Collaborative optimization of berth allocation and yard storage in container terminals

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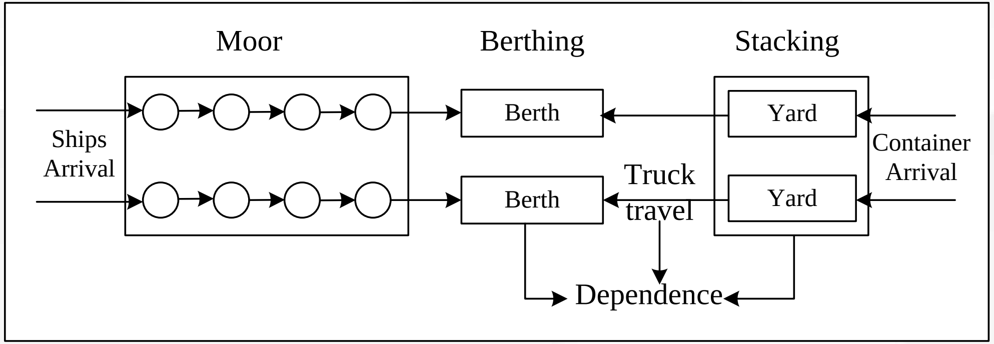
Contents

Problem description

- With the rapid increase of container traffic volume, container terminal systems have become more and more busy
- The efficiency of container handling and the utilization rate of terminal resources affect the efficiency of container terminal
- Berth and yard are the crucial parts, which the efficiency directly influences the terminal operation efficiency

Problem description



- The export containers to be loaded onto the ship are entirely already stacked on different yard
- The ships docked at a particular berth
- The export containers will be transferred using the trucks from the yard where the containers stack to the berth where the ship berthing

- Berth and quay crane
- Yard and quay crane
- Quay crane yard crane and trucks

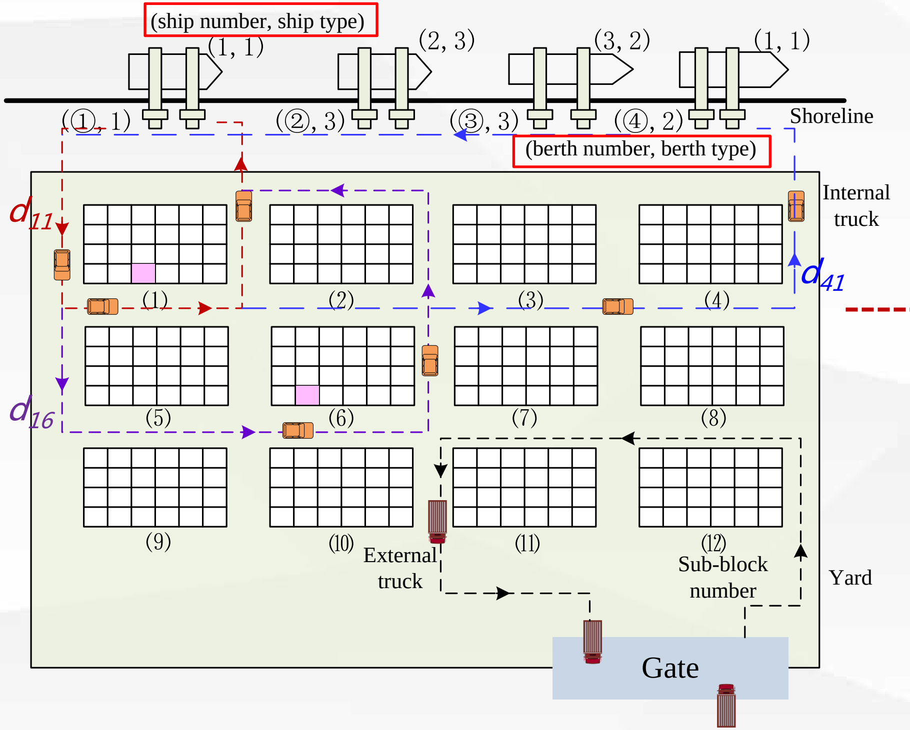
✓ Berth and yard

- Transshipment container terminals
- Certain berthing positions
- Certain yard stacking status

Collaborative optimization of berth and yard

Problem description

Berth + Yard



- Berthing position
- Yard stacking

interaction

Truck travel distance

- berth
- sub-block
- stacking number

- berth allocation
- yard storage

conclusion

Mathematical model

◻ Model assumptions

- ➢ The ship arrival information during the planning period is known, that is, the ship arrival time, ship departure time and the export containers loaded on the ships are known
- ➢ The initial stacking status of the terminal yard is known
- ➢ The export containers loaded on different ships can not stack in the same yard sub-block
- ➢ The congestion of trucks during the travel process is ignored

◻ Model establishment

- ✓ Mixed integer programming model—obtain the ship berthing position, export containers stacking position and stacking numbers

Mathematical model

Objection

— minimize the truck travel distance

$$\min S = \sum_i \sum_j \sum_k d_{jk} \cdot x_{ij} \cdot y_{ik} \cdot z_{ik}$$

- d_{jk}: distance from berth j to sub-block k
- x_{ij}: ship i berthing the berth j
- y_{ik}: container loaded on the ship i is stacked in sub-block k
- z_{ik}: the number of containers loaded on the ship i to stack in the sub-block k

