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# **cameo Documentation**

***Release 0.1.0***

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**Warning:** These pages are under construction. Feel free to look around ...

**cameo** is a python library for computer-aided metabolic engineering and optimization of microbes. It caters to different audiences as it provides a high-level interface that allows computer savvy bench biologists to predict heterologous pathways and enumerate engineering strategies and a modular framework for computational modelers that facilitates methods development and the construction of custom analysis workflows and prediction tools.

cameo is based on [cobrapy](#), the community standard for constraint-based modeling of genome-scale metabolic models, and uses and extends the same data structures. For efficiency reasons, however, it differs quite significantly from cobrapy in the way optimization problems are solved and defined. Nevertheless, cameo models remain 100% compatible with cobrapy. If you are already a cobrapy user you might want to start reading [here](#) to get an overview of the main differences.



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### 1.1 Installation

#### 1.1.1 Setting up a virtual environment first

We highly recommended installing cameo inside a virtual environment (`virtualenv`). `virtualenvwrapper` tremendously simplifies using `virtualenv` and can easily be installed using `virtualenv-burrito`. Once you installed `virtualenv` and `virtualenvwrapper`, run

```
$ mkvirtualenv cameo # or whatever you'd like to call your virtual environment
$ workon cameo
```

and then continue with the installation instructions described below.

#### 1.1.2 Non-python dependencies

cameo relies on `optlang` to solve optimization problems. Currently, `optlang` supports either `glpk` (open source) or `cplex` (academic licenses available), which are not python tools. At least one of them has to be installed before one can proceed with the cameo installation.

##### GLPK

Using cameo with `glpk` also requires `swig` to be installed (in order to generate python bindings). On ubuntu (or other similar linux platforms) we recommend using `apt-get`:

```
$ sudo apt-get install libglpk-dev glpk-utils swig
```

On macs we recommend using `homebrew`.

```
$ brew install swig
$ brew install glpk
```

##### Cplex

The `cplex` contains a python directory (similar to `IBM/ILOG/CPLEX_Studio1251/cplex/python/x86-64_osx`). Inside this directory run

```
$ python setup.py install
```

to install the python bindings.

### 1.1.3 Normal installation

**Warning:** cameo is still under heavy development. We recommend installing the development version (see below) if you would like to stay up-to-date with the latest changes.

cameo can be installed using *pip*.

```
$ pip install cameo
```

### 1.1.4 Development setup

*pip* can also be used to install cameo directly from the [github repository](https://github.com/biosustain/cameo).

```
$ pip install -e git+https://github.com/biosustain/cameo.git@devel#egg=cameo
```

Alternatively, you can clone the repository (or your fork) and then run

```
$ python setup.py install
```

From within the cameo directory.

## 1.2 Quickstart

```
import pandas
pandas.options.display.max_rows = 15
from cameo import load_model
```

```
# model = load_model('Ecoli core Model')
model = load_model('iJO1366')
```

```
solution = model.solve()
```

```
solution.to_frame()
```

## 1.3 High-level interface for users

Users primarily interested in using cameo as a tool for enumerating metabolic engineering strategies have access to cameo's advanced programming interface via `:mod:cameo.api` that provides access to potential products (`:mod:cameo.api.products`), host organisms (`:mod:cameo.api.hosts`) and a configurable design function (`:attr:cameo.api.design`). Running `:func:cameo.api.design` requires only minimal input.

```
from cameo import api
report = api.design(product='L-serine')
```



Found 5 compounds that match query `L-serine`

	name	formula	charge	mass	MNXM53	L-serine	C3H7NO
MNXM114	L-proline	C5H9NO2	0	115.13			
MNXM3635	L-mimosine	C8H10N2O4	0	198.176			
MNXM89905	L-allysine	C6H11NO3	0	145.156			
MNXM384	L-saccharopine	C11H19N2O6	-1	275.278			

	InChI	MNXM53	InChI=1S/C3H7NO3/
MNXM114	InChI=1S/C5H9NO2/c7-5(8)4-2-1-3-6-4/h4,6H,1-3H...		
MNXM3635	InChI=1S/C8H10N2O4/c9-5(8(13)14)3-10-2-1-6(11)...		
MNXM89905	InChI=1S/C6H11NO3/c7-5(6(9)10)3-1-2-4-8/h4-5H,...		
MNXM384	InChI=1S/C11H20N2O6/c12-7(10(16)17)3-1-2-6-13-...		

