2014-05-05.sagews

May 5, 2014

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1 Math 480b Sage Course

1.1 Overview of Sage

1.2 May 5, 2014

Screencast: REMEMBER!!!?! Remind ME.

Plan

- Questions
- Homework remark: all collected, grading assigned, new homework available
- Build Sage from source quick review
- Overview of what is in Sage

1.3 Check on our personal copies of Sage

- Everybody should build their own copy of Sage from source. So far 8 (of 40) of you have: Brian Chan, Taran Dike, Robert Irving, Matt Lorentz, Brad Schlenker, Yueqi Sheng, Bryant Wong, Yamin Zhou. Everybody else, do it! Think of your Sage install as like a tamaguchi or something

  git clone git://github.com/sagemath/sage.git cd sage make

Lets check on our builds.

/sage1.9G . 1.9G total /sage it works; type quit

Lets change something!

/sage /sage /sage /sage

1.4 What is SageMath?

1. A self-contained distribution of open source math-related software that builds from source on Linux, OS X, Solaris, and Cygwin.
2. A Python library that smoothly ties together these packages, and adds (a lot of) new functionality to fill in the gaps.

In addition, you can

- install third-party packages into Sage, including:
  - Python packages (43228 packages): `https://pypi.python.org/pypi`
  - R packages (5509 packages): `http://cran.r-project.org/web/packages/`
  - GAP packages (115 packages): `http://www.gap-system.org/Packages/packages.html`
- use interfaces to most other math software, e.g., Mathematica, Maple, Matlab, Scilab, Octave, etc. Type help(sage.interfaces).

```
# Python moto: "Batteries Included"
salvus.file('python-batteries.png')
```

1.5 Distribution heres whats included

(see also `http://sagemath.org/packages/standard/`)

/sageatlas-3.10.1.tar.bz2 gsl-1.15.tar.bz2 Pillow-2.2.2.tar.gz boehm_gc-7.2d.tar.bz2 iconv-1.14.tar.bz2 polybori-0.8.3.tar.bz2 boost_cropped-1.52.0.tar.bz2 iml-1.0.3.tar.bz2 polytopes_db-20120220.tar.bz2 bzip2-1.0.6.tar.gz ipython-0.13.2.tar.bz2 ppl-1.1pre9.tar.bz2 cddlib-094f.tar.bz2 jinja2-2.5.5.tar.bz2 pycrypto-2.6.1.tar.gz cephes-2.8.tar.bz2 jmol-12.3.27.tar.bz2 pygments-1.3.1.tar.bz2 cliquer-1.21.tar.bz2 lcalc-1.23.tar.bz2 pynac-0.3.0.tar.bz2 conway_polynomials-0.4.tar.bz2 libfplll-4.0.4.tar.bz2 python-2.7.5.tar.bz2 cvxopt-1.1.6.tar.bz2 libgap-4.6.4.tar.bz2 r-3.0.2.tar.bz2 cython-0.19.1.tar.bz2 libm4ri-20130416.tar.bz2 ratpoints-2.1.3.tar.bz2 docutils-0.7.tar.bz2 libm4rie-20130416.tar.bz2 readline-6.2.tar.bz2 ecl-12.12.1.tar.bz2 libpng-1.2.35.tar.bz2 rpy2-2.3.8.tar.gz eclib-20120830.tar.bz2 linbox-1.3.2.tar.bz2 rubiks-20070912.tar.bz2 ecm-6.4.4.tar.bz2 lrcalc-1.1.6.tar.bz2 sagenb-0.10.8.2.tar elliptic_curves-0.7.tar.bz2 matplotlib-1.2.1.tar.bz2 sagetex-2.3.4.tar.bz2 fflas_ffpack-1.6.0.tar.bz2 maxima-5.29.1.tar.bz2 scipy-0.12.0.tar.bz2 flint-2.3.tar.bz2 mpc-1.0.tar.bz2 scons-1.2.0.tar.bz2 flintqs-20070817.tar.bz2 mpfi-1.5.1.tar.bz2 setuptools-0.6.16.tar.bz2 freetype-2.5.2.tar.bz2 mpfr-3.1.2.tar.bz2 singular-3.1.5.tar.bz2 gap-4.6.4.tar.bz2 mpir-2.6.0.tar.bz2 sphinx-1.1.2.tar.bz2 gd-2.0.35.tar.bz2 mpmath-0.17.tar.bz2 sqlalchemy-0.5.8.tar.bz2 gdmodule-0.56.tar.bz2 ncurses-5.9.tar.bz2 sqlite-3.7.17.tar.bz2 genus2reduction-0.3.tar.bz2 networkx-1.8.1.tar.gz symmetrica-2.0.tar.bz2 gf2x-1.1.tar.bz2 ntl-5.5.2.tar.bz2 sympow-1.018.1.tar.bz2 gfan-0.5.tar.bz2 numpy-1.7.0.tar.bz2 sympy-0.7.4.tar.gz git-1.8.4.4.tar.bz2 palp-2.1.tar.bz2 tachyon-0.98.9.tar.bz2 givaro-3.7.1.tar.bz2 pari-2.5.5.tar.bz2 zlib-1.2.8.tar.bz2 glpk-4.44.tar.bz2 patch-2.5.9.tar.bz2 zn_poly-0.9.tar.bz2 graphs-20120404.tar.bz2 pexpect-2.0.tar.bz2

