Sage : une alternative libre à Magma, Maple, Mathematica et Matlab

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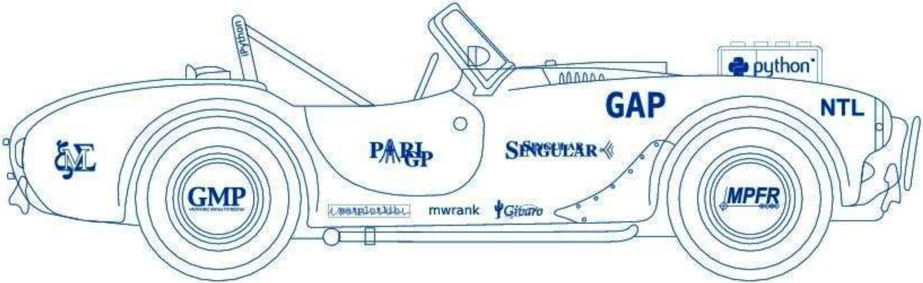
Journée Plume « Les alternatives libres aux outils propriétaires de maths », 4 février 2010

SAGE

Building »The Car«



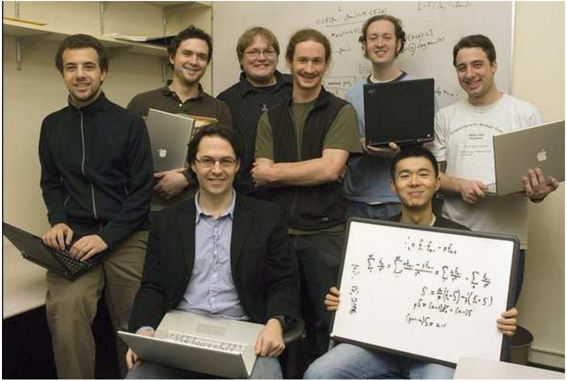
»Every free computer algebra system I've tried has reinvented many times the wheel without being able to build the car.«

Plan

- Historique
- Calculer
- Programmer
- Communiquer avec d’autres logiciels
- Contribuer

Historique

Cf `http://wstein.org/mathsoftbio/history.pdf`



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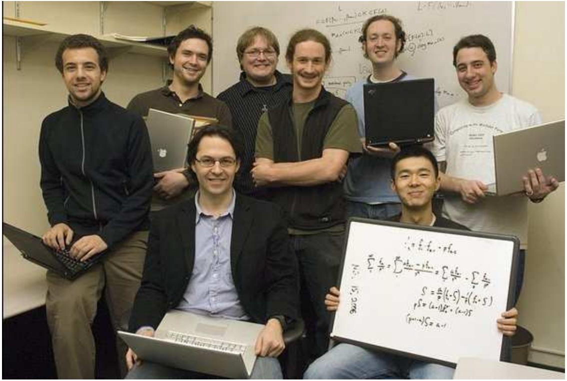

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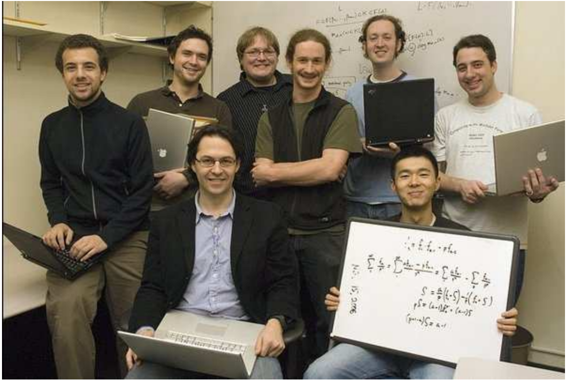

1997, graduate student at Berkeley, découvre Linux.

Ken Ribet : “Existe-t-il un premier *p* tel que l’algèbre de Hecke de niveau *p* est ramifiée en *p* ?”