	SMILES	source	MNXM53
MNXM114	[O-]C(=O)[C@@H]1CCC[NH2+]1	chebi:60039	
MNXM3635	[NH3+][C@@H](CN1C=CC(=O)C(O)=C1)C([O-])=O	chebi:29063	
MNXM89905	[H]C(=O)CCC[C@@H]([NH3+])C([O-])=O	chebi:58321	
MNXM384	[NH3+][C@@H](CCCC[NH2+])[C@@H](CCC([O-])=O)C([O...	chebi:57951	

	search_rank
MNXM53	0
MNXM114	1
MNXM3635	2
MNXM89905	3
MNXM384	4

Choosing best match (L-serine) ... please interrupt if this is not the desired compound.

```
/Users/niko/Arbejder/Dev/cameo/cameo/api/products.py:75 [1;31mSettingWithCopyWarning[0m:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead
```

See the the caveats in the documentation: <http://pandas.pydata.org/pandas-docs/stable/indexing.html#>

```
<IPython.core.display.Javascript at 0x114c52910>
```

```
<IPython.core.display.Javascript at 0x114c52950>
```

```
<IPython.core.display.Javascript at 0x114c52d10>
```

```
<IPython.core.display.Javascript at 0x114c52e10>
```

```
<IPython.core.display.Javascript at 0x11bbcaa90>
```

```
<IPython.core.display.Javascript at 0x11bbcaa50>
```

```
<IPython.core.display.Javascript at 0x1048f3e50>
```

```
<IPython.core.display.Javascript at 0x11aa711d0>
```

```
<IPython.core.display.Javascript at 0x11c280cd0>
```

```
<IPython.core.display.Javascript at 0x11aa71150>
```

```
<IPython.core.display.Javascript at 0x11aa71090>
```

```
<IPython.core.display.Javascript at 0x11aa71110>
```

```
<IPython.core.display.Javascript at 0x11aa5eed0>
```

```
<IPython.core.display.Javascript at 0x11aa5ee90>
```

```
<IPython.core.display.Javascript at 0x11aa5ef10>
```

```
<IPython.core.display.Javascript at 0x11aa5ef50>
```

```
<IPython.core.display.Javascript at 0x114c52e90>
```

```
<IPython.core.display.Javascript at 0x11934d650>
```

```
<IPython.core.display.Javascript at 0x125185510>
```

```
<IPython.core.display.Javascript at 0x1251852d0>
```

```
<IPython.core.display.Javascript at 0x126889f10>
```

```
<IPython.core.display.Javascript at 0x1251851d0>
```

```
<IPython.core.display.Javascript at 0x125185250>
```

```
<IPython.core.display.Javascript at 0x125185190>
```

```
<IPython.core.display.Javascript at 0x125172e10>
```

```
<IPython.core.display.Javascript at 0x125172050>
```

```
<IPython.core.display.Javascript at 0x125185210>
```

```
<IPython.core.display.Javascript at 0x125172d90>
```

### 1.3.1 IPython notebook

Click [here](#) to download this page as an IPython notebook.

## 1.4 Low-level interface for developers

```
import pandas
pandas.options.display.max_rows = 8
from cameo import load_model
model = load_model('iJO1366')
```

### 1.4.1 cameo vs. cobrapy

#### Importing a model

cobrapy (load a model in SBML format):

```
from cobra.io import read_sbml_model
cobrapy_model = read_sbml_model('../tests/data/EcoliCore.xml')
```

cameo (load models from different formats):

```
from cameo import load_model
# read SBML model
model = load_model('../tests/data/EcoliCore.xml')
# ... or read a pickled model
model = load_model('../tests/data/iJ01366.pickle')
# ... or just import a model by ID from http://darwin.di.uminho.pt/models
iAF1260 = load_model('iAF1260')
```

## Solving models

When optimizing models with cobrapy, the status of a returned solution needs to be checked to figure out if the solver found an optimal solution.

```
cobrapy_solution = cobrapy_model.optimize()
if cobrapy_solution.status == 'optimal':
    pass # do something
```

cameo will raise an exception if non-optimal solution was found.

```
print model.objective
```

```
Maximize
1.0*Ec_biomass_iJ01366_core_53p95M
```

```
model.solve() # no exception
cp_model = model.copy()
# demand a very high biomass production rendering the model infeasible
cp_model.reactions.Ec_biomass_iJ01366_core_53p95M.lower_bound = 1000
cp_model.solve()
```

```
-----
Infeasible                                Traceback (most recent call last)

<ipython-input-13-286e284739c2> in <module>()
      2 cp_model = model.copy()
      3 cp_model.reactions.Ec_biomass_iJ01366_core_53p95M.lower_bound = 1000 # demand an unrealistic
----> 4 cp_model.solve()

/Users/niko/Arbejder/Dev/cameo/cameo/solver_based_model.py in solve(self, *args, **kwargs)
    881         raise exceptions._OPTLANG_TO_EXCEPTIONS_DICT.get(status, SolveError)(
    882             'Solving model %s did not return an optimal solution. The returned solution is
--> 883             self, status))
    884         return solution
    885     else:

Infeasible: Solving model iJ01366 did not return an optimal solution. The returned solution status is
```

Therefore, `try-except-else-finally` statements should be used in code that utilizes `py:meth:cameo.solver_based_model.SolverBasedModel.solve`.

```
try:
    solution = model.solve()
except cameo.exceptions.SolverError:
    print "A non-optimal solution was returned by the solver"
else:
    pass # do something
```

It is important to note that cameo models maintain optimize to maintain compatibility with cobrapy but we discourage its use.

## Solution object

```
solution
```

## 1.4.2 Formulating and solving optimization problems

<http://optlang.readthedocs.org/en/latest/>

## 1.4.3 Importing models

cameo has a single function (`load_model`) that can import models stored in different formats.

