

Gurobi Tutorial

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Outline

- Gurobi Introduction
- Gurobi Installation
- Environment Setting
- License Installation
- Usage
- Input File Format
- Example for PA1

Gurobi Introduction

- Gurobi Optimizer
 - The state-of-the-art mathematical programming solver
- Mathematical Program
 - Decision variable (what you control)
 - Constraints (rules you must follow)
 - Objective function (what you want to minimize/ maximize)

- Version

- gurobi7.5.2

$$\begin{aligned} &\text{minimize } B = \sum_{i=1}^n y_i \\ &\text{subject to } \sum_{j=1}^n a_j x_{ij} \leq V y_i, \forall i \in \{1, \dots, n\} \\ &\quad \sum_{i=1}^n x_{ij} = 1, \quad \forall j \in \{1, \dots, n\} \\ &\quad y_i \in \{0, 1\}, \quad \forall i \in \{1, \dots, n\} \\ &\quad x_{ij} \in \{0, 1\}, \quad \forall i \in \{1, \dots, n\} \forall j \in \{1, \dots, n\} \end{aligned}$$

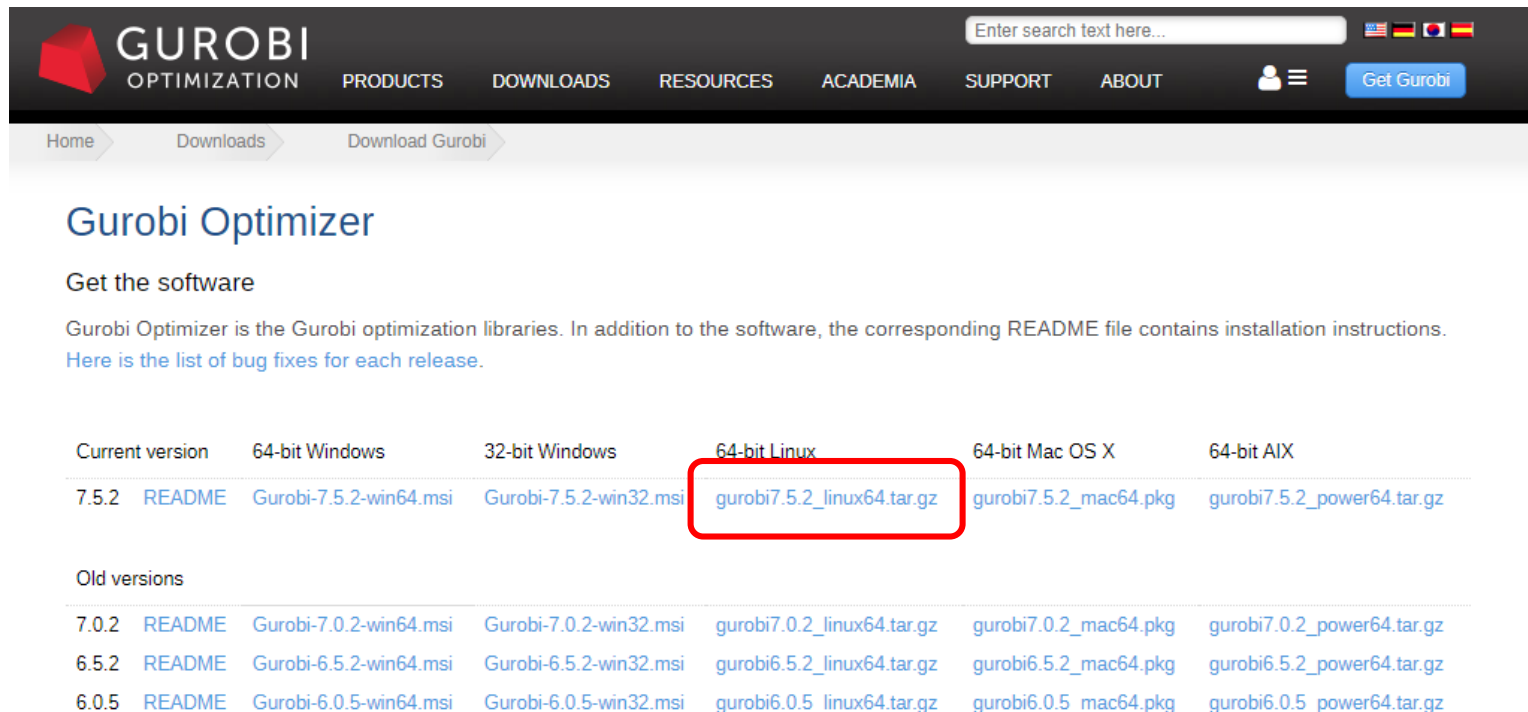
where $y_i = 1$ if bin i is used and $x_{ij} = 1$ if item j is put into bin i .

