10 An efficient MILP formulation for the parallel-load retrieval in puzzle-based storage systems with simultaneous load movements

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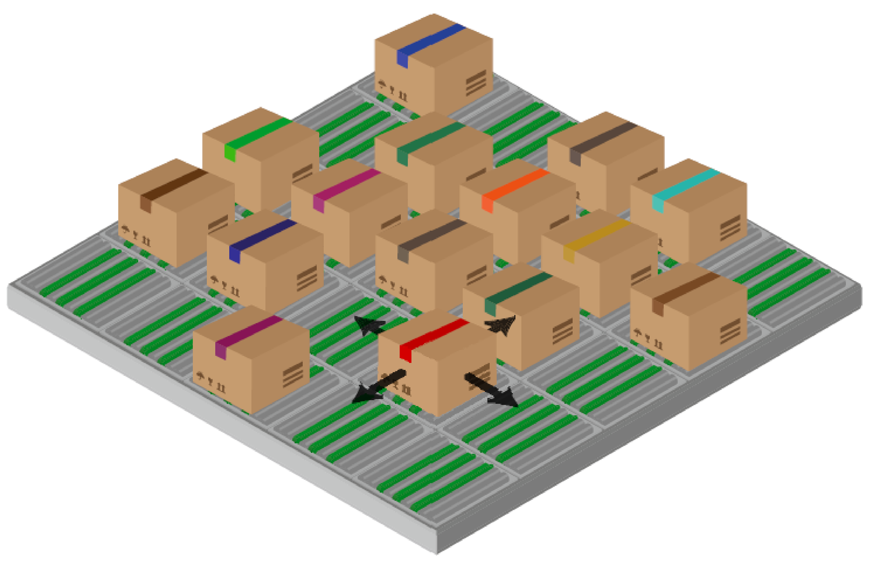
Environment: puzzle-based storage (PBS)



Main Objective: Optimal retrieval of multiple-items

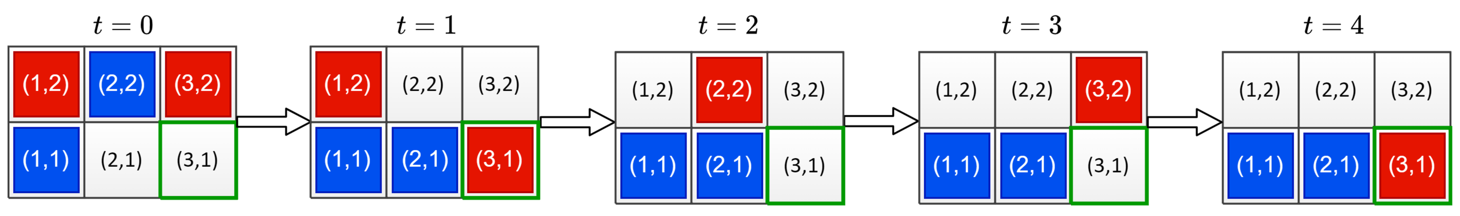
- Minimize (makespan, flowtime, # movements)

