FMU Export of CYMDIST

Release 1.0.0

LBNL - Building Technology and Urban Systems Division

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CONTENTS

CHAPTER

ONE

INTRODUCTION

This user manual explains how to install and use CYMDISTToFMU. CYMDISTToFMU is a software package written in Python which allows users to export the distribution simulation program CYMDIST version 7.2 or as a *Functional Mock-up Unit* (FMU) for co-simulation using the *Functional Mock-up Interface* (FMI) standard version 2.0. This FMU can then be imported into a variety of simulation programs that support the import of the Functional Mock-up Interface for co-simulation.

CHAPTER

TWO

DOWNLOAD

The CYMDISTToFMU release includes scripts and source code to export CYMDIST version 7.2 as an FMU for co-simulation for Windows 32.

To install CYMDISTToFMU, follow the section *Installation and Configuration*.

Release 1.0.0 (March 01, 2017)

Download CYMDISTToFMU-1.0.0.zip.

Release notes

First release that uses FMI version 2.0 for co-simulation.

CHAPTER

THREE

INSTALLATION AND CONFIGURATION

This chapter describes how to install, configure and uninstall CYMDISTToFMU.

Software requirements

To export CYMDIST as an FMU, CYMDISTToFMU needs:

1. Python 3.4.x. 32bit
2. jinja2
3. lxml
4. pandas
5. numpy
6. cython
7. Modelica Parser
8. C-Compiler (for cython and Modelica)

CYMDISTToFMU has been tested with:

- Dymola 2017 (Modelica Parser)
- Microsoft Visual Studio 10 Professional (Includes C-Compiler for cython and Modelica)

Installation

To install CYMDISTToFMU, proceed as follows:

1. Download the installation file from the *Download* page.
2. Unzip the installation file into any subdirectory (hereafter referred to as the "installation directory").

The installation directory should contain the following subdirectories:

- `fmu/cymdisttofmu/`
  - `bin/` (Python scripts for running unit tests)
  - `doc/` (Documentation)
  - `fmuChecker/` (fmuChecker binaries for running unit tests)
  - `fmus/` (FMUs folder)

  - `parser/` (Python scripts, Modelica templates and XML validator files)

3. Add following folders to your system path:

- Python installation folder (e.g. `C:\Python34`)
- Python scripts folder (e.g. `C:\Python34\Scripts`),
- Dymola executable folder (e.g. `C:\Program Files(x86)\Dymola2017\bin`)

  You can add folders to your system path by performing following steps on Windows 8 or 10:

  - In Search, search for and then select: System (Control Panel)
  - Click the Advanced system settings link.
  - Click Environment Variables. In the section System Variables, find the PATH environment variable and select it. Click Edit.
  - In the Edit System Variable (or New System Variable) window, specify the value of the PATH environment variable (e.g. `C:\Python34`, `C:\Python34\Scripts`). Click OK. Close all remaining windows by clicking OK.
  - Reopen Command prompt window for your changes to be active.

  To check if the variables have been correctly added to the system path, type `python` into a command prompt to see if the right version of Python starts up.

4. Install Python dependencies by running

```
pip install -r dev/cymdisttofmu/cymdisttofmu-dependencies.txt
```

Note:

- `cymdisttofmu-dependencies.txt` includes the versions of the Python modules which were tested.
- `lxml` cannot be installed using `pip`. Please download and install the executable (`lxml-3.4.4.win32-py3.4.exe`) from PyPyi.

Uninstallation

To uninstall CYMDISTToFMU, delete the *installation directory*.

CHAPTER

FOUR

CREATING AN FMU

This chapter describes how to create a Functional Mockup Unit, starting from a CYMDIST XML input file. It assumes you have followed the *Installation and Configuration* instructions, and that you have created the CYMDIST model description file following the *Best Practice* guidelines.

Command-line use

To create an FMU, open a command-line window (see *Notation*). The standard invocation of the CYMDISTToFMU tool is:

```
> python  <scriptDir>CYMDISTToFMU.py <input-file-path>
```

where `scriptDir` is the path to the scripts directory of CYMDISTToFMU. This is the `parser` subdirectory of the installation directory. See *Installation and Configuration* for details.