Gurobi Installation

- Notice: Gurobi is available in EDAunion server
 - Only need to get the personal academic license
 - Can jump to environment setting chapter
- Download page
 - <http://www.gurobi.com/downloads/gurobi-optimizer>
- Reference
 - Official document for more detail about Gurobi
 - <http://www.gurobi.com/documentation/>

Installation for Linux (1/2)

- Demonstration for Linux
 - Follow the instruction on “quickstart_linux.pdf” page 7-8
- Download Page
 - <http://www.gurobi.com/downloads/gurobi-optimizer>



The screenshot shows the Gurobi Optimization website. The header includes the Gurobi logo, navigation links (PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, ABOUT), a search bar, and a 'Get Gurobi' button. The breadcrumb trail shows 'Home > Downloads > Download Gurobi'. The main heading is 'Gurobi Optimizer' with the subtext 'Get the software'. A paragraph describes the Gurobi Optimizer and provides a link to bug fixes. Below this is a table of download links for various operating systems. The '64-bit Linux' column is highlighted with a red box, and the link 'gurobi7.5.2_linux64.tar.gz' is also highlighted.

Current version	64-bit Windows	32-bit Windows	64-bit Linux	64-bit Mac OS X	64-bit AIX
7.5.2 README	Gurobi-7.5.2-win64.msi	Gurobi-7.5.2-win32.msi	gurobi7.5.2_linux64.tar.gz	gurobi7.5.2_mac64.pkg	gurobi7.5.2_power64.tar.gz

Old versions

7.0.2 README	Gurobi-7.0.2-win64.msi	Gurobi-7.0.2-win32.msi	gurobi7.0.2_linux64.tar.gz	gurobi7.0.2_mac64.pkg	gurobi7.0.2_power64.tar.gz
6.5.2 README	Gurobi-6.5.2-win64.msi	Gurobi-6.5.2-win32.msi	gurobi6.5.2_linux64.tar.gz	gurobi6.5.2_mac64.pkg	gurobi6.5.2_power64.tar.gz
6.0.5 README	Gurobi-6.0.5-win64.msi	Gurobi-6.0.5-win32.msi	gurobi6.0.5_linux64.tar.gz	gurobi6.0.5_mac64.pkg	gurobi6.0.5_power64.tar.gz

Installation for Linux (2/2)

- Choose a destination directory
- Copy the file to the destination directory
- Extract the content by following command
 - *tar zxvf gurobi7.5.2_linux64.tar.gz*
 - This command will create a sub-directory
 - Example: **<DESTINATION>** / gurobi752 / linux64

Environment Setting for Linux

- Set environment
- **<DESTINATION>** is Gurobi location
 - Default: **/opt** (in EDAunion)
- For **bash** shell
 - Add the following lines to **.bashrc** files
 - **export GUROBI_HOME="**<DESTINATION>**/gurobi752/linux64"**
 - **export PATH=PATH="\${PATH}:\${GUROBI_HOME}/bin"**
 - **export LD_LIBRARY_PATH="\${LD_LIBRARY_PATH}:\${GUROBI_HOME}/lib"**
- For **csh** shell
 - Add the following lines to **.cshrc** files
 - **setenv GUROBI_HOME **<DESTINATION>**/gurobi752/linux64**
 - **setenv PATH \${PATH}:\${GUROBI_HOME}/bin**
 - **setenv LD_LIBRARY_PATH \${LD_LIBRARY_PATH}:\${GUROBI_HOME}/lib**

Environment Setting Example (1/2)

- Example in EDAunion U1 server
 - Bash shell
- Step1: “*vim .bash_profile*”

```
Last login: Fri Mar 16 13:29:39 2018 from edasun3.ee.ntu.edu.tw
-bash-4.1$ vim .bash_profile
```

- Step2: use “*/*” to add the following lines in *.bash_profile*
 - *if [-f ~/.bashrc]; then*
 - *. ~/.bashrc*
 - *fi*

```
# Get the aliases and functions
if [ -f ~/.bashrc ]; then
    . ~/.bashrc
fi
~
~
```

- Step3: “*:wq*” to save the file

Environment Setting Example (2/2)

- Step4: “*vim .bashrc*”

```
Last login: Fri Mar 16 11:50:28 2018 from edasun3.ee.ntu.edu.tw
-bash-4.1$ vim .bashrc
-bash-4.1$
```

