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Mathematica and LaTeX Integration

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Abstract

This document is about *Mathex,* a software package that allows to embed *Mathematica* © macro expressions into a LaTeX document, combining together the power of the two systems. It works in this way: when You click F2 on your preferred editor, before of the TeX to PDF conversion, a pre-processor (written in the PERL language) call Mathematica, do the computation *globally* (i.e. treating the file as a single program) and replaces the macros in the final TeX. The macros should be inserted between the two conventional simbols <% ... %>, and can contain every valid Mathematica's expression, or more espressions, separated by semicolon. As every expression and every graphics object get created everytime on-the-fly, *the process can be slow*.

Keywords: *Mathex*; Mathematica; Symbol; Algebraic expression.

Expressions

The *Mathematica* expressions should be inserted in the form of a macro, i.e with blocks like:

<% expr; expr;...; expr | {opt->value, opt->value,...} %>

Blocks can span over many rows, creating complex expressions or even complete *Mathematica* modules.

A macro, usually, creates some mathematical object but it can also *output* a final result.

If the last espression is followed by a semicolon, as usual for *Mathematica*, no output will be produced.

Example: the following macro [1]:

<%Clear[f,g,h]; w=5; f[x_]:=1/(x^2-Sin[w*x]); f[x] %>

1. Initialize the variables f,g,h.

2. Create the global variable w.

3. Define the function f(x).

4. Embed the last result (in this case $\frac{1}{x^2 - \sin(5x)}$) in to the TeX final code.

You can use the greek symbols in the standard *Mathematica* syntax. For example:

<%\\[Omega]^3 /(\\[Nu]+\\[Mu])%>

will produce:

$\frac{\omega^3}{\mu + \nu}$.

Special Formattings

A macro <% ... %> can have a (limited) number of options (*opt->value*) after the '|' symbol. An option modify some secondary aspects of output:

Examples:

1. Characters dimension: <% x^3/(1-x) | tiny %>: $\frac{x^3}{1-x}$

2. Formatting: <% Sin[x]| bold%>: $\sin(x)$,

3. Box <% 1/Pi | box %>: $\frac{1}{\pi}$

The most important is the *scale* option, that allow to change the size (Figure 1):

<% Plot[Sin[x]/x,{x,-2Pi,2Pi}] | scale->0.4 %>:

Non-standard Evaluation

You can ask *Mathematica* to left unevaluated an expression, adding the keyword *//HoldForm*:

G= <% Sum[x^n, {n,0,Infinity}] //HoldForm %>

$G = \sum_{n=0}^{\infty} x^n$

This allow to use the Mathematica engine in order to compose complex formulas, that otherwise would be reduced and/or simplified.

Some Algebra

Starting with the previously-defined functions:
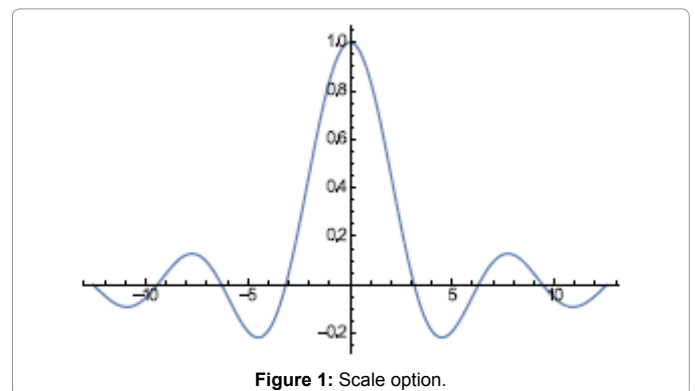
$f(\ x) = \frac{1}{x^2 - \sin(5x)}$.

Figure 1: Scale option.