An example of invoking `CYMDISTToFMU.py` on Windows is

```
# Windows:
> python parser\CYMDISTToFMU.py test.xml
```

All file paths can be absolute or relative. For readability, the rest of these instructions omit the paths to the script and input files.

Note: If any file path contains spaces, then it must be surrounded with double quotes.

Script `CYMDISTToFMU.py` supports the following command-line switches:

option <arguments>	Purpose
<input-file-path>	Path to the input file (if not provided, a default input file which is in `parser\utilities\CYMDISTModelDescription.xml` will be used.
-h	Show help and explanation on how to use this function.

The main functions of CYMDISTToFMU are

- reading, validating, and parsing the CYMDIST XML input file. This includes removing and replacing invalid characters in variable names such as $*+-$ with _,
- writing Modelica code with valid inputs and outputs names,
- invoking Dymola to compile the *Modelica* code as an FMU for co-simulation 2.0.

Note: In the process of creating the FMU, CYMDISTToFMU will rewrite the model description file generated by Dymola to include `needsExecutionTool=true` attribute in the FMU capabilities of the CYMDIST FMU. This is currently not supported by default in Dymola.

Output

The main output from running `CYMDISTToFMU.py` consists of an FMU, named after the `modelName` specified in the input file. The FMU is written to the current working directory, that is, in the directory from which you entered the command.

The FMU is complete and self-contained. Any secondary output from running the CYMDISTToFMU tools can be deleted safely.

Note that the FMU is a zip file. This means you can open and inspect its contents. To do so, it may help to change the "`.fmu`" extension to "`.zip`".

CHAPTER

FIVE

USAGE OF CYMDIST AS AN FMU

The following requirements must be met to import and run a CYMDIST FMU:

1. Python 3.4 must be installed. This is needed by the master algorithm *PyFMI*.
2. CYME version 7.2 must be installed. CYME can be downloaded from www.cyme.com.
3. The `fmu_code` functions directory must be added to the `PYTHONPATH`. This directory contains functions needed at runtime by the CYMDIST FMU. The `fmu_code` functions folder can be found at the top level of the distribution folder of CyDER. It is in `web\docker_django\worker\simulation`.

   To add the `fmu_code` functions folder to the `PYTHONPATH`:

   - In Search, search for and then select: System (Control Panel).
   - Click the Advanced system settings link.
   - Click Environment Variables. In the section System Variables, find a variable named `PYTHONPATH` environment variable and select it.

     If the variable does not exist, create it. Click Edit.
   - In the Edit System Variable (or New System Variable) window, specify the value of the PYTHONPATH environment variable which should be in our case the full path to `web\docker_django\worker\simulation\fmu_code`.
4. The CYMDIST Python API directory must be added to the `PYTHONPATH`. This directory contains scripts needed at runtime by the CYMDIST FMU.

   The CYMDIST Python API directory is in the installation folder of CYME. It can typically be found in `path_to_CYME\CYME\cympy`, where `path_to_CYME` is the path to the installation folder of CYME 7.2.

   To add the CYMDIST Python API scripts folder to the `PYTHONPATH`, add `path_to_CYME\CYME` to the `PYTHONPATH`. Note that `cympy` is not included in the name of the variable.
5. The CYMDIST installation directory must be added to the system `PATH`. This directory contains runtime DLLS (`mkl_core.dll`, `mkl_def.dll`) that are needed at runtime by the CYMDIST FMU.

   The CYMDIST installation directory is typically found in `path_to_CYME\CYME\', where ''path_to_CYME` is the path to the installation folder of CYME 7.2.
6. Upon request, the simulation results are saved in a result file which is created in the current working directory. The name of the result file is `xxx_result_.pickle`, where xxx is the FMU model name as defined in the XML input file.

CHAPTER

SIX

BEST PRACTICE

This section explains to users the best practice in configuring a CYMDIST XML input file for an FMU.

To export CYMDIST as an FMU, the user needs to write an XML file which contains the list of inputs, outputs and parameters of the FMU. The XML snippet below shows how a user has to write such an input file. A template named `CYMDISTModeldescritpion.xml` which shows such a file is provided in the `parser\utilities` installation folder of CYMDISTToFMU. This template should be adapted to create new XML input file.