- Step5: use “*/*” to add the lines from previous page in *.bashrc*

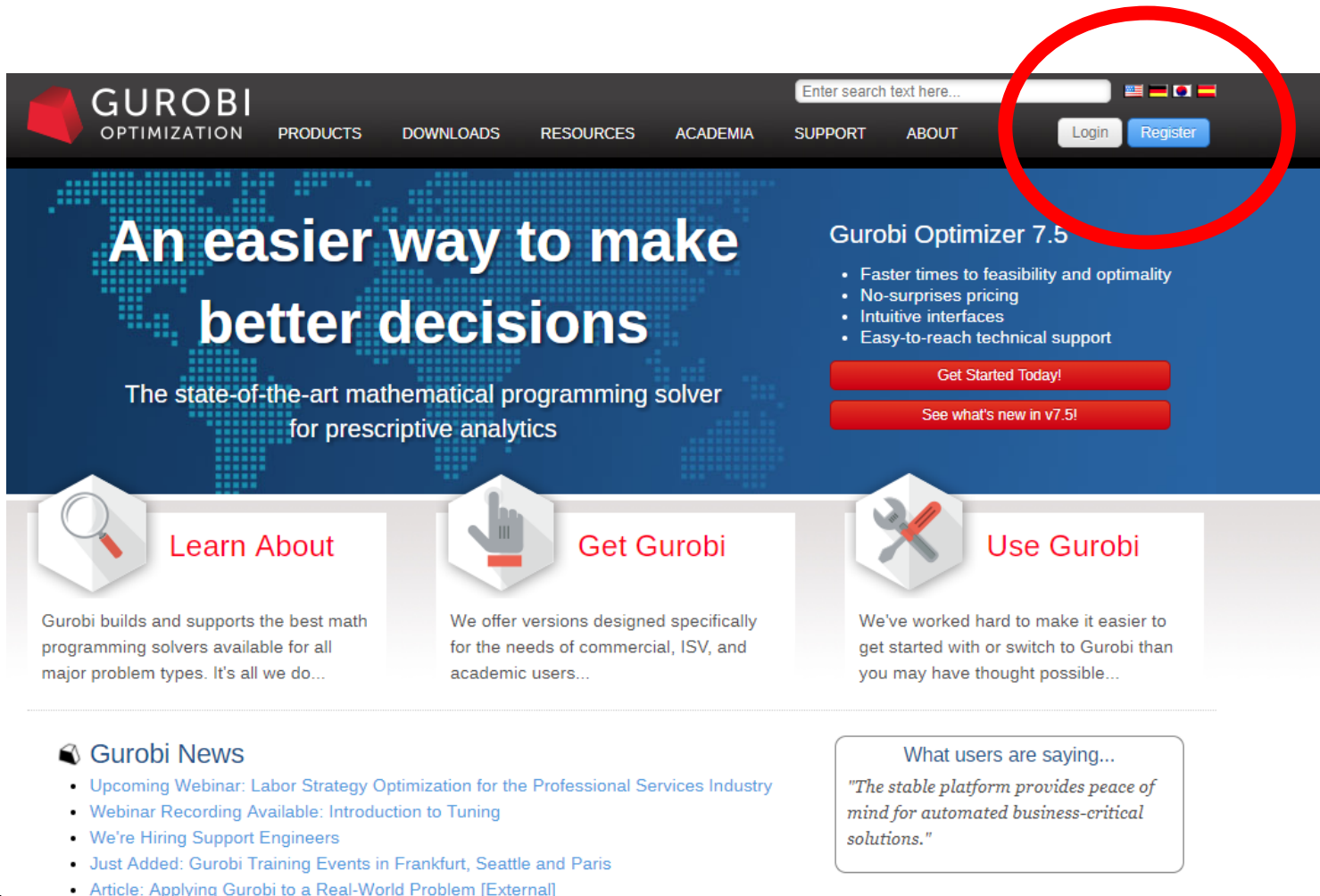
```
export GUROBI_HOME="/opt/gurobi752/linux64"
export PATH="${PATH}:${GUROBI_HOME}/bin"
export LD_LIBRARY_PATH="${LD_LIBRARY_PATH}:${GUROBI_HOME}/lib"
~
~
```

- Step6: “*:wq*” to save the file
- Step7: “*source .bashrc*”
- Done

```
Last login: Thu Mar 15 13:23:49 2018 from edasun3.ee.ntu.edu.tw
-bash-4.1$ vim .bashrc
-bash-4.1$ source .bashrc
-bash-4.1$
```

License Installation (1/8)

- Step1: Register an Gurobi account
 - <http://www.gurobi.com/>



The screenshot shows the Gurobi website homepage. The header includes the Gurobi logo, navigation links (PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, ABOUT), a search bar, and flags for US, UK, and Germany. The 'Login' and 'Register' buttons are circled in red. The main banner features the text 'An easier way to make better decisions' and 'The state-of-the-art mathematical programming solver for prescriptive analytics'. To the right, it promotes 'Gurobi Optimizer 7.5' with a list of features: 'Faster times to feasibility and optimality', 'No-surprises pricing', 'Intuitive interfaces', and 'Easy-to-reach technical support'. Below the banner are three columns: 'Learn About' (with a magnifying glass icon), 'Get Gurobi' (with a hand icon), and 'Use Gurobi' (with a wrench and screwdriver icon). At the bottom, there is a 'Gurobi News' section with a list of updates and a quote from a user.

