Compiling LaTeX to computer algebra-enabled HTML5

Bernard Parisse
Institut Fourier
UMR 5582 du CNRS
Université de Grenoble I
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Abstract

This document explains how to create or modify an existing LaTeX document with commands enabling computations in the HTML5 output: when the reader opens the HTML5 output, he can run a computation in his browser, or modify the command to be executed and run it. This is done by combining different softwares: hevea[6] for compilation to HTML5, giac.js for the CAS computing kernel (itself compiled from the C++ Giac[10] library with emscripten[11]), and a modified version[9] of itex2MML[3] for fast and nice rendering in MathML in browsers that support MathML.

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1 Introduction

Combining \LaTeX rendering quality and CAS computing is not new:

1. math softwares provide converters to export data to a \LaTeX file, or provide automated computations in a way similar to the way bibtex provides bibliography, like sagetex ([2]).

2. some softwares handle both \LaTeX-like rendering and computation, for example texmacs ([5]), lyx ([7]), Jupyter notebook ([8]).

However, in the first case, the reader can not modify the CAS commandlines, and in the second case the data format is not standard \LaTeX (the writer can not start from an existing document) and requires additional software to be installed on the reader device or a net access to a server to run the computations.

The solution presented here is new in that the writer will edit a standard \LaTeX file, add a few easy to learn commands like \texttt{\giacinputmath{factor(x^10-1)}} or \texttt{\giacinput{plot(sin(x))}} and compile it to produce a HTML5+MathML document. The reader can see the document in any browser (it’s optimized for Firefox), without installation, and he can modify computation commandlines and run them on his own computer.

If you are reading this file in PDF format, it is highly recommended to open the HTML5/Mathml version\(^1\) in order to test interactivity and look at the \LaTeX source\(^2\).

2 User manual

2.1 Installation on the writer computer

The writer must install

- the latest unstable version of \texttt{hevea}\(^3\) ([6]) or a forked version \texttt{hevea-mathjax}\(^4\) ([11]),

- \texttt{Giac/Xcas}\(^5\) ([10]) for computing-enabled output

- \texttt{heveatomml}\(^6\) ([9]) for MathML output

The files \texttt{giac.tex}\(^7\) (or the French version \texttt{giacfr.tex}\(^8\)) \texttt{giac.js}\(^9\), \texttt{hevea.sty}\(^10\), \texttt{mathjax.sty}\(^11\) must be copied in the \LaTeX working directory. On an Internet con-

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\(^1\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/castex.html

\(^2\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/castex.tex

\(^3\)http://hevea.inria.fr/distri/unstable/

\(^4\)https://github.com/YannickChevalier/hevea-mathjax

\(^5\)https://www-fourier.ujf-grenoble.fr/~parisse/giac.html

\(^6\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/heveatomml.tgz

\(^7\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/giac.tex

\(^8\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/giacfr.tex

\(^9\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/giac.js

\(^10\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/hevea.sty

\(^11\)https://www-fourier.ujf-grenoble.fr/~parisse/giac/mathjax.sty
nected linux box, the writer can run once the following shell script to install the tools required for HTML5/MathML output:

```bash
#!/bin/bash
wget https://www-fourier.ujf-grenoble.fr/~parisse/giac/giac.tex
wget https://www-fourier.ujf-grenoble.fr/~parisse/giac/giacfr.tex
wget https://www-fourier.ujf-grenoble.fr/~parisse/giac/giac.js
wget https://www-fourier.ujf-grenoble.fr/~parisse/giac/giac/hevea.sty
wget https://www-fourier.ujf-grenoble.fr/~parisse/giac/giac/mathjax.sty
wget http://hevea.inria.fr/distri/unstable/hevea-2017-05-18.tar.gz

tar xvfz hevea-2017-05-18.tar.gz

cd hevea-2017-05-18
make
sudo make install
cd ..

wget https://www-fourier.ujf-grenoble.fr/~parisse/giac/heveatomml.tgz

tar xvfz heveatomml.tgz

cd heveatomml/src
make
sudo make install

cd ../..
```