The following snippet shows an input file where the user defines 6 inputs and 6 output variables.

```
<?xml version="1.0" encoding="UTF-8"?>
<CYMDISTModelDescription
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  fmiVersion="2.0"
  modelName="CYMDIST"
  description="Input data for a CYMDIST FMU"
  generationTool="CYMDISTToFMU">
  <ModelVariables>
    <ScalarVariable
      name="VMAG_A"
      description="VMAG_A"
      causality="input">
      <Real
        unit="V"
        start="0.0"/>
    </ScalarVariable>
    <ScalarVariable
      name="VMAG_B"
      description="VMAG_B"
      causality="input">
      <Real
        unit="V"
        start="0.0"/>
    </ScalarVariable>
    <ScalarVariable
      name="VMAG_C"
      description="VMAG_C"
      causality="input">
      <Real
        unit="V"
        start="0.0"/>
    </ScalarVariable>
    <ScalarVariable
      name="VANG_A"
      description="VANG_A"
      causality="input">
```

```
      <Real
        unit="deg"
        start="0.0"/>
        </ScalarVariable>
    <ScalarVariable
      name="VANG_B"
      description="VANG_B"
      causality="input">
      <Real
        unit="deg"
        start="-120.0"/>
    </ScalarVariable>
    <ScalarVariable
      name="VANG_C"
      description="VANG_C"
      causality="input">
      <Real
        unit="deg"
        start="120.0"/>
    </ScalarVariable>
    <ScalarVariable
      name="IA"
      description="IA"
      causality="output">
      <Real
        unit="A"/>
    </ScalarVariable>
    <ScalarVariable
      name="IB"
      description="IB"
      causality="output">
      <Real
        unit="A"/>
    </ScalarVariable>
    <ScalarVariable
      name="IC"
      description="IC"
      causality="output">
      <Real
        unit="A"/>
    </ScalarVariable>
    <ScalarVariable
      name="IAngleA"
      description="IAngleA"
      causality="output">
      <Real
        unit="deg"/>
    </ScalarVariable>
    <ScalarVariable
      name="IAngleB"
      description="IAngleB"
      causality="output">
      <Real
        unit="deg"/>
    </ScalarVariable>
    <ScalarVariable
      name="IAngleC"
      description="IAngleC"
```

```
95        causality="output">
96        <Real
97          unit="deg"/>
98      </ScalarVariable>
99    </ModelVariables>
100 </CYMDISTModelDescription>
```

To create such an input file, the user needs to specify the name of the FMU (Line 5). This is the `modelName` which should be unique. The user then needs to define the inputs and outputs of the FMUs. This is done by adding `ScalarVariable` into the list of `ModelVariables`.

To parametrize the `ScalarVariable` as an input variable, the user needs to

- define the name of the variable (Line 10),
- give a brief description of the variable (Line 11)
- give the causality of the variable (`input` for inputs, `output` for outputs) (Line 12)
- define the type of variable (Currently only `Real` variables are supported) (Line 13)
- give the unit of the variable (Currently only valid Modelica units are supported) (Line 14)
- give a start value for the input variable (This is optional) (Line 15)

To parametrize the `ScalarVariable` as an output variable, the user needs to

- define the name of the variable (Line 58),
- give a brief description of the variable (Line 59)
- give the causality of the variable (`input` for inputs, `output` for outputs) (Line 60)
- define the type of variable (Currently only `Real` variables are supported) (Line 61)
- give the unit of the variable (Currently only valid Modelica units are supported) (Line 62)

CHAPTER

SEVEN

DEVELOPMENT

The development site of this software is at https://github.com/LBNL-ETA/cyder.

To clone the master branch, type

git clone https://github.com/LBNL-ETA/cyder.git

CHAPTER

EIGHT

HELP

Running PyFMI with Python 3.4 on Windows 32 bit

PyFMI is a python package which can be used to import and run a CYMDIST FMU. In *PyFMI* version 2.3.1, a master algorithm was added to import and link multiple FMUs for co-simulation. At time of writing, there was no *PyFMI* 2.3.1 executable available for Python 3.4 for Windows 32bit (See PyPyi.). The next steps describe requirements and steps to perform to compile *PyFMI* version 2.3.1 from source.