Trouvé un article de Hijikata avec algorithme, mais nécessite de calculer des nombres de classe d'un grand nombre de corps quadratiques. Comment les calculer ?

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WS a entendu parler de Pari : il l'installe sur son ordinateur, et youpi !, Pari peut calculer rapidement les nombres de classe. (premier logiciel mathématique libre pour WS).

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"I had a thesis to finish"

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“At that moment I started designing what would eventually become Sage”

“I then realized that if I did this, I would have to do it myself [. . .] I wouldn’t get to do number theory for years. [. . .] I spent the next 5 years writing and using Magma”

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“I had to make this program trivial for him [David Joyner] to install”

“So I setup something that would do it all automatically in a self contained way”

“We had Sage Days in early February [2006], and I released Sage version 1.0 during my talk”

```
sage-1.0.0.1.tar 39.27MB  2006-02-05 15:47
...
sage-1.5.2.tar   72.01MB  2007-01-05 00:06
sage-1.5.3.tar   73.74MB  2007-01-05 19:58
...
sage-2.8.11.tar 158.24MB  2007-11-03 00:41
sage-2.8.12.tar 163.28MB  2007-11-07 15:34
sage-2.8.13.tar 164.87MB  2007-11-21 21:56
sage-2.8.14.tar 164.90MB  2007-11-25 07:59
...
sage-4.3.tar    260.62MB  2009-12-24 17:45
sage-4.3.1.tar  263.51MB  2010-01-21 00:18
```

Calculer

```
----------------------------------------------------------------------
| Sage Version 4.3.1, Release Date: 2010-01-20                       |
| Type notebook() for the GUI, and license() for information.        |
----------------------------------------------------------------------
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| Sage Version 4.3.1, Release Date: 2010-01-20                       |
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sage: 3 + 5
8
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```
sage: 57.1 ^ 100
4.60904368661396e175
```

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sage: matrix([[1,2], [3,4]])^(-1)
[  -2    1]
[ 3/2 -1/2]
```

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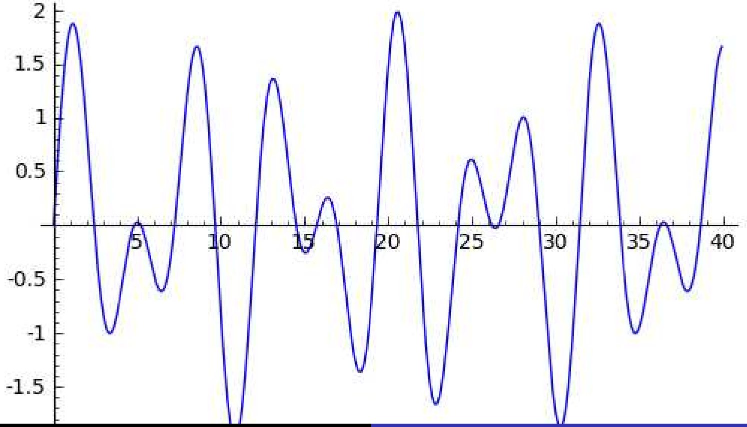
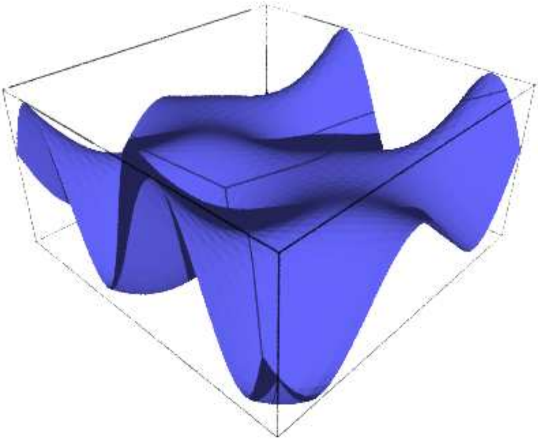
sage: matrix([[1,2], [3,4]])^(-1)
[  -2    1]
[ 3/2 -1/2]

sage: x = var('x')
sage: integrate(sqrt(x)*sqrt(1+x), x)
1/4*((x + 1)^(3/2)/x^(3/2) + sqrt(x + 1)/sqrt(x))/((x +
1)^2/x^2 - 2*(x + 1)/x + 1) + 1/8*log(sqrt(x + 1)/
sqrt(x) - 1) - 1/8*log(sqrt(x + 1)/sqrt(x) + 1)
```

```
sage: a = var(’a’)
sage: S = solve(x^2 + x == a, x); S
[x == -1/2*sqrt(4*a + 1) - 1/2,
 x == 1/2*sqrt(4*a + 1) - 1/2]
```