2.2 On the writer side

We now assume that the installation is done. The writer opens a \LaTeX file with his usual editor. He must add in the preamble the following lines:

\makeindex
\input{giac.tex}
\giacmathjax

For interactive CAS \LaTeX commands support, the writer should add

\begin{giacjshere}
\tableofcontents
\printindex
\end{giacjshere}

just after \begin{document} and \end{giacjshere}

just before \end{document}. Printing the table of contents and index before the first \LaTeX section command is recommended, otherwise the HTML output Table and Index buttons will not link correctly.

The rest of the source file is standard \LaTeX except that

- References to numbered equations should be inside additional backslash-ed parenthesis, for example
\begin{equation} \label{eq:test} \frac{2}{x^2-1}=\frac{1}{x-1}-\frac{1}{x+1} \end{equation}

From equation (\eqref{eq:test}) ... 

\[ \frac{2}{x^2-1} = \frac{1}{x-1} - \frac{1}{x+1} \]  \hspace{1cm} (1)

From equation (1) ...

- \texttt{\textbackslash mathbb{}} should be explicit, commands like \texttt{\textbackslash R} where \texttt{\textbackslash R} is defined by \texttt{\newcommand{\textbackslash R}{\textbackslash mathbb{R}}} will not work.

- New commands are available for interactive CAS support
  - \texttt{\giacinputmath{commandline}} will output an inline commandline that the user can modify and execute, the answer will be displayed in MathML (or SVG for 2-d graph output).
    Example: \texttt{\giacinputmath{factor(x^10-1)}}

\begin{verbatim}
factor(x^10-1)
\end{verbatim}

\[(x^10-1) = (x-1)(x+1)(x^4-x^3+x^2-x+1)(x^4+x^3+x^2+x+1)
\]

\textbf{Warnings}, if your command contains < or >, you must replace them by \texttt{&lt;} or \texttt{&gt;}, otherwise they will be interpreted as HTML delimiters.

You can also use the \texttt{\giacprog} and \texttt{\giaconload} environments explained below.

If the output is a 2-d graph, do not skip a line with \texttt{\textbackslash \textbackslash} after the command for PDF output

- \texttt{\giaccmdmath{command}{arguments}} will output command in a button following the arguments, the reader can only modify the arguments:
  \texttt{\giaccmdmath{factor}{x^4-1}}

\begin{verbatim}
factor(x^4-1)
\end{verbatim}

\[(x^4-1) = (x-1)(x+1)(x^2+1)
\]

- These commands may take an optional HTML style argument, for example
  \texttt{\giacinputmath{style="width:200px;"}{factor(x^10-1)}}

\begin{verbatim}
factor(x^{10-1})
\end{verbatim}

\[(x-1)(x+1)(x^4-x^3+x^2-x+1)(x^4+x^3+x^2+x+1)
\]
\text{factor}(x^4-1)
\begin{equation}
(x-1) \cdot (x+1)(x^2 + 1)
\end{equation}

- There are similar commands for outlined output \texttt{\giacinputbigmath{}}
or \texttt{\giaccmdbigmath{}}{}: 
  
  For example \texttt{\giacinputbigmath{factor}(x^{25}-1)}

\text{factor}(x^{25}-1)
\begin{equation}
(x-1)(x^4 + x^3 + x^2 + x + 1)(x^{20} + x^{15} + x^{10} + x^5 + 1)
\end{equation}

Example with an optional style argument \texttt{\giacinputbigmath[style="width:600px;height:20px;"]{factor}(x^{25}-1)}

\text{factor}(x^{25}-1)
\begin{equation}
(x-1)(x^4 + x^3 + x^2 + x + 1)(x^{20} + x^{15} + x^{10} + x^5 + 1)
\end{equation}

- Similar commands with text (or plot) output \texttt{\giacinput and \giacinputbig and \giaccmd, example:}

\texttt{\giacinput{factor}(x^4-1)}:

\text{factor}(x^{4}-1)
\begin{equation}
(x-1) \cdot (x+1)(x^2 + 1)
\end{equation}
\giaccmd{print}{"Hello world"}:

\begin{verbatim}
print("Hello world")
\end{verbatim}

0

With optional style argument
\giacinput{style="font-size:x-large"}{plot(1/x)}

\begin{verbatim}
plot(1/x)
\end{verbatim}

\giaccmd{factor}{x^4-1}

\begin{verbatim}
factor(x^4-1)
\end{verbatim}

\begin{verbatim}
(x - 1) \cdot (x + 1)(x^2 + 1)
\end{verbatim}

- The \texttt{giacprog} environment should be used for programs or multi-line commands
  \begin{verbatim}
  \begin{giacprog}...
  \end{giacprog}
  \end{verbatim}
  If you want the program to be parsed at load-time, replace \texttt{giacprog} with \texttt{giaconload}:
  \begin{verbatim}
  \begin{giaconload}...
  \end{giaconload}
  \end{verbatim}

- The \texttt{giacsider} command will add a slider. When the user modifies the slider interactively,
The new value is stored in idname and the command (depending on idname) is executed. Example:
\giacslider{a}{-5}{5}{0.1}{0.5}{plot(sin(a*x))}

\begin{align*}
    a:=0.5; \text{plot}\{\sin(a*x)\}
\end{align*}

- The \giachidden command behaves like \giaccmd except that the default HTML5 style is “hidden” until the command button has been pressed.
- The \giaclink command will add a link in the HTML version and nothing in PDF/DVI. The links open in a new tab, and the corresponding text may be specified as optional argument (default is Test online). Note that hevea.sty provides similar commands (\ahref, \footahref, \ahrefurl) with output in PDF/DVI.

Example with a link to Xcas for Firefox with a few commands
\giaclink{http://www-fourier.ujf-grenoble.fr/~parisse/xcasen.html#+factor(x

Once the source file is written, it is compiled to HTML5 with the command
hevea2mml sourcefile.tex
The HTML output and the giac.js files should be in the same directory on the web server. Index and bibliography should be processed with makeindex and bibhva.

If a PDF output is desired, the command icas from a Giac/Xcas installation should be used instead of pdflatex because it will run all CAS commands, output them in a temporary \LaTeX file, and run pdflatex on the output (this was inspired by the pgiac script\footnote{http://melusine.eu.org/syracuse/giac/pgiac/} from Jean-Michel Sarlat\footnote{https://www-fourier.ujf-grenoble.fr/~parisse/giac/castex.pdf}). The temporary file name is obtained by adding a _ at the end of the initial file name (without the .tex extension). Therefore, if you have an index and or citations, you should run makeindex and bibtex on the file name with _ appended. For bibtex citations in the HTML files, you should run bibhva. For example, the PDF version of this document is available here\footnote{https://www-fourier.ujf-grenoble.fr/~parisse/giac/castex.pdf}.
2.3 On the reader side

The reader’s browser opens an HTML5+MathML file (linking to the JavaScript giac.js). The MathML is rendered natively on Firefox or Safari, while Chrome or Internet Explorer will automatically load MathJax to render MathML (this is of course noticeably slower if the document is large). Computations are run by the reader’s browser (the CAS is JavaScript code). This is slower than native code but faster than net access to a server and it does not require setting up a specific server for computations.

2.4 More examples

2.4.1 Trace (2-d graph)

This example illustrates with a slider that the evolute of a curve is the envelope of the normals to the curve, here the curve is an ellipsis and the envelop an astroid. The list of normals \( L \) is initialized empty at load-time.

\[
L := []
\]

Now move the slider:

\[
t0 := 0.7; gl_x = -6..6; gl_y = -4..4; G := plotparam([2*cos(t), sin(t)], t = 0..2*pi); M := element(G, evalf(t0)); T := tangent(M); N := perpendicular(M, T); L := append(L, N); evolute(G, color = red)
\]

