CUHK-SZ MAT3007 Environment Setup Guide

Course Teaching Team

Contents

In this guide, we will introduce how to install the following softwares/packages:

1. MATLAB and CVX package;
2. Python and CVXPY package;
3. Mathematical programming solver, e.g., COPT.

You can follow one of the first two sections according to your preference. If you need to solve some larger problems, you may follow Section 3 to install a Mathematical Programming solver, e.g., COPT.

1 MATLAB and CVX Package

In this section, we will introduce how to install MATLAB and its corresponding convex optimization package CVX.

1.1 MATLAB Introduction

MATLAB (an abbreviation of "MATrix LABoratory") is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. It allows *matrix manipulations*, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.

1.2 MATLAB Installation

The university has purchased the MATLAB campus version, and provides it to teachers and students. You can follow the procedures below to install MATLAB.

1. Create a "Mathworks" account.
   (a) Go to the webpage https://mathworks.com/.
   (b) Create an account using your university email (ended with "cuhk.edu.cn").
   (c) Verify the account and fill in personal information. After that, you will see a page as below:

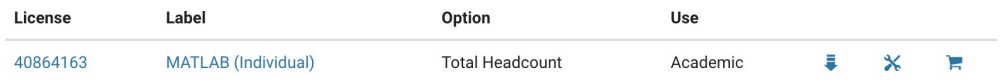

Figure 1: Individual License Example

2. Download MATLAB through the following links.
   (a) On-campus: https://cuhko365.sharepoint.com/sites/swcenter

(b) Off-campus: https://www.mathworks.com/downloads

3. Install MATLAB.

   (a) Windows: Unzip and click setup.exe.

   (b) MacOS: Unzip and click InstallForMacOSX.app.

4. Activate MATLAB. If you log in your Mathworks account, it will be activated automatically.

5. Start MATLAB and run `ver` command to see the status.

```
>> ver
-----------------------------------------------------------------------------------------------------
MATLAB Version: 9.13.0.2105380 (R2022b) Update 2
MATLAB License Number: 40864163
Operating System: macOS  Version: 12.5.1 Build: 21G83
Java Version: Java 1.8.0_202-b08 with Oracle Corporation Java HotSpot(TM) 64-Bit Server VM mixed mode
-----------------------------------------------------------------------------------------------------
MATLAB                                                Version 9.13        (R2022b)
Statistics and Machine Learning Toolbox               Version 12.4        (R2022b)
Symbolic Math Toolbox                                 Version 9.2         (R2022b)
```

Figure 2: Version Information Example

6. Read MATLAB Document and get started.

1.3 CVX Introduction

CVX is implemented in MATLAB, effectively turning MATLAB into an optimization modeling language. It is a modeling system for constructing and solving a number of standard convex optimization problems, including linear and quadratic programs (LPs/QPs), second-order cone programs (SOCPs), and semidefinite programs (SDPs).

1.4 CVX Installation

CVX is free for use in both academic and commercial settings. You can follow the procedures below to install the CVX package.

1. Download the latest version of the CVX standard bundle from http://cvxr.com/cvx/download/. You are recommended to download the .zip file.

2. Unzip the file and get a folder named "cvx".

3. Start MATLAB.

4. Change the MATLAB directory to the "cvx" folder. Or, you can drag the folder to the "Current Folder" window and double click the folder in the window.

5. Run the command `cvx_setup`, and then you can see the following information.

OS	mexext	Download links		SDPT3	SeDuMi	Gurobi	MOSEK
Standard bundles, including Gurobi and/or MOSEK							
Linux	mexa64	cvx-a64.zip	cvx-a64.tar.gz	✓	✓	✓	✓
Mac	mexmaci64	cvx-maci64.zip	cvx-maci64.tar.gz	✓	✓	✓	✓
Windows	mexw64	cvx-w64.zip	cvx-w64.tar.gz	✓	✓	✓	✓