1.6 Distribution discuss some notable components of Sage that dont require a Ph.D. to appreciate

More notable components:

- atlas: Automatically Tuned Linear Algebra software = operations with floating point matrices quickly; used by numpy

```
import numpy.random, numpy
n = 1000
a = numpy.random.rand(n,n)  # see http://docs.scipy.org/doc/numpy/\
   reference/routines.random.html
b = numpy.random.rand(n,n)
%time c = a*b  # component-wise multiplication
%time d = numpy.dot(a,b)   # matrix multiplication (probably uses ATLAS \
   heavily)
```

```
CPU time: 0.00 s, Wall time: 0.00 s
CPU time: 0.29 s, Wall time: 0.00 s
```

- cvxopt: big convex optimization package; Convex minimization has applications in a wide range of disciplines, such as automatic control systems, estimation and signal processing, communications and networks, electronic circuit design, data analysis and modeling, statistics (optimal design), and finance. Wikipedia

Example here: `http://cvxopt.org/examples/tutorial/lp.html`

```
%python  # disable preparsing in this cell; alternatively, do RealNumber=\
   float
```

```
from cvxopt import matrix, solvers
A = matrix([ [-1.0, -1.0, 0.0, 1.0], [1.0, -1.0, -1.0, -2.0] ])
b = matrix([ 1.0, -2.0, 0.0, 4.0 ])
c = matrix([ 2.0, 1.0 ])
sol=solvers.lp(c,A,b)
print(sol['x'])
```

```
     pcost       dcost       gap    pres   dres   k/t
 0:  2.6471e+00 -7.0588e-01  2e+01  8e-01  2e+00  1e+00
 1:  3.0726e+00  2.8437e+00  1e+00  1e-01  2e-01  3e-01
 2:  2.4891e+00  2.4808e+00  1e-01  1e-02  2e-02  5e-02
 3:  2.4999e+00  2.4998e+00  1e-03  1e-04  2e-04  5e-04
 4:  2.5000e+00  2.5000e+00  1e-05  1e-06  2e-06  5e-06
 5:  2.5000e+00  2.5000e+00  1e-07  1e-08  2e-08  5e-08
Optimal solution found.
[ 5.00e-01]
[ 1.50e+00]
```

- cython: Cython is an optimising static compiler for both the Python programming language and the extended Cython programming language. It makes writing C extensions for Python as easy as Python itself. Cython gives you the combined power of Python and C. Hundreds of thousands of lines of Sage are written in Cython; were learn the basics very soon.

```
%python
def f0(n):
    k = 0
    for m in range(n):
        k += 2*m+1
    return k
```

```
%cython
def f1(int n):
    cdef long m, k=0
    for m in range(n):
        k += 2*m+1
    return k
```

```
%time f0(10^7)
```

```
100000000000000

CPU time: 3.63 s, Wall time: 3.08 s
```

```
%time f1(10^7)   # very fast, C semantics (so silent overflow), etc.
```

```
100000000000000
CPU time: 0.01 s, Wall time: 0.00 s
```

```
3.63/0.01
```

```
363.000000000000
```

- ecl: Embedded Common Lisp used by Maxima; but makes using lisp from Sage fast. If you like lisp try

```
%lisp
(+ 3 5)
```
```
8
```

```
%lisp
(setq a 13)
(setq b 17)
```
```
13
```

```
%lisp
(* a b)
```
```
221
```

```
%lisp
(defun factors (n &aux (lows '()) (highs '()))
  (do ((limit (isqrt n)) (factor 1 (1+ factor)))
      ((= factor limit)
       (when (= n (* limit limit))
         (push limit highs))
       (nreconc lows highs))
    (multiple-value-bind (quotient remainder) (floor n factor)
      (when (zerop remainder)
        (push factor lows)
        (push quotient highs)))))
```
```
FACTORS
```

```
%lisp
(factors 2014)
```
```
(1 2 19 38 53 106 1007 2014)
```