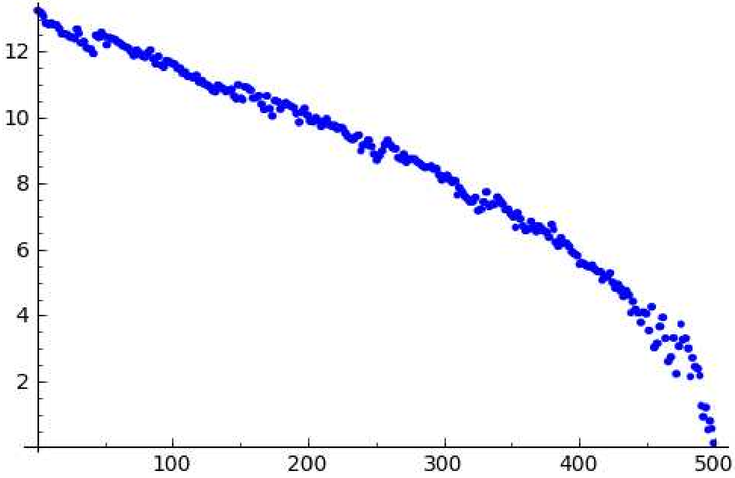
```
sage: a = var(’a’)
sage: S = solve(x^2 + x == a, x); S
[x == -1/2*sqrt(4*a + 1) - 1/2,
 x == 1/2*sqrt(4*a + 1) - 1/2]
sage: S[0].rhs()
-1/2*sqrt(4*a + 1) - 1/2
sage: show(plot(sin(x) + sin(1.6*x), 0, 40))
```





```
sage: var(’y’);
sage: P=plot3d(sin(x-y)*y*cos(x),(x,-3,3),(y,-3,3),
                  mesh=True)
sage: show(P, viewer=’tachyon’)
```

```
m = random_matrix(RDF,500)
sage: e = m.eigenvalues()
sage: w = [(i, abs(e[i])) for i in range(len(e))]
sage: show(points(w))
```



```
sage: factorial(100)
93326215443944152681699238856266700490715968264381621\
46859296389521759999322991560894146397615651828625369\
7920827223758251185210916864000000000000000000000000
sage: time n = factorial(1000000)
CPU times: user 0.81 s, sys: 0.00 s, total: 0.82 s
Wall time: 0.82 s
```

```
sage: factorial(100)
93326215443944152681699238856266700490715968264381621\
46859296389521759999322991560894146397615651828625369\
7920827223758251185210916864000000000000000000000000
sage: time n = factorial(1000000)
CPU times: user 0.81 s, sys: 0.00 s, total: 0.82 s
Wall time: 0.82 s

sage: N(pi, digits=100)
3.1415926535897932384626433832795028841971693993751\
0582097494459230781640628620899862803482534211706 8
```

```
sage: R.<x,y> = QQ[]; F = factor(x^99 + y^99); F
(x + y) * (x^2 - x*y + y^2) * (x^6 - x^3*y^3 + y^6)
* (x^10 - x^9*y + x^8*y^2 - x^7*y^3 + x^6*y^4 -
x^5*y^5 + x^4*y^6 - x^3*y^7 + x^2*y^8 - x*y^9 +
y^10) * (x^20 + x^19*y - x^17*y^3 - x^16*y^4 +
x^14*y^6 + x^13*y^7 - x^11*y^9 - x^10*y^10 -
x^9*y^11 + x^7*y^13 + x^6*y^14 - x^4*y^16 -
x^3*y^17 + x*y^19 + y^20) * (x^60 + x^57*y^3 -
x^51*y^9 - x^48*y^12 + x^42*y^18 + x^39*y^21 -
x^33*y^27 - x^30*y^30 - x^27*y^33 + x^21*y^39 +
x^18*y^42 - x^12*y^48 - x^9*y^51 + x^3*y^57 + y^60)
sage: F.expand()
x^99 + y^99
```

```
sage: R.<x,y> = QQ[]; F = factor(x^99 + y^99); F
(x + y) * (x^2 - x*y + y^2) * (x^6 - x^3*y^3 + y^6)
* (x^10 - x^9*y + x^8*y^2 - x^7*y^3 + x^6*y^4 -
x^5*y^5 + x^4*y^6 - x^3*y^7 + x^2*y^8 - x*y^9 +
y^10) * (x^20 + x^19*y - x^17*y^3 - x^16*y^4 +
x^14*y^6 + x^13*y^7 - x^11*y^9 - x^10*y^10 -
x^9*y^11 + x^7*y^13 + x^6*y^14 - x^4*y^16 -
x^3*y^17 + x*y^19 + y^20) * (x^60 + x^57*y^3 -
x^51*y^9 - x^48*y^12 + x^42*y^18 + x^39*y^21 -
x^33*y^27 - x^30*y^30 - x^27*y^33 + x^21*y^39 +
x^18*y^42 - x^12*y^48 - x^9*y^51 + x^3*y^57 + y^60)
sage: F.expand()
x^99 + y^99

sage: time z = Partitions(10^8).cardinality()
CPU times: user 4.68 s, sys: 0.00 s, total: 4.69 s
Wall time: 4.69 s
sage: str(z)[:40]
’1760517045946249141360373894679135204009’
```

