BPL_CHO_Fedbatch script with PyFMI ver 2.7.4

The key library PyFMI v2.7.4 is installed and downgrading is done Numpy v1.19.1. To simplify this we first install conda.

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

```
!lsb_release -a # Actual VM Ubuntu version used by Google
```

```
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 18.04.6 LTS
Release:        18.04
Codename:       bionic
```

```
%env PYTHONPATH=
```

```
env: PYTHONPATH=
```

```
!wget https://repo.anaconda.com/miniconda/Miniconda3-py37_4.12.0-Linux-x86_64.sh
!chmod +x Miniconda3-py37_4.12.0-Linux-x86_64.sh
!bash ./Miniconda3-py37_4.12.0-Linux-x86_64.sh -b -f -p /usr/local
import sys
sys.path.append('/usr/local/lib/python3.7/site-packages/')
```

```
--2022-08-29 12:20:17--  https://repo.anaconda.com/miniconda/Miniconda3-py37_4
Resolving repo.anaconda.com (repo.anaconda.com)... 104.16.131.3, 104.16.130.3,
Connecting to repo.anaconda.com (repo.anaconda.com)|104.16.131.3|:443... conne
HTTP request sent, awaiting response... 200 OK
Length: 104996770 (100M) [application/x-sh]
Saving to: 'Miniconda3-py37_4.12.0-Linux-x86_64.sh'

Miniconda3-py37_4.1 100%[===================>] 100.13M   251MB/s    in 0.4s

2022-08-29 12:20:17 (251 MB/s) - 'Miniconda3-py37_4.12.0-Linux-x86_64.sh' save

PREFIX=/usr/local
Unpacking payload ...
Collecting package metadata (current_repodata.json): done
Solving environment: done

## Package Plan ##

  environment location: /usr/local

  added / updated specs:
    - _libgcc_mutex==0.1=main
    - _openmp_mutex==4.5=1_gnu
    - brotlipy==0.7.0=py37h27cfd23_1003
    - ca-certificates==2022.3.29=h06a4308_1
    - certifi==2021.10.8=py37h06a4308_2
```

```
  - cffi==1.15.0=py37hd667e15_1
  - charset-normalizer==2.0.4=pyhd3eb1b0_0
  - colorama==0.4.4=pyhd3eb1b0_0
  - conda-content-trust==0.1.1=pyhd3eb1b0_0
  - conda-package-handling==1.8.1=py37h7f8727e_0
  - conda==4.12.0=py37h06a4308_0
  - cryptography==36.0.0=py37h9ce1e76_0
  - idna==3.3=pyhd3eb1b0_0
  - ld_impl_linux-64==2.35.1=h7274673_9
  - libffi==3.3=he6710b0_2
  - libgcc-ng==9.3.0=h5101ec6_17
  - libgomp==9.3.0=h5101ec6_17
  - libstdcxx-ng==9.3.0=hd4cf53a_17
  - ncurses==6.3=h7f8727e_2
  - openssl==1.1.1n=h7f8727e_0
  - pip==21.2.2=py37h06a4308_0
  - pycosat==0.6.3=py37h27cfd23_0
  - pycparser==2.21=pyhd3eb1b0_0
  - pyopenssl==22.0.0=pyhd3eb1b0_0
  - pysocks==1.7.1=py37_1
  - python==3.7.13=h12debd9_0
  - readline==8.1.2=h7f8727e_1
  - requests==2.27.1=pyhd3eb1b0_0
  - ruamel_yaml==0.15.100=py37h27cfd23_0
  - setuptools==61.2.0=py37h06a4308_0
  - six==1.16.0=pyhd3eb1b0_1
  - sqlite==3.38.2=hc218d9a_0
  - tk==8.6.11=h1ccaba5_0
  - tqdm==4.63.0=pyhd3eb1b0_0
  - urllib3==1.26.8=pyhd3eb1b0_0
  - wheel==0.37.1=pyhd3eb1b0_0
```

