

▼ BPL_TEST2_Perfusion script with FMPy ver 0.3.15

The key library FMPy v0.3.15 is installed.

After the installation a small application BPL_TEST2_Perfusion is loaded and run. You can continue with this example if you like.

```
lslsb_release -a # Actual VM Ubuntu version used by Google

No LSB modules are available.
Distributor ID: Ubuntu
Description:   Ubuntu 20.04.5 LTS
Release:      20.04
Codename:     focal

%env PYTHONPATH=

env: PYTHONPATH=

!wget https://repo.anaconda.com/miniconda/Miniconda3-py38_22.11.1-1-Linux-x86_64.sh
!chmod +x Miniconda3-py38_22.11.1-1-Linux-x86_64.sh
!bash ./Miniconda3-py38_22.11.1-1-Linux-x86_64.sh -b -f -p /usr/local
import sys
sys.path.append('/usr/local/lib/python3.8/site-packages/')

--2023-03-28 08:04:04--  https://repo.anaconda.com/miniconda/Miniconda3-py38_22.11.1-1-Linux-x86_64.sh
Resolving repo.anaconda.com (repo.anaconda.com)... 104.16.131.3, 104.16.130.3, 2606:4700::6810:8203, ...
Connecting to repo.anaconda.com (repo.anaconda.com)|104.16.131.3|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 64630241 (62M) [application/x-sh]
Saving to: 'Miniconda3-py38_22.11.1-1-Linux-x86_64.sh'

Miniconda3-py38_22. 100%[=====] 61.64M  128MB/s   in 0.5s

2023-03-28 08:04:05 (128 MB/s) - 'Miniconda3-py38_22.11.1-1-Linux-x86_64.sh' saved [64630241/64630241]

PREFIX=/usr/local
Unpacking payload ...

Installing base environment...

Downloading and Extracting Packages

Downloading and Extracting Packages

Preparing transaction: done
Executing transaction: done
installation finished.

!conda update -n base -c defaults conda --yes
```

```
Preparing transaction: done  
Verifying transaction: done  
Executing transaction: done
```

```
!conda --version  
!python --version
```

```
conda 23.1.0  
Python 3.8.15
```

```
!conda install -c conda-forge fmpy --yes # Install the key package
```

```
Preparing transaction: done
Verifying transaction: done

!conda install -c conda-forge matplotlib --yes
matplotlib-base-3.7. | 6.7 MB | : 100% 1.0/1 [00:00<00:00, 1.21it/s]
```

```
Preparing transaction: done
Verifying transaction: done
Executing transaction: done
```

```
#!conda install -c conda-forge scipy --yes
```

```
#!conda install -c conda-forge openpyxl --yes
```

```
#!conda install -c conda-forge xlrd --yes
```

▼ Notes of BPL_TEST2_Perfusion

This notebook explore perfusion cultivation in comparison with ordinary continuous cultivation (chemostat) and use comparable settings to earlier notebook. Further you see here examples of interaction with the simplified commands `par()`, `init()`, `simu()` etc as well as direct interaction with the FMU which is called "model" here. The last simulation is always available in the workspace and called "sim_res". Note that `describe()` brings mainly up from descriptive information from the Modelica code from the FMU but is complemented by some information given in the Python setup file.

Now specific installation run a simulation and notebook for that Start with connecting to Github. Then upload the two files:

