      :returns: The pixel value.  If the image is a multi-laye
r image,
     |         this method returns a tuple.
     |
     |  getprojection(self)
     |      Get projection to x and y axes
     |
     |      :returns: Two sequences, indicating where there are non-
zero
     |          pixels along the X-axis and the Y-axis, respectivel
y.
     |
     |  histogram(self, mask=None, extrema=None)
     |      Returns a histogram for the image. The histogram is retu
rned as
     |      a list of pixel counts, one for each pixel value in the
source
     |      image. If the image has more than one band, the histogra
ms for
     |      all bands are concatenated (for example, the histogram f
or an
     |      "RGB" image contains 768 values).
     |
     |      A bilevel image (mode "1") is treated as a greyscale
("L") image
     |      by this method.
     |
     |      If a mask is provided, the method returns a histogram fo
r those
     |      parts of the image where the mask image is non-zero. The
mask
     |      image must have the same size as the image, and be eithe
r a
     |      bi-level image (mode "1") or a greyscale image ("L").
     |
     |      :param mask: An optional mask.
     |      :returns: A list containing pixel counts.
     |
     |  load(self)
     |      Allocates storage for the image and loads the pixel dat
a.  In
     |      normal cases, you don't need to call this method, since
the
     |      Image class automatically loads an opened image when it
is
     |      accessed for the first time.
     |
     |      If the file associated with the image was opened by Pill
ow, then this
     |      method will close it. The exception to this is if the im
age has
     |      multiple frames, in which case the file will be left ope
n for seek
     |      operations. See :ref:`file-handling` for more informatio
n.
     |
     |      :returns: An image access object.
     |      :rtype: :ref:`PixelAccess` or :py:class:`PIL.PyAccess`
     |
     |  offset(self, xoffset, yoffset=None)
     |
     |  paste(self, im, box=None, mask=None)
     |      Pastes another image into this image. The box argument i
s either
     |      a 2-tuple giving the upper left corner, a 4-tuple defini
ng the
     |      left, upper, right, and lower pixel coordinate, or None
(same as
     |      (0, 0)). See :ref:`coordinate-system`. If a 4-tuple is g
iven, the size
     |      of the pasted image must match the size of the region.
     |
     |      If the modes don't match, the pasted image is converted
to the mode of
     |      this image (see the :py:meth:`~PIL.Image.Image.convert`
method for
     |      details).
     |
     |      Instead of an image, the source can be a integer or tupl
e
     |      containing pixel values.  The method then fills the regi
on
     |      with the given color.  When creating RGB images, you can
     |      also use color strings as supported by the ImageColor mo
dule.
     |
     |      If a mask is given, this method updates only the regions
     |      indicated by the mask.  You can use either "1", "L" or
"RGBA"
     |      images (in the latter case, the alpha band is used as ma
sk).
     |      Where the mask is 255, the given image is copied as is.
Where
     |      the mask is 0, the current value is preserved.  Intermed
iate
     |      values will mix the two images together, including their
alpha
     |      channels if they have them.
     |
     |      See :py:meth:`~PIL.Image.Image.alpha_composite` if you w
ant to
     |      combine images with respect to their alpha channels.
     |
     |      :param im: Source image or pixel value (integer or tupl
e).
     |      :param box: An optional 4-tuple giving the region to pas
te into.
     |         If a 2-tuple is used instead, it's treated as the upp
er left
     |         corner.  If omitted or None, the source is pasted int
o the
     |         upper left corner.
     |
     |         If an image is given as the second argument and there
is no
     |         third, the box defaults to (0, 0), and the second arg
ument
```

```
     |          is interpreted as a mask image.
     |       :param mask: An optional mask image.
     |
     |  point(self, lut, mode=None)
     |      Maps this image through a lookup table or function.
     |
     |      :param lut: A lookup table, containing 256 (or 65536 if
     |         self.mode=="I" and mode == "L") values per band in th
e
     |         image.  A function can be used instead, it should tak
e a
     |         single argument. The function is called once for each
     |         possible pixel value, and the resulting table is appl
ied to
     |         all bands of the image.
     |      :param mode: Output mode (default is same as input).  In
the
     |         current version, this can only be used if the source
image
     |         has mode "L" or "P", and the output has mode "1" or t
he
     |         source image mode is "I" and the output mode is "L".
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  putalpha(self, alpha)
     |      Adds or replaces the alpha layer in this image.  If the
image
     |      does not have an alpha layer, it's converted to "LA" or
"RGBA".
     |      The new layer must be either "L" or "1".
     |
     |      :param alpha: The new alpha layer.  This can either be a
n "L" or "1"
     |         image having the same size as this image, or an integ
er or
     |         other color value.
     |
     |  putdata(self, data, scale=1.0, offset=0.0)
     |      Copies pixel data to this image.  This method copies dat
a from a
     |      sequence object into the image, starting at the upper le
ft
     |      corner (0, 0), and continuing until either the image or
the
     |      sequence ends.  The scale and offset values are used to
adjust
     |      the sequence values: **pixel = value*scale + offset**.
     |
     |      :param data: A sequence object.
     |      :param scale: An optional scale value.  The default is
1.0.
     |      :param offset: An optional offset value.  The default is
0.0.
     |
     |  putpalette(self, data, rawmode='RGB')
     |      Attaches a palette to this image.  The image must be a
"P" or
     |      "L" image, and the palette sequence must contain 768 int
eger
     |      values, where each group of three values represent the r
ed,
     |      green, and blue values for the corresponding pixel
     |      index. Instead of an integer sequence, you can use an 8-
bit
     |      string.
     |
     |      :param data: A palette sequence (either a list or a stri
ng).
     |      :param rawmode: The raw mode of the palette.
     |
     |  putpixel(self, xy, value)
     |      Modifies the pixel at the given position. The color is g
iven as
     |      a single numerical value for single-band images, and a t
uple for
     |      multi-band images. In addition to this, RGB and RGBA tup
les are
     |      accepted for P images.
     |
     |      Note that this method is relatively slow.  For more exte
nsive changes,
     |      use :py:meth:`~PIL.Image.Image.paste` or the :py:mod:`~P
IL.ImageDraw`
     |      module instead.
     |
     |      See:
     |
     |      * :py:meth:`~PIL.Image.Image.paste`
     |      * :py:meth:`~PIL.Image.Image.putdata`
     |      * :py:mod:`~PIL.ImageDraw`
     |
     |      :param xy: The pixel coordinate, given as (x, y). See
     |         :ref:`coordinate-system`.
     |      :param value: The pixel value.
     |
     |  quantize(self, colors=256, method=None, kmeans=0, palette=No
ne)
     |      Convert the image to 'P' mode with the specified number
     |      of colors.
     |
     |      :param colors: The desired number of colors, <= 256
     |      :param method: 0 = median cut
     |                     1 = maximum coverage
     |                     2 = fast octree
     |                     3 = libimagequant
     |      :param kmeans: Integer
     |      :param palette: Quantize to the palette of given
     |                      :py:class:`PIL.Image.Image`.
     |      :returns: A new image
     |
     |  remap_palette(self, dest_map, source_palette=None)
     |      Rewrites the image to reorder the palette.
     |
     |      :param dest_map: A list of indexes into the original pal
ette.
     |         e.g. [1,0] would swap a two item palette, and list(ra
nge(255))
     |         is the identity transform.
     |      :param source_palette: Bytes or None.
     |      :returns:  An :py:class:`~PIL.Image.Image` object.
     |
     |  resize(self, size, resample=0, box=None)
     |      Returns a resized copy of this image.
     |
     |      :param size: The requested size in pixels, as a 2-tuple:
     |         (width, height).
     |      :param resample: An optional resampling filter.  This ca
n be
     |         one of :py:attr:`PIL.Image.NEAREST`, :py:attr:`PIL.Im
age.BOX`,
     |         :py:attr:`PIL.Image.BILINEAR`, :py:attr:`PIL.Image.HA
MMING`,
     |         :py:attr:`PIL.Image.BICUBIC` or :py:attr:`PIL.Image.L
ANCZOS`.
     |         If omitted, or if the image has mode "1" or "P", it i
s
     |         set :py:attr:`PIL.Image.NEAREST`.
     |         See: :ref:`concept-filters`.
     |      :param box: An optional 4-tuple of floats giving the reg
ion
     |         of the source image which should be scaled.
     |         The values should be within (0, 0, width, height) rec
tangle.
     |         If omitted or None, the entire source is used.
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  rotate(self, angle, resample=0, expand=0, center=None, trans
late=None, fillcolor=None)
     |      Returns a rotated copy of this image.  This method retur
ns a
     |      copy of this image, rotated the given number of degrees
counter
     |      clockwise around its centre.
     |
     |      :param angle: In degrees counter clockwise.
     |      :param resample: An optional resampling filter.  This ca
n be
     |         one of :py:attr:`PIL.Image.NEAREST` (use nearest neig
hbour),
     |         :py:attr:`PIL.Image.BILINEAR` (linear interpolation i
n a 2x2
     |         environment), or :py:attr:`PIL.Image.BICUBIC`
     |         (cubic spline interpolation in a 4x4 environment).
     |         If omitted, or if the image has mode "1" or "P", it i
s
     |         set :py:attr:`PIL.Image.NEAREST`. See :ref:`concept-f
ilters`.
     |      :param expand: Optional expansion flag.  If true, expand
s the output
     |         image to make it large enough to hold the entire rota
ted image.
     |         If false or omitted, make the output image the same s
ize as the
     |         input image.  Note that the expand flag assumes rotat
ion around
     |         the center and no translation.
     |      :param center: Optional center of rotation (a 2-tuple).
Origin is
     |         the upper left corner.  Default is the center of the
image.
     |      :param translate: An optional post-rotate translation (a
2-tuple).
     |      :param fillcolor: An optional color for area outside the
```