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

```
Collecting package metadata (current_repodata.json): done
Solving environment: done

## Package Plan ##

  environment location: /usr/local

  added / updated specs:
    - conda


The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    _openmp_mutex-5.1          |            1_gnu          21 KB
    ca-certificates-2022.07.19 |       h06a4308_0         124 KB
    certifi-2022.6.15          |   py37h06a4308_0         153 KB
    cffi-1.15.1                |   py37h74dc2b5_0         227 KB
    conda-4.14.0               |   py37h06a4308_0         909 KB
    cryptography-37.0.1        |   py37h9ce1e76_0         1.3 MB
    cytoolz-0.11.0             |   py37h7b6447c_0         328 KB
    ld_impl_linux-64-2.38      |       h1181459_1         654 KB
    libgcc-ng-11.2.0           |       h1234567_1         5.3 MB
    libgomp-11.2.0             |       h1234567_1         474 KB
```

```
  libstdcxx-ng-11.2.0        |       h1234567_1         4.7 MB
  ncurses-6.3                |       h5eee18b_3         781 KB
  openssl-1.1.1q             |       h7f8727e_0         2.5 MB
  pip-22.1.2                 |   py37h06a4308_0         2.4 MB
  requests-2.28.1            |   py37h06a4308_0          92 KB
  setuptools-63.4.1          |   py37h06a4308_0         1.1 MB
  sqlite-3.39.2              |       h5082296_0         1.1 MB
  tk-8.6.12                  |       h1ccaba5_0         3.0 MB
  toolz-0.11.2               |     pyhd3eb1b0_0          49 KB
  tqdm-4.64.0                |   py37h06a4308_0         126 KB
  urllib3-1.26.11            |   py37h06a4308_0         181 KB
  xz-5.2.5                   |       h7f8727e_1         339 KB
  zlib-1.2.12                |       h7f8727e_2         106 KB
  ------------------------------------------------------------
                                         Total:        25.9 MB

The following NEW packages will be INSTALLED:

  cytoolz            pkgs/main/linux-64::cytoolz-0.11.0-py37h7b6447c_0
  toolz              pkgs/main/noarch::toolz-0.11.2-pyhd3eb1b0_0

The following packages will be REMOVED:

  colorama-0.4.4-pyhd3eb1b0_0
  conda-content-trust-0.1.1-pyhd3eb1b0_0
  six-1.16.0-pyhd3eb1b0_1

The following packages will be UPDATED:

  _openmp_mutex                                 4.5-1_gnu --> 5.1-1_gnu
  ca-certificates                    2022.3.29-h06a4308_1 --> 2022.07.19-h06
  certifi                           2021.10.8-py37h06a4308_2 --> 2022.6.15-py37
  cffi                                1.15.0-py37hd667e15_1 --> 1.15.1-py37h74
```