Note: To avoid having to recompile *PyFMI* dependent libraries from source, we recommend to use pre-compiled Windows binaries whenever available.

Requirements

The next table shows the list of Python modules and softwares used to compile version 2.3.1 of PyFMI from source so it can run with Python 3.4 on Windows 32 bit.

Install PyFMI dependencies with

```
pip install -r dev/master/bin/pyfmi-dependencies.txt
```

Below is a table with dependencies which fail to install using pip. For those, we recommend to use the MS Windows installer directly.

Modules	Version	Link
FMI Library	2.0.2 (source)	http://www.jmodelica.org/FMILibrary
Scipy	0.16.1	https://sourceforge.net/projects/scipy/files/scipy/0.16.1
lxml	3.4.4	https://pypi.python.org/pypi/lxml/3.4.4
Assimulo	2.7b1	https://pypi.python.org/pypi/Assimulo/2.7b1
PyFMI	2.3.1 (source)	https://pypi.python.org/pypi/PyFMI

Note: *PyFMI* needs a C-compiler to compile the source codes. We used the Microsoft Visual Studio 10 Professional.

Compilation

To compile *PyFMI* from source, run

```
python setup.py install --fmil-home=path_to_FMI_Library\
```

where `path_to_FMI_Library\` is the path to the FMI library.

To use *PyFMI* as a master algorithm to couple a CYMDIST FMU with GridDyn FMU, we refer to the documentation located in `fmu/master/doc/userGuide`.

CHAPTER

NINE

NOTATION

This chapter shows the formatting conventions used throughout the User Guide.

The command-line is an interactive session for issuing commands to the operating system. Examples include a DOS prompt on Windows, a command shell on Linux, and a Terminal window on MacOS.

The User Guide represents a command window like this:

```
# This is a comment.
> (This is the command prompt, where you enter a command)
(If shown, this is sample output in response to the command)
```

Note that your system may use a different symbol than ">" as the command prompt (for example, "`$`"). Furthermore, the prompt may include information such as the name of your system, or the name of the current subdirectory.

CHAPTER

TEN

GLOSSARY

Dymola Dymola, Dynamic Modeling Laboratory, is a modeling and simulation environment for the Modelica language.

Functional Mock-up Interface The Functional Mock-up Interface (FMI) is the result of the Information Technology for European Advancement (ITEA2) project *MODELISAR*. The FMI standard is a tool independent standard to support both model exchange and co-simulation of dynamic models using a combination of XML-files, C-header files, C-code or binaries.

Functional Mock-up Unit A simulation model or program which implements the FMI standard is called Functional Mock-up Unit (FMU). An FMU comes along with a small set of C-functions (FMI functions) whose input and return arguments are defined by the FMI standard. These C-functions can be provided in source and/or binary form. The FMI functions are called by a simulator to create one or more instances of the FMU. The functions are also used to run the FMUs, typically together with other models. An FMU may either require the importing tool to perform numerical integration (model-exchange) or be self-integrating (co-simulation). An FMU is distributed in the form of a zip-file that contains shared libraries, which contain the implementation of the FMI functions and/or source code of the FMI functions, an XML-file, also called the model description file, which contains the variable definitions as well as meta-information of the model,additional files such as tables, images or documentation that might be relevant for the model.

Modelica Modelica is a non-proprietary, object-oriented, equation-based language to conveniently model complex physical systems containing, e.g., mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents.

MODELISAR MODELISAR is an ITEA 2 (Information Technology for European Advancement) European project aiming to improve the design of systems and of embedded software in vehicles.

PyFMI PyFMI is a package for loading and interacting with Functional Mock-Up Units (FMUs), which are compiled dynamic models compliant with the Functional Mock-Up Interface (FMI).

Python Python is a dynamic programming language that is used in a wide variety of application domains.

CHAPTER

ELEVEN

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CHAPTER

TWELVE

DISCLAIMERS

CHAPTER

THIRTEEN

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