- GAP: Groups, Algorithms and Programming a System for Computational Discrete Algebra

GAP is a system for computational discrete algebra, with particular emphasis on Computational Group Theory. GAP provides a programming language, a library of thousands of functions implementing algebraic algorithms written in the GAP language as well as large data libraries of algebraic objects. `http://www.gap-system.org/`

```
G = SymmetricGroup(4); G
```
```
Symmetric group of order 4! as a permutation group
```

```
# This uses nontrivial functionality of GAP behind the scenes...
for H in G.normal_subgroups():
    print H
```
```
Subgroup of (Symmetric group of order 4! as a permutation group) generated by [()]
Subgroup of (Symmetric group of order 4! as a permutation group) generated by [(1,3)(2,4),
(1,4)(2,3)]
Subgroup of (Symmetric group of order 4! as a permutation group) generated by [(2,4,3),
(1,3)(2,4), (1,4)(2,3)]
Subgroup of (Symmetric group of order 4! as a permutation group) generated by [(1,2),
(1,2,3,4)]
```

```
groups.permutation.<tab>
```

Directly using GAP (see http://www.gap-system.org/Manuals/doc/tut/chap5.html#X8171DAF2833FF728)

```
%gap
s8 := Group( (1,2), (1,2,3,4,5,6,7,8) );
Group([ (1,2), (1,2,3,4,5,6,7,8) ])
```

```
%gap
a8 := DerivedSubgroup( s8 );
Group([ (1,2,3), (2,3,4), (2,4)(3,5), (2,6,4), (2,4)(5,7), (2,8,6,4)(3,5) ])
```

```
%gap
Size( a8 ); IsAbelian( a8 ); IsPerfect( a8 );
20160
false
true
```

```
%gap
IsNaturalAlternatingGroup(a8);
true
```

NOTE: You can switch a whole worksheet into gap mode by typing

```
# next time, some subset of these...

gdmodule-0.56.tar.bz2
genus2reduction-0.3.tar.bz2
gf2x-1.1.tar.bz2
gfan-0.5.tar.bz2
git-1.8.4.4.tar.bz2
givaro-3.7.1.tar.bz2
glpk-4.44.tar.bz2
graphs-20120404.tar.bz2
gsl-1.15.tar.bz2
iconv-1.14.tar.bz2
iml-1.0.3.tar.bz2
ipython-0.13.2.tar.bz2
jinja2-2.5.5.tar.bz2
jmol-12.3.27.tar.bz2
lcalc-1.23.tar.bz2
libfplll-4.0.4.tar.bz2
libgap-4.6.4.tar.bz2
libm4ri-20130416.tar.bz2
libm4rie-20130416.tar.bz2
libpng-1.2.35.tar.bz2
linbox-1.3.2.tar.bz2
lrcalc-1.1.6.tar.bz2
matplotlib-1.2.1.tar.bz2
maxima-5.29.1.tar.bz2
mpc-1.0.tar.bz2
mpfi-1.5.1.tar.bz2
mpfr-3.1.2.tar.bz2
```

```
mpir-2.6.0.tar.bz2
mpmath-0.17.tar.bz2
ncurses-5.9.tar.bz2
networkx-1.8.1.tar.gz
ntl-5.5.2.tar.bz2
numpy-1.7.0.tar.bz2
palp-2.1.tar.bz2
pari-2.5.5.tar.bz2
patch-2.5.9.tar.bz2
pexpect-2.0.tar.bz2
Pillow-2.2.2.tar.gz
polybori-0.8.3.tar.bz2
polytopes_db-20120220.tar.bz2
ppl-1.1pre9.tar.bz2
pycrypto-2.6.1.tar.gz
pygments-1.3.1.tar.bz2
pynac-0.3.0.tar.bz2
python-2.7.5.tar.bz2
r-3.0.2.tar.bz2
ratpoints-2.1.3.tar.bz2
readline-6.2.tar.bz2
rpy2-2.3.8.tar.gz
rubiks-20070912.tar.bz2
sagenb-0.10.8.2.tar
sagetex-2.3.4.tar.bz2
scipy-0.12.0.tar.bz2
scons-1.2.0.tar.bz2
setuptools-0.6.16.tar.bz2
singular-3.1.5.tar.bz2
sphinx-1.1.2.tar.bz2
sqlalchemy-0.5.8.tar.bz2
sqlite-3.7.17.tar.bz2
symmetrica-2.0.tar.bz2
sympow-1.018.1.tar.bz2
sympy-0.7.4.tar.gz
tachyon-0.98.9.tar.bz2
zlib-1.2.8.tar.bz2
zn_poly-0.9.tar.bz2
```