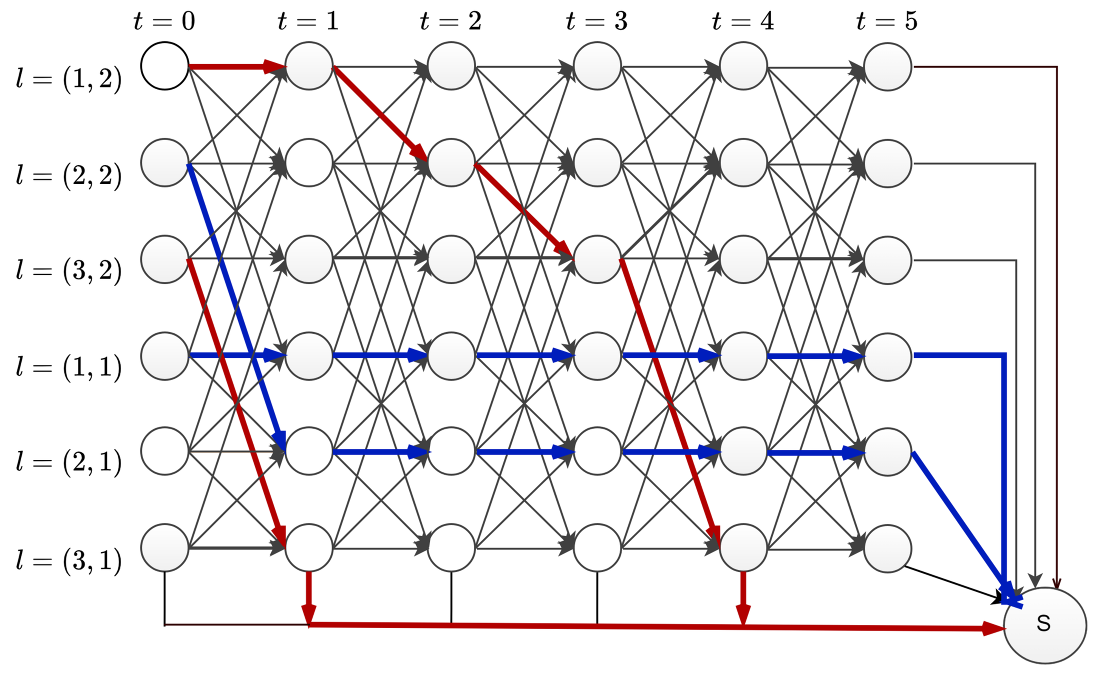
Assumptions

- Static problem
- Multiple loads retrieved in parallel
- Simultaneous moves
- Block movements

Methodology

- Time-expanded graph (TEG) based formulation
- 2-commodity (blocking and target loads) network flow model on the TEG





Conclusion & further research

- Fast (close to) optimal solutions for up to 100 cells
- Suitable for static order-picking problems in modular configurations
- Sorting systems?
- Dynamic environments?

Formulation

$$\min \alpha z+\beta \sum_{t=0}^{T}\sum_{l\in\mathcal{L}}\sum_{l'\in N'(l)} u_{l,l',t,1}+\gamma\sum_{k=1}^{2}\sum_{t=0}^{T}\sum_{l\in\mathcal{L}}\sum_{l'\in N(l)} u_{l,l',t,k} \quad (1)$$

subject to

$$\sum_{l\in N'(l)} u_{l,l',0,k}=1 \qquad \forall k\in\{1,2\}, l\in I_k \quad (2)$$

$$\sum_{l'\in N'(l)} u_{l',l,t-1,1}=\sum_{l'\in N'(l)} u_{l,l',t,1} \qquad \forall t=1,\ldots,T, l\in\mathcal{L}\backslash O \quad (3)$$

$$\sum_{l'\in N'(l)} u_{l',l,t-1,2}=\sum_{l'\in N'(l)} u_{l,l',t,2} \qquad \forall t=1,\ldots,T, l\in\mathcal{L} \quad (4)$$

Load movement

$$u_{l',l,T,1}=0 \qquad \forall l\in\mathcal{L}\setminus O, l'\in N'(l) \quad (5)$$

$$\sum_{k=1}^{2}\sum_{l'\in N(l)} u_{l,l',t,k}\le 1 \qquad \forall l\in\mathcal{L}, t=0,\ldots,T \quad (6)$$

$$\sum_{k=1}^{2}\left(\sum_{l'\in N(l)} u_{l',l,t-1,k}+\sum_{l'\in N(l)} u_{l,l',t,k}\right)\le 1 \qquad \forall l\in\mathcal{L}, t=1,\ldots,T \quad (7)$$

$$t\sum_{l'\in N(l)} u_{l,l',t,1}\le z \qquad \forall l\in\mathcal{L}, t=1,\ldots,T \quad (8)$$

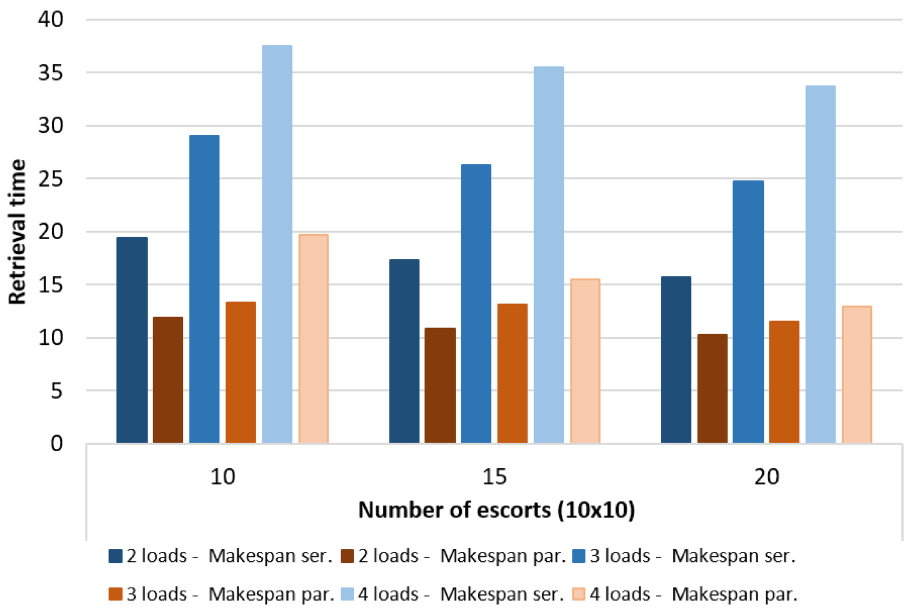
$$u_{l,l',t,k}\in\{0,1\} \qquad \forall l\in\mathcal{L}, l'\in N(l), t=0,\ldots,T, k\in\{1,2\} \quad (9)$$