2.4.2 Cone section (3-d graph)

\( C \) is a cone of center the origin, axis of direction \((0, 0, 1)\), and angle \( \pi/6 \). \( P \) is a plane of equation \( z = my + 3 \). \( m \) is controlled by the slider, when \( m \) moves the intersection is an ellipsis or hyperbola (limit value is a parabola).

\[
m := 0.7; C := cone([0, 0, 0], [0, 0, 1], pi/6, display = green+filled); P := plane(z = evalf(m)*y + 3, display = cyan+filled);
\]
2.4.3 Dunford decomposition (CAS)

A program computing the Dunford decomposition of a matrix with Newton method. It is parsed at load-time (giaconload environment).

```plaintext
function dunford(A)
    local U,p,q,q1,j,d,n;
    U:=A;
    n:=nrows(U);
    p:=charpoly(U);
    q:=p/gcd(p,p'); // square free part
    q1:=q';
    for (j:=1; j<n; j:=2*j) {
        d:=inv(horner(q1,U))*horner(q,U); // Newton step
        if (d==0*d) return U,A-U;
        U:=U-d;
    }
    return U,A-U;
end;
```

Example: we define $J$ an almost diagonal matrix and $A$ a similar matrix and we check the Dunford decomposition of $A$.

$$J = \begin{pmatrix} 2 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}, \quad P = \begin{pmatrix} 1 & 0 & 0 \\ 2 & -1 & 0 \\ 3 & 4 & 1 \end{pmatrix}, \quad A = PJP^{-1}$$

$J:=[[2,0,0],[0,1,1],[0,0,1]]; P:=trn([[1,2,3],[0,-1,4],[0,0,1]]); A:=P*J*inv(P)$

$$J:=\begin{pmatrix} 2 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}, \quad P:=\begin{pmatrix} 1 & 0 & 0 \\ 2 & -1 & 0 \\ 3 & 4 & 1 \end{pmatrix}, \quad A:=P*J*inv(P)$$
\[ D, N := \text{dunford}(A); \quad N^2; \quad P^* \text{diag} \left( \text{diag}(J) \right)^* \text{inv}(P) \]

\[
\begin{pmatrix}
2 & 0 & 0 \\
2 & 1 & 0 \\
3 & 0 & 1
\end{pmatrix},
\begin{pmatrix}
0 & 0 & 0 \\
11 & -4 & -1 \\
-44 & 16 & 4
\end{pmatrix},
\begin{pmatrix}
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0
\end{pmatrix},
\begin{pmatrix}
2 & 0 & 0 \\
2 & 1 & 0 \\
3 & 0 & 1
\end{pmatrix}
\]

2.4.4 Slopefield

This will display the slopefield of an ordinary differential equation

\[ \frac{dy}{dt} = -y + \cos(t) \]

and one solution corresponding to an initial condition \( y(0) \) that the user may modify with the slider.

\[
y_0 := 1.0; \quad \text{gl\_x} = -5..5; \quad \text{gl\_y} = -3..3; \quad \text{plotfield} (-y+\cos(t), [t=-5..5, y=-3..3], xstep=0.4, ystep=0.4)
\]

\[
\text{plotode} (-y+\cos(t), [t=-5..5, y], [0,y0], tstep=0.1, color=red)
\]

2.4.5 Gröbner basis (CAS)

The CAS kernel can compute non-trivial Gröbner basis. Of course, the JavaScript version is significantly slower than the native Giac/Xcas kernel.