### SBML

#### Models available on the web

cameo provides an interface to models hosted online by the [University of Minho](#).

```
from cameo.webmodels import index_models
index_models()
```

If `load_model` is provided with a valid model name, it will automatically download the model in SBML format and import it.

```
load_model('iMM904')
```

### Strain-design

All strain-design methods have been coded as python classes t

## 1.4.4 Predicting heterologous pathways

```
from cameo.strain_design.pathway_prediction import PathwayPredictor
```

```
PathwayPredictor(model)
```

```
pathway_predictor = PathwayPredictor(model)
```

```
-----
NameError                                Traceback (most recent call last)

<ipython-input-4-9e8d88b43feb> in <module>()
----> 1 pathway_predictor = PathwayPredictor(model)

NameError: name 'model' is not defined
```

## 1.4.5 Deterministic methods

## 1.4.6 Heuristic methods

## 1.4.7 Avoid copies at all costs

Copying models is expensive!

```
%time model_copy = model.copy()
```

```
CPU times: user 3.17 s, sys: 84.7 ms, total: 3.26 s
Wall time: 3.25 s
```

To avoid excessive copying of models, we suggest the following utility included in cameo. For example, temporary reaction deletion, solve the model and magically returns to it original state.

```
from functools import partial
from cameo.util import TimeMachine
with TimeMachine() as tm:
    tm
```

TimeMachine performs do steps immediately and stores all corresponding undo actions in order. Running all undo steps can be achieved with `TimeMachine.reset()` (which is run). We recommend using `TimeMachine` in conjunction with `with`, as in case of an unforeseen exception all undo steps will be run and manipulated models will return to their original states. This is more elegant than using explicit `try-except-else-finally` statements.

## 1.4.8 IPython notebook

Click [here](#) to download this page as an IPython notebook.

## 1.5 Parallelization

Most methods in cameo can be parallelized using views.

## 1.6 cameo vs. cobrapy

### 1.6.1 Importing a model

cobrapy (load a model in SBML format):

```
from cobra.io import read_sbml_model
model = read_sbml_model('path/to/model.xml')
```

cameo (load models from different formats):

```
from cameo import load_model
# read SBML model
model = load_model('path/to/model.xml')
# ... or read a pickled model
model = load_model('path/to/model.pickle')
# ... or just import a model by ID from http://darwin.di.uminho.pt/models
iAF1260 = load_model('iAF1260')
```

## 1.6.2 Solving models

cobrapy:

```
solution = model.optimize()
if solution.status == 'optimal':
    # proceed
```

```
try:
    solution = model.solve()
except cameo.exceptions.SolverError:
    print "A non-optimal solution was returned by the solver"
else:
    # proceed
```

It is important to note that cameo models maintain *optimize* to maintain compatibility with cobrapy but we discourage its use.

## 1.7 How to ...

- ... run differential flux-variability analysis
- ... perform a heuristic gene knockout optimization (single-objective)
- ... perform a heuristic gene knockout optimization (multi-objective)

## 1.8 API

### 1.8.1 cameo package

#### Subpackages

cameo.api package

#### Submodules

cameo.api.designer module

**cameo.api.hosts module**

**cameo.api.products module**

**Module contents**

**cameo.core package**

**Submodules**

**cameo.core.reaction module**

**cameo.core.solution module**

**cameo.core.solver\_based\_model module**

**Module contents**

**cameo.flux\_analysis package**

**Submodules**

**cameo.flux\_analysis.analysis module**

**cameo.flux\_analysis.simulation module**

**Module contents**

**cameo.strain\_design package**

**Subpackages**

**cameo.strain\_design.deterministic package**

**Submodules**

**cameo.strain\_design.deterministic.flux\_variability\_based module**

**Module contents**

**cameo.strain\_design.heuristic package**

## Subpackages

`cameo.strain_design.heuristic.multiprocess` package

## Submodules

`cameo.strain_design.heuristic.multiprocess.migrators` module

`cameo.strain_design.heuristic.multiprocess.observers` module

`cameo.strain_design.heuristic.multiprocess.optimization` module

`cameo.strain_design.heuristic.multiprocess.plotters` module

## Module contents

## Submodules

`cameo.strain_design.heuristic.archivers` module

`cameo.strain_design.heuristic.decoders` module

`cameo.strain_design.heuristic.generators` module

`cameo.strain_design.heuristic.genomes` module

`cameo.strain_design.heuristic.metrics` module

`cameo.strain_design.heuristic.objective_functions` module

`cameo.strain_design.heuristic.observers` module

`cameo.strain_design.heuristic.optimization` module

`cameo.strain_design.heuristic.plotters` module

`cameo.strain_design.heuristic.stats` module

`cameo.strain_design.heuristic.variators` module

## Module contents



**cameo.strain\_design.pathway\_prediction package**

**Module contents**

**Module contents**

**Submodules**

**cameo.config module**

**cameo.exceptions module**

**cameo.io module**

**cameo.parallel module**

**cameo.stuff module**

**cameo.util module**

**cameo.visualization module**

**cameo.webmodels module**

**Module contents**



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## Indices and tables

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- `modindex`
- `search`