```
rotated image.
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  save(self, fp, format=None, **params)
     |      Saves this image under the given filename.  If no format
is
     |      specified, the format to use is determined from the file
name
     |      extension, if possible.
     |
     |      Keyword options can be used to provide additional instru
ctions
     |      to the writer. If a writer doesn't recognise an option,
it is
     |      silently ignored. The available options are described in
the
     |      :doc:`image format documentation
     |      <../handbook/image-file-formats>` for each writer.
     |
     |      You can use a file object instead of a filename. In this
case,
     |      you must always specify the format. The file object must
     |      implement the ``seek``, ``tell``, and ``write``
     |      methods, and be opened in binary mode.
     |
     |      :param fp: A filename (string), pathlib.Path object or f
ile object.
     |      :param format: Optional format override.  If omitted, th
e
     |         format to use is determined from the filename extensi
on.
     |         If a file object was used instead of a filename, this
     |         parameter should always be used.
     |      :param params: Extra parameters to the image writer.
     |      :returns: None
     |      :exception ValueError: If the output format could not be
determined
     |         from the file name.  Use the format option to solve t
his.
     |      :exception IOError: If the file could not be written.  T
he file
     |         may have been created, and may contain partial data.
     |
     |  seek(self, frame)
     |      Seeks to the given frame in this sequence file. If you s
eek
     |      beyond the end of the sequence, the method raises an
     |      **EOFError** exception. When a sequence file is opened,
the
     |      library automatically seeks to frame 0.
     |
     |      Note that in the current version of the library, most se
quence
     |      formats only allows you to seek to the next frame.
     |
     |      See :py:meth:`~PIL.Image.Image.tell`.
     |
     |      :param frame: Frame number, starting at 0.
     |      :exception EOFError: If the call attempts to seek beyond
the end
     |          of the sequence.
     |  
     |  show(self, title=None, command=None)
     |      Displays this image. This method is mainly intended for
     |      debugging purposes.
     |      
     |      On Unix platforms, this method saves the image to a temp
orary
     |      PPM file, and calls either the **xv** utility or the **d
isplay**
     |      utility, depending on which one can be found.
     |      
     |      On macOS, this method saves the image to a temporary BMP
file, and
     |      opens it with the native Preview application.
     |      
     |      On Windows, it saves the image to a temporary BMP file,
and uses
     |      the standard BMP display utility to show it (usually Pai
nt).
     |      
     |      :param title: Optional title to use for the image windo
w,
     |         where possible.
     |      :param command: command used to show the image
     |  
     |  split(self)
     |      Split this image into individual bands. This method retu
rns a
     |      tuple of individual image bands from an image. For examp
le,
     |      splitting an "RGB" image creates three new images each
     |      containing a copy of one of the original bands (red, gre
en,
     |      blue).
     |      
     |      If you need only one band, :py:meth:`~PIL.Image.Image.ge
tchannel`
     |      method can be more convenient and faster.
     |      
     |      :returns: A tuple containing bands.
     |  
     |  tell(self)
     |      Returns the current frame number. See :py:meth:`~PIL.Ima
ge.Image.seek`.
     |      
     |      :returns: Frame number, starting with 0.
     |  
     |  thumbnail(self, size, resample=3)
     |      Make this image into a thumbnail.  This method modifies
the
     |      image to contain a thumbnail version of itself, no large
r than
     |      the given size.  This method calculates an appropriate t
humbnail
     |      size to preserve the aspect of the image, calls the
     |      :py:meth:`~PIL.Image.Image.draft` method to configure th
e file reader
     |      (where applicable), and finally resizes the image.
     |      
     |      Note that this function modifies the :py:class:`~PIL.Ima
ge.Image`
```

```
     |      object in place.  If you need to use the full resolution
image as well,
     |      apply this method to a :py:meth:`~PIL.Image.Image.copy`
of the original
     |      image.
     |
     |      :param size: Requested size.
     |      :param resample: Optional resampling filter.  This can b
e one
     |         of :py:attr:`PIL.Image.NEAREST`, :py:attr:`PIL.Image.
BILINEAR`,
     |         :py:attr:`PIL.Image.BICUBIC`, or :py:attr:`PIL.Image.
LANCZOS`.
     |         If omitted, it defaults to :py:attr:`PIL.Image.BICUBI
C`.
     |         (was :py:attr:`PIL.Image.NEAREST` prior to version 2.
5.0)
     |      :returns: None
     |
     |  tobitmap(self, name='image')
     |      Returns the image converted to an X11 bitmap.
     |
     |      .. note:: This method only works for mode "1" images.
     |
     |      :param name: The name prefix to use for the bitmap varia
bles.
     |      :returns: A string containing an X11 bitmap.
     |      :raises ValueError: If the mode is not "1"
     |
     |  tobytes(self, encoder_name='raw', *args)
     |      Return image as a bytes object.
     |
     |      .. warning::
     |
     |          This method returns the raw image data from the inte
rnal
     |          storage.  For compressed image data (e.g. PNG, JPEG)
use
     |          :meth:`~.save`, with a BytesIO parameter for in-memo
ry
     |          data.
     |
     |      :param encoder_name: What encoder to use.  The default i
s to
     |                           use the standard "raw" encoder.
     |      :param args: Extra arguments to the encoder.
     |      :rtype: A bytes object.
     |
     |  toqimage(self)
     |      Returns a QImage copy of this image
     |
     |  toqpixmap(self)
     |      Returns a QPixmap copy of this image
     |
     |  tostring(self, *args, **kw)
     |
     |  transform(self, size, method, data=None, resample=0, fill=1,
fillcolor=None)
     |      Transforms this image.  This method creates a new image
with the
     |      given size, and the same mode as the original, and copie
```

```
s data
     |      to the new image using the given transform.
     |
     |      :param size: The output size.
     |      :param method: The transformation method.  This is one o
f
     |        :py:attr:`PIL.Image.EXTENT` (cut out a rectangular sub
region),
     |        :py:attr:`PIL.Image.AFFINE` (affine transform),
     |        :py:attr:`PIL.Image.PERSPECTIVE` (perspective transfor
m),
     |        :py:attr:`PIL.Image.QUAD` (map a quadrilateral to a re
ctangle), or
     |        :py:attr:`PIL.Image.MESH` (map a number of source quad
rilaterals
     |        in one operation).
     |
     |        It may also be an :py:class:`~PIL.Image.ImageTransform
Handler`
     |        object::
     |          class Example(Image.ImageTransformHandler):
     |              def transform(size, method, data, resample, fill
=1):
     |                  # Return result
     |
     |        It may also be an object with a :py:meth:`~method.getd
ata` method
     |        that returns a tuple supplying new **method** and **da
ta** values::
     |          class Example(object):
     |              def getdata(self):
     |                  method = Image.EXTENT
     |                  data = (0, 0, 100, 100)
     |                  return method, data
     |      :param data: Extra data to the transformation method.
     |      :param resample: Optional resampling filter.  It can be
one of
     |         :py:attr:`PIL.Image.NEAREST` (use nearest neighbour),
     |         :py:attr:`PIL.Image.BILINEAR` (linear interpolation i
n a 2x2
     |         environment), or :py:attr:`PIL.Image.BICUBIC` (cubic
spline
     |         interpolation in a 4x4 environment). If omitted, or i
f the image
     |         has mode "1" or "P", it is set to :py:attr:`PIL.Imag
e.NEAREST`.
     |      :param fill: If **method** is an
     |        :py:class:`~PIL.Image.ImageTransformHandler` object, t
his is one of
     |        the arguments passed to it. Otherwise, it is unused.
     |      :param fillcolor: Optional fill color for the area outsi
de the
     |         transform in the output image.
     |      :returns: An :py:class:`~PIL.Image.Image` object.
     |
     |  transpose(self, method)
     |      Transpose image (flip or rotate in 90 degree steps)
     |
     |      :param method: One of :py:attr:`PIL.Image.FLIP_LEFT_RIGH
T`,
     |        :py:attr:`PIL.Image.FLIP_TOP_BOTTOM`, :py:attr:`PIL.Im
```