Programmer

- soit en Python directement dans l'interprète
- soit via un fichier Python `*.py` avec `load` ou `attach`
- soit en utilisant le compilateur Cython avec un fichier `*.pyx`

Exemple

Référence : exposé de Robert Bradshaw aux Sage Days 6

Calcul de $0 + 1 + 2 + \cdots + N - 1$:

```
def sum1(N):
   s = 0
   for k in range(N):
      s += k
   return s
```

Exemple

Référence : exposé de Robert Bradshaw aux Sage Days 6

Calcul de $0 + 1 + 2 + \cdots + N - 1$:

```
def sum1(N):
   s = 0
   for k in range(N):
      s += k
   return s
```

```
sage: time sum1(10^6)
CPU times: user 1.78 s, sys: 0.01 s, total: 1.78 s
499999500000
```

La même chose avec Cython

```
sage: cat sum2.pyx
def sum2(long N):
    cdef long s = 0, k
    for k in range(N):
        s += k
    return s
```

La même chose avec Cython

```
sage: cat sum2.pyx
def sum2(long N):
    cdef long s = 0, k
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```

```
sage: load sum2.pyx
Compiling sum2.pyx...
```

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Compiling sum2.pyx...
```

```
sage: time sum2(10^6)
CPU times: user 0.00 s, sys: 0.00 s, total: 0.00 s
499999500000
```

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sage: cat sum2.pyx
def sum2(long N):
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sage: load sum2.pyx
Compiling sum2.pyx...

sage: time sum2(10^6)
CPU times: user 0.00 s, sys: 0.00 s, total: 0.00 s
499999500000

sage: time sum2(10^9)
CPU times: user 1.01 s, sys: 0.00 s, total: 1.01 s
499999999500000000
```

La même chose avec Cython et GMP

