(some) LaTeX environments in Jupyter notebook

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```
%%javascript
IPython.load_extensions('calico-document-tools');
```

```
<IPython.core.display.Javascript object>
```

```
%%javascript
IPython.load_extensions('latex_envs');
```

```
<IPython.core.display.Javascript object>
```

```
%%html
<style>
    .prompt{
        display: none;
    }

</style>
```

1 Goal

1.1 Initial goal

The initial goal was only to add an environment `theorem` in my workflow. That is to be able to type something like

```
\begin{theorem}
Let $u$ and $v$ be two vectors of $\mathbb{R}^n$. The dot product can be
expressed as \begin{equation}u^Tv = |u||v| \cos \theta,\end{equation}
    where $\theta$ is the angle
between $u$ and $v$ \ldots{}
\end{theorem}
```

in a markdown cell and have it rendered, like

Theorem 1. *Let u and v be two vectors of $\mathbb{R}^n$. The dot product can be expressed as*

$$u^T v = |u||v| \cos\theta, \tag{1}$$

where θ is the angle between u and v ...

1.2 Features

The initial project has evolved to account for more environments and introduce some other features.

1.2.1 Support for simple LaTeX commands

We also added some LaTeX commands (e.g. `\textit`, `\textbf`, `\underline`) – this is useful in the case of copy-paste from a LaTeX document. Labels and references are supported, including for equations.

1.2.2 Available environments

- **theorems-like environments**: *property, theorem, lemma, corollary, proposition, definition,remark, problem, exercise, example*,
- **lists**: *enumerate, itemize*,

- limited support for a *figure* environment,
- an environment *listing*,
- *textboxa*, wich is a `textbox` environment defined as a demonstration (see below).

More environments can be added easily in the javascript source file `thmsInNb.js`. The rendering is done according to the stylesheet `latex_env.css`, which can be customized.

1.2.3 Automatic numerotation

Counters for numbering are implemented: one for theorems-like environments, a second for exercises-like environments and a third one for numbering figures.
Mathjax-equations with a label are also numbered document-wide (in contrast with standard notebook/mathjax numbering where the scope of numbering is limited to cells). An anchor is created for any label which enables to links things in the document: `\label` and `\ref` are both supported. A limitation is that numbering is updated (incremented) each time a cell is rendered. A toolbar button is provided to reset the counters and refresh the rendering of the whole document.

1.2.4 Other features

- It is possible to mix LaTeX and markdown markup in environments
- Environments can be nested. However, this is not always perfect...

2 Usage and examples

2.1 Installation

The extension consists in two javascript scripts: `latex_envs.js`, `thmsInNb.js` together with a stylesheet `latex_envs.css`. Follow the instructions in the wiki to install the extension. You can simply copy these files in the notebook extension directory (usually ~/.ipython/nbextensions) and load the extension in the notebook by

```
%%javascript
IPython.load_extensions('latex_envs');
```

2.2 A first example

This example shows another example of environment, featuring automatic numerotation, and the use of labels and references. Also note that standard markdown can be present in the environment and is interpreted. *The rendering is done according to the stylesheet `latex_env.css`, which of course, can be tailored to specific uses and tastes.*

```
\begin{definition}
\label{def:FT} Let $x[n]$ be a sequence of length $N$. Then, its
\textbf{Fourier transform} is given by

\begin{equation}
\label{eq:FT}
X[k]= \frac{1}{N} \sum_{n=0}^{N-1} x[n] e^{-j2\pi \frac{kn}{N}}
\end{equation}
\end{definition}
```

Definition 1. *Let $x[n]$ be a sequence of length N. Then, its **Fourier transform** is given by*

$$X[k] = \frac{1}{N} \sum_{n=0}^{N-1} x[n] e^{-j2\pi \frac{kn}{N}} \tag{2}$$

This is an extremely important tool in signal processing. We put this in evidence using the `textboxa` environment – which is defined here in the css, and that one should define in the LaTeX counterpart:

```
\begin{textboxa}
The Fourier transform is an extremely useful tool to have in your toolbox!
\end{textboxa}
```

The Fourier transform is an extremely useful tool to have in your toolbox!

As an example, consider the Fourier transform (2) of a pure cosine wave given by

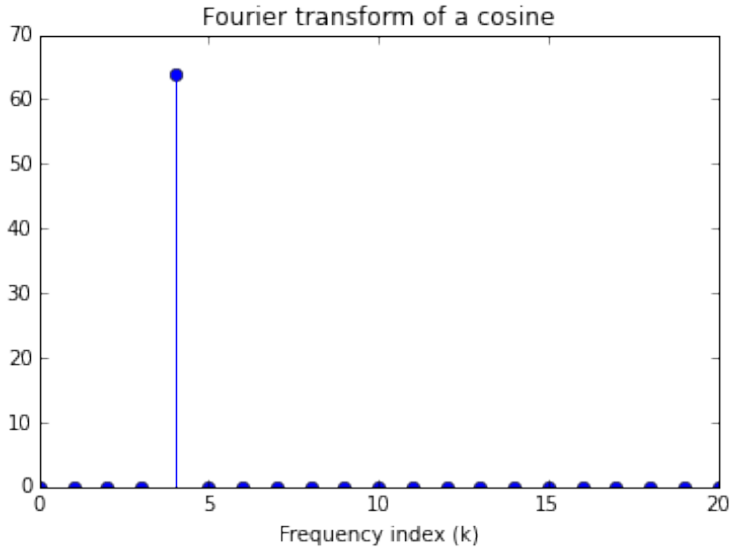
$$x[n] = \cos(2\pi k_0 n/N), \tag{3}$$

where k_0 is an integer. Its Fourier transform is given by

$$X[k] = \frac{1}{2}\left(\delta[k-k_0] + \delta[k-k_0]\right), \tag{4}$$

modulo N. This is illustrated in the following simple script:

```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
from numpy.fft import fft
k0=4; N=128; n=np.arange(N); k=np.arange(N)
x=np.sin(2*np.pi*k0*n/N)
X=fft(x)
plt.stem(k,np.abs(X))
plt.xlim([0, 20])
plt.title("Fourier transform of a cosine")
_=plt.xlabel("Frequency index (k)")
```



2.3 Second example

This example shows a series of environments, with different facets; **links, references, markdown or/and LaTeX formatting within environments**. Again, the rendering is done according to the stylesheet `latex_env.css`, which can be tailored. The listing of environments below is typed using the environment *listing*...

```
\begin{definition}
\label{def:diffeq} We call \textbf{difference equation} an equation of
the form \begin{equation}
\label{eq:diffeq}
y[n]= \sum_{k=1}^{p} a_k y[n-k] + \sum_{i=0}^q b_i x[n-i]
\end{equation}
\end{definition}

\begin{property}
If all the $a_k$ in equation (\ref{eq:diffeq}) of definition
\ref{def:diffeq} are zero, then the filter has a \textbf{finite impulse
response}.
\end{property}

\begin{proof}
Let $\delta[n]$ denote the Dirac impulse. Take $x[n]=\delta[n]$ in
(\ref{eq:diffeq}). This yields, by definition, the impulse response: \
    begin{equation}
\label{eq:fir}
h[n]= \sum_{i=0}^q b_i \delta[n-i],
\end{equation} which has finite support.
\end{proof}

\begin{theorem}
The poles of a causal stable filter are located within the unit circle
in the complex plane.
\end{theorem}

\begin{example}
\label{ex:IIR1} Consider $y[n]= a y[n-1] +  x[n]$. The pole of the
transfer function is $z=a$. The impulse response $h[n]=a^n$ has infinite
support.
\end{example}

In the following exercise, you will check that the filter is stable iff $a
    $<1.