GUROBI
OPTIMIZATION

PRODUCTS DOWNLOADS RESOURCES ACADEMIA SUPPORT ABOUT

Enter search text here...

Login Register

An easier way to make better decisions

The state-of-the-art mathematical programming solver for prescriptive analytics

Gurobi Optimizer 7.5

- Faster times to feasibility and optimality
- No-surprises pricing
- Intuitive interfaces
- Easy-to-reach technical support

Get Started Today!

See what's new in v7.5!

Learn About

Gurobi builds and supports the best math programming solvers available for all major problem types. It's all we do...

Get Gurobi

We offer versions designed specifically for the needs of commercial, ISV, and academic users...

Use Gurobi

We've worked hard to make it easier to get started with or switch to Gurobi than you may have thought possible...

Gurobi News

- Upcoming Webinar: Labor Strategy Optimization for the Professional Services Industry
- Webinar Recording Available: Introduction to Tuning
- We're Hiring Support Engineers
- Just Added: Gurobi Training Events in Frankfurt, Seattle and Paris
- Article: Applying Gurobi to a Real-World Problem [External]

What users are saying...

"The stable platform provides peace of mind for automated business-critical solutions."

License Installation (2/8)

- Step2: Choose an “Academic” type

Account Type: ☐ Commercial ☒ Academic → Choose Academic

First Name: *

Last Name: *

Email Address: *

University: *

Academic Position: Select one... ▼ → Pick Student

Phone Number:

Check this box if you also consult with commercial businesses: ☐

Access Now

License Installation (3/8)

- Step3: Reset your account password and login in
 - Check the email title “Password reset on Gurobi”
- Step4: Login in the website
 - <http://www.gurobi.com/>



License Installation (4/8)

- Step5: Enter the following link
 - <https://user.gurobi.com/download/licenses/free-academic>
- Step6: Request License

Free Academic License

Request a free academic license

To request a free academic license, please read and accept the End User License Agreement.

End User License Agreement ([View in PDF](#))

I accept the End User License Agreement: ☐

Conditions for the use of an Academic License: An academic license may only be used by a faculty member, a student, or a member of the research or administrative staffs of a degree-granting academic institution. The code may be used only for research and educational purposes. Access for commercial purposes is forbidden.