```
sage: sum2(5*10^9)
-5946744076209551616
```

La même chose avec Cython et GMP

```
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```

```
sage: cat sum3.pyx
include "gmp.pxi"
def sum3(long N):
    cdef long k
    cdef mpz_t s
    mpz_init_set_ui (s, 0)
    for k from 0 <= k < N:
        mpz_add_ui (s, s, k)
    res = int(mpz_to_str(s))
    mpz_clear (s)
    return res
```

La même chose avec Cython et GMP

```
sage: sum2(5*10^9)
-5946744076209551616
```

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sage: cat sum3.pyx
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        mpz_add_ui (s, s, k)
    res = int(mpz_to_str(s))
    mpz_clear (s)
    return res
```

```
sage: load sum3.pyx
Compiling sum3.pyx...
sage: time sum3(5*10^9)
CPU times: user 89.46 s, sys: 0.10 s, total: 89.56
12499999997500000000L
```

Le concept de spkg

Sage 4.3.1 utilise 96 “packages”, dont `atlas-3.8.3.p10`, `numpy-1.3.0.p2`, `matplotlib-0.99.1.p4`, `scipy-0.7.p3`, `python-2.6.4.p4`, `libfplll-3.0.12.p0`, `linbox-1.1.6.p2`, `maxima-5.20.1`, `pari-2.3.3.p7`.

```
$ cd /usr/local/sage-4.3.1/sage/spkg/standard
$ tar jtvf mpfr-2.4.1.p0.spkg
   0 2009-07-24 08:01 mpfr-2.4.1.p0/
   0 2009-07-17 02:51 mpfr-2.4.1.p0/patches/
6271 2009-07-17 02:25 mpfr-2.4.1.p0/patches/mpn_exp.c
 894 2009-07-17 02:33 mpfr-2.4.1.p0/patches/mpn_exp.c.patch
3963 2009-07-18 00:56 mpfr-2.4.1.p0/SPKG.txt
...
5271 2009-07-18 00:47 mpfr-2.4.1.p0/spkg-install
 106 2007-09-14 22:03 mpfr-2.4.1.p0/spkg-check
   0 2009-07-17 02:54 mpfr-2.4.1.p0/src/
1327 2009-02-20 10:43 mpfr-2.4.1.p0/src/setmin.c
```

```
$ tar jxf mpfr-2.4.1.p0.spkg; cd mpfr-2.4.1.p0
$ cat SPKG.txt
...
== SPKG Maintainers ==
 * Michael Abshoff
 * David Kirkby

== Upstream Contact ==
The MPFR website is located at http://mpfr.org/
The MPFR team can be contact via the MPFR mailing list:

== Dependencies ==
 * GMP

== Changelog ==
=== mpfr-2.4.1p0 (David Kirkby, July 17th 2009) ===
 * Sage TRAC #6453 http://sagetrac.org/sage_trac/ticket/
...
=== mpfr-2.4.1 (Michael Abshoff, March 2nd, 2009) ===
 * update to the official MPFR 2.4.1 release
...
```

Comment installer Sage sur son ordinateur ?

Télécharger `sage-4.3.1.tar` depuis `sagemath.org` (276MB).

```
$ tar xf sage-4.3.1.tar
$ cd sage-4.3.1
$ make
```

Aller prendre un café (ou plusieurs). . .

Quelques commandes utiles pour commencer

```
sage: a=17
sage: a.<tab>
a.abs                          a.kronecker
a.additive_order               a.lcm
a.base_extend                  a.leading_coefficient
...
sage: a.abs?
Return the absolute value of self.  (This just calls
the __abs__ method, so it is equivalent to the abs()
built-in function.)