```
age.ROTATE_90`,
     |          :py:attr:`PIL.Image.ROTATE_180`, :py:attr:`PIL.Image.R
OTATE_270`,
     |          :py:attr:`PIL.Image.TRANSPOSE` or :py:attr:`PIL.Image.
TRANSVERSE`.
     |        :returns: Returns a flipped or rotated copy of this imag
e.
     |  
     |  verify(self)
     |      Verifies the contents of a file. For data read from a fi
le, this
     |      method attempts to determine if the file is broken, with
out
     |      actually decoding the image data.  If this method finds 
any
     |      problems, it raises suitable exceptions.  If you need to
load
     |      the image after using this method, you must reopen the i
mage
     |      file.
     |  
     |  --------------------------------------------------------------
----------
     |  Data descriptors defined here:
     |  
     |  __array_interface__
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
     |  
     |  height
     |  
     |  size
     |  
     |  width
     |  
     |  --------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  __hash__ = None
     |  
     |  format = None
     |  
     |  format_description = None
    
    class ImagePointHandler(builtins.object)
     |  Data descriptors defined here:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class ImageTransformHandler(builtins.object)
     |  Data descriptors defined here:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

FUNCTIONS
    alpha_composite(im1, im2)
        Alpha composite im2 over im1.

        :param im1: The first image. Must have mode RGBA.
        :param im2: The second image.  Must have mode RGBA, and the
same size as
           the first image.
        :returns: An :py:class:`~PIL.Image.Image` object.

    blend(im1, im2, alpha)
        Creates a new image by interpolating between two input image
s, using
        a constant alpha.::

            out = image1 * (1.0 - alpha) + image2 * alpha

        :param im1: The first image.
        :param im2: The second image.  Must have the same mode and s
ize as
           the first image.
        :param alpha: The interpolation alpha factor.  If alpha is
0.0, a
           copy of the first image is returned. If alpha is 1.0, a c
opy of
           the second image is returned. There are no restrictions o
n the
           alpha value. If necessary, the result is clipped to fit i
nto
           the allowed output range.
        :returns: An :py:class:`~PIL.Image.Image` object.

    coerce_e(value)

    composite(image1, image2, mask)
        Create composite image by blending images using a transparen
cy mask.

        :param image1: The first image.
        :param image2: The second image.  Must have the same mode an
d
           size as the first image.
        :param mask: A mask image.  This image can have mode
           "1", "L", or "RGBA", and must have the same size as the
           other two images.

    effect_mandelbrot(size, extent, quality)
        Generate a Mandelbrot set covering the given extent.

        :param size: The requested size in pixels, as a 2-tuple:
           (width, height).
        :param extent: The extent to cover, as a 4-tuple:
           (x0, y0, x1, y2).
        :param quality: Quality.
    effect_noise(size, sigma)
        Generate Gaussian noise centered around 128.

        :param size: The requested size in pixels, as a 2-tuple:
           (width, height).
        :param sigma: Standard deviation of noise.

    eval(image, *args)
        Applies the function (which should take one argument) to eac
h pixel
        in the given image. If the image has more than one band, the
same
        function is applied to each band. Note that the function is
        evaluated once for each possible pixel value, so you cannot
use
        random components or other generators.

        :param image: The input image.
        :param function: A function object, taking one integer argum
ent.
        :returns: An :py:class:`~PIL.Image.Image` object.

    fromarray(obj, mode=None)
        Creates an image memory from an object exporting the array i
nterface
        (using the buffer protocol).

        If **obj** is not contiguous, then the tobytes method is cal
led
        and :py:func:`~PIL.Image.frombuffer` is used.

        If you have an image in NumPy::

          from PIL import Image
          import numpy as np
          im = Image.open('hopper.jpg')
          a = np.asarray(im)

        Then this can be used to convert it to a Pillow image::

          im = Image.fromarray(a)

        :param obj: Object with array interface
        :param mode: Mode to use (will be determined from type if No
ne)
          See: :ref:`concept-modes`.
        :returns: An image object.

        .. versionadded:: 1.1.6

    frombuffer(mode, size, data, decoder_name='raw', *args)
        Creates an image memory referencing pixel data in a byte buf
fer.

        This function is similar to :py:func:`~PIL.Image.frombytes`,
but uses data
        in the byte buffer, where possible.  This means that changes
to the
        original buffer object are reflected in this image).  Not al
l modes can
        share memory; supported modes include "L", "RGBX", "RGBA", a
```

```
nd "CMYK".

        Note that this function decodes pixel data only, not entire
images.
        If you have an entire image file in a string, wrap it in a
        **BytesIO** object, and use :py:func:`~PIL.Image.open` to lo
ad it.

        In the current version, the default parameters used for the
"raw" decoder
        differs from that used for :py:func:`~PIL.Image.frombytes`.
This is a
        bug, and will probably be fixed in a future release.  The cu
rrent release
        issues a warning if you do this; to disable the warning, you
should provide
        the full set of parameters.  See below for details.

        :param mode: The image mode. See: :ref:`concept-modes`.
        :param size: The image size.
        :param data: A bytes or other buffer object containing raw
            data for the given mode.
        :param decoder_name: What decoder to use.
        :param args: Additional parameters for the given decoder.  F
or the
            default encoder ("raw"), it's recommended that you provi
de the
            full set of parameters::

                frombuffer(mode, size, data, "raw", mode, 0, 1)

        :returns: An :py:class:`~PIL.Image.Image` object.

        .. versionadded:: 1.1.4

    frombytes(mode, size, data, decoder_name='raw', *args)
        Creates a copy of an image memory from pixel data in a buffe
r.

        In its simplest form, this function takes three arguments
        (mode, size, and unpacked pixel data).

        You can also use any pixel decoder supported by PIL.  For mo
re
        information on available decoders, see the section
        :ref:`Writing Your Own File Decoder <file-decoders>`.

        Note that this function decodes pixel data only, not entire
images.
        If you have an entire image in a string, wrap it in a
        :py:class:`~io.BytesIO` object, and use :py:func:`~PIL.Imag
e.open` to load
        it.

        :param mode: The image mode. See: :ref:`concept-modes`.
        :param size: The image size.
        :param data: A byte buffer containing raw data for the given
mode.
        :param decoder_name: What decoder to use.
        :param args: Additional parameters for the given decoder.
        :returns: An :py:class:`~PIL.Image.Image` object.
    fromqimage(im)
        Creates an image instance from a QImage image

    fromqpixmap(im)
        Creates an image instance from a QPixmap image

    fromstring(*args, **kw)

    getmodebandnames(mode)
        Gets a list of individual band names.  Given a mode, this fu
nction returns
        a tuple containing the names of individual bands (use
        :py:method:`~PIL.Image.getmodetype` to get the mode used to
store each
        individual band.

        :param mode: Input mode.
        :returns: A tuple containing band names.  The length of the
tuple
            gives the number of bands in an image of the given mode.
        :exception KeyError: If the input mode was not a standard mo
de.

    getmodebands(mode)
        Gets the number of individual bands for this mode.

        :param mode: Input mode.
        :returns: The number of bands in this mode.
        :exception KeyError: If the input mode was not a standard mo
de.

    getmodebase(mode)
        Gets the "base" mode for given mode.  This function returns
"L" for
        images that contain grayscale data, and "RGB" for images tha
t
        contain color data.

        :param mode: Input mode.
        :returns: "L" or "RGB".
        :exception KeyError: If the input mode was not a standard mo
de.

    getmodetype(mode)
        Gets the storage type mode.  Given a mode, this function ret
urns a
        single-layer mode suitable for storing individual bands.

        :param mode: Input mode.
        :returns: "L", "I", or "F".
        :exception KeyError: If the input mode was not a standard mo
de.

    init()
        Explicitly initializes the Python Imaging Library. This func
tion
        loads all available file format drivers.

    isImageType(t)
        Checks if an object is an image object.
        .. warning::

           This function is for internal use only.

        :param t: object to check if it's an image
        :returns: True if the object is an image

    linear_gradient(mode)
        Generate 256x256 linear gradient from black to white, top to
bottom.

        :param mode: Input mode.

    merge(mode, bands)
        Merge a set of single band images into a new multiband imag
e.

        :param mode: The mode to use for the output image. See:
            :ref:`concept-modes`.
        :param bands: A sequence containing one single-band image fo
r
            each band in the output image.  All bands must have the
            same size.
        :returns: An :py:class:`~PIL.Image.Image` object.

    new(mode, size, color=0)
        Creates a new image with the given mode and size.

