Elevator Dispatching as Mixed Integer Linear Optimization Problem

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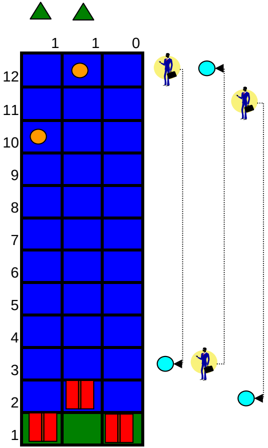
Elevator group

- In high-rise and big buildings, elevators are arranged into groups
- Elevators in a group share joint call panels
- Elevator dispatching problem deals with one elevator group
- Example: a group of three elevators in a 12-floor building



Destination Control System

- Destination operation panels at each landing floor
- No call buttons inside elevators
- Calls given from these panels are called destination calls
- Destination calls are allocated to elevators immediately
- Passenger information available in allocation
  - Departure floors
  - Destination floors
  - Number of waiting and traveling passengers

Elevator Dispatching Problem (EDP)

- Allocate destination calls to elevators, immediately after they have been given
- while satisfying constraints
  - Capacity constraints
  - Already allocated passengers
  - Time window constraints
  - Commonly accepted rules for an elevator behavior (Closs 1970)
- and minimizing a cost function
- *Controlling an elevator group continuously in real time consists of a series of EDP instances*

Closs Rules

- A car may not stop at a floor where no passenger enters or exits
- A car may not pass a floor at which a passenger wishes to exit
- A passenger may not enter a car carrying passengers and traveling in the reverse direction to his required direction of travel
- A car may not reverse its direction of travel while carrying passengers

Optimization methods

- Current optimization methods
  - Practical implementation of Genetic Algorithm (Tyni et al. 2001)
  - Guarantees locally optimal solutions
- *Here, the first mixed integer linear optimization formulation for the EDP is defined and solved*
  - Globally optimal solutions
- Passenger Allocation to Capacitated Elevators, PACE
  - Defined on a directed graph
    - T terminals, P pickup and D delivery nodes
    - A arcs which satisfy Closs rules

Sets

- C_1 = Destination calls to be allocated
- P = Pickup nodes
- D = Delivery nodes
- T = Terminal nodes
- E = Elevators
- A_e = Arcs of elevator e, $A = \bigcup_{e \in E} A_e$
- $\mathcal{R}_q$ = Family of minimal infeasible sets of passengers with respect to capacity limitation

Constants

- τ^e_{jk} = Travel time along arc (j, k) with elevator e + stop time at node j
- M^e_{jk} = Big constant
- l_j = lower bound of the time window at node j
- u_j = upper bound of the time window at node j

Variables

- x_c^e = 1, if passenger c is allocated to elevator e, 0 otherwise
- t_j = the time at which the service begin at j
- v_j^e = 1, if node j is allocated to elevator e, 0 otherwise
- y^e = 1, if the vacant elevator e goes upwards, 0 otherwise

Formulation of PACE (1/2)

$$
\begin{aligned}
\min \quad & \sum_{i \in P} \frac{1}{|P|} t_i \\
\text{s.t.} \quad & \sum_{e \in E'} x_c^e = 1 && \forall c \in C_1 \\
& x_c^e \in \{0, 1\} && \forall c \in C_1, e \in E' \\
& t_k \geq t_j + \tau_{jk}^e - (2 - v_j^e - v_k^e) M_{jk}^e && \forall e \in E', (j, k) \in A_e \\
& t_j = 0 && \forall j \in T \\
& e_j \leq t_j \leq l_j && \forall j \in P \cup D
\end{aligned}
$$

Formulation of PACE (2/2)

$$\sum_{c \in R^e} x_c^e \leq |R^e| - 1 \qquad \forall R^e \in \mathcal{R}_q$$

$$\sum_{c \in C_1} x_c^e \leq |C_1| y^e \qquad \forall e \in E'$$

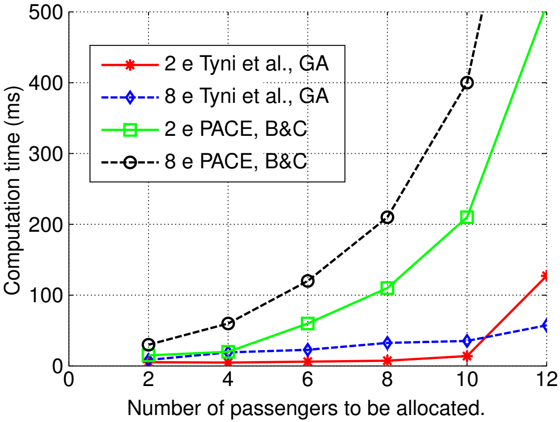
$$1 - y^{e+|E|} = y^e \qquad \forall e \in E$$

$$y^e \in \{0, 1\} \qquad \forall e \in E'$$

Solution mathematics

- Our formulation allows exact method
- We use modified branch-and-cut algorithm (B&C)
- We have analyzed valid inequalities for PACE (Ruokokoski et al. 2008):
  - Symmetry breaking constraints
    - Can be used in other vehicle indexed routing problems
  - Bounds on time variables

Computation time comparison



Conclusion

- Features of the PACE
  - Mixed integer linear formulation defined and solved by B&C
  - Globally optimal solutions
  - Computation time with B&C short up to 10 passengers to be allocated
  - In practice, PACE with B&C can be used in Destination Control
  - Can be used as a benchmark system in continuous call allocation
  - Forms a base for heuristic methods
- Future research
  - Implement our method into a simulation environment
  - Modification so that arbitrary heuristic method can be used
  - Modification so that passenger forecasts can be used in allocation

References

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