AMPL Tutorial

IEOR 240 - Fall 2021

Linear Programming

$$
\begin{aligned}
&\min(\max) && \sum_{i=1}^{n} c_i x_i \\
&\text{s.t.} && \sum_{i=1}^{n} a_{1i} x_i \begin{pmatrix} \leq \\ = \\ \geq \end{pmatrix} b_1 \\
& && \sum_{i=1}^{n} a_{2i} x_i \begin{pmatrix} \leq \\ = \\ \geq \end{pmatrix} b_2 \\
& && \vdots \\
& && \sum_{i=1}^{n} a_{mi} x_i \begin{pmatrix} \leq \\ = \\ \geq \end{pmatrix} b_m
\end{aligned}
$$

x_i - decision variables,

a_{ji}, c_i, b_j - problem data

Installation Instructions

1. Download AMPL
    - MacOS: http://ampl.com/demo/amplide.macosx64.tgz
    - Windows: http://ampl.com/demo/amplide.mswin64.zip
    - Linux: http://ampl.com/demo/amplide.linux64.tgz
2. Extract the archive.
3. In the `amplide` folder, you should find the `amplide` application.
4. Open the `amplide` application.
5. Type into the console: `printf "Hello World!\n";`
6. Press Enter.
7. If it prints `Hello World!`, then you are done!

Special Instrustion for Mac OSX

Special note for users of macOS 10.12 Sierra: As a side-effect of a new security feature introduced with this version, you may see an error message beginning `The IDE cannot find the AMPL executable...` To fix this problem, quit the IDE application and then follow these steps:

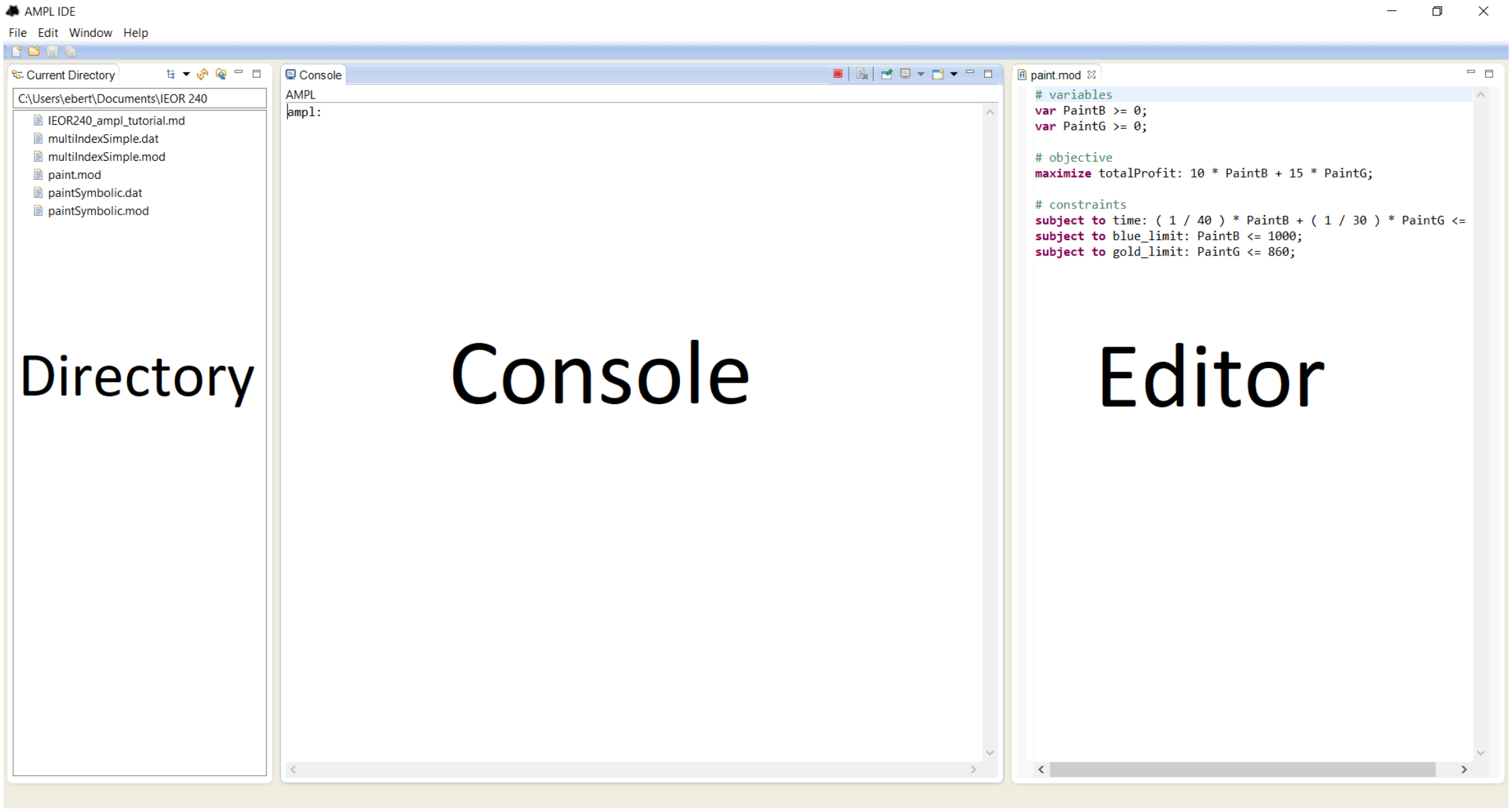
(1) In your amplide.macosx64 folder, find the Amplide file (with a cat's head icon).

