IEE 574 - Applied Deterministic Operations Research Models (Summer 2020)
AMPL Project Part 2

Last updated: 06/15/2020.

Objective: The purpose of the second part of the project is to enhance your skills and knowledge of the AMPL/CPLEX mathematical programming software towards the completion of an operations research study. For this purpose, you will gather data, build mathematical models, apply optimization techniques, analyze their results, and prepare a professional-quality report of your findings. This part of the project is worth 2/3 of the "Assignments" score in the syllabus.

Problem Context: For certain thrill seekers, the countrywide lockdowns caused by the COVID-19 pandemic have opened up previously unthinkable opportunities. It was recently reported that a team of 3-4 anonymous drivers took advantage of the unusually empty streets and highways across the U.S. to break the previously standing "cannonballing" speed record by over 40 minutes. The new record is likely to endure for some time, as authorities are now on high alert for copycats who may attempt to complete the fast-paced coast-to-coast drive.

Adventurous drivers have concocted a new challenge that will allow them to race competitively but at a lower risk of violating federal law and attracting undesired attention. A newly proposed "boomerang" race entails driving in the fastest time possible from city 'A' in a particular U.S. state, visiting 14 additional "differently lettered" cities within the state in any order but without repetition, and ending back at city 'A'. A wealthy driver would like to hire your team of analysts to use your knowledge of operations research to figure out the best circuit to drive in the race. You suspect that the problem can be addressed through the use of Traveling Salesperson Problem (TSP) solution techniques. However, because you have little working knowledge of this context and you are paranoid types, you will cover your bases by solving the problem using multiple techniques learned in class.

Instructions:

1. You must work in teams of 2-3 students. Collaboration with other teams is explicitly disallowed.
2. Each team must choose a unique U.S. state on which to base its project. Try to select states that have numerous cities to simplify the data collection tasks. Specify your choices in the team sign-up document. Choices are on a first come first served basis.
3. Complete the activities described in the ensuing sections and upload your project files as a zipped file to Canvas (one submission per team). The project due date is Monday 07/06/2020 at 3pm.
4. To discourage procrastination, we will not answer any questions regarding the project after 11:59pm of Friday 07/03/2020.

Data Collection and Processing

- Find 15 cities in your state that begin with a different letter of the alphabet; one of the cities must start with the letter 'A' (this is the starting city). Break ties between multiple cities that begin with the same letter based on highest population. If your state does not contain 15 cities that begin with a different letter, then your search for cities would continue by focusing on the second letters of the city names (then the third, if needed, etc.). For example, assuming there are less than 15 cities starting with a unique letter in your state and a 'z'-city is not yet part of your list, the city "Azusa" could be used as the representative for the letter 'z' (ties for cities with the same second or higher letters can be broken arbitrarily). City information must be obtained from a relatively reputable source and be cited in the report.
- Collect the pairwise distances between the 15 selected cities. The distance between city i and city j, d_{ij}, must be the shortest distance retried from Google Maps (or other reputable source) between the cities, for $i \neq j$; you may assume that the pairwise distances are symmetric. You may want to explore tools that can gather multiple city pairwise distances at a time rather than gathering them one by one. As a suggestion

make the M-values of your distance matrix large enough to avoid errors (e.g., 5 times larger than the largest distance). Make sure to follow the posted "distances.dat" data file template as this will enable the grader to verify your solutions and minimize the chance for grading mistakes.

TSP Solution Methods:

- Off-the-Shelf: Write MTZ TSP model formulation (see section 9.6 in the book and/or class notes) using AMPL and solve with the CPLEX solver.
- Branch-and-Cut: Use the assignment problem relaxation of the TSP formulation and iteratively add **cut-set constraints** to remove subtours (see class notes), as needed, to solve the overall problem. Solve the relaxed model (call it "TSP_BC_iter_0.mod"), detect if the relaxation solution contains a subtour and, if so, generate a constraint that will remove that relaxation solution from recurring (call the new model "TSP_BC_iter_1.mod"). Repeat this process (naming subsequent mod files accordingly) until either (i) no subtours are detected or (ii) at least 15 such iterations are performed. An alternative to producing a new model file after each iteration is to add the constraints dynamically within AMPL; this process must be clearly evident within the AMPL log file.
- Heuristic (Bonus - must be completed on an individual basis and submitted separately via email): Define an ADD&SWAP heuristic to solve the problem. Perform the ADD operation until reaching a feasible solution. Then, perform SWAP operations until either no improvement in the optimal solution results or (ii) 15 such iterations are performed. The procedure should be performed with Excel with detailed individual steps.
- For the first two solution methods, submit appropriately titled log files that record the solution process. These must be clean from scratch work (i.e., clear previous log files before performing your final run).

Final Report:

- Prepare a report detailing your study for your wealthy sponsor. Your report should consist of the following sections: Introduction, Model, Description of Solution Methods, Results, and Recommendations.
- The Introduction should state the problem and any relevant assumptions you made clearly; include a geographical map of your problem instance. In the Model section, provide the algebraic form of the model (i.e., with minimal numerical data) and intuitive explanations of its individual components. Give a concise but clear description of the solution methods in the Description of Solution Methods section. The Results section should include AMPL timing statistics/iteration counts and other helpful metrics for assessing the performance and different advantages of the different solution algorithms. Helpful visuals are highly recommended.
- Submit all of the files as a single zipped file. An upload section with further instructions will be opened on the course web portal as the due date approaches.
- There is no minimum length for the report. That said, there should be sufficient details for someone unfamiliar with this project description document to understand the problem context, solution approaches, your team's work, and the results/recommendations.

Note: We may add further information to this document; please check regularly for updates.