Figure 3: CVX Download Links

```
>> cvx_setup

------------------------------------------------------------------------
CVX: Software for Disciplined Convex Programming       (c)2014 CVX Research
Version 2.2, Build 1148 (62bfcca)                 Tue Jan 28 00:51:35 2020
------------------------------------------------------------------------
```

Figure 4: CVX Installation Infomation

1.5 Example

In this part, we will use a simple example to illustrate how to use CVX to solve a linear programming problem. We want to solve the following LP problem:

$$\begin{aligned} \max \quad & 6x + 5y \\ \text{s.t.} \quad & x + y \leq 5 \\ & 3x + 2y \leq 12 \\ & x, y \geq 0 \end{aligned} \tag{1}$$

Then we can create a new script and write the code as follows:

test.m

```
cvx_begin
    variable x(1)
    variable y(1) % Define decision variables
    maximize (6*x+5*y) % Define the objective function
    subject to
        x + y <= 5
        3*x + 2*y <= 12
        x >= 0
        y >= 0 % Add constraints
cvx_end
```

Figure 5: CVX Code Example

Run the code. We get the result 27.

2 Python and CVXPY Package

In this section, we will introduce how to install Python and its corresponding convex optimization package CVXPY.

2.1 Python Introduction

Python is an interpreted high-level general-purpose programming language. Its design philosophy emphasizes code readability with its use of significant indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.

2.2 Python Installation

We recommend you install Anaconda which is an open-source Python distribution with many useful packages. You can follow the procedures below to install it.

1. Download the graphical installer through the official website: `https://www.anaconda.com/products/individual`.
2. Double-click the downloaded file and follow the guidance.
3. Open the IDE to write your code.
   (a) Windows: Open the "Anaconda Navigator" and double-click the IDE Spyder to write your Python code.
   (b) MacOS: Since Spyder does not fully support Big Sur OS, we recommend you to use PyCharm or VSCode.

2.3 CVXPY Introduction

CVXPY is an open source Python-embedded modeling language for convex optimization problems. It lets you express your problem in a natural way that follows the math, rather than in the restrictive standard form required by solvers.

2.4 CVXPY Installation

You can install the CVXPY package by executing the command

```
conda install -c conda-forge cvxpy
```

in the terminal. You can follow the procedures below to open the terminal.

1. Windows: Press Win+R, type "cmd" and click "OK".
2. MacOS: Press Command+Space, type "terminal" and press "Return".

Note: MacOS users may encounter the problem "zsh: command not found: conda". To solve it, you can follow the procedures below:

1. Open the Finder, press Command+Shift+G, type "~" and press Return.
2. Press Command+Shift+. to see hidden files.
3. Open the file ".zshrc" and add a line "source ~/.bash_profile".
4. Reopen the terminal.

2.5 Example

We still use (1) as an example. The code are as follows:

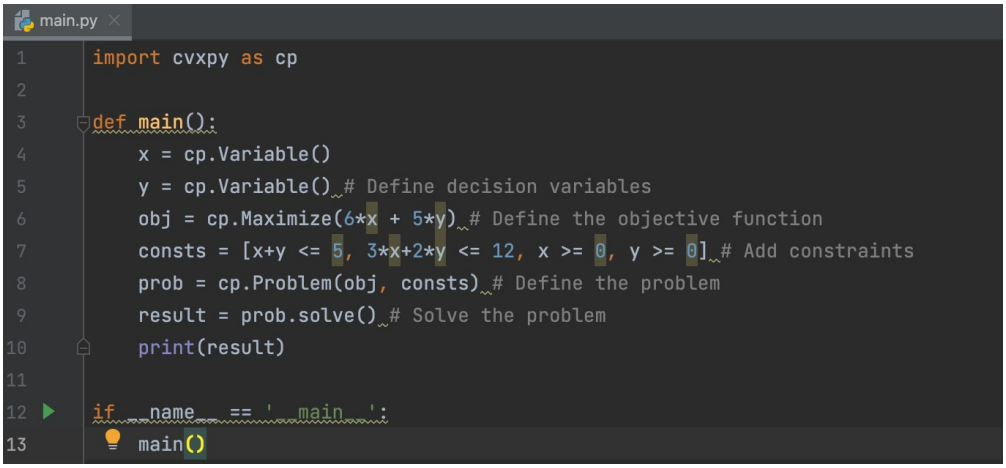

Figure 6: CVXPY Code Example

Run the code. We can get the result 27.

