Advanced Models and Methods in Operations Research
Project: Crew pairing

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For each problem considered, instances and a code skeleton containing an instance parser and a solution checker are provided in the `data/` and `python/` folders of the project.

The algorithms must be implemented in the provided files between the tags `TODO START` and `TODO END`.

They must be tested on all the provided instances with the command: `python3 problem.py -i instance.json -c certificate.json`

And each solution file must be validated by the provided checker: `python3 problem.py -a checker -i instance.json -c certificate.json`

The results must be reproducible.

The delivrable must contain:

- A *short* report describing and justifying the proposed algorithms
- The code implementing the algorithms
- The solution files obtained on the provided instances

Introduction

Excerpts from Saddoune, Desaulniers, and Soumis 2013.

> A crew pairing is a sequence of flights, connections and rests that starts and ends at a crew base and is assigned to a single crew. The crew pairing problem consists of determining a minimum cost set of feasible crew pairings such that each flight is covered exactly once and side constraints are satisfied.

1 Dynamic Programming

We consider the following crew pairing problem:

- Input:
  - n flights; for each flight $j = 1, \dots, n$
    - a profit p_j
    - a cost c_j^s of going from the base of the crew to this flight
    - a cost c_j^e of going from this flight to the base
  - For each pair of flights $j_1, j_2 = 1, \dots, n$, $j_1 \neq j_2$, a cost c_{j_1,j_2} of going from the arrival of the first one to the departure of the second one. This might not be possible for all pairs of flights.
  - A maximum number of flights in the pairing $f^{\max}$
- Problem: find a crew pairing, *i.e.* a list of consecutive flights such that
  - The crew pairing starts and ends at the base
  - The crew pairing contains at most $f^{\max}$ flights
- Objective: maximize the profit of the crew pairing

Propose and implement an algorithm based on Dynamic Programming for this problem.

2 Heuristic Tree Search

We consider the following crew pairing problem:

- Input:

  - n flights; for each flight $j = 1, \dots, n$
    * a profit p_j
    * a cost c_j^s of going from the base of the crew to this flight
    * a cost c_j^e of going from this flight to the base
    * a duration t_j^s of going from the base of the crew to this flight
    * a duration t_j^e of going from this flight to the base
    * a duration t_j^d
    * a starting time s_j
    * an arrival time e_j
  - For each pair of flights $j_1, j_2 = 1, \dots, n$, $j_1 \neq j_2$
    * a cost c_{j_1,j_2} of going from the arrival of the first one to the departure of the second one. This might not be possible for all pairs of flights.
    * a duration t_{j_1,j_2} of going from the arrival of the first one to the departure of the second one. This might not be possible for all pairs of flights.
  - A maximum number of flights in the pairing $f^{\max}$
  - A maximum duration of a pairing $t^{t,\max}$
  - A maximum flying time in the pairing $t^{\max}$

- Problem: find a crew pairing, *i.e.* a list of consecutive flights such that
  - The crew pairing starts and ends at the base
  - The crew pairing contains at most $f^{\max}$ flights
  - The maximum flying time is lesser than $t^{f,\max}$
  - The duration of the pairing is lesser than $t^{\max}$
- Objective: maximize the profit of the crew pairing

Propose and implement an algorithm based on Heuristic Tree Search with Dynamic Programming for this problem.

3 Column Generation + Dynamic Programming

Propose an exponential formulation and implement an algorithm based on a Column Generation heuristic for this problem.

4 Column Generation + Heuristic Tree Search

Propose an exponential formulation and implement an algorithm based on a Column Generation heuristic for this problem.

References

Saddoune, Mohammed, Guy Desaulniers, and François Soumis (2013). "Aircrew pairings with possible repetitions of the same flight number". In: *Computers & Operations Research*. Transport Scheduling 40.3, pp. 805–814. ISSN: 0305-0548. DOI: 10.1016/j.cor.2010.11.003. URL: https://www.sciencedirect.com/science/article/pii/S030505481000273X (visited on 10/14/2023).