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

```
conda 4.14.0
Python 3.7.13
```

```
!conda install -c conda-forge pyfmi==2.7.4 --yes # Install the key package
```

```
  libblapack                conda-forge/linux-64::libblapack-3.9.0-15_linux64_openblas
  libopenblas               conda-forge/linux-64::libopenblas-0.3.20-pthreads_h78a6411
  libxml2                   conda-forge/linux-64::libxml2-2.9.12-h72842e0_0
  libxslt                   conda-forge/linux-64::libxslt-1.1.33-h15afd5d_2
  lxml                      conda-forge/linux-64::lxml-4.8.0-py37h540881e_2
  metis                     conda-forge/linux-64::metis-5.1.0-h58526e2_1006
  mpfr                      conda-forge/linux-64::mpfr-4.1.0-h9202a9a_1
  numpy                     conda-forge/linux-64::numpy-1.21.6-py37h976b520_0
  pyfmi                     conda-forge/linux-64::pyfmi-2.7.4-py37h161383b_0
  python_abi                conda-forge/linux-64::python_abi-3.7-2_cp37m
  scipy                     conda-forge/linux-64::scipy-1.7.3-py37hf2a6cf1_0
  suitesparse               conda-forge/linux-64::suitesparse-5.10.1-h9e50725_1
  sundials                  conda-forge/linux-64::sundials-5.8.0-h558c624_0
  tbb                       conda-forge/linux-64::tbb-2021.5.0-h924138e_1

The following packages will be UPDATED:

  certifi                   pkgs/main/linux-64::certifi-2022.6.15~ --> conda-forge/no
```

```
  The following packages will be SUPERSEDED by a higher-priority channel:

    ca-certificates    pkgs/main::ca-certificates-2022.07.19~ --> conda-forge::c
    conda              pkgs/main::conda-4.14.0-py37h06a4308_0 --> conda-forge::c
    openssl              pkgs/main::openssl-1.1.1q-h7f8727e_0 --> conda-forge::c



  Downloading and Extracting Packages
  metis-5.1.0           | 4.1 MB    | : 100% 1.0/1 [00:00<00:00,  1.01it/s]
  libgfortran5-12.1.0   | 1.8 MB    | : 100% 1.0/1 [00:00<00:00,  2.53it/s]
  libcblas-3.9.0        | 12 KB     | : 100% 1.0/1 [00:00<00:00, 20.78it/s]
  libblas-3.9.0         | 12 KB     | : 100% 1.0/1 [00:00<00:00, 23.40it/s]
  tbb-2021.5.0          | 1.9 MB    | : 100% 1.0/1 [00:00<00:00,  2.02it/s]
  numpy-1.21.6          | 6.1 MB    | : 100% 1.0/1 [00:01<00:00,  1.73s/it]
  ca-certificates-2022  | 149 KB    | : 100% 1.0/1 [00:00<00:00, 15.92it/s]
  liblapack-3.9.0       | 12 KB     | : 100% 1.0/1 [00:00<00:00, 20.64it/s]
  assimulo-3.2.9        | 2.6 MB    | : 100% 1.0/1 [00:00<00:00,  1.63it/s]
  gmp-6.2.1             | 806 KB    | : 100% 1.0/1 [00:00<00:00,  5.31it/s]
  libiconv-1.16         | 1.4 MB    | : 100% 1.0/1 [00:00<00:00,  4.28it/s]
  libopenblas-0.3.20    | 10.1 MB   | : 100% 1.0/1 [00:02<00:00,  2.78s/it]
  fmilib-2.2.3          | 532 KB    | : 100% 1.0/1 [00:00<00:00,  4.36it/s]
  scipy-1.7.3           | 21.8 MB   | : 100% 1.0/1 [00:04<00:00,  4.92s/it]
  lxml-4.8.0            | 1.4 MB    | : 100% 1.0/1 [00:00<00:00,  2.42it/s]
  libxml2-2.9.12        | 772 KB    | : 100% 1.0/1 [00:00<00:00,  5.18it/s]