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and with the Taylor's formula of order 21:

$$F(0) + xF'(0) + \frac{1}{2}x^2 F''(0) + \frac{1}{6}F^{(3)}(0)x^3 +$$

$$\frac{1}{24}F^{(4)}(0)x^4 + \frac{1}{120}F^{(5)}(0)x^5 + \frac{1}{720}F^{(6)}(0)x^6 + \frac{F^{(7)}(0)x^7}{5040} +$$

$$\frac{F^{(8)}(0)x^8}{40320} + \frac{F^{(9)}(0)x^9}{362880} + \frac{F^{(10)}(0)x^{10}}{3628800} + \frac{F^{(11)}(0)x^{11}}{39916800} +$$

$$\frac{F^{(12)}(0)x^{12}}{479001600} + \frac{F^{(13)}(0)x^{13}}{6227020800} + \frac{F^{(14)}(0)x^{14}}{87178291200} + \frac{F^{(15)}(0)x^{15}}{1307674368000} +$$

$$\frac{F^{(16)}(0)x^{16}}{20922789888000} + \frac{F^{(17)}(0)x^{17}}{355687428096000} + \frac{F^{(18)}(0)x^{18}}{6402373705728000} +$$

$$\frac{F^{(19)}(0)x^{19}}{121645100408832000} + \frac{F^{(20)}(0)x^{20}}{2432902008176640000} + O(x^{21})$$

we have:

$$\frac{1}{x^2 - \sin(5x)} = -\frac{1}{5x} - \frac{1}{25} - \frac{631x}{750} - \frac{628x^2}{1875} - \frac{569447x^3}{225000} -$$

$$\frac{79378x^4}{46875} - \frac{1682593649x^5}{236250000} - \frac{506446439x^6}{73828125} - \frac{957223523567x^7}{47250000000} -$$

$$\frac{45791485814x^8}{1845703125} - \frac{13862154603008141x^9}{233887500000} - \frac{128514389784362x^{10}}{1522705078125} -$$

$$\frac{1135730229825947045597x^{11}}{6385128750000000000} - \frac{8653043710783205603x^{12}}{31177386474609375} -$$

$$\frac{1735716809885787836636819x^{13}}{319256437500000000000} - \frac{697996797619464659353x^{14}}{779434661865234375} -$$

$$\frac{10951887148844768614328983679x^{15}}{6512831325000000000000000} - \frac{2840880569427626923252628x^{16}}{993779193878173828125} -$$

$$\frac{2042135660931607970239977333313151x^{17}}{3897929548012500000000000000} - \frac{269735690427560354275294768841x^{18}}{29738842376804351806640625} -$$

$$\frac{7028783136576696140370634072854793019x^{19}}{4287722502813750000000000000000} - \frac{2895600743925511431935636279696x^{20}}{100965205600261688232421875} + O(x^{21})$$

The serie expansion of its 6th power is:

$$y = \frac{1}{\left(x^2 - \sin(5x)\right)^6} = \frac{1}{15625x^6} + \frac{6}{78125x^5} + \frac{646}{390625x^4} + \frac{4431}{1953125x^3} +$$

$$\frac{677878}{29296875x^2} + \frac{20867399}{585937500x} + \frac{10798096693}{46142578125} + \frac{3870050711x}{9765625000} +$$

$$\frac{2220430875118x^2}{1153564453125} + \frac{185471893536331x^3}{52734375000000} + \frac{13054452676986586x^4}{951690673828125} +$$

$$\frac{2310234552040733539x^5}{87011718750000000} + \frac{81660365138067183934x^6}{927898406982421875} +$$

$$\frac{140552234174130259363721x^7}{7918066406250000000000} + \frac{846167985402319977750353x^8}{162382221221923828125} +$$

$$\frac{129589137978738038287247x^9}{1199707031250000000000} + \frac{1798570858872918972675375922x^{10}}{621111996173858642578125} +$$

$$\frac{6334999460938188662126059778957x^{11}}{1038397851562500000000000000} + \frac{40571623621273385144876082276812x^{12}}{2655253783643245697021484375} +$$

$$\frac{4704831173648364403298509865239381937x^{13}}{1450122599707031250000000000000} + \frac{78931443365406230576386049435399876x^{14}}{1022272706702649593353271484375} +$$

$$\frac{5239713364822407948539979785743625423017x^{15}}{31902697193554687500000000000000000} + O(x^{16})$$

Its 5th derivative, that we will insert in this way:

<% D[f[x],{x,5}] %>:

is:

$$-\frac{120(2x - 5\cos(5x))^5}{\left(x^2 - \sin(5x)\right)^6} + \frac{240(25\sin(5x) + 2)(2x - 5\cos(5x))^3}{\left(x^2 - \sin(5x)\right)^5} -$$

$$\frac{7500\cos(5x)(2x - 5\cos(5x))^2}{\left(x^2 - \sin(5x)\right)^4} - \frac{90(25\sin(5x) + 2)^2(2x - 5\cos(5x))}{\left(x^2 - \sin(5x)\right)^4} -$$

$$\frac{6250\sin(5x)(2x - 5\cos(5x))}{\left(x^2 - \sin(5x)\right)^3} + \frac{2500(25\sin(5x) + 2)\cos(5x)}{\left(x^2 - \sin(5x)\right)^3} + \frac{3125\cos(5x)}{\left(x^2 - \sin(5x)\right)^2}$$

and its definite integral between 1 and 2π is:

$$I = \int_1^{2\pi} \frac{1}{x^2 - \sin(5x)} dx$$

that, evaluated numerically, give us I=0.874779.

Now, we generate the following array:

$$A = \begin{pmatrix} x & \frac{x}{2} & \frac{x}{3} \\ x^2 & \frac{x^2}{2} & \frac{x^2}{3} \\ x^3 & \frac{x^3}{2} & \frac{x^3}{3} \end{pmatrix}$$

and will apply f(x) on it, obtaining the new array:

$$f(A) = \begin{pmatrix} \dfrac{1}{x^2 - \sin(5x)} & \dfrac{1}{\frac{x^2}{4} - \sin\left(\frac{5x}{2}\right)} & \dfrac{1}{\frac{x^2}{9} - \sin\left(\frac{5x}{3}\right)} \\ \dfrac{1}{x^4 - \sin\left(5x^2\right)} & \dfrac{1}{\frac{x^4}{4} - \sin\left(\frac{5x^2}{2}\right)} & \dfrac{1}{\frac{x^4}{9} - \sin\left(\frac{5x^2}{3}\right)} \\ \dfrac{1}{x^6 - \sin\left(5x^3\right)} & \dfrac{1}{\frac{x^6}{4} - \sin\left(\frac{5x^3}{2}\right)} & \dfrac{1}{\frac{x^6}{9} - \sin\left(\frac{5x^3}{3}\right)} \end{pmatrix}$$

We can compute the value of its determinants in $x = \frac{\pi}{2}$, obtaining:

$$|f(A)| = \frac{\langle\langle 1 \rangle\rangle}{\left(-\frac{9}{2} + \frac{\pi^2}{4}\right)\langle\langle 7 \rangle\rangle \left(\frac{\pi^6}{64} - \sin\left(\frac{\langle\langle 1 \rangle\rangle}{8}\right)\right)}$$

Algebraic expressions with large output are not a problem, neither for *Mathematica*, nor for TeX [2]:

$$(x - 4y)^{30} = x^{30} - 120x^{29}y + 6960x^{28}y^2 - 259840x^{27}y^3 +$$

$$7015680x^{26}y^4 - 145926144x^{25}y^5 + 2432102400x^{24}y^6 -$$

$$33354547200x^{23}y^7 + 383577292800x^{22}y^8 -$$

$$3750533529600x^{21}y^9 + 31504481648640x^{20}y^{10} -$$

$$229123502899200x^{19}y^{11} + 1451115518361600x^{18}y^{12} -$$

$$8036947486310400x^{17}y^{13} + 39036602076364800x^{16}y^{14} -$$

$$166556168859156480x^{15}y^{15} + 624585633221836800x^{14}y^{16} -$$

$$2057458556495462400x^{13}y^{17} + 5943769163209113600x^{12}y^{18} -$$

$$15015837886001971200x^{11}y^{19} + 33034843349204336640x^{10}y^{20} -$$

$$62923511141341593600x^9y^{21} + 102965745504013516800x^8y^{22} -$$

$$143256689396888371200x^7y^{23} + 167132804296369766400x^6y^{24} -$$

$$160447492124514975744x^5y^{25} + 123421147788088442880x^4y^{26} -$$

$$73138457948496855040x^3y^{27} + 31345053406498652160x^2y^{28} -$$

$$8646911284551352320xy^{29} + 1152921504606846976y^{30}$$

We consider, now, the following integral function:

$$g(a) = \int_1^{2\pi} \frac{1}{x^2 - a\sin(x)} dx$$

and expand it in Taylor's serie:

$$g(a) = \left(1 - \frac{1}{2\pi}\right) + a\left(\frac{Ci(1)}{6} - \frac{Ci(2\pi)}{6} - \frac{1}{24\pi^2} + \frac{\sin(1)}{6} + \frac{\cos(1)}{6}\right) + a^2\left(-\frac{2Si(2)}{15} + \frac{2Si(4\pi)}{15} + \frac{1}{10} - \frac{1}{240\pi^3} + \frac{1}{30\pi} + \frac{\sin(2)}{60} - \frac{2\cos(2)}{15}\right) + O(a^3)$$

, or, in numerical form:

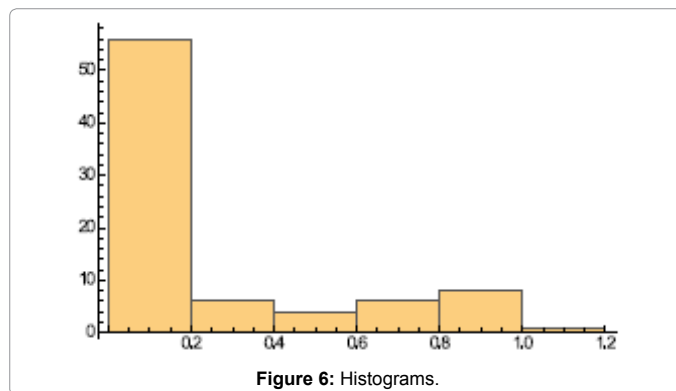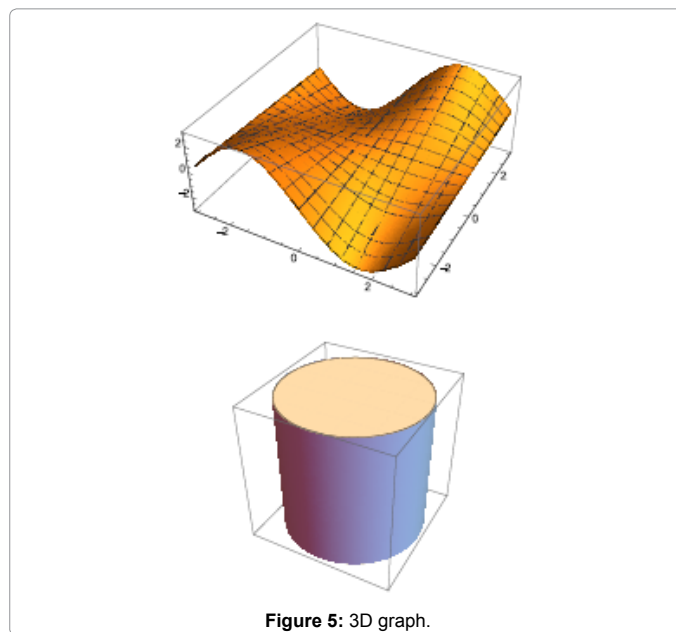$$g(\text{ }a) = 0.840845 + 0.286068(a + 0.) + 0.166017(a + 0.)^2 + O\left((a + 0.)^3\right)$$
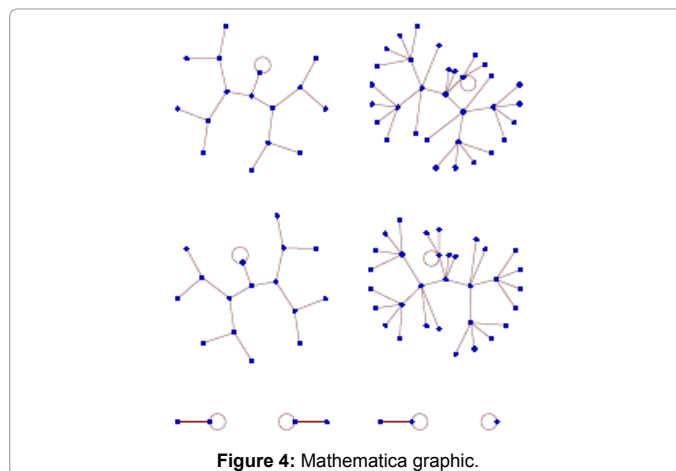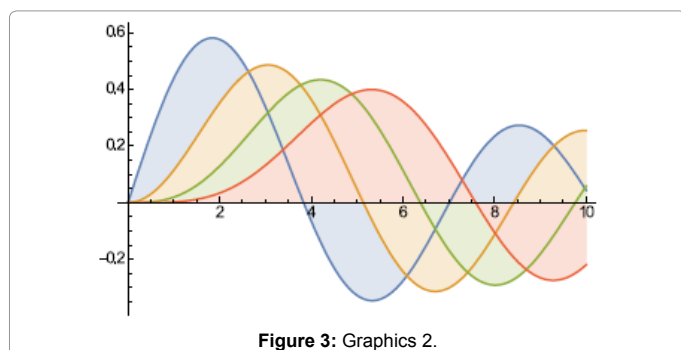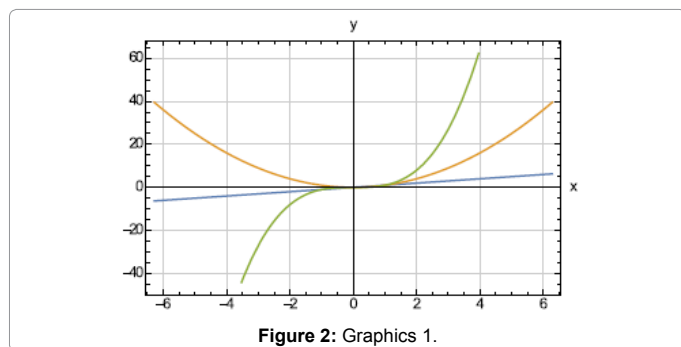
,

