

Integer Linear Programming

Spoken Tutorial Project

<https://spoken-tutorial.org>

National Mission on Education through ICT

<http://sakshat.ac.in>

Script: Siddharth Agarwal & Mankrit Singh

Video: Mankrit Singh

FOSSEE TEAM

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Learning Objectives

In this tutorial, we will learn how to:



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- ▶ Use the `fot_intlinprog` function in Scilab



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In this tutorial, we will learn how to:

- ▶ Use the `fot_intlinprog` function in Scilab
- ▶ Solve integer linear programming problems using `fot_intlinprog` function



System Requirement

To record this tutorial, I am using



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► **Ubuntu 18.04**



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- ▶ **FOSSEE Optimization Toolbox
version 0.4.1**



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To follow this tutorial, you should:



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- ▶ **Have basic understanding of Scilab and optimization theory**
- ▶ **If not, for relevant tutorials please visit: <https://spoken-tutorial.org>**



Code Files

- ▶ The files used in this tutorial have been provided in the Code files link



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- ▶ Make a copy and then use them while practising



What is Integer Linear Programming?

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An Integer Linear Program is a mathematical optimization model with:

- ▶ **Linear objective function**
- ▶ **Linear constraints**
- ▶ **Some decision variables as integers**



Mathematical Formulation

A general form of an Integer Linear Program is:

$$\min_x c^T x$$

subject to:

$$Ax \leq b,$$

$$A_{eq}x = b_{eq},$$

$$lb \leq x \leq ub,$$

$$x_i \in \mathbb{Z}, i \in \text{intcon},$$

where c , intcon , A , b , A_{eq} , b_{eq} ,

lb , and ub are given.



Example

$$\min_x 2x_1 - x_2 - 2x_3 - x_4$$

subject to:

$$2x_2 - 8x_3 \leq 0,$$

$$x_1 + x_2 - 2x_3 \geq 1,$$

$$x_1 + x_2 + x_3 + x_4 = 10,$$

$$0 \leq x_j \leq 10, \quad j \in \{1, 4\},$$

$$x_j \in \mathbb{Z}, \quad j \in \{1, 4\}.$$



Alternate Input Arguments

- ▶ **file:** A string containing the path of the mps file to be read



Alternate Input Arguments

- ▶ **file:** A string containing the path of the mps file to be read
- ▶ **options:** A list containing the parameters of the solver that is to be set



Options

The options allow the user to set various parameters of the Optimization problem



Options

Two such options are:



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- ▶ **MaxTime:** The maximum amount of CPU time in seconds that the solver should take



Options

Two such options are:

- ▶ **MaxTime:** The maximum amount of CPU time in seconds that the solver should take
- ▶ **MaxNodes:** The maximum number of nodes that the solver should search



Exitflags

- ▶ In the example we have executed, you have seen the exitflag



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- ▶ In the example we have executed, you have seen the exitflag
- ▶ This indicates the status of execution



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- ▶ This indicates the status of execution
- ▶ The documentation explains what they mean for each function



Exitflags

For **fot_intlinprog**,



Exitflags

For `fot_intlinprog`,

► **0: Optimal Solution Found**



Exitflags

For **fot_intlinprog**,

- ▶ **0: Optimal Solution Found**
- ▶ **1: Converged to a point of primal infeasibility**



Exitflags

For **fot_intlinprog**,

- ▶ **0: Optimal Solution Found**
- ▶ **1: Converged to a point of primal infeasibility**
- ▶ **2: Solution Limit is reached**



Exitflags

For **fot_intlinprog**,

- ▶ **0: Optimal Solution Found**
- ▶ **1: Converged to a point of primal infeasibility**
- ▶ **2: Solution Limit is reached**
- ▶ **3: Node Limit is reached**
Output may not be optimal



► 4: Numerical Difficulties



Exitflags

- ▶ 4: Numerical Difficulties
- ▶ 5: Maximum amount of CPU Time exceeded



Exitflags

- ▶ 4: Numerical Difficulties
- ▶ 5: Maximum amount of CPU Time exceeded
- ▶ 6: Continuous Solution Unbounded



Exitflags

- ▶ 4: Numerical Difficulties
- ▶ 5: Maximum amount of CPU Time exceeded
- ▶ 6: Continuous Solution Unbounded
- ▶ 7: Converged to a point of dual infeasibility



Example

In this example, we will learn how to:



Example

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- ▶ Use mps files for large optimization problems



Example

In this example, we will learn how to:

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- ▶ Use options



Example

In this example, we will learn how to:

- ▶ Use mps files for large optimization problems
- ▶ Use options
- ▶ Interpret exitflags



In case you get a different solution

- ▶ Change the working directory of Scilab by typing `cd <location of liu.mps file>` in the scilab console **OR**
- ▶ In the Scilab code edit the line `file = "liu.mps";` to `file = "absolute location of the liu.mps file";`



Summary

In this tutorial, we have learnt how to:

- ▶ Use `fot_intlinprog` function of FOSSEE Optimization Toolbox
- ▶ Solve an integer linear programming example using `fot_intlinprog` in Scilab



Summary

- ▶ Use options to exert control on the solver
- ▶ Read exitflags
- ▶ Use MPS files as inputs



Assignment

Solve the following integer linear programming problem

$$\min_x 5000x_1 + 5550x_2 + 1000x_3 + 1500x_4$$

subject to:

$$5x_1 + 7x_2 + 2x_3 \geq 9,$$

$$3x_1 + 2x_2 \geq 3,$$

$$425x_1 + 300x_2 + 50x_3 + 100x_4 \geq 500,$$

$$0 \leq x_j \leq 1, \quad j \in \{1, 4\},$$

$$x_j \in \mathbb{Z}, \quad j \in \{1, 4\}.$$



Assignment Solution

$$x_{opt} = [1; 0; 2; 0]$$

$$f_{opt} = 7000$$



About Spoken Tutorial project

- ▶ Watch the video available at https://spoken-tutorial.org/What_is_a_Spoken_Tutorial
- ▶ It summarises the Spoken Tutorial project
- ▶ If you do not have good bandwidth, you can download and watch it



Spoken Tutorial Workshops

The Spoken Tutorial Project Team

- ▶ Conducts workshops using spoken tutorials
- ▶ Gives certificates to those who pass an online test
- ▶ For more details, please write to contact@spoken-tutorial.org



Answers for THIS Spoken Tutorial

- ▶ Questions in THIS Spoken Tutorial?
- ▶ Visit <https://forums.spoken-tutorial.org/>
- ▶ Choose the minute and second where you have the question
- ▶ Explain your question briefly
- ▶ The Spoken Tutorial project will ensure an answer



FOSSEE Forum

- For any general or technical questions on Scilab, visit the FOSSEE forum and post your question

<https://forums.fossee.in/>



Textbook Companion project

- ▶ The FOSSEE team coordinates the Textbook Companion project
- ▶ We give Certificates and Honorarium to the contributors
- ▶ For more details, please visit:
https://scilab.in/Textbook_Companion_Project



Lab Migration

- ▶ The FOSSEE team coordinates the Lab Migration project
- ▶ For more details, please visit:
[https://scilab.in/
Lab_Migration_Project](https://scilab.in/Lab_Migration_Project)



Acknowledgements

- ▶ **Spoken Tutorial and FOSSEE projects are funded by MoE, Government of India.**



Thank you

- ▶ This is Mankrit Singh, a FOSSEE intern 2021, IIT Bombay signing off
- ▶ Thanks for joining