  icu-68.2              | 13.1 MB   | : 100% 1.0/1 [00:02<00:00,  2.45s/it]
  python_abi-3.7        | 4 KB      | : 100% 1.0/1 [00:00<00:00, 21.27it/s]
  libxslt-1.1.33        | 522 KB    | : 100% 1.0/1 [00:00<00:00,  3.69it/s]
  libgfortran-ng-12.1.  | 23 KB     | : 100% 1.0/1 [00:00<00:00, 19.28it/s]
  certifi-2022.6.15     | 154 KB    | : 100% 1.0/1 [00:00<00:00, 16.21it/s]
  sundials-5.8.0        | 1.0 MB    | : 100% 1.0/1 [00:00<00:00,  2.22it/s]
  conda-4.14.0          | 1010 KB   | : 100% 1.0/1 [00:00<00:00,  2.38it/s]
  suitesparse-5.10.1    | 2.4 MB    | : 100% 1.0/1 [00:00<00:00,  1.35it/s]
  mpfr-4.1.0            | 2.6 MB    | : 100% 1.0/1 [00:00<00:00,  1.97it/s]
  pyfmi-2.7.4           | 12.4 MB   | : 100% 1.0/1 [00:02<00:00,  2.37s/it]
  openssl-1.1.1o        | 2.1 MB    | : 100% 1.0/1 [00:00<00:00,  2.07it/s]
  Preparing transaction: done
  Verifying transaction: done
  Executing transaction: done
  Retrieving notices: ...working... done
```

```
!conda install numpy=1.19.1 --yes # Need to downgrade numpy
```

```
  Collecting package metadata (current_repodata.json): done
  Solving environment: failed with initial frozen solve. Retrying with flexible
  Collecting package metadata (repodata.json): done
  Solving environment: done

  ## Package Plan ##

    environment location: /usr/local

    added / updated specs:
      - numpy=1.19.1


  The following packages will be downloaded:

      package                    |            build
```

```
    ---------------------------|-----------------
    blas-1.0                   |         openblas          46 KB
    numpy-1.19.1               |   py37h30dfecb_0          21 KB
    numpy-base-1.19.1          |   py37h75fe3a5_0         4.1 MB
    ------------------------------------------------------------
                                           Total:         4.2 MB

The following NEW packages will be INSTALLED:

  blas               pkgs/main/linux-64::blas-1.0-openblas
  numpy-base         pkgs/main/linux-64::numpy-base-1.19.1-py37h75fe3a5_0

The following packages will be UPDATED:

  ca-certificates    conda-forge::ca-certificates-2022.6.1~ --> pkgs/main::ca-
  openssl            conda-forge::openssl-1.1.1o-h166bdaf_0 --> pkgs/main::ope

The following packages will be SUPERSEDED by a higher-priority channel:

  certifi            conda-forge/noarch::certifi-2022.6.15~ --> pkgs/main/linu
  conda              conda-forge::conda-4.14.0-py37h89c186~ --> pkgs/main::con
  numpy              conda-forge::numpy-1.21.6-py37h976b52~ --> pkgs/main::num



Downloading and Extracting Packages
numpy-base-1.19.1    | 4.1 MB    | : 100% 1.0/1 [00:00<00:00,  2.88it/s]
numpy-1.19.1         | 21 KB     | : 100% 1.0/1 [00:00<00:00, 16.55it/s]
blas-1.0             | 46 KB     | : 100% 1.0/1 [00:00<00:00, 12.34it/s]
Preparing transaction: done
Verifying transaction: done
Executing transaction: done
Retrieving notices: ...working... done
```