    EXAMPLES::

    sage: RR(-1).abs()
    1.00000000000000
```

```
sage: search_src("integration",extra1="numerical")
gsl/all.py:14:from integration import numerical_integral
gsl/integration.pyx:117:       that implements numerical
            integration using Maxima.  It is potentially
ext/fast_eval.pyx:4:For many applications such as
            numerical integration, differential
ext/fast_callable.pyx:4:For many applications such as
            numerical integration, differential
functions/piecewise.py:359:        numerical integration
            based on a subdivision into N subintervals.
functions/piecewise.py:394:        numerical integration
            based on a subdivision into N subintervals.
functions/piecewise.py:444:        for numerical integra
            based on a subdivision into N
functions/transcendental.py:27:from sage.gsl.integration
            import numerical_integral
interfaces/maxima.py:2021:        Note that GP also does
            numerical integration, and can do so to very
calculus/desolvers.py:811:    Used to determine bounds f
            numerical integration.
```

Polynômes

```
sage: P.<x> = PolynomialRing(GF(17))
sage: p = P.random_element(); p
16*x^2 + 6*x + 9
sage: p^3
16*x^6 + x^5 + 4*x^4 + 11*x^3 + 15*x^2 + 13*x + 15
sage: p.roots()
[(4, 1), (2, 1)]
```

Matrices

```
sage: m = Matrix(P,2,2)
sage: m.randomize(); m

[13*x^2 + 12*x + 15     11*x^2 + x + 8]
[          4*x + 14  16*x^2 + 11*x + 1]
sage: m.rank() # used to fail (#5014)
2
sage: m.det()
4*x^4 + 2*x^3 + 6*x^2 + 12*x + 5
sage: factor(_)
(4) * (x^4 + 9*x^3 + 10*x^2 + 3*x + 14)
```

```
sage: z = gp(m)
sage: z
[Mod(13, 17)*x^2 + Mod(12, 17)*x + Mod(15, 17),
 Mod(11, 17)*x^2 + Mod(1, 17)*x + Mod(8, 17);
 Mod(4, 17)*x + Mod(14, 17),
 Mod(16, 17)*x^2 + Mod(11, 17)*x + Mod(1, 17)]
sage: type(z)
<class 'sage.interfaces.gp.GpElement'>
sage: z.matrank()
2
```

```
sage: gp.eval(’intnum(x=1,[1],sin(x)/x^2)’)
’0.50720744201747388836088625125948735826’
sage: res = eval(_); res
0.50720744201747392

sage: s = gp.eval(’Mod(8,17)’); s
’Mod(8, 17)’
sage: a = eval(s); a
8
sage: a.parent()
Ring of integers modulo 17
```

Interface sous l’interprète Sage

```
sage: %gp

  --> Switching to GP/PARI interpreter <--

,,

gp: a = factorint(2^128+1)


[59649589127497217 1]

[5704689200685129054721 1]

gp: quit

  --> Exiting back to SAGE <--
```

```
sage: m = gp(’a’); m
[59649589127497217, 1; 5704689200685129054721, 1]
sage: m * m
[3558073483084938890843851471799810,
    59649589127497218;
340282366920938469168063808116897266178,
    5704689200685129054722]
```

Using two different packages

```
sage: %maple
maple: m := linalg[hilbert](5);
m := matrix([[1, 1/2, 1/3, 1/4, 1/5], [1/2, 1/3, 1/4,
1/5, 1/6], [1/3, 1/4, 1/5, 1/6, 1/7], [1/4, 1/5, 1/6,
1/7, 1/8], [1/5, 1/6, 1/7, 1/8, 1/9]])
maple: d := linalg[charpoly](m, x);
d := x^5-563/315*x^4+735781/2116800*x^3-852401/
222264000*x^2+61501/53343360000*x-1/266716800000
maple: quit
sage: d = maple('d')
sage: d = gp(d)
sage: d.polroots()
[0.000003287928772171862957115004760 + 0.E-28*I,
0.0003058980401511917268794978407 + 0.E-28*I,
0.01140749162341980655945145887 + 0.E-28*I,
0.2085342186110133359050025101 + 0.E-28*I,
1.567050691098230795533011006 + 0.E-28*I]~
```

Ressources

A Tour of Sage :
`http://sagemath.org/doc/a_tour_of_sage/`

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sage-support :
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sage-edu :
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Comment contribuer ?

- envoyer un bug report sur la liste `sage-support`

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- encore mieux : proposer un *patch* !

Comment corriger sa propre version

Chaque utilisateur a une version de développement de Sage !

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Chaque utilisateur a une version de développement de Sage !

Sage 4.3 installé à partir des sources, dans