3 Mathematical Programming Solver – COPT

In this section, we will introduce how to install the mathematical programming solver COPT.

3.1 Introduction

COPT (Cardinal Optimizer) is a mathematical optimization solver for large-scale optimization problems. It is independently developed by Cardinal Operations ("杉数科技"), and it provides linear, integer, and nonlinear optimization solutions to its customers. A complete user guide of COPT can be found at this link: https://arxiv.org/abs/2208.14314.

3.2 COPT Installation

- In the following, we first introduce the installation of COPT with **Windows** OS.

  1. First, you should fill out the user application form on https://www.shanshu.ai/copt. Please carefully check your information. After you submit, you will receive an email which contains the latest version of COPT package and a key within 7 working days:

     感谢您申请杉数求解器Cardinal Optimizer (COPT)。我们很高兴为您提供 365 天的免费试用权限。
     Thanks for your application for Cardinal Optimizer (COPT). We are pleased to offer you a 365-day free trial.

     Figure 7: COPT Email Example

  2. If you download the executable installer for Windows from our website, just double-click it and follow the guidance.

     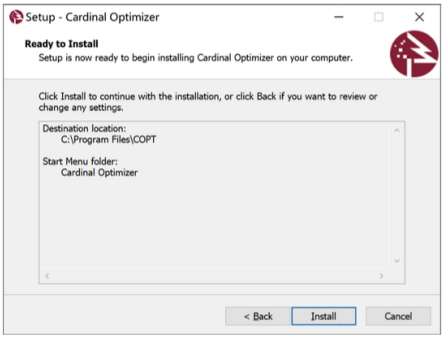

     Figure 8: COPT Installation

     When installation completed, the software requires restart of your machine since the installer has automatically made the required modifications to environment variables for you. If you downloaded the zip-format installer archive, you should set up environment variables as in the attached user guide.

- Then, we introduce the installation of COPT with **MacOS**.

  1. Download the DMG-format installer for MacOS from the website https://www.shanshu.ai/copt.

  2. Double-click the DMG-format installer, waiting for the OS to mount the DMG installer automatically.

  3. Simply drag the copt folder into `Applications` folder, see Figure 9:

  4. The next step is to setup the environment variables by adding the following commands to the `.bash_profile` file in your $HOME directory using any editors that you preferred:

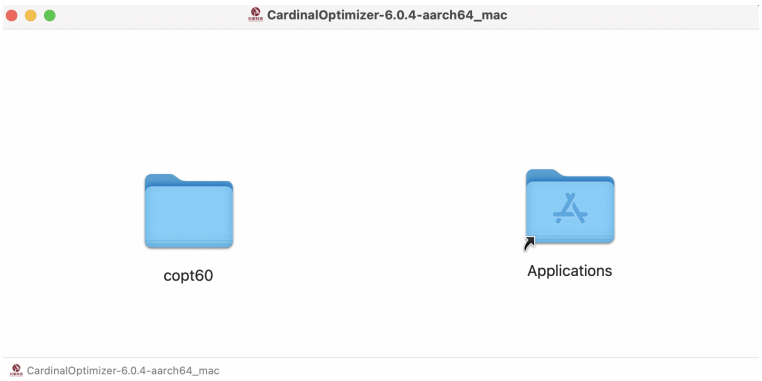

Figure 9: COPT MacOs Installation

```
export COPT_HOME=/Applications/copt60
export COPT_LICENSE_DIR=/Applications/copt60
export PATH=$COPT_HOME/bin:$PATH
export DYLD_LIBRARY_PATH=$COPT_HOME/lib:$DYLD_LIBRARY_PATH
```

Remember to save your modifications to the `.bash_profile` file.