BPL_CHO_Fedbatch demo

Now specific installation and the run simulations. Start with connecting to Github. Then upload the two files:

- FMU - BPL_CHO_Fedbatch_linux_jm_cs.fmu
- Setup-file - BPL_CHO_Fedbatch_explore

```
# Filter out DepracationWarnings for 'np.float as alias' is needed - wish I could m
import warnings
warnings.filterwarnings("ignore")
```

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

```
Cloning into 'BPL_CHO_Fedbatch'...
```

```
%cd BPL_CHO_Fedbatch
```

```
/content/BPL_CHO_Fedbatch/BPL_CHO_Fedbatch
```

```
run -i BPL_CHO_Fedbatch_explore.py
```

```
Linux - run FMU pre-comiled JModelica 2.4

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 simulatic
 - describe()  - describe culture, broth, parameters, variables with values /

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]
```

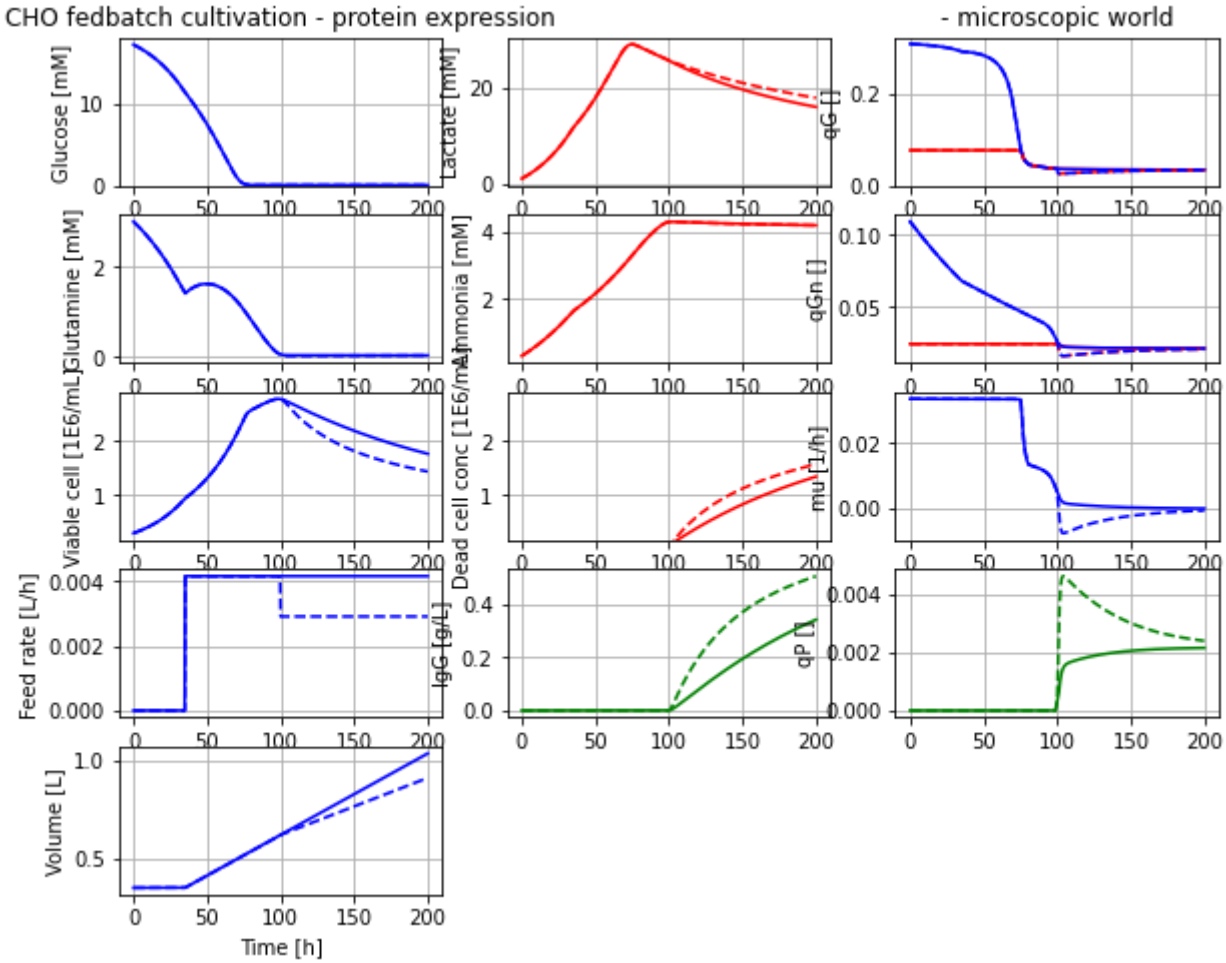
```
describe('culture'); print(); describe('liquidphase')
```

```
Reactor culture CHO-MAb - cell line HB-58 American Culture Collection ATCC

Reactor broth substances included in the model

Cells viable index =  1 molecular weight =  24.6 Da
Cells dead   index =  2 molecular weight =  24.6 Da
Glucose      index =  3 molecular weight =  180.0 Da
Glutamine    index =  4 molecular weight =  146.1 Da
Lactate      index =  5 molecular weight =  90.1 Da
Ammonia      index =  6 molecular weight =  17.0 Da
Protein      index =  7 molecular weight =  150000.0 Da
```

```
# Slide 3
newplot('CHO fedbatch cultivation - protein expression', plotType='Textbook_3')

# Data from Table 1 and 2 for experiment 3
V_0=0.35
init(V_0=V_0, VXv_0=V_0*0.29, VXd_0=V_0*0.010)
init(VG_0=V_0*17.17, VGn_0=V_0*3.02, VL_0=V_0*1.12, VN_0=V_0*0.29)

# Feeding
Feed=0.1/24
par(G_in=15, Gn_in=9.3)
par(t0=0, F0=0, t1=35, F1=Feed, t2=100, F2=Feed, t3=300, F3=Feed)

# Culture parameters
par(alpha=-1.0, beta=0.01)
```

```
# Simulation
simu(200)
par(t2=100, F2=0.7*Feed, t3=300, F3=0.7*Feed); simu(200)
par(F2=Feed, F3=Feed)
```

```
Simulation interval    : 0.0 - 200.00000000000003 seconds.
Elapsed simulation time: 0.023053809999510122 seconds.
Simulation interval    : 0.0 - 200.00000000000003 seconds.
Elapsed simulation time: 0.01600876800057449 seconds.
```




```
disp('culture', decimals=4)
```

```
qG_max1 : 0.2971
qG_max2 : 0.0384
qGn_max1 : 0.1238
qGn_max2 : 0.0218
mu_d_max : 0.1302
alpha : -1.0
beta : 0.01
```

```
system_info()
```

```
System information
 -OS: Linux
 -Python: 3.7.13
 -PyFMI: 2.7.4
 -FMU by: JModelica.org
 -FMI: 2.0
```

```
-Type: FMUModelCS2
-Name: BPL_CHO.Fedbatch
-Generated: 2022-08-29T12:13:26
-MSL: 3.2.2 build 3
-Description: Bioprocess Library version 2.1.0 beta
-Interaction: FMU-explore ver 0.9.2
```

Double-click (or enter) to edit

✓ 0s completed at 14:24