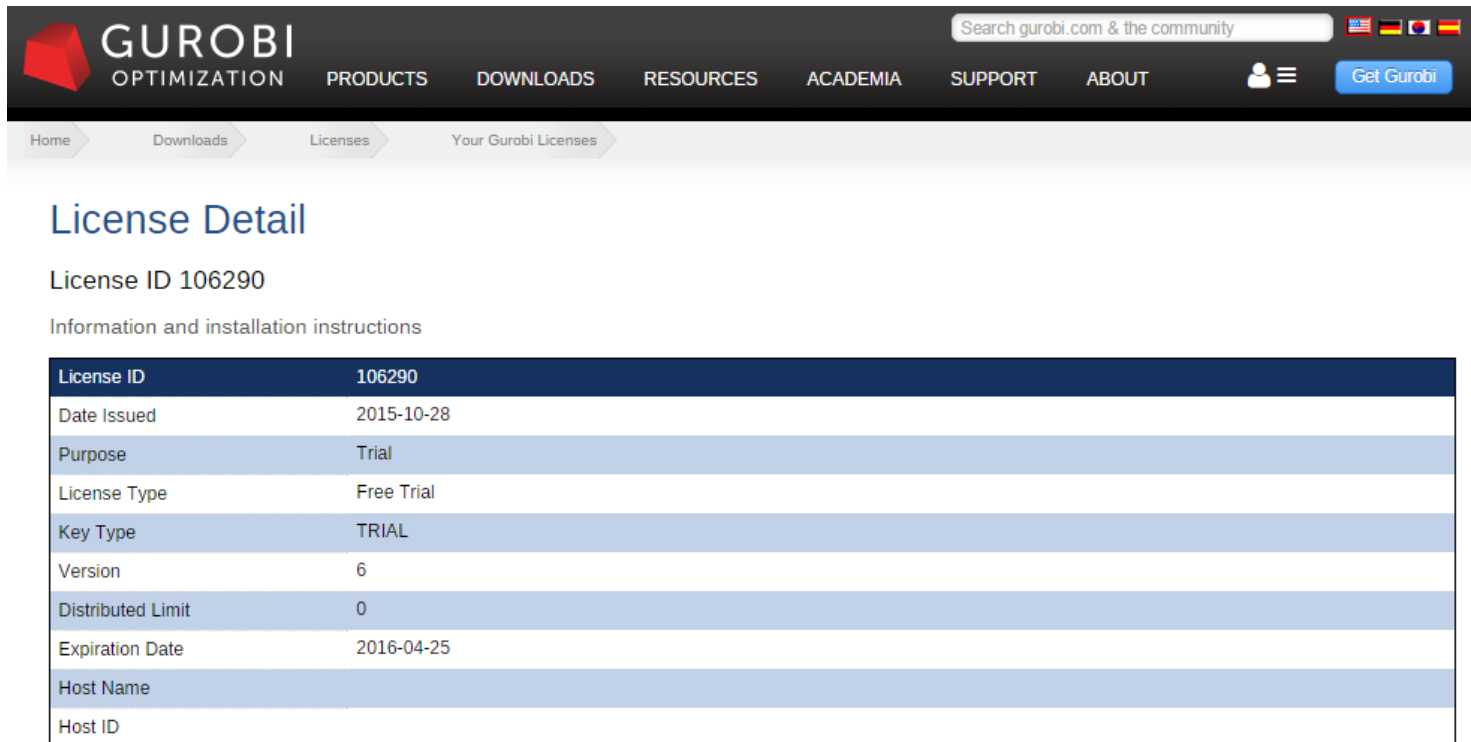
I accept these conditions: ☐

We urge academic users to upgrade to the latest version of Gurobi Optimizer. Some features, such as `grbgetkey`, may not work correctly in older releases.

Request License

License Installation (5/8)

- The website after you request the license



The screenshot shows the Gurobi Optimization website. The header includes the Gurobi logo, navigation links (PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, ABOUT), a search bar, and a 'Get Gurobi' button. The breadcrumb trail indicates the user is in the 'Licenses' section. The main content area is titled 'License Detail' and shows 'License ID 106290'. Below this, a table provides details about the license.

License ID	106290
Date Issued	2015-10-28
Purpose	Trial
License Type	Free Trial
Key Type	TRIAL
Version	6
Distributed Limit	0
Expiration Date	2016-04-25
Host Name	
Host ID	

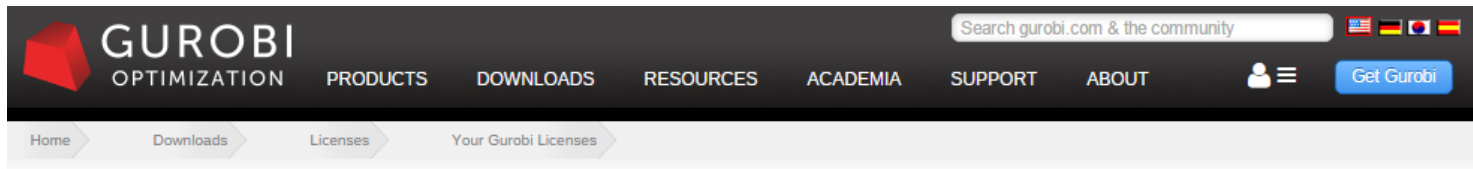
To install this license on a computer where Gurobi Optimizer is installed, copy and paste the following command to the Start/Run menu (Windows only) or a command/terminal prompt (any system):

```
grbgetkey 9f712a83-32db-0e10-8285-5630dfa56756
```

The `grbgetkey` command requires an active internet connection. If you get no response or an error message such as "Unable to contact key server", please [click here for additional instructions](#).

License Installation (6/8)

- The website after you request the license
 - Copy the command in red frame below



License Detail

License ID 106290

Information and installation instructions

License ID	106290
Date Issued	2015-10-28
Purpose	Trial
License Type	Free Trial
Key Type	TRIAL
Version	6
Distributed Limit	0
Expiration Date	2016-04-25
Host Name	
Host ID	

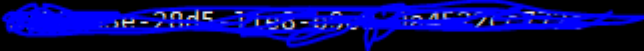
To install this license on a computer where Gurobi Optimizer is installed, copy and paste the following command to the Start/Run menu (Windows only)

```
grbgetkey 9f712a83-32db-0e10-8285-5630dfa56756
```

The command will return a response. If you get no response or an error message such as "Unable to contact key server", please [click here for additional instructions](#).