Obviously, you can access the enourmous collection of functions of Mathematica. So, if You need the first 20 Chebyshev's polynomials $T_n(x)$, You just can ask:

<% Table[ChebyshevT[n,x],{n,1,20}] | small %>

$(x, 2x^2 - 1, 4x^3 - 3x, 8x^4 - 8x^2 + 1, 16x^5 - 20x^3 + 5x, 32x^6 -$
$48x^4 + 18x^2 - 1, 64x^7 - 112x^5 + 56x^3 - 7x, 128x^8 - 256x^6 +$
$160x^4 - 32x^2 + 1, 256x^9 - 576x^7 + 432x^5 - 120x^3 +$
$9x, 512x^{10} - 1280x^8 + 1120x^6 - 400x^4 + 50x^2 - 1, 1024x^{11} -$
$2816x^9 + 2816x^7 - 1232x^5 + 220x^3 - 11x, 2048x^{12} -$
$6144x^{10} + 6912x^8 - 3584x^6 + 840x^4 - 72x^2 + 1, 4096x^{13} -$
$13312x^{11} + 16640x^9 - 9984x^7 + 2912x^5 - 364x^3 +$
$13x, 8192x^{14} - 28672x^{12} + 39424x^{10} - 26880x^8 + 9408x^6 -$
$1568x^4 + 98x^2 - 1, 16384x^{15} - 61440x^{13} + 92160x^{11} -$
$70400x^9 + 28800x^7 - 6048x^5 + 560x^3 - 15x, 32768x^{16} -$
$131072x^{14} + 212992x^{12} - 180224x^{10} + 84480x^8 - 21504x^6 +$
$2688x^4 - 128x^2 + 1, 65536x^{17} - 278528x^{15} + 487424x^{13} -$
$452608x^{11} + 239360x^9 - 71808x^7 + 11424x^5 - 816x^3 +$
$17x, 131072x^{18} - 589824x^{16} + 1105920x^{14} - 1118208x^{12} +$
$658944x^{10} - 228096x^8 + 44352x^6 - 4320x^4 + 162x^2 -$
$1, 262144x^{19} - 1245184x^{17} + 2490368x^{15} - 2723840x^{13} +$
$1770496x^{11} - 695552x^9 + 160512x^7 - 20064x^5 + 1140x^3 -$
$19x, 524288x^{20} - 2621440x^{18} + 5570560x^{16} - 6553600x^{14} +$
$4659200x^{12} - 2050048x^{10} + 549120x^8 - 84480x^6 + 6600x^4 - 200x^2 + 1)$

Graphics

The system creates a graphic file if the last expression of the macro produces a Mathematica *Graphics[]* object. You can obtain the simplest graphs directly from the standard plotting functions (Figures 2 and 3):

Figure 2: Graphics 1.