        :param mode: The mode to use for the new image. See:
           :ref:`concept-modes`.
        :param size: A 2-tuple, containing (width, height) in pixel
s.
        :param color: What color to use for the image.  Default is b
lack.
           If given, this should be a single integer or floating poi
nt value
           for single-band modes, and a tuple for multi-band modes
(one value
           per band).  When creating RGB images, you can also use co
lor
           strings as supported by the ImageColor module.  If the co
lor is
           None, the image is not initialised.
        :returns: An :py:class:`~PIL.Image.Image` object.

    open(fp, mode='r')
        Opens and identifies the given image file.

        This is a lazy operation; this function identifies the file,
but
        the file remains open and the actual image data is not read
from
        the file until you try to process the data (or call the
        :py:meth:`~PIL.Image.Image.load` method).  See
        :py:func:`~PIL.Image.new`. See :ref:`file-handling`.

        :param fp: A filename (string), pathlib.Path object or a fil
e object.
           The file object must implement :py:meth:`~file.read`,
           :py:meth:`~file.seek`, and :py:meth:`~file.tell` methods,
           and be opened in binary mode.
        :param mode: The mode.  If given, this argument must be "r".
        :returns: An :py:class:`~PIL.Image.Image` object.
        :exception IOError: If the file cannot be found, or the imag
e cannot be
           opened and identified.

    preinit()
        Explicitly load standard file format drivers.

    radial_gradient(mode)
        Generate 256x256 radial gradient from black to white, centre
 to edge.

        :param mode: Input mode.

    register_decoder(name, decoder)
        Registers an image decoder.  This function should not be
        used in application code.

        :param name: The name of the decoder
        :param decoder: A callable(mode, args) that returns an
                        ImageFile.PyDecoder object

        .. versionadded:: 4.1.0

    register_encoder(name, encoder)
        Registers an image encoder.  This function should not be
        used in application code.

        :param name: The name of the encoder
        :param encoder: A callable(mode, args) that returns an
                        ImageFile.PyEncoder object

        .. versionadded:: 4.1.0

    register_extension(id, extension)
        Registers an image extension.  This function should not be
        used in application code.

        :param id: An image format identifier.
        :param extension: An extension used for this format.

    register_extensions(id, extensions)
        Registers image extensions.  This function should not be
        used in application code.

        :param id: An image format identifier.
        :param extensions: A list of extensions used for this forma
t.

    register_mime(id, mimetype)
        Registers an image MIME type.  This function should not be u
sed
        in application code.

        :param id: An image format identifier.
        :param mimetype: The image MIME type for this format.

    register_open(id, factory, accept=None)
        Register an image file plugin.  This function should not be
```

```
used
        in application code.

        :param id: An image format identifier.
        :param factory: An image file factory method.
        :param accept: An optional function that can be used to quic
kly
           reject images having another format.

    register_save(id, driver)
        Registers an image save function.  This function should not
be
        used in application code.

        :param id: An image format identifier.
        :param driver: A function to save images in this format.

    register_save_all(id, driver)
        Registers an image function to save all the frames
        of a multiframe format.  This function should not be
        used in application code.

        :param id: An image format identifier.
        :param driver: A function to save images in this format.

    registered_extensions()
        Returns a dictionary containing all file extensions belongin
g
        to registered plugins

DATA
    ADAPTIVE = 1
    AFFINE = 0
    ANTIALIAS = 1
    BICUBIC = 3
    BILINEAR = 2
    BOX = 4
    CONTAINER = 2
    CUBIC = 3
    DECODERS = {}
    DEFAULT_STRATEGY = 0
    ENCODERS = {}
    EXTENSION = {}
    EXTENT = 1
    FASTOCTREE = 2
    FILTERED = 1
    FIXED = 4
    FLIP_LEFT_RIGHT = 0
    FLIP_TOP_BOTTOM = 1
    FLOYDSTEINBERG = 3
    HAMMING = 5
    HAS_PATHLIB = True
    HUFFMAN_ONLY = 2
    ID = []
    LANCZOS = 1
    LIBIMAGEQUANT = 3
    LINEAR = 2
    MAXCOVERAGE = 1
    MAX_IMAGE_PIXELS = 89478485
    MEDIANCUT = 0
    MESH = 4
    MIME = {}
    MODES = ['1', 'CMYK', 'F', 'HSV', 'I', 'L', 'LAB', 'P', 'RGB',
'RGBA',...
    NEAREST = 0
    NONE = 0
    NORMAL = 0
    OPEN = {}
    ORDERED = 1
    PERSPECTIVE = 2
    PILLOW_VERSION = '5.4.1'
    QUAD = 3
    RASTERIZE = 2
    RLE = 3
    ROTATE_180 = 3
    ROTATE_270 = 4
    ROTATE_90 = 2
    SAVE = {}
    SAVE_ALL = {}
    SEQUENCE = 1
    TRANSPOSE = 5
    TRANSVERSE = 6
    USE_CFFI_ACCESS = False
    VERSION = '1.1.7'
    WEB = 0
    logger = <Logger PIL.Image (WARNING)>
    py3 = True

VERSION
    5.4.1

FILE
    /opt/conda/lib/python3.7/site-packages/PIL/Image.py
```

Running help() on Image tells us that this object is "the Image class wrapper". We see from the top level documentation about the image object that there is "hardly ever any reason to call the Image constructor directly", and they suggest that the open function might be the way to go.

In [9]:

```
# Lets call help on the open function to see what it's all about. Remember that
 since we want to pass in the
# function reference, and not run the function itself, we don't put paretheses b
ehind the function name.
help(Image.open)
```

```
Help on function open in module PIL.Image:

open(fp, mode='r')
    Opens and identifies the given image file.

    This is a lazy operation; this function identifies the file, but
    the file remains open and the actual image data is not read from
    the file until you try to process the data (or call the
    :py:meth:`~PIL.Image.Image.load` method).  See
    :py:func:`~PIL.Image.new`. See :ref:`file-handling`.

    :param fp: A filename (string), pathlib.Path object or a file ob
ject.
       The file object must implement :py:meth:`~file.read`,
       :py:meth:`~file.seek`, and :py:meth:`~file.tell` methods,
       and be opened in binary mode.
    :param mode: The mode.  If given, this argument must be "r".
    :returns: An :py:class:`~PIL.Image.Image` object.
    :exception IOError: If the file cannot be found, or the image ca
nnot be
       opened and identified.
```

In [10]:

```
# It looks like Image.open() is a function that loads an image from a file and r
eturns an instance
# of the Image class. Lets give it a try. In the read_only directory there is an
image I've provided
# which is from our Master's of Information program recruitment flyer. Lets try
 and load that now

file="readonly/msi_recruitment.gif"
image=Image.open(file)
print(image)
```

```
<PIL.GifImagePlugin.GifImageFile image mode=P size=800x450 at 0x7FEC
344F4EB8>
```

`getmro()` to examine Child Classes

In [12]:

```
# Ok, we see that this returns us a kind of PIL.GifImagePlugin.GifImageFile. At
 first this might
# seem a bit confusing, since because we were told by the docs that we should be
exepcting a
# PIL.Image.Image object back. But this is just object inheritance working! In f
act, the object
# returned is both an Image and a GifImageFile. We can use the python inspect mo
dule to see this
# as the getmro function will return a list of all of the classes that are being
inherited by a
# given object. Lets try it.

import inspect
print("The type of the image is " + str(type(image)))
inspect.getmro(type(image))
# Note that the Image.Image is the most general, (the root)
#and GifImagePlugin.GifImageFile is the most specific (lowest on the inheritance
chain)
```

```
The type of the image is <class 'PIL.GifImagePlugin.GifImageFile'>
```

Out[12]:

```
(PIL.GifImagePlugin.GifImageFile,
 PIL.ImageFile.ImageFile,
 PIL.Image.Image,
 object)
```

Showing Images on `.show()`

In [13]:

```
# Now that we are comfortable with the object. How do we view the image? It turn
s out that the
# image object has a show function. You can find this by looking at all of the p
roperties of
# the object if you wanted to, using the dir() function.
image.show()
```

Using `IPython.display` to show images

In [14]:

```
# Hrm, that didn't seem to have the intended effect. The problem is that the ima
ge is stored
# remotely, on Coursera's server, but show tries to show it locally to you. So,
 if the Coursera
# server software was running on someone's workstation in Mountain View Californ
ia, where Coursera
# has its offices, then you just popped up a picture of our recruitment material
s. Thanks! :)
# Instead, we want to render the image in the Jupyter notebook. It turns out Jup
yter has a function
# which can help with this.
from IPython.display import display
display(image)
```

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HEALTH INFORMATICS
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For those who would like to understand this in more detail, the Jupyter environment is running a **special wrapper around the Python interpretor, called IPython**. IPython allows the kernel back end to communicate with a browser front end, among other things. The IPython package has a display function which can take objects and use custom formatters in order to render them. A number of formatters are provided by default, including one which knows how to handle image types.

That's a quick overview of how to read and display images using pillow, in the next lecture we'll jump in a bit more detail to understand how to use pillow to manipulate images.

Common Functions in the Python Imaging Library

Lets take a look at some of the common tasks we can do in python using the pillow library.

In [15]:

```
# First, lets import the PIL library and the Image object
import PIL
from PIL import Image
# And lets import the display functionality
from IPython.display import display
# And finally, lets load the image we were working with last time
file="readonly/msi_recruitment.gif"
image=Image.open(file)
```

Using `image.copy` and `image.save`

In [16]:

```
# Great, now lets check out a few more methods of the image library. First, we'l
l look at copy
# And if you remember, we can do this using the built in python help() function
help(image.copy)
```

```
Help on method copy in module PIL.Image:

copy() method of PIL.GifImagePlugin.GifImageFile instance
    Copies this image. Use this method if you wish to paste things
    into an image, but still retain the original.