```
SAGE=/usr/local/sage-4.3-core2
sage: plot?
...
        EXAMPLES: We plot the sin function::
```

- éditer le fichier `SAGE/devel/sage-main/sage/plot/plot.py`
- lancer `sage -br` (build and run)

```
sage: plot?
...
        EXAMPLES: We plot the sin function:
```

Comment exporter son patch

```
sage: hg_sage.commit()
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(taper ’q’ et mettre un message de commit)

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```

(taper ’q’)

Exporter le patch :

```
sage: hg_sage.export(’tip’)
```

Comment exporter son patch

```
sage: hg_sage.commit()
```

(taper 'q' et mettre un message de commit)

```
sage: hg_sage.log()
```

(taper 'q')

Exporter le patch :

```
sage: hg_sage.export('tip')
```

```
tarte% ls -l *patch*
-rw-r--r-- 1 zimmerma caramel 707 2010-02-02
16:47 13535.patch
```

```
tarte% cat 13535.patch
# HG changeset patch
# User Paul Zimmermann <zimmerma@loria.fr>
# Date 1265125578 -3600
# Node ID 40b1293e7fbe4fe22a267103e3e90bf37670f647
# Parent  21efb0b3fc474972b5c7f617d99173536a3d79d0
fixed typo

diff -r 21efb0b3fc47 -r 40b1293e7fbe sage/plot/plot.py
--- a/sage/plot/plot.py Thu Dec 24 09:44:02 2009 -0800
+++ b/sage/plot/plot.py Tue Feb 02 16:46:18 2010 +0100
@@ -2210,7 +2210,7 @@
     possibility of, e.g., sampling sin only at multiples of
     ‘2\pi‘, which would yield a very misleading graph.

-    EXAMPLES: We plot the sin function::
+    EXAMPLES: We plot the sin function:

         sage: P = plot(sin, (0,10)); print P
         Graphics object consisting of 1 graphics primitive
```

Comment soumettre son patch

- aller sur `http://trac.sagemath.org/sage_trac`
- s'enregistrer puis cliquer sur *New Ticket*
- Summary : `[with patch] typo in documentation`
- Type : `enhancement`, Priority : `trivial`
- Milestone : `sage-4.3.2`, Component : `documentation`
- cliquer sur “I have files to attach to this ticket”
- cliquer sur “Preview” puis sur “Create ticket”
- uploader le patch
- cliquer sur “View Tickets” puis sur “needs review”

`http://trac.sagemath.org/sage_trac/ticket/8153`

Revue du code

```
   http://trac.sagemath.org/sage_trac/ticket/7876
symbolic expression displayed wrong [3 weeks ago]
Reported by:  iandrus
sage: f=(1/2-1/2*I )*sqrt(2)
sage: f
-(1/2*I + 1/2)*sqrt(2)
```

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trac_7876-pynac_print.take2.patch  Download  (2.6 KB)
added by burcin 2 weeks ago
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I get a single reject from the patch,
in symbolic/random_tests.py on sage.math.
```

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I get a single reject from the patch,
in symbolic/random_tests.py on sage.math.

Changed 9 days ago by rossk:
* status changed from needs_review to positive_review
sage: f=(1/2-1/2*I )*sqrt(2); f
(-1/2*I + 1/2)*sqrt(2)
```

Efficacité : entiers

Core 2 à 2.83Ghz, sous Linux.