Figure 3: Graphics 2.

Figure 4: Mathematica graphic.

Figure 5: 3D graph.

Figure 6: Histograms.

<% opt={scale->0.5}; Plot[{x,x^2,x^3},{x,-2Pi,2Pi}] %>

but You can have more elaborated graphs merging Mathematica graphic primitives (Figures 4-6):

<%opt={scale->0.4}; GraphPlot[Table[i -> Mod[i^2, 102], {i, 0, 102}]] %>

or 3D graph:

or histograms:

etc.

Each graphs file is saved in the directory *./eps*, under the current path.

For the Mathematica graphical primitives, please consults a Mathematica book.

Caching

With the efficiency in mind, the system call Mathematica only if needed. For example, if You change only the text and no equations at all, the program will try to reuse the previous results. This caching activity is a sperimental feature, so it is possible to disable it, adding the following directive:

<% NOCACHE=1; %>

Requirements

This sofware is available (and tested) only on the Linux Operating System, and its derivatives.

It requires [3,4]:

1. Wolfram's *Mathematica* installed (tested versions form 8 to 10)

2. Latex typesetting system

3. Perl (version >5) with modules: *JSON; Digest::MD5.*

4. Lyx, Emacs, or Vim (for editing)

5. A pdf viewer (*evince, atril, okular, qpdfview, acroread, gv, xpdf, ...)*

6. *kdialog* and *xedit* (strongly suggested)

Installation

Please, download the latest version of this package from the following url:

http://github.com/michele.andreoli/mathex/

Once downloaded the *tgz* package in a temporary directory, you can run these commands:

```
# tar -zxf mathex-VERSION.tgz

#./install.sh
```

The *install.sh* command copy the files in the installation directory (usually *$HOME/.math*) and integrate that software with the supported editors (Lyx, Emacs and Vim).
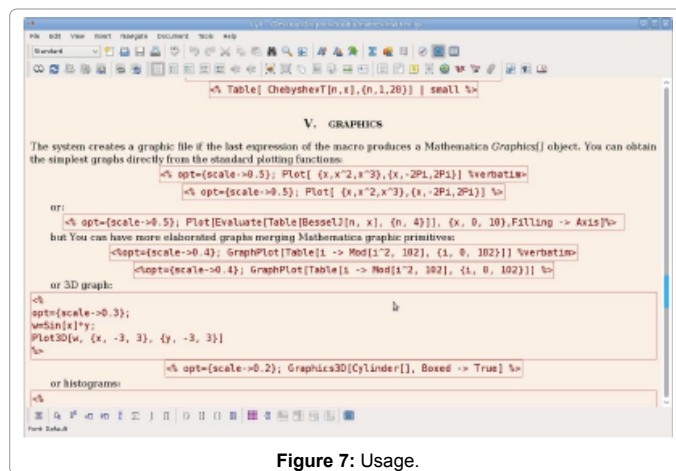

Figure 7: Usage.

Customization

Mathex calls *Mathematica* via a script wrapper. You can find the script (called *math.run*) in the installation directory. A little tuning allows to use local (or *sudo*) installation, or also remote Mathematica host (via *ssh*).

Usage

If You are using a supported editor, the <F2> shortcut should be available. As alternative, you can pre-process by yourself with the command:

#/path/to/replace.pl file.in > file.out

As the Lyx editor is concerned, we suggest to insert the macros <% ...%> using the Lyx TeX blocks (with Control-L) (Figure 7).

Disclaimer

References

1. Wolfram Mathematica.

2. LaTeX-A document preparation system.

3. The Perl programming language.

4. LyX-The document processor.