    :rtype: :py:class:`~PIL.Image.Image`
    :returns: An :py:class:`~PIL.Image.Image` object.
```

In [17]:

```
# We can see that copy takes no arguments, and that the return object is an Imag
e object itself. Now lets
# look at save
help(image.save)
```

```
Help on method save in module PIL.Image:

save(fp, format=None, **params) method of PIL.GifImagePlugin.GifImag
eFile instance
    Saves this image under the given filename.  If no format is
    specified, the format to use is determined from the filename
    extension, if possible.

    Keyword options can be used to provide additional instructions
    to the writer. If a writer doesn't recognise an option, it is
    silently ignored. The available options are described in the
    :doc:`image format documentation
    <../handbook/image-file-formats>` for each writer.

    You can use a file object instead of a filename. In this case,
    you must always specify the format. The file object must
    implement the ``seek``, ``tell``, and ``write``
    methods, and be opened in binary mode.

    :param fp: A filename (string), pathlib.Path object or file obje
ct.
    :param format: Optional format override.  If omitted, the
       format to use is determined from the filename extension.
       If a file object was used instead of a filename, this
       parameter should always be used.
    :param params: Extra parameters to the image writer.
    :returns: None
    :exception ValueError: If the output format could not be determi
ned
       from the file name.  Use the format option to solve this.
    :exception IOError: If the file could not be written.  The file
       may have been created, and may contain partial data.
```

In [18]:

```
# The save method has a couple of parameters which are interesting. The first, c
alled fp, is the filename
# we want to save the object too. The second, format, is interesting, it allows
 us to change the type of
# the image, but the docs tell us that this should be done automatically by look
ing at the file extension
# as well. Lets give it a try -- this file was originally a GifImageFile, but I
 bet if we save it with a
# .png format and read it in again we'll get a different kind of file
image.save("msi_recruitment.png")
image=Image.open("msi_recruitment.png")
import inspect
inspect.getmro(type(image))
```

Out[18]:

```
(PIL.PngImagePlugin.PngImageFile,
 PIL.ImageFile.ImageFile,
 PIL.Image.Image,
 object)
```

Using `ImageFilter`

In [19]:

```
# Indeed, this created a new file, which we could view by going to the Jupyter notebook file list by clicking
# on the logo at the top of the browser, and we can see this new object is actually a PngImageFile object
# For the purposes of this class the difference in image formats isn't so important, but it's nice that you can
# explore how a library works using the functions of help(), dir() and getmro().
#
# The PILLOW library also has some nice image filters to add some effects. It does this through the filter()
# function. The filter() function takes a Filter object, and those are all stored in the ImageFilter object.
# Lets take a look.
from PIL import ImageFilter
help(ImageFilter)
```

```
Help on module PIL.ImageFilter in PIL:

NAME
    PIL.ImageFilter

DESCRIPTION
    # The Python Imaging Library.
    # $Id$
    #
    # standard filters
    #
    # History:
    # 1995-11-27 fl   Created
    # 2002-06-08 fl   Added rank and mode filters
    # 2003-09-15 fl   Fixed rank calculation in rank filter; added e
xpand call
    #
    # Copyright (c) 1997-2003 by Secret Labs AB.
    # Copyright (c) 1995-2002 by Fredrik Lundh.
    #
    # See the README file for information on usage and redistributio
n.
    #

CLASSES
    builtins.object
        Filter
            ModeFilter
            MultibandFilter
                BoxBlur
                BuiltinFilter
                    BLUR
                    CONTOUR
                    DETAIL
                    EDGE_ENHANCE
                    EDGE_ENHANCE_MORE
                    EMBOSS
                    FIND_EDGES
                    Kernel
                    SHARPEN
                    SMOOTH
                    SMOOTH_MORE
                Color3DLUT
                GaussianBlur
                UnsharpMask
            RankFilter
                MaxFilter
                MedianFilter
                MinFilter

    class BLUR(BuiltinFilter)
     |  Method resolution order:
     |      BLUR
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((5, 5), 16, 0, (1, 1, 1, 1, 1, 1, 0, 0, 0, 1,
1, 0, 0, 0...
     |  
     |  name = 'Blur'
     |  
     |  ------------------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class BoxBlur(MultibandFilter)
     |  BoxBlur(radius)
     |  
     |  Blurs the image by setting each pixel to the average value o
f the pixels
     |  in a square box extending radius pixels in each direction.
     |  Supports float radius of arbitrary size. Uses an optimized i
mplementation
     |  which runs in linear time relative to the size of the image
     |  for any radius value.
     |  
     |  :param radius: Size of the box in one direction. Radius 0 do
es not blur,
     |                 returns an identical image. Radius 1 takes 1
pixel
     |                 in each direction, i.e. 9 pixels in total.
     |  
     |  Method resolution order:
     |      BoxBlur
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |  
     |  Methods defined here:
     |  
     |  __init__(self, radius)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  name = 'BoxBlur'
     |  
     |  ------------------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class BuiltinFilter(MultibandFilter)
     |  Method resolution order:
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Methods defined here:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class CONTOUR(BuiltinFilter)
     |  Method resolution order:
     |      CONTOUR
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((3, 3), 1, 255, (-1, -1, -1, -1, 8, -1, -1, -
1, -1))
     |
     |  name = 'Contour'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class Color3DLUT(MultibandFilter)
     |  Color3DLUT(size, table, channels=3, target_mode=None, **kwar
gs)
```

