C++/Cplex for Optimization Problems: a short tutorial and implementation

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Part 1

Why C++/Cplex for optimization

C++

- It is generally (very) fast compared to interpreter-based languages like Python
- Many open-source solvers are developed in (C/C++)/Cplex. See, for example, COIN-OR, and COR@L
- Still many researchers use C++

Why C++/Cplex for optimization

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Cplex

- More popular among OR practitioners
- Free for academic use
- Good documentations, but not the best
- More established than similar solvers such as Gurobi (another good one!)

Example 1: Transportation Problem

- $\mathcal{S}$: set of supplier $\mathcal{D}$: set of customers (demand points)
- S: supply array D: Demand array
- c_{sd}: cost of sending a unit from supplier s to demand point d
- X_{sd} (decision variable): amount of shipment from supplier s to demand point d

$$\min \sum_{s\in\mathcal{S}}\sum_{d\in\mathcal{D}} c_{sd}X_{sd} \tag{1a}$$

$$s.t. \sum_{d\in\mathcal{D}} X_{sd} \leq S_s \qquad s\in\mathcal{S} \tag{1b}$$

$$\sum_{s\in\mathcal{S}} X_{sd} \geq D_d \qquad d\in\mathcal{D} \tag{1c}$$

$$X_{sd} \in \mathbb{Z}^+ \qquad s\in\mathcal{S}, d\in\mathcal{D} \tag{1d}$$

Setup Cplex for C++ in Visual Studio (VS)

Make sure the Ilog Cplex is installed, and you have at least one ".cpp" file in your project:

1. Make sure the compiler is using the x64-bit platform

2. In the solution Explorer tab, click on the project name and select properties

3. Go to C/C++ general ->" additional include directories" -> paste (find) these two directories:
   - C: \Program Files\IBM\ILOG\CPLEX_Studio129\concert\include
   - C: \Program Files\IBM\ILOG\CPLEX_Studio129\cplex\include

Setup Cplex for C++ in Visual Studio (VS)

4. Go to C/C++ general ->"Preprocessors"->"Preprocessor Definitions" and add these commands:
   - WIN32
     _CONSOLE
     IL_STD
     _CRT_SECURE_NO_WARNINGS
   - or
   - NDEBUG
     _CONSOLE
     IL_STD

5. In the Project1 property page, select: "C/C++" - "code generation" - "runtime library", set to "multithreaded DLL (/MD)".

Setup Cplex for C++ in Visual Studio (VS)

6. In the Project1 property page, select: "Linker" - "Input" - "Additional Dependencies", and add these paths:
   - C:\Program Files\IBM\ILOG\CPLEX_Studio129\cplex\lib\x64_windows_vs2017\stat_mda\cplex129.lib
   - C:\Program Files\IBM\ILOG\CPLEX_Studio129\cplex\lib\x64_windows_vs2017\stat_mda\ilocplex.lib
   - C:\Program Files\IBM\ILOG\CPLEX_Studio129\concert\lib\x64_windows_vs2017\stat_mda\concert.lib

7. Add #include"ilcplex/ilocplex.h" to the ".cpp" file when needed

if you're using visual studio 2017 with cplex 12.8, you may encounter an error for which you can find a fix at:
https://www-01.ibm.com/support/docview.wss?uid=ibm10718671

Essential Cplex Commands

- IloEnv: to create a modeling environment
- IloModel: to create a model object
- IloNumVarArray: to define a one-dimensional decision variable
- IloRangeArray: to get the duals
- IloExpr: to define a variable to store a collection of terms
- IloMinimize: to add a minimization objective
- IloCplex: to create a cplex object and solve the model

Essential Cplex Object Methods

IloEnv env; IloModel Model(env); IloCplex cplex(Model);

- Model.add: add objective function and constraints
- cplex.solve(): solve the model
- cplex.cplex.getObjValue(): get objective function value
- cplex.getMIPRelativeGap(): get the gap
- cplex.getValue(IloNumVar): get the value of a decision variable
- cplex.getDual(IloRange): get dual value of a constraint
- cplex.getRay(IloNumArray,IloNumVarArray): get extreme rays

Essential Cplex Parameters

IloEnv env; IloModel Model(env); IloCplex cplex(Model);

- cplex.setParam(IloCplex::TiLim, 3600): set a time limit of 3600 seconds
- cplex.setParam(IloCplex::EpGap, 0.60): set the minimum required gap
- cplex.setOut(env.getNullStream()): turn off logging output on the console window
- cplex.exportModel("Name.lp"): print the model in a ".lp" format.
- cplex.getStatus(): status of the solution (optimal, unbounded, infeasible)

Example 1: Transportation Problem

Codes in the "TP0" to "TP4" folders, with varying automation level

Part 2:

to be presented on March 11th, 2021

Thank You