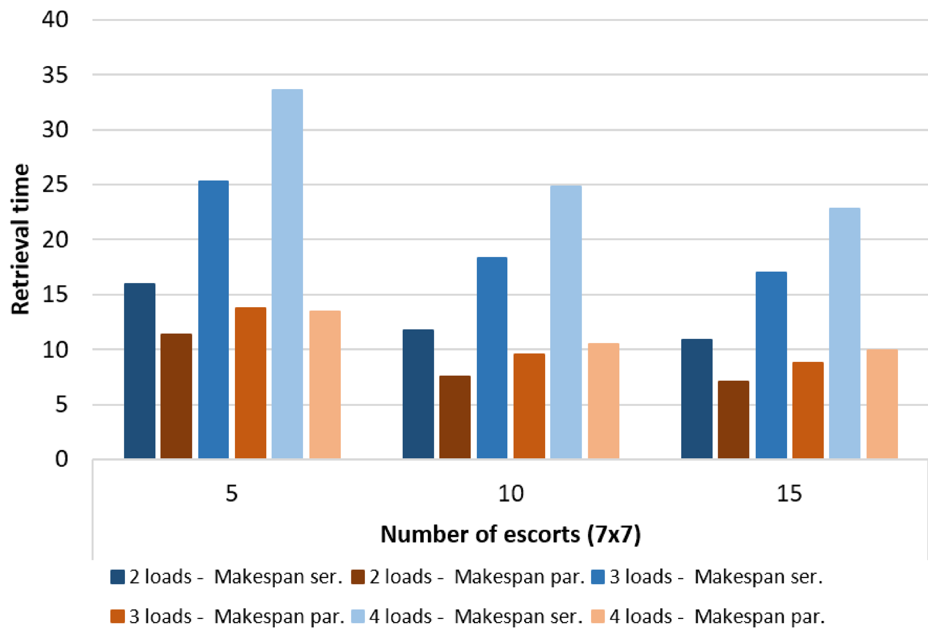
Block Movement [replace (7)]

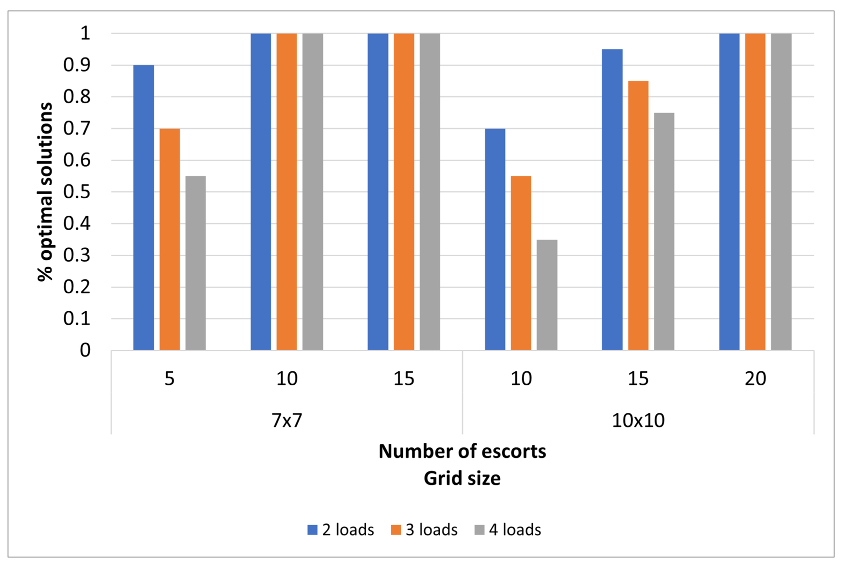
$$\sum_{k=1}^{2}(u_{l,l',t,k}+u_{l',l,t,k})\le 1 \quad \forall l\in\mathcal{L}, l'\in N(l), t\in\{0,\ldots,T\} \quad (10)$$

$$\sum_{k=1}^{2}\sum_{d\in\{-1,1\}}\left(u_{(x+d,y),(x,y),t,k}+u_{((x,y),(x,y+d),t-1,k}\right)\le 1 \qquad \forall (x,y)\in\mathcal{L}, t\in\{1,\ldots,T\} \quad (11)$$

$$\sum_{k=1}^{2}\sum_{d\in\{-1,1\}}\left(u_{(x,y+d),(x,y),t-1,k}+u_{((x,y),(x+d,y),t,k}\right)\le 1 \qquad \forall (x,y)\in\mathcal{L}, t\in\{1,\ldots,T\} \quad (12)$$







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