```
     |
     |  Three-dimensional color lookup table.
     |
     |  Transforms 3-channel pixels using the values of the channels
as coordinates
     |  in the 3D lookup table and interpolating the nearest element
s.
     |
     |  This method allows you to apply almost any color transformat
ion
     |  in constant time by using pre-calculated decimated tables.
     |
     |  .. versionadded:: 5.2.0
     |
     |  :param size: Size of the table. One int or tuple of (int, in
t, int).
     |               Minimal size in any dimension is 2, maximum is 
65.
     |  :param table: Flat lookup table. A list of ``channels * size
**3``
     |                float elements or a list of ``size**3`` channe
ls-sized
     |                tuples with floats. Channels are changed firs
t,
     |                then first dimension, then second, then third.
     |                Value 0.0 corresponds lowest value of output, 
1.0 highest.
     |  :param channels: Number of channels in the table. Could be 3 
or 4.
     |                   Default is 3.
     |  :param target_mode: A mode for the result image. Should have 
not less
     |                      than ``channels`` channels. Default is `
`None``,
     |                      which means that mode wouldn't be change
d.
     |
     |  Method resolution order:
     |      Color3DLUT
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Methods defined here:
     |
     |  __init__(self, size, table, channels=3, target_mode=None, **
kwargs)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |
     |  __repr__(self)
     |      Return repr(self).
     |
     |  filter(self, image)
     |
     |  transform(self, callback, with_normals=False, channels=None, 
target_mode=None)
     |      Transforms the table values using provided callback and 
returns
     |      a new LUT with altered values.
     |
     |      :param callback: A function which takes old lookup table
values
     |                       and returns a new set of values. The nu
mber
     |                       of arguments which function should take
is
     |                       ``self.channels`` or ``3 + self.channel
s``
     |                       if ``with_normals`` flag is set.
     |                       Should return a tuple of ``self.channel
s`` or
     |                       ``channels`` elements if it is set.
     |      :param with_normals: If true, ``callback`` will be calle
d with
     |                           coordinates in the color cube as th
e first
     |                           three arguments. Otherwise, ``callb
ack``
     |                           will be called only with actual col
or values.
     |      :param channels: The number of channels in the resulting
lookup table.
     |      :param target_mode: Passed to the constructor of the res
ulting
     |                          lookup table.
     |
     |  ------------------------------------------------------------
----------
     |  Class methods defined here:
     |
     |  generate(size, callback, channels=3, target_mode=None) from
builtins.type
     |      Generates new LUT using provided callback.
     |
     |      :param size: Size of the table. Passed to the constructo
r.
     |      :param callback: Function with three parameters which co
rrespond
     |                       three color channels. Will be called ``
size**3``
     |                       times with values from 0.0 to 1.0 and s
hould return
     |                       a tuple with ``channels`` elements.
     |      :param channels: The number of channels which should ret
urn callback.
     |      :param target_mode: Passed to the constructor of the res
ulting
     |                          lookup table.
     |
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |
     |  name = 'Color 3D LUT'
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class DETAIL(BuiltinFilter)
     |  Method resolution order:
     |      DETAIL
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((3, 3), 6, 0, (0, -1, 0, -1, 10, -1, 0, -1,
0))
     |
     |  name = 'Detail'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class EDGE_ENHANCE(BuiltinFilter)
     |  Method resolution order:
     |      EDGE_ENHANCE
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((3, 3), 2, 0, (-1, -1, -1, -1, 10, -1, -1, -1,
-1))
     |
     |  name = 'Edge-enhance'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class EDGE_ENHANCE_MORE(BuiltinFilter)
     |  Method resolution order:
     |      EDGE_ENHANCE_MORE
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |  
     |  Data and other attributes defined here:
     |  
     |  filterargs = ((3, 3), 1, 0, (-1, -1, -1, -1, 9, -1, -1, -1, 
-1))
     |  
     |  name = 'Edge-enhance More'
     |  
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class EMBOSS(BuiltinFilter)
     |  Method resolution order:
     |      EMBOSS
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |  
     |  Data and other attributes defined here:
     |  
     |  filterargs = ((3, 3), 1, 128, (-1, 0, 0, 0, 1, 0, 0, 0, 0))
     |  
     |  name = 'Emboss'
     |  
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class FIND_EDGES(BuiltinFilter)
     |  Method resolution order:
     |      FIND_EDGES
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((3, 3), 1, 0, (-1, -1, -1, -1, 8, -1, -1, -1,
-1))
     |
     |  name = 'Find Edges'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class Filter(builtins.object)
     |  Data descriptors defined here:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class GaussianBlur(MultibandFilter)
     |  GaussianBlur(radius=2)
     |
     |  Gaussian blur filter.
     |
     |  :param radius: Blur radius.
     |
     |  Method resolution order:
     |      GaussianBlur
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Methods defined here:
     |
     |  __init__(self, radius=2)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  name = 'GaussianBlur'
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class Kernel(BuiltinFilter)
     |  Kernel(size, kernel, scale=None, offset=0)
     |  
     |  Create a convolution kernel.  The current version only
     |  supports 3x3 and 5x5 integer and floating point kernels.
     |  
     |  In the current version, kernels can only be applied to
     |  "L" and "RGB" images.
     |  
     |  :param size: Kernel size, given as (width, height). In the c
urrent
     |                      version, this must be (3,3) or (5,5).
     |  :param kernel: A sequence containing kernel weights.
     |  :param scale: Scale factor. If given, the result for each pi
xel is
     |                      divided by this value.  the default is the s
um of the
     |                      kernel weights.
     |  :param offset: Offset. If given, this value is added to the 
result,
     |                      after it has been divided by the scale facto
r.
     |  
     |  Method resolution order:
     |      Kernel
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |  
     |  Methods defined here:
     |  
     |  __init__(self, size, kernel, scale=None, offset=0)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |  
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  name = 'Kernel'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class MaxFilter(RankFilter)
     |  MaxFilter(size=3)
     |
     |  Create a max filter.  Picks the largest pixel value in a win
dow with the
     |  given size.
     |
     |  :param size: The kernel size, in pixels.
     |
     |  Method resolution order:
     |      MaxFilter
     |      RankFilter
     |      Filter
     |      builtins.object
     |
     |  Methods defined here:
     |
     |  __init__(self, size=3)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |
     |  name = 'Max'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from RankFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)
    class MedianFilter(RankFilter)
     |  MedianFilter(size=3)
     |  
     |  Create a median filter. Picks the median pixel value in a wi
ndow with the
     |  given size.
     |  
     |  :param size: The kernel size, in pixels.
     |  
     |  Method resolution order:
     |      MedianFilter
     |      RankFilter
     |      Filter
     |      builtins.object
     |  
     |  Methods defined here:
     |  
     |  __init__(self, size=3)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |  
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  name = 'Median'
     |  
     |  ------------------------------------------------------------
----------
     |  Methods inherited from RankFilter:
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class MinFilter(RankFilter)
     |  MinFilter(size=3)
     |  
     |  Create a min filter.  Picks the lowest pixel value in a wind
ow with the
     |  given size.
     |  
     |  :param size: The kernel size, in pixels.
     |  
     |  Method resolution order:
     |      MinFilter
     |      RankFilter
     |      Filter
     |      builtins.object
     |  
     |  Methods defined here:
     |  
     |  __init__(self, size=3)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |
     |  name = 'Min'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from RankFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class ModeFilter(Filter)
     |  ModeFilter(size=3)
     |
     |  Create a mode filter. Picks the most frequent pixel value in
a box with the
     |  given size.  Pixel values that occur only once or twice are
ignored; if no
     |  pixel value occurs more than twice, the original pixel value
is preserved.
     |
     |  :param size: The kernel size, in pixels.
     |
     |  Method resolution order:
     |      ModeFilter
     |      Filter
     |      builtins.object
     |
     |  Methods defined here:
     |
     |  __init__(self, size=3)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |
     |  name = 'Mode'
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class MultibandFilter(Filter)
     |  Method resolution order:
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |  
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    
    class RankFilter(Filter)
     |  RankFilter(size, rank)
     |  
     |  Create a rank filter.  The rank filter sorts all pixels in
     |  a window of the given size, and returns the **rank**'th valu
e.
     |  
     |  :param size: The kernel size, in pixels.
     |  :param rank: What pixel value to pick.  Use 0 for a min filt
er,
     |               ``size * size / 2`` for a median filter, ``size
 * size - 1``
     |               for a max filter, etc.
     |  
     |  Method resolution order:
     |      RankFilter
     |      Filter
     |      builtins.object
     |  
     |  Methods defined here:
     |  
     |  __init__(self, size, rank)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  name = 'Rank'
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)
    class SHARPEN(BuiltinFilter)
     |  Method resolution order:
     |      SHARPEN
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((3, 3), 16, 0, (-2, -2, -2, -2, 32, -2, -2, -
2, -2))
     |
     |  name = 'Sharpen'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class SMOOTH(BuiltinFilter)
     |  Method resolution order:
     |      SMOOTH
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((3, 3), 13, 0, (1, 1, 1, 1, 5, 1, 1, 1, 1))
     |
     |  name = 'Smooth'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)
    class SMOOTH_MORE(BuiltinFilter)
     |  Method resolution order:
     |      SMOOTH_MORE
     |      BuiltinFilter
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Data and other attributes defined here:
     |
     |  filterargs = ((5, 5), 100, 0, (1, 1, 1, 1, 1, 1, 5, 5, 5, 1,
1, 5, 44,...
     |
     |  name = 'Smooth More'
     |
     |  ------------------------------------------------------------
----------
     |  Methods inherited from BuiltinFilter:
     |
     |  filter(self, image)
     |
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |
     |  __dict__
     |      dictionary for instance variables (if defined)
     |
     |  __weakref__
     |      list of weak references to the object (if defined)

