Dynamic batching for order picking in warehouses

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Introduction

- There is a need for more efficient ways to organize the order picking process as
  - the number of daily orders to be processed increase
  - the required lead time becomes shorter
- We propose/analyze
  - an analytical model for dynamic batching
  - the difference between static and dynamic batching

Dynamic batching

- Dynamic batching is characterized by combining product demand from multiple customer orders into one pick tour where new orders are continuously received.
- Updated picking instructions can be included in the current pick tours which allows pickers to be re-routed to pick for new orders even when they already started a pick tour.

Difference between static and dynamic batching

- Static batching
  - picker is assigned to a batch and the batch includes the orders to be picked by the picker
  - picker is assigned to the batch only after the batch has been completed.
- Dynamic batching
  - picker is assigned to a batch and then assigned to the next batch
  - picker is assigned to the next batch only after the batch has been completed.

Column generation algorithm

- In order to optimize the model we apply column generation.

Model description

- At time $t$, a customer order $i$ is either assigned to a current pick batch of an order picker (current batches) or to the backlog of orders for which an initial batching is made (future batches).
- The following model can be formulated

$$ \min \left( \frac{1}{|M_t|} \left( \sum_{j \in J} \sum_{k \in \Omega} c_{jk} \theta_{jk} + \sum_{c \in \Psi} c_{s} \delta_{s} \right) \right) $$

subject to

$$ \sum_{j \in J} \sum_{k \in \Omega} a_{jk} \theta_{jk} + \sum_{c \in \Psi} b_{c} \delta_{c} = 1 \quad i \in M_t, $$

$$ \sum_{j \in J} \sum_{r \in \Omega} \delta_{r} = 1 \quad j \in J, $$

$$ \theta_{jk}, \delta_{s} \in \{0, 1\} \quad j \in J, r \in \Omega, s \in \Psi. $$

- $\theta_{jk} = 1$ if batch $r_k$ is the current pick batch of picker $j$.
- $\delta_s = 1$ if batch $r_s$ is a selected future pick batch.
- $a_{jk} = 1$ if and only if order $i$ is included in current batch $r_k$ of picker $j$.
- $b_{c} = 1$ if and only if order $i$ is included in future batch $r_s$.
- $c_{s}, \bar{c}_s$ be the cost to pick the orders in batch $r_s$ for order picker $j \in J$ or future batch $r_s$.

Flow diagram dynamic batching

- Order arrival rate ($\lambda$)
  - Mean throughput time (s)
  - Order arrival rate ($\lambda$)
  - Mean total walking time (m)

Conclusions and further research

- Dynamic batching leads to significant improvements in throughput and other statistics.
- Well suited for e-commerce companies that deliver same-day.
- Possible extensions
  - Robust route planning
  - Joint transportation planning

Figure: The difference between static and dynamic batching, $\square$ denotes a storage location, $\square$ denotes a picking location for the current pick tour and $\square$ denotes a picking location for an incoming customer order that can be picked in the current pick tour in case of dynamic batching.