\begin{exercise}
\label{ex:exofilter} Consider the filter defined in Example
\ref{ex:IIR1}. Using the \textbf{function} \texttt{lfilter} of scipy,
compute and plot the impulse response for several values of $a$.
\end{exercise}
```

The lines above are rendered as follows (of course everything can be tailored in the stylesheet):

Definition 2. *We call **difference equation** an equation of the form*

$$y[n] = \sum_{k=1}^{p} a_k y[n-k] + \sum_{i=0}^{q} b_i x[n-i] \tag{5}$$

Properties of the filter are linked to the coefficients of the difference equation. For instance, an immediate property is

Property 1. *If all the a_k in equation (5) of definition 2 are zero, then the filter has a* ***finite impulse response****.*

Proof. Let $\delta[n]$ denote the Dirac impulse. Take $x[n] = \delta[n]$ in (5). This yields, by definition, the impulse response:

$$h[n] = \sum_{i=0}^{q} b_i \delta[n-i], \tag{6}$$

which has finite support. □

Theorem 2. *The poles of a causal stable filter are located within the unit circle in the complex plane.*

Example 1. *Consider $y[n] = ay[n-1] + x[n]$. The pole of the transfer function is $z = a$. The impulse response $h[n] = a^n$ has infinite support.*

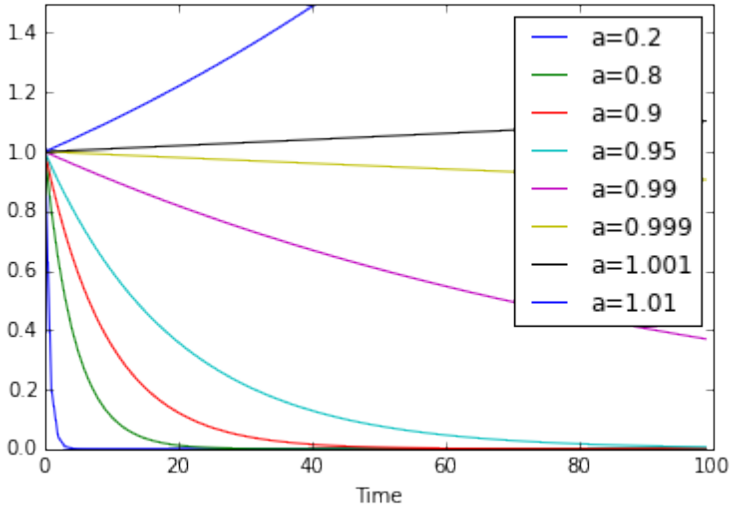
In the following exercise, you will check that the filter is stable iff $a<1$.

Exercise 1. *Consider the filter defined in Example 1. Using the* ***function*** `lfilter` *of scipy, compute and plot the impulse response for several values of a.*

```
The solution of exercise \ref{ex:exofilter}, which uses a difference
    equation as in Definition \ref{def:diffeq}:
```

The solution of exercise 1, which uses a difference equation as in Definition 2:

```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter
d=np.zeros(100); d[0]=1 #dirac impulse
alist=[0.2, 0.8, 0.9, 0.95, 0.99, 0.999, 1.001, 1.01]
for a in alist:
    h=lfilter([1], [1, -a],d)
    _=plt.plot(h, label="a={}".format(a))
plt.ylim([0,1.5])
plt.xlabel('Time')
_=plt.legend()
```



Finally, it is sometimes useful to integrate a figure within a markdown cell. The standard markdown markup for that is `![link](image)`, but a limitation is that the image can not be resized, can not be referenced and is not numbered. Furthermore it can be useful to re-use existing code. Threfore we have added a limited support for the `figure` environment. This enables to do something like

```
\begin{figure}[H]
\centerline{\includegraphics[width=10cm]{example.png}}
\caption{\label{fig:example} This is an example of figure included using
    LaTeX commands.}
\end{figure}
```

which renders as

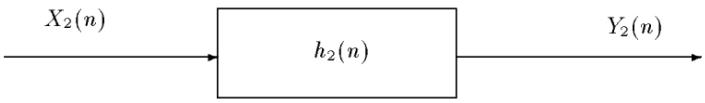


Figure 1: This is an example of figure included using LaTeX commands.

Of course, this Figure can now be referenced:

```
Figure \ref{fig:example} shows a second filter with input $X_2$, output $Y
    _2$  and an impulse response denoted as $h_2(n)$
```

Figure 1 shows a second filter with input X_2, output Y_2 and an impulse response denoted as $h_2(n)$

2.4 Third example:

This example shows that environments like itemize or enumerate are also available. As already indicated, this is useful for copying text from a TeX file. Following the same idea, text formating commands `\textit`, `\textbf`, `\underline`, etc are also available.