- FMU - BPL_TEST2_Perfusion_linux_om_me.fmu
- Setup-file - BPL_TEST2_Perfusion_fmпы_explore.py

```
%%bash
git clone https://github.com/janpeter19/BPL_TEST2_Perfusion

Cloning into 'BPL_TEST2_Perfusion'...

%cd BPL_TEST2_Perfusion

/content/BPL_TEST2_Perfusion

run -i BPL_TEST2_Perfusion_fmпы_explore.py

Linux - run FMU pre-compiled OpenModelica 1.21.0

Model for bioreactor has been setup. Key commands:
- par()      - change of parameters and initial values
- init()     - change initial values only
- simu()     - simulate and plot
- newplot()  - make a new plot
- show()     - show plot from previous simulation
- disp()     - display parameters and initial values from the last simulation
- describe() - describe culture, broth, parameters, variables with values/units

Note that both disp() and describe() takes values from the last simulation

Brief information about a command by help(), eg help(simu)
Key system information is listed with the command system_info()

%matplotlib inline
plt.rcParams['figure.figsize'] = [25/2.54, 20/2.54]

# Process parameters used throughout
par(Y=0.5, qSmax=0.75, Ks=0.1)
par(filter_eps=0.10, filter_alpha_X=0.02, filter_alpha_S=0.10)
par(S_in=30.0)
init(V_0=1.0, VX_0=1.0)
eps = parDict['filter_eps']

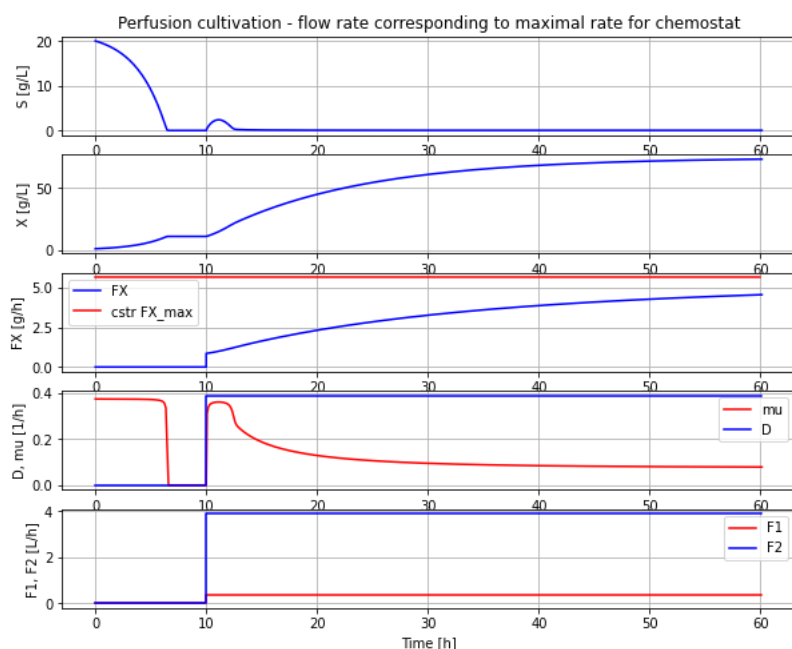
# Culture
# Filter
# Inlet substrate conc
# Process initial conditions that are common
# Pump schedule parameter

# Simulation of process with flow rate plot to wash-out for chemostat

init(VS_0=20)
par(pump1_t1=10, pump2_t1=10)
par(pump1_F1=2.5*0.155, pump2_F1=2.5*0.155/eps)
par(pump1_t2=940, pump2_t2=940, pump1_t3=950, pump2_t3=950, pump1_t4=960, pump2_t4=960)

# Process initial
# Pump schedule - recycle flow 10 times perfusion flow

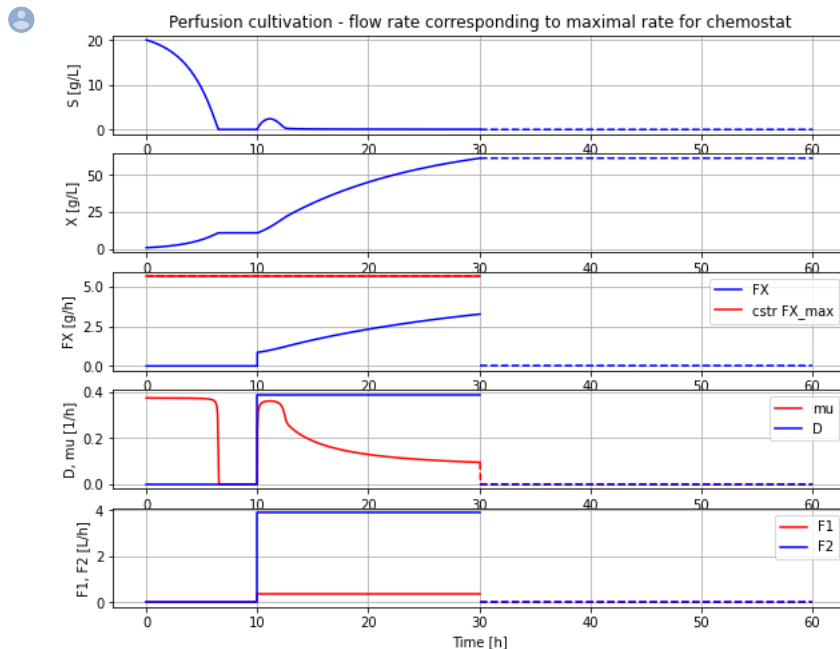
newplot(title='Perfusion cultivation - flow rate corresponding to maximal rate for chemostat')
simu(60)
```



```
# Simulation of process with flow rate close to wash-out for chemostat
```

```
init(VS_0=20) # Process initial
par(pump1_t1=10, pump2_t1=10) # Pump schedule - recycle flow 10 times perfusion flow
par(pump1_F1=2.5*0.155, pump2_F1=2.5*0.155/eps)
par(pump1_t2=940, pump2_t2=940, pump1_t3=950, pump2_t3=950, pump1_t4=960, pump2_t4=960)

newplot(title='Perfusion cultivation - flow rate corresponding to maximal rate for chemostat')
simu(30)
simu(30, 'cont')
```



```
# Concentration factor of the filter
c=model_get('filter.retentate.c[1]')/model_get('filter.inlet.c[1]')
print('Conc factor of perfusion filter =', np.round(c,3))
```

```
Conc factor of perfusion filter = nan
<ipython-input-18-4726d2554b9f>:2: RuntimeWarning: invalid value encountered in double_scalars
c=model_get('filter.retentate.c[1]')/model_get('filter.inlet.c[1]')
```

```
c_data=sim_res['filter.retentate.c[1]']/sim_res['filter.inlet.c[1]']
print('Conc factor variation', np.round(min(c_data[151:]), 3), np.round(max(c_data[151:]),3))
```