Maple 13 :

```
> a := 3^20959032: b := 7^11832946:
> st:=time(): c:=a*b: time()-st;
                          1.523
> st:=time(): d:=c/a: time()-st;
                         1419.373
```

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> st:=time(): c:=a*b: time()-st;
                          1.523
> st:=time(): d:=c/a: time()-st;
                         1419.373
```

Sage 4.3 :

```
sage: a = 3^20959032; b = 7^11832946
sage: time c=a*b
CPU times: user 0.73 s, sys: 0.06 s, total: 0.79 s
sage: time d=c/a
CPU times: user 7.77 s, sys: 0.12 s, total: 7.89 s
```

Efficacité : flottants

Maple 13 :

```
> Digits:=5000000: a:=3.^10479516: b:=7.^5916473:
> st:=time(): c:=a*b: time()-st;
                                     5.964
> st:=time(): d:=c/a: time()-st;
                                     5.945
```

Efficacité : flottants

Maple 13 :

```
> Digits:=5000000: a:=3.^10479516: b:=7.^5916473:
> st:=time(): c:=a*b: time()-st;
                                          5.964
> st:=time(): d:=c/a: time()-st;
                                          5.945
```

Sage 4.3 :

```
sage: R = RealField(ceil(5000000*log(10)/log(2)))
sage: a = R(3)^10479516; b = R(7)^5916473
sage: time c=a*b
CPU times: user 0.32 s, sys: 0.00 s, total: 0.32 s
sage: time d=c/a
CPU times: user 1.62 s, sys: 0.00 s, total: 1.62 s
```

Efficacité : polynômes

Maple 13 :

```
> st:=time(): d:=expand((a+b+c+1)^100): time()-st;
                                     0.748

> st:=time(): factor(d), time()-st;
                        100
         (a + c + b + 1)   , 8.857
```

Efficacité : polynômes

Maple 13 :

```
> st:=time(): d:=expand((a+b+c+1)^100): time()-st;
                                     0.748


> st:=time(): factor(d), time()-st;
                        100
         (a + c + b + 1)   , 8.857
```

Sage 4.3 :

```
sage: var('a,b,c'); time d=expand((a+b+c+1)^100)
CPU times: user 4.06 s, sys: 0.17 s, total: 4.23 s
sage: time e=factor(d)
<does not answer in reasonable time>
sage: P.<a,b,c> = PolynomialRing(QQ)
sage: time d=(a+b+c+1)^100
CPU times: user 10.28 s, sys: 0.07 s, total: 10.35
sage: time e=d.factor()
CPU times: user 28.87 s, sys: 0.36 s, total: 29.23
```

Efficacité : matrices

Maple 13 :

```
> m:=LinearAlgebra:-HilbertMatrix(100):
> st:=time(): i:=LinearAlgebra:-MatrixInverse(m): t
                                     6.581
> st:=time(): evalm(i &* m): time()-st;
                                     4.200
```

Efficacité : matrices

Maple 13 :

```
> m:=LinearAlgebra:-HilbertMatrix(100):
> st:=time(): i:=LinearAlgebra:-MatrixInverse(m): t
                                     6.581
> st:=time(): evalm(i &* m): time()-st;
                                     4.200
```

Sage 4.3 :

```
sage: n=100; m=matrix(QQ,n)
sage: for i in range(n):
         for j in range(n):
            m[i,j]=1/(1+i+j)
sage: time i=m^(-1)
CPU times: user 8.11 s, sys: 0.05 s, total: 8.16 s
sage: time j=i*m
CPU times: user 0.16 s, sys: 0.00 s, total: 0.16 s
```

Sage Days 20

CIRM, Luminy, 22-26 février 2010