```
The following \textit{environments} are available:
\begin{itemize}
    \item \textbf{Theorems and likes}
    \begin{enumerate}
        \item theorem,
        \item lemma,
        \item corollary
        \item ...
    \end{enumerate}
    \item \textbf{exercises}
    \begin{enumerate}
        \item problem,
        \item example,
        \item exercise
    \end{enumerate}
\end{itemize}
```

which gives...
The following *environments* are available:

- **Theorems and likes**

1. theorem,
2. lemma,
3. corollary
4. ...

- **exercises**

1. problem,
2. example,
3. exercise

3 (post)-Converters

The extension works in the live-notebook. Since it relies on a bunch of javascript, the notebook does not render as is in very nice services such as `nbviewer` or `github` viewer. Similarly, `nbconvert` does not know of the LaTeX constructs which are used and therefore do not fully convert notebooks making use of this extension. Therefore, it is necessary to add a post conversion step to conversions provided by `nbconvert`. Though an interface exists for adding post-converters to nbconvert, this (first) author was too lazy and not enough strong to implement the post conversion along these lines. What has be done are simple `bash` and `python` scripts that perform this conversion.

3.1 Installation

Copy the scripts files to a directory in your search path, or launch the scripts with the complete path. The two main scripts are `ipynb_thms_to_html` (conversion to html, of course:) and `ipynb_thms_to_latex` (conversion to LaTeX!).

3.2 Conversion to html

Requirements: You will need `perl`, `nodejs`, and `ipython3` (the script calls `ipython3`; if your interpreter is `ipython`, edit the script and replace the different occurences).

The conversion to html is done by something like

```
[path/]ipynb_thms_to_html filename
```

or a list of files such as

```
[path/]ipynb_thms_to_html *.ipynb
```

In turn, this script makes somes substitutions using `perl`, and then uses the `nodesj` javascript interpreter to make the very same substitutions that are done in the live notebook. The conversion uses the template `thmsInNb.tpl` (located in the script directory). It also copies the css `latex_env.css` in the directory of the output html file (it must be copied with html files in the case of web upload).

3.3 Conversion to LaTeX

Requirements: You will need `perl` and `ipython3`.

The conversion to LaTeX is done by something like

```
[path/]ipynb_thms_to_latex filename
```

or a list of files such as

```
[path/]ipynb_thms_to_latex *.ipynb
```

The script makes some substitutions and cleaning in arkdown cells, then calls the legacy `nbconvert`. Afterward, it runs through the LaTeX environments and converts their contents (which can contain markdown markup) to LaTeX. Note that the script contains a list of the LaTeX environments to process. In the case of the addition of an environment in the main javascript (`thmsInNb.js`), this list must also be updated.

Finally, the script removes the header and footer in the LaTeX file. This is a personnal choice, and the corresponding line can be safely commented.

Example 2. *As for an example, the present document has been converted using*

```
ipynb_thms_to_latex latex_env_doc.ipynb
```

Then the resulting file (without header/footer) has been included in the main file `documentation.tex`*, where some LaTeX definitions of environments are done (namely listings, colors, etc) and compiled using*

```
xelatex documentation
```

The output can be consulted here.

4 Disclaimer, sources and thanks

This is a not-quick but certainly dirty hack. I am a complete beginner in javascript and of course there are obviously a large amount of possible improvements of the code, in cleaning, factorizing, etc! Language also needs improvement.

Contributions will be welcome and deeply appreciated.

Originally, I used a piece of code from the nice online markdown editor `stackedit` https://github.com/benweet/stackedit/issues/187, where the authors also considered the problem of incorporating LaTeX markup in their markdown. I also used examples and code from https://github.com/ipython-contrib/IPython-notebook-extensions.

```
%%javascript
IPython.load_extensions('latex_envs');
```

```
<IPython.core.display.Javascript object>
```