License Installation (7/8)

- Notice: Before you continue, you must have done environment setting
- The following steps are for EDAunion users
 - Others please refer to official reference
- Step7: Open the terminal of EDAunion server
- Step8: Paste the “*grbgetkey*” command and **enter**

```
Last login: Fri Mar 16 13:36:03 2018 from edasun3.ee.ntu.edu.tw
-bash-4.1$ grbgetkey 
```


License Installation (8/8)

- Step9: hit **Enter**

```
-bash-4.1$ grbgetkey 28d5-11e8-b9c0-0a4522cc772c
Gurobi license key client (version 7.5.2)
Copyright (c) 2017, Gurobi Optimization, Inc.

-----
Contacting Gurobi key server...
-----

Key for license ID 227628 was successfully retrieved.
License expires at the end of the day on 2019-03-15.

-----
Saving license key...
-----

In which directory would you like to store the Gurobi license key file?
[hit Enter to store it in /raid4/userr/r06/r06088]:
```

- License installation done.

```
In which directory would you like to store the Gurobi license key file?
[hit Enter to store it in /raid4/userr/r06/r06088]:

--> License key saved to file '/raid4/userr/r06/r06088/gurobi.lic'.
-bash-4.1$
```

Usage (1): Command Line (1/3)

- Use the example in Gurobi to check if it is available
- Input format for command line
 - *gurobi_cl* [input.lp]
 - *gurobi_cl ResultFile* = [output.sol] [input.lp]
- Example: type following line
 - *gurobi_cl /opt/gurobi752/linux64/examples/data/coins.lp*

```
Last login: Fri Mar 16 13:39:31 2018 from edasun3.ee.ntu.edu.tw  
-bash-4.1$ gurobi_cl /opt/gurobi752/linux64/examples/data/coins.lp
```

Usage (1): Command Line (2/3)

- The result of example
 - `gurobi_cl /opt/gurobi752/linux64/examples/data/coins.lp`

```
-bash-4.1$ gurobi_cl /opt/gurobi752/linux64/examples/data/coins.lp
Academic license - for non-commercial use only

Gurobi Optimizer version 7.5.2 build v7.5.2rc1 (linux64)
Copyright (c) 2017, Gurobi Optimization, Inc.

Read LP format model from file /opt/gurobi752/linux64/examples/data/coins.lp
Reading time = 0.00 seconds
: 4 rows, 9 columns, 16 nonzeros
Optimize a model with 4 rows, 9 columns and 16 nonzeros
Variable types: 4 continuous, 5 integer (0 binary)
Coefficient statistics:
  Matrix range      [6e-02, 7e+00]
  Objective range   [1e-02, 1e+00]
  Bounds range      [5e+01, 1e+03]
  RHS range         [0e+00, 0e+00]
Found heuristic solution: objective -0.0000000
Presolve removed 1 rows and 5 columns
Presolve time: 0.00s
Presolved: 3 rows, 4 columns, 9 nonzeros
Variable types: 0 continuous, 4 integer (0 binary)

Root relaxation: objective 1.134615e+02, 2 iterations, 0.00 seconds

      Nodes      |      Current Node      |      Objective Bounds      |      Work
  Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time
-----
    0     0 113.46154    0    1 -0.000000  113.46154    -    -    0s
H    0     0                  113.4500000  113.46154  0.01%    -    0s

Explored 1 nodes (2 simplex iterations) in 0.01 seconds
Thread count was 16 (of 16 available processors)

Solution count 2: 113.45 -0

Optimal solution found (tolerance 1.00e-04)
Best objective 1.134500000000e+02, best bound 1.134600000000e+02, gap 0.0088%
-bash-4.1$
```

Usage (1): Command Line (3/3)

- The result file of example
 - `gurobi_cl ResultFile=example.sol /opt/gurobi752/linux64/examples/data/coins.lp`

```
-bash-4.1$ gurobi_cl ResultFile=example.sol /opt/gurobi752/linux64/examples/data/coins.lp
Academic license - for non-commercial use only

Gurobi Optimizer version 7.5.2 build v7.5.2rc1 (linux64)
Copyright (c) 2017, Gurobi Optimization, Inc.

Read LP format model from file /opt/gurobi752/linux64/examples/data/coins.lp
Reading time = 0.00 seconds
: 4 rows, 9 columns, 16 nonzeros
Optimize a model with 4 rows, 9 columns and 16 nonzeros
Variable types: 4 continuous, 5 integer (0 binary)
Coefficient statistics:
  Matrix range      [6e-02, 7e+00]
  Objective range   [1e-02, 1e+00]
  Bounds range      [5e+01, 1e+03]
  RHS range         [0e+00, 0e+00]
Found heuristic solution: objective -0.0000000
Presolve removed 1 rows and 5 columns
Presolve time: 0.00s
Presolved: 3 rows, 4 columns, 9 nonzeros
Variable types: 0 continuous, 4 integer (0 binary)

Root relaxation: objective 1.134615e+02, 2 iterations, 0.00 seconds

   Nodes      |   Current Node   |   Objective Bounds   |   Work
Expl Unexpl | Obj Depth IntInf | Incumbent    BestBd   Gap | It/Node Time
-----
    0     0 113.46154    0    1  -0.000000  113.46154    -    -    0s
    4     0     0          113.4500000  113.46154  0.01%    -    0s

Explored 1 nodes (2 simplex iterations) in 0.01 seconds
Thread count was 16 (of 16 available processors)

Solution count 2: 113.45 -0

Optimal solution found (tolerance 1.00e-04)
Best objective 1.134500000000e+02, best bound 1.134600000000e+02, gap 0.0088%

Wrote result file 'example.sol'
```

```
Objective value = 113.45
Pennies 0
Nickels 0
Dimes 2
Quarters 53
Dollars 100
Cu 999.8
Ni 46.9
Zi 50
Mn 30
~
```