(2) Drag the Amplide file to your desktop.

(3) Drag the Amplide file back into the amplide.macosx64 folder.

(4) Then double-click the file icon to start the AMPL IDE again.

AMPL IDE


AMPL IDE
File Edit Window Help
Current Directory
C:\Users\ebert\Documents\IEOR 240
IEOR240_ampl_tutorial.md
multiIndexSimple.dat
multiIndexSimple.mod
paint.mod
paintSymbolic.dat
paintSymbolic.mod
Directory
Console
AMPL
ampl:
Console
paint.mod
# variables
var PaintB >= 0;
var PaintG >= 0;
# objective
maximize totalProfit: 10 * PaintB + 15 * PaintG;
constraints
subject to time: (1 / 40) * PaintB + (1 / 30) * PaintG <=
subject to blue_limit: PaintB <= 1000;
subject to gold_limit: PaintG <= 860;
Editor

Modelling: Berkeley Paint Company

Berkeley Paint Company makes two colors of paint: Blue and Gold

The type of paints have the following characteristics (per gallon):

Paint	Blue	Gold
Profit (p_i)	10	15
Production/hour (r_i)	40	30
Maximum demand (u_i)	1000	860

Berkeley Paint Company has 40 hours of production capacity available to produce paint.

Formulate an LP to help Berkeley Paint Company maximize profit.

Model

x_1 = Amount of Blue paint to produce

x_2 = Amount of Gold paint to produce

$$
\begin{aligned}
\max \quad & 10x_1 + 15x_2 \\
\text{s.t.} \quad & (1/40)x_1 + (1/30)x_2 \leq 40 \\
& x_1 \leq 1000 \\
& x_2 \leq 860 \\
& x_1 \geq 0 \\
& x_2 \geq 0
\end{aligned}
$$

Formulating the model in AMPL

```
# variables
var PaintB;
var PaintG;

# objective function
maximize totalProfit: 10 * PaintB + 15 * PaintG;
# constraints
subject to time: (1/40)*PaintB + (1/30)*PaintG <= 40;
subject to blue_limit: 0 <= PaintB <= 1000;
subject to gold_limit: 0 <= PaintG <= 860;
```

Another way to write it

```
# variables
var PaintB >= 0;
var PaintG >= 0;

# objective function
maximize totalProfit: 10 * PaintB + 15 * PaintG;
# constraints
subject to time: (1/40)*PaintB + (1/30)*PaintG <= 40;
subject to blue_limit: PaintB <= 1000;
subject to gold_limit: PaintG <= 860;
```

Save as `paint.mod`

Comments on Syntax

- # starts a comment
- All lines of code end with a `;`
- Variables are declared with `var`
- The objective function has the following format:

  `maximize <name>: <objective>;` or

  `minimize <name>: <objective>;`
- The constraints have the following format:

  `subject to <name>: <constraint>;`
- Names must be unique.

  Also, a variable and constraint cannot have the same name.
- AMPL is case sensitive. Keywords must be lower case.

Setup AMPL

Type the following commands into the **console**:

1. Set the solver to be CPLEX:

```
option solver cplex;
```

There are many solvers included with AMPL but we will mostly use CPLEX

Time to solve!

Type the following commands into the **console**:

1. Load the model:

   ```
   model paint.mod;
   ```

2. Solve!

   ```
   solve;
   ```

3. Output:

```
CPLEX 12.7.0.0: optimal solution; objective 17433.33333
0 simplex iterations (0 in phase I)
```

What is the solution?