\[
kat7 := [-x1+2*x8^2+2*x7^2+2*x6^2+2*x5^2+2*x4^2+2*x3^2+2*x2^2+x1^2, \\
-x2+2*x8*x7+2*x6+2*x5+2*x4+2*x3+2*x2+2*x1, \\
-x3+2*x8*x6+2*x7+2*x5+2*x4+2*x3+2*x2+2*x1, \\
-x4+2*x8*x5+2*x7+2*x6+2*x5+2*x4+2*x3+2*x2, \\
-x5+2*x8*x4+2*x7+2*x6+2*x5+2*x4+2*x3+2*x2, \\
-x6+2*x8*x3+2*x7+2*x6+2*x5+2*x4+2*x3, \\
-x7+2*x8+2*x7+2*x6+2*x5+2*x4+2*x3+2*x2, \\
-1+2*x8+2*x7+2*x6+2*x5+2*x4+2*x3+2*x2+2*x1];
\]
Basis over $\mathbb{Z}_{16777213}$

$$G := \text{gbasis}(\text{kat7 \ mod \ 16777213}, [x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8]); \ \text{size}(G); \ G[20];$$

Done, 74, \(x_5 \cdot x_7 \cdot x_8^4 + 6710886 \cdot x_4 \cdot x_8^5 - 3938997 \cdot x_5 \cdot x_8^5 + 5106109 \cdot x_6 \cdot x_8^5 - 5543774 \cdot x_7 \cdot x_8^5 + 4960220 \cdot x_8^6 - 1622886 \cdot x_8^5 + 18489624116678107161957583274880000$$

Basis over $\mathbb{Q}$

$$G := \text{gbasis}(\text{kat7}, [x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8]); \ \text{size}(G); \ G[20];$$

Done, 74, \(18489624116678107161957583274880000 \cdot x_5 \cdot x_7 \cdot x_8^4 + 14791699293342485729566066619904000 \cdot x_4 \cdot x_8^5 + 15434816653922}{\text{How this is done}}$

The \LaTeX \texttt{giac...} commands are defined in \texttt{giac.tex}. For example \texttt{\giacinput} is defined like this:

\begin{verbatim}
\newcommand{
\verb||\$
$
[2][style="width:400px; font-size:large"]{
\ifhevea
}@print{<textarea onkeypress="UI.ckenter(event,this,1)" }
@getprint{#1>#2}
}@print{</textarea><button onclick="previousSibling.style.display='inherit';var tmp=UI.caseval(previousSibling.value)"
@getprint{#1>#2}
@print{</button>}
\fi
\end{verbatim}

If \texttt{hevea} compiles the command, the \texttt{\ifhevea} part is active, and the command will output an HTML5 \texttt{textarea} element and a OK \texttt{button}, with a callback to JavaScript code that will evaluate the CAS command inside the textarea

\begin{verbatim}
var tmp=UI.caseval(previousSibling.value)
\end{verbatim}

and fill the next HTML5 \texttt{span} field with the result of the CAS command.

The CAS evaluation is performed by a call to \texttt{giaceval} in the \texttt{UI.caseval} code (defined in \texttt{giac.tex}), where \texttt{giaceval} is a global JavaScript variable assigned at page load-time from the Module interface created by compiling Giac/Xcas with the C++ to JavaScript compiler \texttt{emscripten}\textsuperscript{14}. The CAS code being in JavaScript, it can be run on every JavaScript-enabled browser. It will be faster on browsers that have support for \texttt{asm.js (asmjs.org)} like Mozilla Firefox: numerical computations are 1 to 2 times slower than native code, while exact computations are 2 to 10 times slower than native code (the main reason being that JavaScript has currently no 64 bits integer type).

\textsuperscript{14}http://kripken.github.io/emscripten-site/
For a PDF output, if \texttt{pdflatex} is run on the tex file, giac commands will be written verbatim, but they will not be processed. The \texttt{icas} command from the Giac/Xcas package will filter all giac commands, process them and output the result in math mode in a temporary \LaTeX file. If the answer is a 2-d graph output, \texttt{icas} will output a pdf file on the hard disk and output a corresponding \texttt{\includegraphics} command in the temporary \LaTeX file. After that, the temporary file will be processed by \texttt{pdflatex}.

4 Conclusion

The current version of \texttt{icas} and \texttt{giac.tex} are already usable to easily produce HTML interactive CAS-enabled document from \LaTeX documents. They may be completed in future versions depending on user requests. For example, online courses might have commands to enable student exercises answers auto-check.

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