CONTROL OF AIRCRAFT

PYTHON AND CONTROL

October 13, 2023

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We have seen commands using Matlab. Most of them, except the block diagram approach with Simulink, are available under Octave, a free software.

An alternative approach is to use Scilab, which has control tools and an almost Simulink equivalent, Xcos, which handles block diagram simulation. But the syntax is different from Matlab.

Another alternative is to use Python, which also has a control package and packages to handle graphics and matrix calculations.
In the next slides, we will see Python equivalent to Matlab commands.
Your configuration of Python should include the following packages:

- control
- slycot
- scipy
- numpy
- pylab
- matplotlib
- math (should be installed)
- ipython

We will see how to install them on Windows, Linux and Mac OS X.

INTRODUCTION TO PYTHON

In the mini project, the Python programming language will be used. You should download and install this free software Python (3.xx version) with the following packages:

- scipy: a scientific library (offers integration, optimization ...)
- numpy: a package to deal with arrays and matrices
- slycot: a mathematical library
- pylab: a part of matplotlib which gives a Matlab like environment
- matplotlib: a package to create plots
- control: a package for control
- ipython: an enhanced interactive console

Python can be used with a command line shell, or alternatively with and IDE. An IDE such as Spyder provides an interface similar to Matlab interface. It must be installed separately.

In Spyder, to act interactively with the plots of sisopy31, in `Preferences/Python console/Graphics`, change `Backend` to another option than `Inline`. Then close and reopen Spyder.
You can also, once matplotlib has been loaded, type `%matplotlib qt5` in the command line (not in a script) to otain the same behavior.

There is now an equivalent to Matlab `sisotool` in python control package (with limited capabilities), but there is a python script available on Moodle which provides an equivalent to sisotool with more information provided to the user: `sisopy31.py`

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PYTHON INSTALLATION ON WINDOWS, MACOS AND LINUX

On Windows, Mac OS X and Linux, the Python Anaconda distribution can be used because slycot and control are available for these 3 OS. You can download the distribution at
https://www.anaconda.com/download

You must choose a **64 bit** version.

- This has been tested on Mac OS X and Linux Ubuntu in 2018 and python **3.6**.
- It has also been tested with Python **3.9** on Windows 11.
- It has also been tested with Python **3.11** on Linux Ubuntu in october 2023 (and this is the recommended version).

Then type the following command in a terminal under macOS or Linux and an Anaconda prompt under Windows, to install the required packages (this command does not work inside Python)

```
conda install -c conda-forge slycot control
```

The last versions in October 2023 are available for Python 3.11:

- v0.5.4.0 for the slycot package, see https://anaconda.org/conda-forge/slycot
- v0.9.4 for the control package (Windows 64, Linux 64 and OSX 64), see https://anaconda.org/conda-forge/control

ANACONDA ENVIRONMENT

You can create an environment in Anaconda. This allows you to have several concurrent versions of Python installed on your computer and may prove useful if you have to deal with incompatible libraries needed in different courses.
To create your environment named myenv, with a specific version of Python (e.g. 3.11):

```
conda create --name myenv python=3.11
```

To activate the environment you have created

```
conda activate myenv
```

And to deactivate the environment

```
conda deactivate myenv
```

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How to use python:

- Launch ipython or spyder (preferred to python because ipython is more interactive)
- in the prompt, you can type commands such as

```
>>> a=0.127
>>>a
0.127
>>> print("a=%.3f"%a)
a=0.127
```

- you can run a script (a text file you have written, call myscript.py) by typing:

```
>>> run myscript.py
```

A few things to know about python:

- indentation counts and is used to delimit blocks. For example:

```
i=True
if  i==True  :
    print("i true")
else:
    print("i false")
```

Note also the use of :

- in numpy, the indice of matrices begin at 0
- the indice of the end is not included.

```
>>> import numpy as np
>>> a=np.matrix([[1],[2],[3],[4]])
>>> # row 2 to 3
>>> a[1:3]
matrix([[2],
        [3]])
```

At the beginning of your script, you should put the following commands, in order to make all the packages available for the mini project (and you must copy sisopy31.py in your working directory):

PYTHON HEADINGS

```
#!/usr/bin/python
# coding: utf-8

from __future__ import unicode_literals
from matplotlib.pyplot import *
import control
from control.matlab import *
from math import *
from scipy.interpolate import interp1d
from pylab import *
from matplotlib.widgets import Slider
import numpy as np
import scipy.interpolate
```

The first line is used to make the script executable on a UNIX system.
The second line defines the coding convention of the text (utf-8).
The line with unicode allows the use of unicode in matplotlib plots.
To import a package, you have several options:

- import *packagename*: all commands of the package are available via *packagename.command*
- import *packagename* as *pk*: creates an alias and the commands are available via *pk.command*
- from *packagename* import *: all commands are directly available via *command*
- from *packagename* import *command*: import only the command *command* which is directly available via *command*

PYTHON CODE EXAMPLES

```
# Define a matrix in Python
A=np.matrix([[ -4.232e-02,  -2.418e-02,  -4.764e-02,
                0.0,    0.0,    0.0],
        [  4.727e-02,   0.0,    1.628,
                0.0,    0.0,    0.0],
        [ -4.727e-02,   0.0,   -1.628e+00,
                1.0,    0.0,    0.0],
        [  0.0,    0.0,   -6.420e+01,
               -9.048e-01,   0.0,    0.0],
        [  0.0,    0.0,    0.0,
                1.0,    0.0,    0.0],
        [  0.0,    4.056e+02,   0.0,
                0.0,    0.0,    0.0]])
```

```
B=np.matrix([[   0.          ,   0.          ],
        [   0.4424,    0.          ],
        [  -0.4424,    0.          ],
        [-76.3469,    0.          ],
        [   0.          ,   0.          ],
        [   0.          ,   0.          ]])
```

```
# submatrix (matrix slicing)
# note that indices begin at 0 and
# the indice of the end is not included
Ar=A[2:4,2:4]
Br=B[2:4,0:1]
Cr=np.matrix([0.0,1.0])
Dr=0.0

# define a state space system
sys_q=ss(Ar,Br,Cr,Dr)
# define a transfer function
sys_q_tf=tf(sys_q)
# damping ratio
control.matlab.damp(sys_q)
# dcgain
dcgain(sys_q)
```

```
# step response
figure(1)
Yq,Tq=control.step(sys_q)
plot(Tq,Yq,'b',lw=2)
grid(True)
title('Réponse indicielle q/Dm')
show()

# feedback
Kq=-0.115
Tqbo=feedback(Kq*sys_q,1.0)
```

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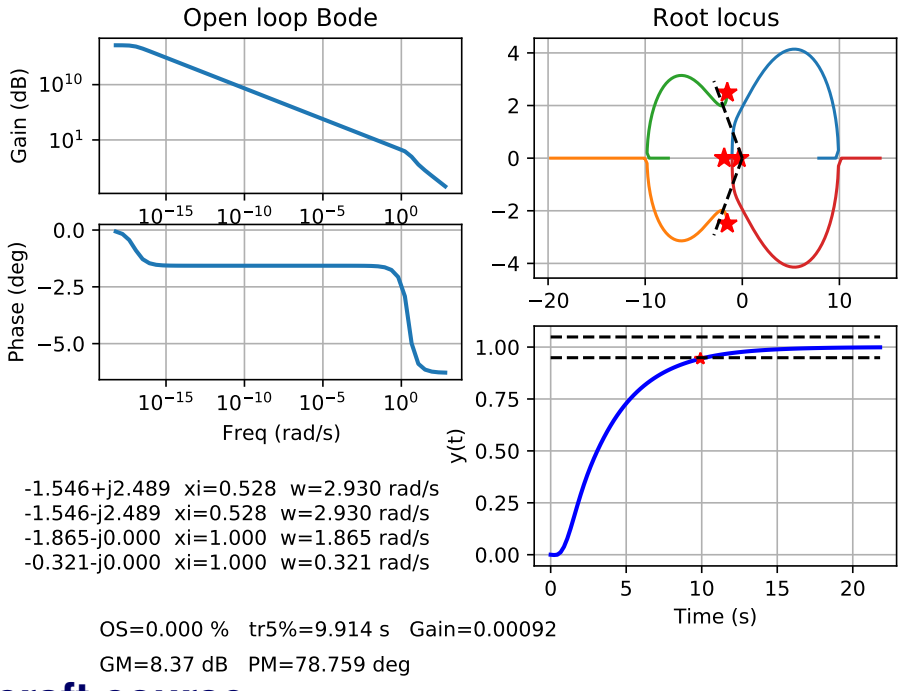
The sisotool in python is provided in Python file `sisopy31.py`. Its usage is:

```
from sisopy31 import *
sisotool(sys) # or sisotool(sys,gainmin,gainmax)
```

The gain is tunable with by clicking on root locus plot which moves the closed loop poles.



There is a plot giving closed loop poles, with their corresponding damping ratio.
On the main figure:

- OS is the overshoot of the closed loop step response.
- tr5% is the settling time to within 5%.
- GM is the gain margin.
- PM is the phase margin.