Usage (2): Interactive Shell (1/2)

- Step1: enter the shell
 - *gurobi.sh*
- Step2: read the lp file
 - *m = read('<input.lp>')*
- Step3: solve the model
 - *m.optimize()*
- Step4: write out the result
 - *m.write('<output.sol>')*
- Step5: exit
 - *quit()*

```
-bash-4.1$ gurobi.sh
Python 2.7.13 (default, Sep  4 2017, 15:40:17)
[GCC 4.4.7 20120313 (Red Hat 4.4.7-18)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
Academic license - for non-commercial use only

Gurobi Interactive Shell (linux64), Version 7.5.2
Copyright (c) 2017, Gurobi Optimization, Inc.
Type "help()" for help

gurobi> █
```

Usage (2): Interactive Shell (2/2)

- Example:
 - *gurobi.sh*
 - *m = read('coins.lp')*
 - *m = optimize()*
 - *m.write('output.sol')*
 - *quit()*

```
-bash-4.1$ gurobi.sh
Python 2.7.13 (default, Sep  4 2017, 15:40:17)
[GCC 4.4.7 20120313 (Red Hat 4.4.7-18)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
Academic license - for non-commercial use only

Gurobi Interactive Shell (linux64), Version 7.5.2
Copyright (c) 2017, Gurobi Optimization, Inc.
Type "help()" for help

gurobi> m = read('/opt/gurobi752/linux64/examples/data/coins.lp')
gurobi> m.optimize()
Optimize a model with 4 rows, 9 columns and 16 nonzeros
Variable types: 4 continuous, 5 integer (0 binary)
Coefficient statistics:
  Matrix range      [6e-02, 7e+00]
  Objective range   [1e-02, 1e+00]
  Bounds range      [5e+01, 1e+03]
  RHS range         [0e+00, 0e+00]
Found heuristic solution: objective -0.0000000
Presolve removed 1 rows and 5 columns
Presolve time: 0.00s
Presolved: 3 rows, 4 columns, 9 nonzeros
Variable types: 0 continuous, 4 integer (0 binary)

Root relaxation: objective 1.134615e+02, 2 iterations, 0.00 seconds

   Nodes      |   Current Node   |   Objective Bounds   |         Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent  BestBd   Gap | It/Node Time
-----
  0    0 113.46154   0   1   -0.000000  113.46154   -    -    0s
H  0    0                    113.450000  113.46154  0.01%   -    0s

Explored 1 nodes (2 simplex iterations) in 0.01 seconds
Thread count was 16 (of 16 available processors)

Solution count 2: 113.45 -0

Optimal solution found (tolerance 1.00e-04)
Best objective 1.134500000000e+02, best bound 1.134600000000e+02, gap 0.0088%
gurobi> m.write('output.sol')
gurobi> quit()
-bash-4.1$ ls
example.sol  gurobi.lic  gurobi.log  output.sol
```

Input File LP Format Example

- Example: coins.lp
 - provided by Gurobi, in examples/data/

```
Maximize
    .01 Pennies + .05 Nickels + .1 Dimes + .25 Quarters + 1 Dollars
Subject To
    Copper: .06 Pennies + 3.8 Nickels + 2.1 Dimes + 5.2 Quarters + 7.2 Dollars -
        Cu = 0
    Nickel: 1.2 Nickels + .2 Dimes + .5 Quarters + .2 Dollars -
        Ni = 0
    Zinc: 2.4 Pennies + .5 Dollars - Zi = 0
    Manganese: .3 Dollars - Mn = 0
Bounds
    Cu <= 1000
    Ni <= 50
    Zi <= 50
    Mn <= 50
Integers
    Pennies Nickels Dimes Quarters Dollars
End
```

Input File LP Format

- Four blocks
 - Objective (**Maximize...**)
 - Constraint (**Subject To...**)
 - Variable Bound (**Bounds...**)
 - Integrality (**Integers..., Binary...**)
- Tokens must be separated by either a space or a newline
 - Ex. “**+ .1 Dollars**”
 - Include a space between **+** and **.1**
 - Another space between **.1** and **Dollars**

