Today:

- Reproducible research
- Binary I/O
- Animation: plots to movies
- Sage
- Parallel IPython
- Course evaluations

Some new examples:

$CLASSHG/codes/io
$CLASSHG/codes/graphics
$CLASSHG/codes/python/mectest.py
Often need to write out a large array of floats with full precision. For example, one solution value on 3d grid ...

```
  do i=1,n
    do j=1,n
      do k=1,n
        write(21,210) u(i,j,k)
      210  format(e24.16)
      enddo; enddo; enddo
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How much disk space does this take?
ASCII vs. binary output

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This writes 24 ASCII characters (1 byte each) for each number, requires 24 bytes to store e.g. \(0.4000000000000000E+01\) so \(24n^3\) bytes (24 MB if \(n = 100\)) for full array.
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**Note:** In memory storing one 8-byte float takes only 8 bytes. (8 MB if $n = 100$.) ASCII takes $3 \times$ the space.
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Can use **unformatted** write in Fortran:

```fortran
! $CLASSHG/codes/io/binwrite.f90
open(unit=20, file="u.bin", form="unformatted", &
   access="direct", recl=8*m*n)

do j=1,n
   do i=1,m
      u(i,j) = real(m*(j-1) + i, kind=8)
   enddo
enddo

write(20,rec=1) u
close(20)
```

This writes 1 record of length $\text{recl}=8*m*n$.

The resulting binary file $u.bin$ cannot be edited directly.

But we can read it into Python...
To recover $U$ array of dimension $m \times n$ in Python:

```python
# $CLASSHG/codes/io/binread.py

from scipy.io import numpyio

file = open('u.bin', 'rb')
m = ...
n = ...
u = numpyio.fread(file, m*n, 'd')

# now use Fortran ordering to reshape, 
# filling U by columns:
U = u.reshape((m,n), order='F')
```
Other options for binary data

Binary formats that contain a lot of metadata...

Hierarchical Data Format: HDF, HDF4, HDF5

HDF5 file structure includes two major types of object:
- **Datasets**: multidimensional arrays of a homogenous type
- **Groups**: container structures for datasets and other groups
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NetCDF:

http://www.unidata.ucar.edu/software/netcdf/

“a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.”
5 possible ways to animate...

1. Some graphics packages have animation tools.

2. Create a sequence of images, view them one by one, On the fly, pausing between frames.
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Create sequence of image files, e.g.

   frame0001.png, frame0002.png, etc.

and then either:

3. Combine into single animated file,

   movie.gif or movie.mpg, etc.

4. Create html page that loads them one by one to create animation.

Examples: $CLASSHG/codes/graphics/movies
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Examples: $CLASSHG/codes/graphics/movies

5. Use Sage.
On the fly plotting

from matplotlib import pyplot as plt
import time

pause_time = 0.4  # seconds between frames

for n in range(nsteps+1):
    plt.clf()  # clear frame
    # plot frame n with necessary plot commands
    plt.draw()  # make sure screen updated
    time.sleep(pause_time)

Disadvantages: Cannot view again without recomputing,
               Hard to share with others.
Creating a sequence of image files

for n in range(nsteps+1):
    plt.clf()  # clear frame
    # plot frame n with necessary plot commands
    plt.draw()  # make sure screen updated
    fname = "frame%s.png" % str(n).rjust(4,'0')
    plt.savefig(fname)

This creates frame0000.png, frame0001.png, etc.

Can combine into a single animated gif via Unix convert:

    $ convert -delay 20 frame*.png movie.gif

Other formats also possible. See man page or

    http://www.imagemagick.org/script/convert.php
ImageMagick convert

For documentation see:

http://www.imagemagick.org/script/convert.php

Useful for converting single image between file types, e.g.

$ convert myplot.png myplot.pdf

For resizing image:

$ convert myplot.png -resize 50% smallplot.png

and many image processing tools (blurring, etc.)
Animating a sequence of image files in html

```
import html_movie
plotfiles = []
for n in range(nsteps+1):
    # plot frame n with necessary plot commands
    fname = "frame%s.png" % str(n).rjust(4,'0')
    plt.savefig(fname)
    plotfiles.append(fname)
html_movie.make_movie(plotfiles, "movie.html")
```

This creates an html file that uses JavaScript to loop through frame0000.png, frame0001.png, etc. in the browser.

Includes buttons to pause movie, change speed, etc.
Sage is an open source math software project.

http://www.sagemath.org

Founded by Prof. William Stein of the UW Math Department.

Python-based, includes $> 100$ packages in all fields of mathematics, symbolic manipulation, etc.

**Sage notebook** web-based interface, useful for experimenting and writing up notes.

Try it out on-line: http://www.sagenb.org

Many sample worksheets give an idea of what’s possible.
Parallelization in IPython

There are good instructions on how to do this at:

http://ipython.scipy.org/doc/rel-0.9.1/html/parallel/

Example: $CLASSHG/codes/python/mectest.py
Thanks for participating in this class.
The End

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Many thanks to our awesome TA, Grady Lemoine!
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Have a good summer.