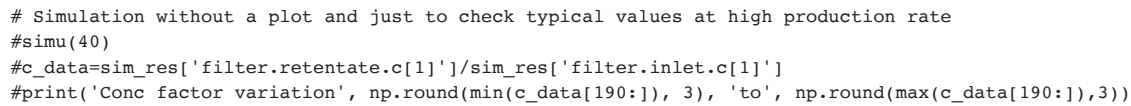
```
Conc factor variation nan nan
<ipython-input-19-0b550512bc49>:1: RuntimeWarning: invalid value encountered in true_divide
c_data=sim_res['filter.retentate.c[1]']/sim_res['filter.inlet.c[1]']
```

```
# Simulation of process with step-wise increase of perfusion rate until wash-out.
# This means that re-circulation rate change at the same time as the perfusion rate.
```

```
init(VS_0=150) # Process initial varied

par(pump1_t1=12, pump2_t1=12) # Pump schedule - recycle flow 10 times perfusion flow
par(pump1_F1=2.5*0.155, pump2_F1=2.5*0.155/eps)
par(pump1_t2=22, pump2_t2=22)
par(pump1_F2=2.5*0.35, pump2_F2=2.5*0.35/eps)
par(pump1_t3=32, pump2_t3=32)
par(pump1_F3=2.5*0.63, pump2_F3=2.5*0.63/eps)
par(pump1_t4=42, pump2_t4=42)
par(pump1_F4=2.5*0.83, pump2_F4=2.5*0.83/eps)

newplot(title='Perfusion cultivation - step wise increase of perfusion rate and max productivity 4x chemostat')
simu(60)
```



-18.674999999999997

```
system info()
```

System information

-OS: Linux
-Python: 3.9.16
-Scipy: not installed in the notebook
-FMPy: 0.3.15
-FMU by: OpenModelica Compiler OpenModelica 1.21.0-dev-185-g9d983b8
-FMI: 2.0
-Type: ME
-Name: BPL_TEST2.Perfusion
-Generated: 2023-01-25T11:02:31Z
-MSL: 3.2.3
-Description: Bioprocess Library version 2.1.1-beta
-Interaction: FMU-explore for FMPy version 0.9.7

✓ 0s completed at 10:10