Input File LP Format

- Constraint format
- Left-hand side
 - Variables
- Right-hand side
 - Constant

```
Subject To
  R_3_4_1 + R_3_4_2 + R_3_4_3 + R_3_4_4 <= 1
  R_4_3_1 + R_4_3_3 + R_4_3_4 <= 1
  R_3_2_1 + R_3_2_2 + R_3_2_3 + R_3_2_4 <= 1
  R_5_3_1 + R_5_3_2 + R_5_3_3 <= 1
  R_3_4_3 + R_4_3_4 + R_3_2_1 <= 1
  R_4_3_3 + R_3_2_2 <= 1
  R_3_4_2 + R_4_3_1 <= 1
```

```
Subject To
  Copper: .06 Pennies + 3.8 Nickels + 2.1 Dimes + 5.2 Quarters + 7.2 Dollars - Cu = 0
  Nickel: 1.2 Nickels + .2 Dimes + .5 Quarters + .2 Dollars - Ni = 0
  Zinc: 2.4 Pennies + .5 Dollars - Zi = 0
  Manganese: .3 Dollars - Mn = 0
```

- Variable default bounds
 - Zero lower bound
 - Infinite upper bound

Example for PA1

- In programming assignment#1, use “Binary” to replace “Integers”
- Example:
 - example.lp
- Maximize
 - Sum of all variable
- Subject To
 - Constraints
- Bounds
 - Nothing here
- Binary
 - 0-1 variables

```
Maximize
    R_3_4_1 + R_3_4_2 + R_3_4_3 + R_3_4_4
    + R_4_3_1 + R_4_3_3 + R_4_3_4
    + R_3_2_1 + R_3_2_2 + R_3_2_3 + R_3_2_4
    + R_5_3_1 + R_5_3_2 + R_5_3_3
Subject To
    R_3_4_1 + R_3_4_2 + R_3_4_3 + R_3_4_4 <= 1
    R_4_3_1 + R_4_3_3 + R_4_3_4 <= 1
    R_3_2_1 + R_3_2_2 + R_3_2_3 + R_3_2_4 <= 1
    R_5_3_1 + R_5_3_2 + R_5_3_3 <= 1
    R_3_4_3 + R_4_3_4 + R_3_2_1 <= 1
    R_4_3_3 + R_3_2_2 <= 1
    R_3_4_2 + R_4_3_1 <= 1
Bounds
Binary
    R_3_4_1 R_3_4_2 R_3_4_3 R_3_4_4
    R_4_3_1 R_4_3_3 R_4_3_4
    R_3_2_1 R_3_2_2 R_3_2_3 R_3_2_4
    R_5_3_1 R_5_3_2 R_5_3_3
End
```

Example for PA1

- Command

- *gurobi_cl ResultFile = testcase1.sol testcase1.lp*

Expected output from terminal

```
-bash-4.1$ gurobi_cl ResultFile=testcase1.sol testcase1.lp
Academic license - for non-commercial use only

Gurobi Optimizer version 7.5.2 build v7.5.2rc1 (linux64)
Copyright (c) 2017, Gurobi Optimization, Inc.

Read LP format model from file testcase1.lp
Reading time = 0.00 seconds
: 7 rows, 14 columns, 21 nonzeros
Optimize a model with 7 rows, 14 columns and 21 nonzeros
Variable types: 0 continuous, 14 integer (14 binary)
Coefficient statistics:
  Matrix range      [1e+00, 1e+00]
  Objective range   [1e+00, 1e+00]
  Bounds range      [1e+00, 1e+00]
  RHS range         [1e+00, 1e+00]
Found heuristic solution: objective 4.00000000
Presolve removed 7 rows and 14 columns
Presolve time: 0.00s
Presolve: All rows and columns removed

Explored 0 nodes (0 simplex iterations) in 0.00 seconds
Thread count was 1 (of 16 available processors)

Solution count 1: 4

Optimal solution found (tolerance 1.00e-04)
Best objective 4.000000000000e+00, best bound 4.000000000000e+00, gap 0.0000%

Wrote result file 'testcase1.sol'
```

testcase1.sol

```
# Objective value = 4
R_3_4_1 0
R_3_4_2 0
R_3_4_3 0
R_3_4_4 1
R_4_3_1 1
R_4_3_3 0
R_4_3_4 0
R_3_2_1 0
R_3_2_2 0
R_3_2_3 0
R_3_2_4 1
R_5_3_1 0
R_5_3_2 1
R_5_3_3 0
~
```

Online Resources

- Gurobi
 - Official documentation (quick_start, reference manual)
 - <http://www.gurobi.com/documentation/>
 - Simple guide
 - <https://wxz159d22.blogspot.tw/2013/09/gurobi.html>
- Linux
 - Bash
 - http://linux.vbird.org/linux_basic/0320bash.php