    class UnsharpMask(MultibandFilter)
     |  UnsharpMask(radius=2, percent=150, threshold=3)
     |
     |  Unsharp mask filter.
     |
     |  See Wikipedia's entry on `digital unsharp masking`_ for an e
xplanation of
     |  the parameters.
     |
     |  :param radius: Blur Radius
     |  :param percent: Unsharp strength, in percent
     |  :param threshold: Threshold controls the minimum brightness
change that
     |    will be sharpened
     |
     |  .. _digital unsharp masking: https://en.wikipedia.org/wiki/U
nsharp_masking#Digital_unsharp_masking
     |
     |  Method resolution order:
     |      UnsharpMask
     |      MultibandFilter
     |      Filter
     |      builtins.object
     |
     |  Methods defined here:
     |
     |  __init__(self, radius=2, percent=150, threshold=3)
     |      Initialize self.  See help(type(self)) for accurate sign
ature.
```

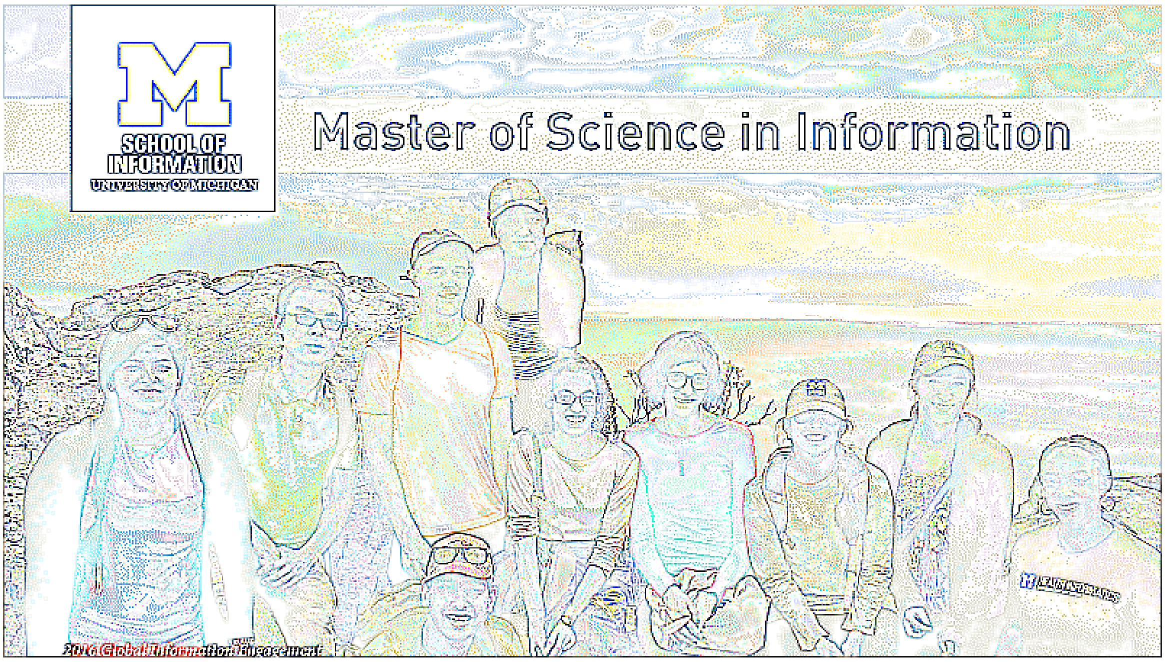
```
     |  
     |  filter(self, image)
     |  
     |  ------------------------------------------------------------
----------
     |  Data and other attributes defined here:
     |  
     |  name = 'UnsharpMask'
     |  
     |  ------------------------------------------------------------
----------
     |  Data descriptors inherited from Filter:
     |  
     |  __dict__
     |      dictionary for instance variables (if defined)
     |  
     |  __weakref__
     |      list of weak references to the object (if defined)

DATA
    division = _Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 
0), 8192...

FILE
    /opt/conda/lib/python3.7/site-packages/PIL/ImageFilter.py
```

In [22]:

```
# There are a bunch of different filters here, but lets just try and apply the B
LUR filter. Before we do this
# we have to convert the image to RGB mode. This is a bit magical -- images like
gifs are limited in how many
# colors can be displayed at once based on the size of the pallet. This is simil
ar to a painters pallet, which
# only has so much room. This is actually a very old image file format. If we co
nvert the image into something
# more sophisticated we can apply these interesting image transforms. Sometimes
 learning a new library means
# digging a bit deeper into the domain the library is about. We can convert the
 image using the convert()
# function.
image=image.convert('RGB') # this stands for red, green blue mode
blurred_image=image.filter(PIL.ImageFilter.CONTOUR)
display(blurred_image)
```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Using `crop()` to crop an Image

In [23]:

```
# Ok, let me show you one more function in the lecture, which is crop(). This re
moves portions of the image
# except for the bounding box you describe. When you think of images, think of i
ndividual dots or pixels
# which make up that image being lined up in a grid. You can actually see the nu
mber of pixels high the image
# is and the width of the image
print("{}x{}".format(image.width, image.height))
```

```
800x450
```

In [24]:

```
# This means that the image is 800 pixels wide (the X axis), and 450 pixels high
(the Y axis). If we take a
# look at the crop documentation we see that the first parameter to the function
is a tuple which is the
# left, upper, right, and lower values of the X/Y coordinates
help(image.crop)
```

```
Help on method crop in module PIL.Image:

crop(box=None) method of PIL.Image.Image instance
    Returns a rectangular region from this image. The box is a
    4-tuple defining the left, upper, right, and lower pixel
    coordinate. See :ref:`coordinate-system`.

    Note: Prior to Pillow 3.4.0, this was a lazy operation.

    :param box: The crop rectangle, as a (left, upper, right, lower)
-tuple.
    :rtype: :py:class:`~PIL.Image.Image`
    :returns: An :py:class:`~PIL.Image.Image` object.
```

In [25]:

```
# With PIL images, we define the bounding box using the upper left corner and the lower right corner. And
# we count the number of pixels out from the upper left corner, which is 0,0. This might seem odd if you're
# used to coordinate systems where you start in the lower left -- just remember that we define our box in the
# same way we count out positions in the image.
#
# So, if we wanted to get the Michigan logo out of this image, we might start with the left at, say 50 pixels,
# and the top at 0 pixels, then we might walk to the right another 190 pixels, and set the lower bound to say
# 150 pixels
display(image.crop((50,0,190,150)))
```

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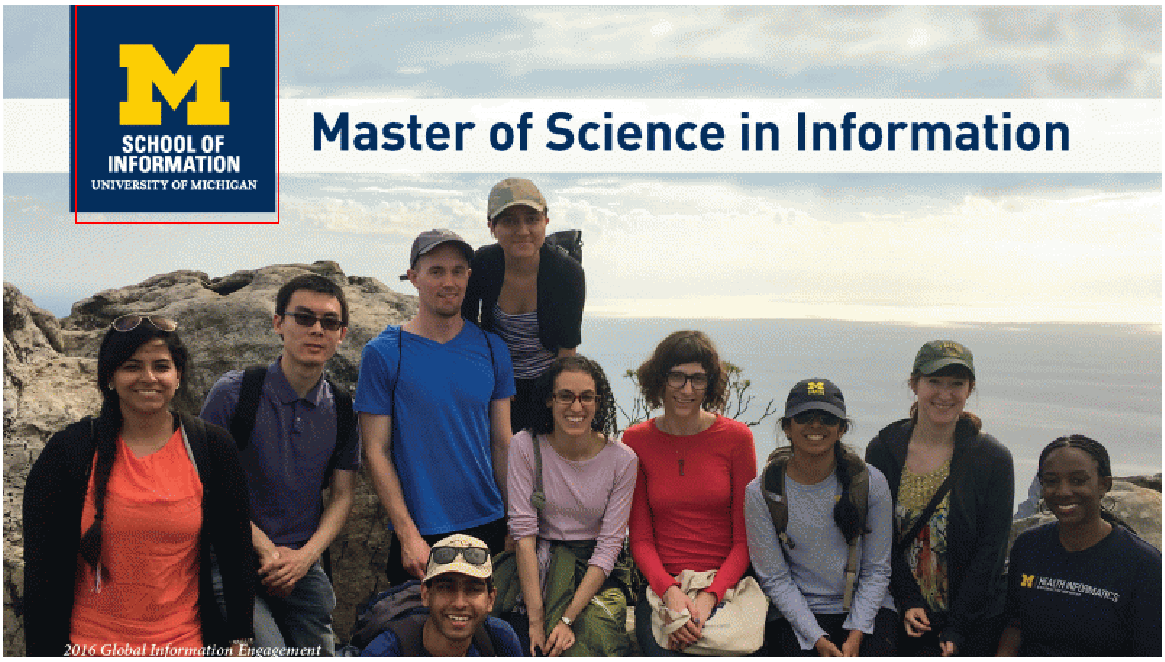
Using `ImageDraw`

In [26]:

```
# Of course crop(), like other functions, only returns a copy of the image, and doesn't change the image itself.
# A strategy I like to do is try and draw the bounding box directly on the image, when I'm trying to line things
# up. We can draw on images using the ImageDraw object. I'm not going to go into this in detail, but here's a
# quick example of how. I might draw the bounding box in this case.
from PIL import ImageDraw
drawing_object=ImageDraw.Draw(image)
drawing_object.rectangle((50,0,190,150), fill = None, outline ='red')
display(image)
```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Ok, that's been an overview of how to use PIL for single images. But, a lot of work might involve multiple images, and putting images together. In the next lecture we'll tackle that, and set you up for the assignment.

Additional PILLOW functions

Lets take a look at some other functions we might want to use in PILLOW to modify images.

In [28]:

```
# First, lets import all of the library functions we need
import PIL
from PIL import Image
from IPython.display import display
import inspect
# And lets load the image we were working, and we can just convert it to RGB inline
file="readonly/msi_recruitment.gif"
image=Image.open(file).convert('RGB')

display(image)
```

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Modifying Brightness

In [29]:

```python
# A task that is fairly common in image and picture manipulation is to create contact sheets of images.
# A contact sheet is one image that actually contains several other different images. Lets try and make
# a contact sheet for the Master of Science in Information advertisment image. In particular, lets change
# the brightness of the image in ten different ways, then scale the image down smaller, and put them side
# by side so we can get the sense of which brightness we might want to use.
#
# First up, lets import the ImageEnhance module, which has a nice object called Brightness
from PIL import ImageEnhance
# Checking the online documentation for this function, it takes a value between 0.0 (a completely black
# image) and 1.0 (the original image) to adjust the brightness. All of the classes in the ImageEnhance module
# do this the same way, you create an object, in this case Brightness, then you call the enhance function()
# on that object with an appropriate parameter.
#
# Lets write a little loop to generate ten images of different brightness. First we need the Brightness
# object with our image
enhancer=ImageEnhance.Brightness(image)
images=[]
for i in range(0, 10):
    # We'll divide i by ten to get the decimal value we want, and append it to the images list
    # we actually call the brightness routine by calling the enhance() function. Remember, you can dig into
    # details of this using the help() function, or by consulting web docs
    images.append(enhancer.enhance(i/10))
# We can see the result here is a list of ten PIL.Image.Image objects. Jupyter nicely prints out the value
# of python objects nested in lists
print(images)
```

```
[<PIL.Image.Image image mode=RGB size=800x450 at 0x7FEC2C1B0C18>, <P
IL.Image.Image image mode=RGB size=800x450 at 0x7FEC2C1B0DA0>, <PIL.
Image.Image image mode=RGB size=800x450 at 0x7FEC2C1B0EF0>, <PIL.Ima
ge.Image image mode=RGB size=800x450 at 0x7FEC2C1B0F60>, <PIL.Image.
Image image mode=RGB size=800x450 at 0x7FEC2C1C1048>, <PIL.Image.Ima
ge image mode=RGB size=800x450 at 0x7FEC2C1C12B0>, <PIL.Image.Image
image mode=RGB size=800x450 at 0x7FEC2C1C1320>, <PIL.Image.Image ima
ge mode=RGB size=800x450 at 0x7FEC2C1C1390>, <PIL.Image.Image image
mode=RGB size=800x450 at 0x7FEC2C1C1400>, <PIL.Image.Image image mod
e=RGB size=800x450 at 0x7FEC2C1C1470>]
```

In [30]:

```
# Lets take these images now and composite them, one above another, in a contact
sheet.
# There are several different approaches we can use, but I'll simply create a ne
w image which is like
# the first image, but ten times as high. Lets check out the PIL.Image.new funct
ionality
help(PIL.Image.new)
```

```
Help on function new in module PIL.Image:

new(mode, size, color=0)
    Creates a new image with the given mode and size.

    :param mode: The mode to use for the new image. See:
       :ref:`concept-modes`.
    :param size: A 2-tuple, containing (width, height) in pixels.
    :param color: What color to use for the image.  Default is blac
k.
       If given, this should be a single integer or floating point v
alue
       for single-band modes, and a tuple for multi-band modes (one
value
       per band).  When creating RGB images, you can also use color
       strings as supported by the ImageColor module.  If the color
is
       None, the image is not initialised.
    :returns: An :py:class:`~PIL.Image.Image` object.
```

In [31]:

```
# The new function requires that we pass it a mode. We're going to use the mode 'RGB' which stands for
# Red, Green, and Blue, and is the mode of our current first image. There are lots of different image mode
# formats, and this one is most common.
# For the size we have a tuple, which is the width of the image and the height. We'll use the width of our
# current first image, but for the height we'll multiple this by ten. This will make a sort of "canvas" for
# our contact sheet. Finally, the color is optional, and we'll just leave it at black.
first_image=images[0]
from PIL import Image
contact_sheet=PIL.Image.new(first_image.mode, (first_image.width,10*first_image.height))

# So now we have a black image that's ten times the size of the other images in the contact_sheet
# variable. Now lets just loop through the image list and paste() the results in. The paste() function
# will be called on the contact_sheet object, and takes in a new image to paste, as well as an (x,y)
# offset for that image. In our case, the x position is always 0, but the y location will change by
# 450 pixels each time we iterate through the loop.
#
# Lets first create a counter variable for the y location. It will start at zero
current_location = 0
for img in images:
    # Lets paste the current image into the contact sheet
    contact_sheet.paste(img, (0, current_location) )
    # And update the current_location counter
    current_location=current_location+450

# This contact sheet has gotten big: 4,500 pixels tall! Lets just resize this sheet for display. We can do
# this using the resize() function. This function just takes a tuple of width and height, and we'll resize
# everything down to the size of just two individual images
contact_sheet = contact_sheet.resize((160,900) )
# Now lets just display that composite image
display(contact_sheet)
```

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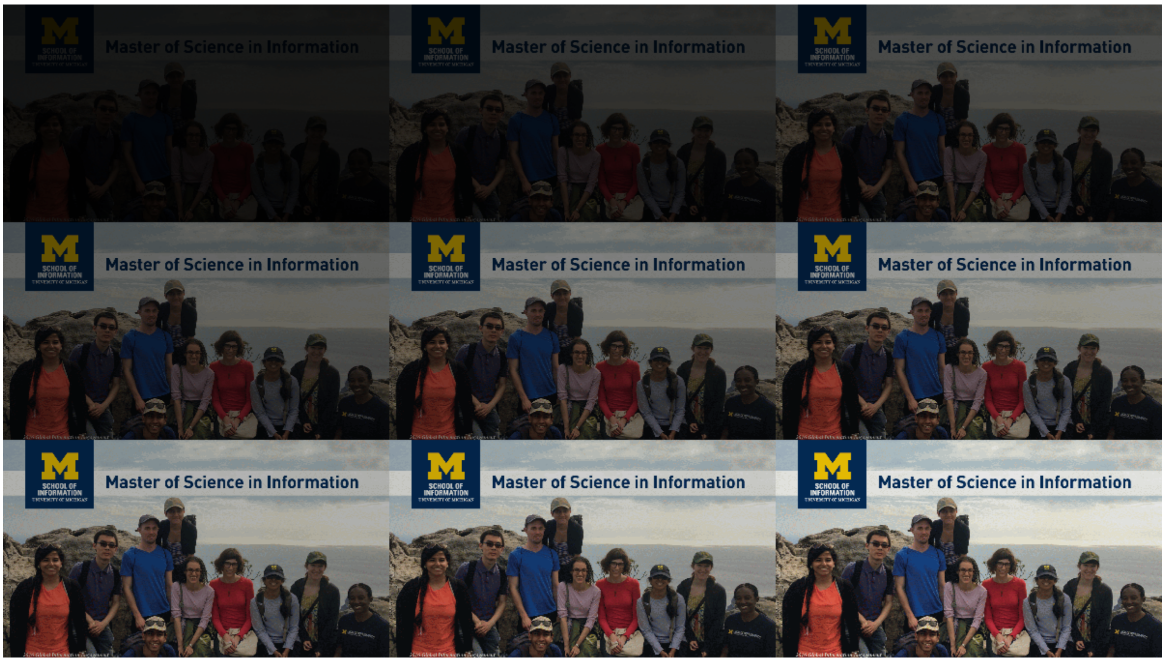
In [32]:

```
# Ok, that's a nice proof of concept. But it's a little tough to see. Lets inste
ad change this to a three
# by three grid of values. First thing we should do is make our canvas, and we'l
l make it 3 times the
# width of our image and 3 times the height of our image - a nine image square
contact_sheet=PIL.Image.new(first_image.mode, (first_image.width*3,first_image.h
eight*3))
# Now we want to iterate over our images and place them into this grid. Remember
that in PIL we manage the
# location of where we refer to as an image in the upper right hand corner, so t
his will be 0,0. Lets use
# one variable for the X dimension, and one for the Y dimension.
x=0
y=0

# Now, lets iterate over our images. Except, we don't want to both with the firs
t one, because it is
# just solid black. Instead we want to just deal with the images after the first
one, and that should
# give us nine in total
for img in images[1:]:
    # Lets paste the current image into the contact sheet
    contact_sheet.paste(img, (x, y) )
    # Now we update our X position. If it is going to be the width of the image,
then we set it to 0
    # and update Y as well to point to the next "line" of the contact sheet.
    if x+first_image.width == contact_sheet.width:
        x=0
        y=y+first_image.height
    else:
        x=x+first_image.width

# Now lets resize the contact sheet. We'll just make it half the size by dividin
g it by two. And, because
# the resize function needs to take round numbers, we need to convert our divisi
ons from floating point
# numbers into integers using the int() function.
contact_sheet = contact_sheet.resize((int(contact_sheet.width/2),int(contact_she
et.height/2) ))
# Now lets display that composite image
display(contact_sheet)
```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Well, that's been a tour of our first external API, the Python Imaging Library, or pillow module. In this series of lectures you've learned how to read and write images, manipulat them with pillow, and explore the functionality of third party APIs using features of Python like dir(), help(), and getmro(). You've also been introduced to the console, and how python stores these libraries on the computer. While for this course all of the libraries are included for you in the Coursera system, and you won't need to install your own, it's good to get a the idea of how this work in case you wanted to set this up on your own.

Finally, while you can explore PILLOW from within python, most good modules also put their documentation up online, and you can read more about PILLOW here: https://pillow.readthedocs.io/en/latest/ (https://pillow.readthedocs.io/en/latest/)