3.3 Setting up License

As we have mentioned in Section 3.2, a license key is sent to users once the registration is done. It is a unique token binding with user's registration information. Afterwards, users may run the `copt_licgen` tool, shipped with Cardinal Optimizer, to obtain license files from COPT licensing server. The following steps show you how to obtain COPT license file:

1. First, please open a terminal and change directory to the installation directory of COPT, i.e. the path which pointed to by the environmental variable `COPT_HOME` For Windows, the default installation directory is: `"C:\Program Files\COPT"`, so that users should change to this directory, and open the terminal with **administration priviledge**.

2. To obtain COPT license files, execute the following command:

   ```
   copt_licgen -key 19200817f147gd9f60abc791def047fb
   ```

   You should copy your own sequence of key to the command-line.

3. The following message indicates that the license file has been successfully obtained.

   If the license key binding to registration information is verified by COPT license server, two license files, `license.dat` and `license.key`, are downloaded to the current working directory.

```
copt_licgen -key 19200817f147gd9f60abc791def047fb
  [Info] Cardinal Optimizer   COPT v6.0.0 20221010
  [Info] Use specific key 19200817f147gd9f60abc791def047fb
  [Info] * get new COPT license from licensing server *
  [Info] Write to license.dat
  [Info] Write to license.key
  [Info] Received new license files from server
```

Figure 10: COPT License Generating Example

3.4 Python Interface

Currently, the Python interface of COPT supports Python 3.6 and later versions of Python. Before using the Python interface, please ensure that COPT has been installed correctly.

• For windows, assuming the installation path of COPT is: `"C:\Program Files\COPT"`, please switch to the directory `"C:\Program Files\COPT\lib\python"` and execute the following commands on command line:

```
python setup.py install
```

Note that if COPT is installed on the system disk, you need to execute with **administrator privileges** to open the command prompt.

To test whether the Python interface is installed correctly, users can switch to the directory `"C:\Program Files\COPT\examples\python"` and execute the following commands on the command line:

```
python lp_ex1.py
```

If the model is solved correctly, it means that the Python interface has been installed correctly.

• For MacOS, assuming that the installation path of COPT is: `/Applications/copt60`, please switch the directory to `/Applications/copt60/lib/python` and execute the following commands on terminal:

```
sudo python setup.py install
```

The test code is the same as Windows.

3.5 CVXPY Interface

This section introduces how to use COPT in CVXPY. The CVXPY interface of COPT is the Python file `copt_cvxpy.py` in the COPT package, and also depends on the Python interface of COPT. Suppose Python version is 3.7, users should install the Python 3.7 version of COPT Python interface, see Python Interface for detailed install guide. After installing and configuring COPT, users only need to put the interface file in the project directory and import the plugin:

$$\boxed{\text{from copt\_cvxpy import } *}$$

In the solving function `solve`, specify the solver to COPT to solve:

$$\boxed{\text{prob.solve(solver = COPT())}}$$

3.6 Example

You can use the following example to test your installation:

```
import cvxpy as cp
from copt_cvxpy import *

x = cp.Variable(7)

A = np.ones((7,7))

for i in range(7):
    for j in range(7):
        if (j-i)% 7 == 1 or (j-i)% 7 == 2:
            A[i,j] = 0

c = np.ones(7)
b = np.array([14, 15, 15, 16, 12, 5, 7])

objective = cp.Minimize(c@x)
constraints = [A@x >= b, x>=0]

prob = cp.Problem(objective, constraints)
# prob.solve()
prob.solve(solver=COPT())

print(prob.value)
print(x.value)
```

The output is as follows:

```
16.8
[7.4 2.4 0.4 1.4 0.4 0.4 4.4]
```

Figure 11: COPT Code Example Output