BLG 368E Operations Research Term Project

Due: Monday, May 20, 2024

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18.05.2024

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Factory AI Automation Problem

Fatih is the head of information technologies in a well-known company. The company produces in-demand goods and is known for its good-quality products and customer service. As AI technologies progressed, companies started to offer AI tool services with specific capabilities. Also, departments want to integrate AI into their business to adapt to the future.

Each department needs different capabilities from the tools on the market and those tools have different monthly subscription fees. The table below gives AI tools with their capabilities and their subscription fees.

AI Tool Name	Cost $/Month	Image Recognition	Audio Recognition	File Analysis	Speech Synthesis	NLP	Anomaly Detection	Predictive Analysis
AccuBot	1600	NO	NO	NO	NO	YES	YES	YES
Sentinel	800	YES	YES	NO	NO	NO	YES	NO
AssistLine	1200	NO	YES	NO	YES	YES	NO	NO
Guardian	150	NO	NO	YES	NO	NO	NO	NO
MustRead	650	NO	NO	YES	NO	YES	NO	NO
AudioPop	100	NO	NO	NO	YES	NO	NO	NO
CastMaster	550	NO	NO	NO	NO	YES	NO	YES
SuperVis	250	YES	NO	NO	NO	NO	YES	NO
MaintainAI	1650	YES	YES	YES	NO	NO	YES	YES

Table 1: AI tools, their capabilities, their monthly fees.

By selecting these AI tools, Fatih needs to address the needs of different departments with minimal cost. Note that it is possible to feed an output of an AI tool to the input of another AI tool, effectively merging the capabilities of different AI tools. Therefore, he needs to cover all these business needs with such a set of AI tools that it should yield the minimum cost.

Objective Function and Constraints

This question is a 0-1 minimization problem. Fatih can either use or don't use a particular AI Tool. He needs to minimize his costs while covering all the needs of the departments. Department needs would be his constraints. His variables are:

- x_1 : Whether to use AccuBot
- x_2 : Whether to use Sentinel
- x_3 : Whether to use AssistLine
- x_4 : Whether to use Guardian
- x_5 : Whether to use MustRead
- x_6 : Whether to use AudioPop
- x_7 : Whether to use CastMaster
- x_8 : Whether to use SuperVis
- x_9 : Whether to use MaintainAI

Objective Function and Constraints continued on next page...

His objective function is:
$min\ z = 1600 \times x_1 + 800 \times x_2 + 1200 \times x_3 + 150 \times x_4 + 650 \times x_5 + 100 \times x_6 + 550 \times x_7 + 250 \times x_8 + 1650 \times x_9$

With the table above, his constraints are:

- For image recognition: $x_2 + x_8 + x_9 \geq 1$
- For audio recognition: $x_2 + x_3 + x_9 \geq 1$
- For file analysis: $x_4 + x_5 + x_9 \geq 1$
- For speech synthesis: $x_3 + x_6 \geq 1$
- For NLP: $x_1 + x_3 + x_5 + x_7 \geq 1$
- For anomaly detection: $x_1 + x_2 + x_8 + x_9 \geq 1$
- For predictive analysis: $x_1 + x_7 + x_9 \geq 1$

And lastly, for all x_i where $1 \leq i \leq 9$, 0-1 constraint is $0 \leq x_i \leq 1$.

Solution Using CPLEX

I have used IBM's CPLEX program to solve this problem. I have selected the variable types as `boolean` since this is a 0-1 assignment problem with a minimization objective function.

Using the CPLEX solver, x_2, x_4, x_6, x_7 were 1 and the rest was 0. The total cost was 1600. This means Fatih would subscribe the company to Sentinel, Guardian, AudioPop, and CastMaster AI tools to cover the needs of all departments. In the screenshot below, the output of CPLEX is given.

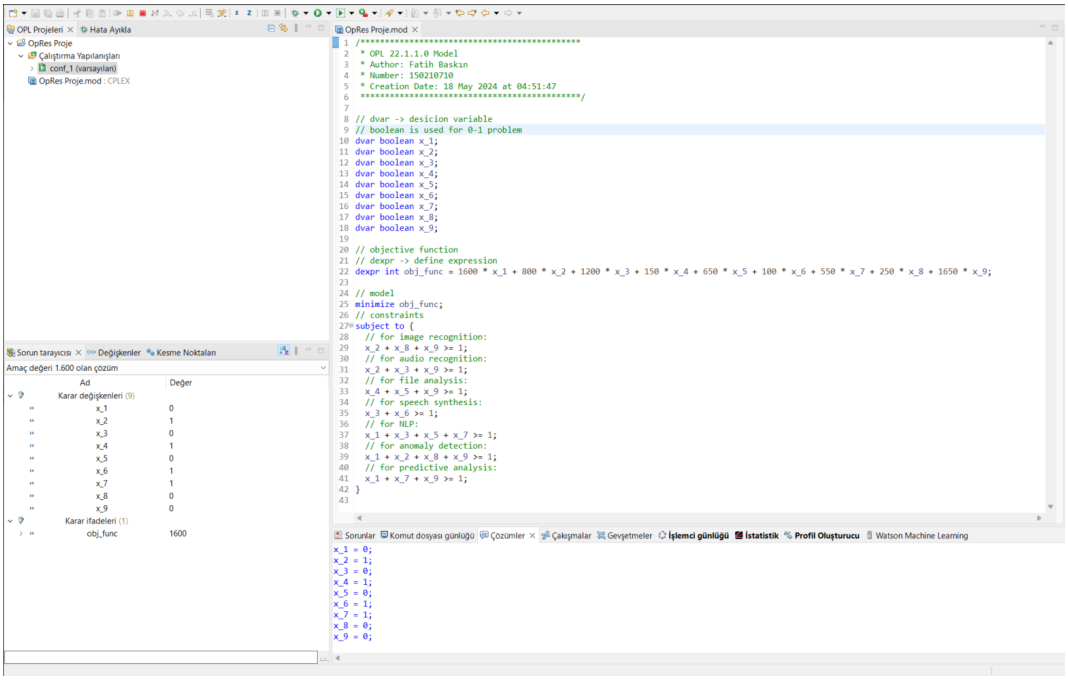

Figure 1: Screenshot of the CPLEX program containing the output.

CPLEX Solver Code

CPLEX solver is programmed with a `.mod` file and I have coded a simple 0-1 problem for this particular problem. The code is provided below:

```
// dvar -> desicion variable
// boolean is used for 0-1 problem
dvar boolean x_1;
dvar boolean x_2;
dvar boolean x_3;
dvar boolean x_4;
dvar boolean x_5;
dvar boolean x_6;
dvar boolean x_7;
dvar boolean x_8;
dvar boolean x_9;

// objective function
// dexpr -> define expression
dexpr int obj_func = 1600 * x_1 + 800 * x_2 + 1200 * x_3 + 150 * x_4 + 650 * x_5
                   + 100 * x_6 + 550 * x_7 + 250 * x_8 + 1650 * x_9;

// model
minimize obj_func;
// constraints
subject to {
  // for image recognition:
  x_2 + x_8 + x_9 >= 1;
  // for audio recognition:
  x_2 + x_3 + x_9 >= 1;
  // for file analysis:
  x_4 + x_5 + x_9 >= 1;
  // for speech synthesis:
  x_3 + x_6 >= 1;
  // for NLP:
  x_1 + x_3 + x_5 + x_7 >= 1;
  // for anomaly detection:
  x_1 + x_2 + x_8 + x_9 >= 1;
  // for predictive analysis:
  x_1 + x_7 + x_9 >= 1;
}
```