- Display the objective function, constraint or variable:

  `display <name>;`

  For example:

  `display totalProfit;`
- Display all variables:

  `display _varname, _var;`

Reset AMPL

- `reset;`

Modelling: Berkeley Paint Company

Berkeley Paint Company makes two colors of paint: Blue and Gold

The type of paints have the following characteristics (per gallon):

Paint	Blue	Gold
Profit (p_i)	10	15
Production/hour (r_i)	40	30
Maximum demand (u_i)	1000	860

Berkeley Paint Company has 40 hours of production capacity available to produce paint.

Formulate a **symbolic** LP to help Berkeley Paint Company maximize profit.

Symbolic model

n = number of paints to produce

x_i = Amount of paint i to produce

$$
\begin{aligned}
\max \quad & p_1 x_1 + p_2 x_2 + p_3 x_3 + \ldots p_n x_n \\
\text{s.t.} \quad & \tfrac{1}{r_1} x_1 + \tfrac{1}{r_2} x_2 + \tfrac{1}{r_3} x_3 + \ldots + \tfrac{1}{r_n} x_n \leq t \\
& 0 \leq x_i \leq u_i \text{ for } i = 1 \ldots n
\end{aligned}
$$

Or equivalently:

$$
\begin{aligned}
\max \quad & \textstyle\sum_{i=1}^{n} p_i x_i \\
\text{s.t.} \quad & \textstyle\sum_{i=1}^{n} \tfrac{1}{r_i} x_i \leq t \\
& 0 \leq x_i \leq u_i \text{ for } i = 1 \ldots n
\end{aligned}
$$

Writing a symbolic model in AMPL

```
# parameters
param n;
param capacity;
param profit{i in 1..n};
param r{i in 1..n};
param maxDemand{i in 1..n};

# variables
var paint{i in 1..n} >= 0;

# objective function
maximize totalProfit:
    sum{i in 1..n} profit[i]*paint[i];

# constraints
subject to time:
    sum{i in 1..n} ( 1 / r[i] ) * paint[i] <= capacity;
subject to demand_limit {i in 1..n}:
    paint[i] <= maxDemand[i];
```

Save as `paintSymbolic.mod`

Syntax comments

- Use more elaborate names than in your LP.
- `param` is used to define a parameter.
- We define an indexed variable / parameter with:
  - `<name>{<index> in <range>}`
  - Typical indices are: `i,j,k`
  - Range: `1..n` **TWO dots!**
- Use `<name>[2]` to access the second index.
- Summation are defined similarly:
  `sum{<index> in <range>}`
- Indexed constraints are defined with:
  `subject to <name> {<index> in <range>}:`

What is missing? Data!

Specifying data in AMPL

```
param n := 2;
param capacity := 40;

param profit :=
        1 10
        2 15;
param r :=
        1 40
        2 30;
param maxDemand :=
        1 1000
        2 860;
```

Save as `paintSymbolic.dat`

Syntax comments:

- Defining the value of a simple parameter:
  `param <name> := <value>;`
- Defining the value of an indexed parameter:

```
param <name> :=
    <index> <value>
    ...
    <index> <value>;
```

Parameters with multiple indices:

- Definition: `<name>{<ind1> in <range1>, <ind2> in <range2>}`
- Accessing an index: `<name>[<index1>,<index2>]`
- Example definition:

```
var paint{i in 1..m, j in 1..n} >= 0;
```

- Example constraint:

```
subject to demandConstraint {j in 1..n}:
    sum{i in 1..m} paint[i,j] = demand[j];
```

- Data with multiple indices:

```
param <name> :=
    <index1> <index2> <value>
    ...
    <index1> <index2> <value>;
```

Solving a symbolic model

- Load model:
  `model paint.mod;`
- Load data:
  `data paintSymbolic.dat;`
- Solve: `solve;`

Setup AMPL - Sensitivity Analysis

Type the following commands into the **console**:

1. Set the solver to be CPLEX:
   ```
   option solver cplex;
   ```
2. Enable sensitivity analysis:
   ```
   option cplex_options 'sensitivity';
   ```
3. Turn off presolve (needed for sensitivity analysis):
   ```
   option presolve 0;
   ```
4. Load model and solve as usual.
   ```
   model paint.mod;
   ```
   ```
   solve;
   ```

Sensitivity Analysis Outputs

- Display the objective function, constraint or variable:

  ```
  display <name>;
  ```

  For example:

  ```
  display totalProfit;
  ```

- Display all variables:

  ```
  display _varname, _var, _var.rc, _var.down, _var.current, _var.up;
  ```

- Display all constraints:

  ```
  display _conname, _con, _con.slack, _con.up, _con.current, _con.down;
  ```