Constraints

$$\sum_k z_{ik} = n_i$$

constraint of export container numbers

$$\sum_i y_{ik} = 1$$

$$\sum_k y_{ik} \le q_i$$

$$\sum_i z_{ik} \le Q_k$$

constraints of sub-block numbers and capacity

$$\sum_j x_{ij} = 1$$

$$g_i \cdot x_{ij} \le b_j$$

$$(x_{ij} + x_{i'j}) \cdot (g_{i'} - g_i) \cdot \delta_{ii'} \le (g_{i'} - g_i) \cdot \delta_{ii'}$$

$$(x_{ij} + x_{i'j}) \cdot (g_{i'} - g_i) \cdot (1 - \delta_{ii'}) \cdot (a_{i'} - l_i) \cdot (1 - \xi_{ii'}) \le (g_{i'} - g_i) \cdot (1 - \delta_{ii'}) \cdot (a_{i'} - l_i) \cdot (1 - \xi_{ii'})$$

constraints of berth allocation

$$(g_{i'} - g_i) \cdot \delta_{ii'} \cdot M \ge g_{i'} - g_i$$

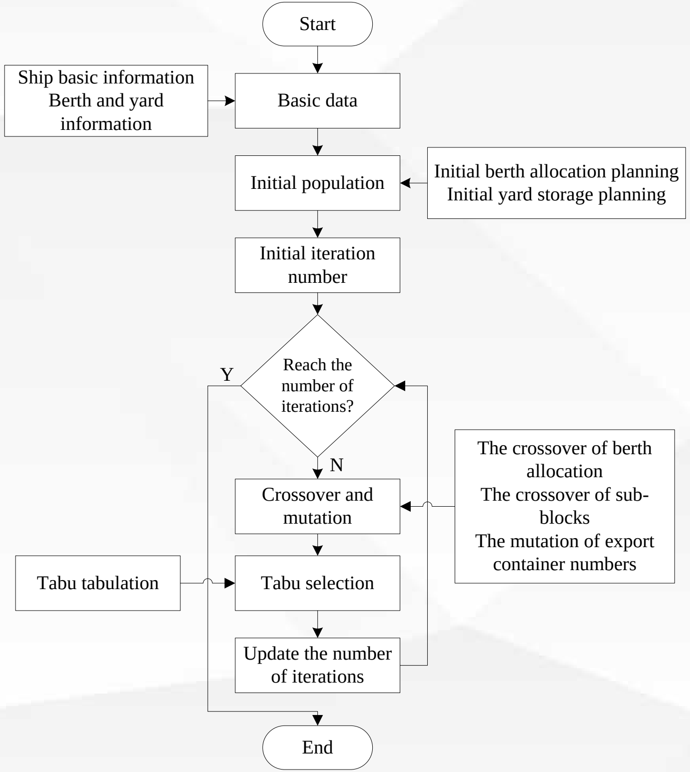
$$(a_{i'} - l_i) \cdot \xi_{ii'} \cdot M \ge a_{i'} - l_i$$

$$z_{ik} \ge y_{ik}$$

$$z_{ik} \le M \cdot y_{ik}$$

relationships among the variables

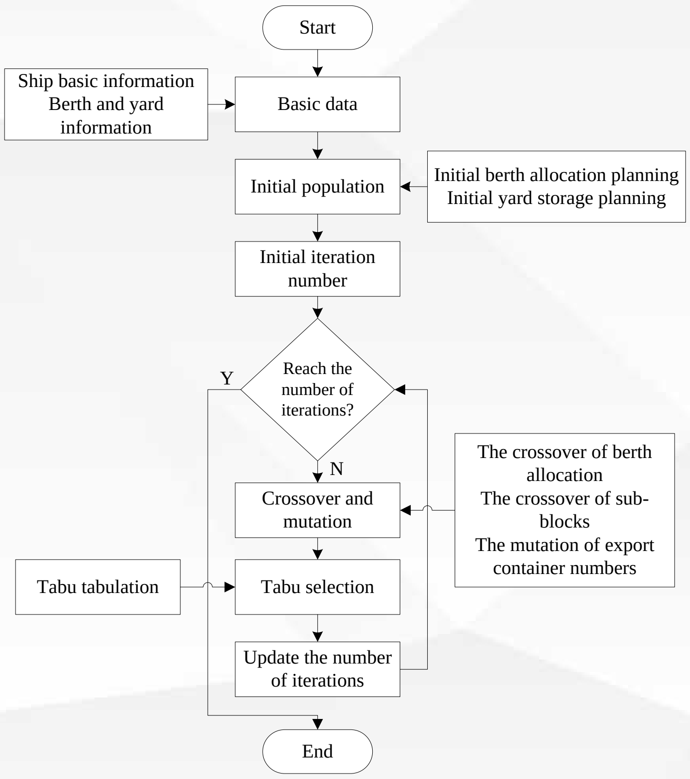
Algorithm design



Hybrid tabu genetic algorithm

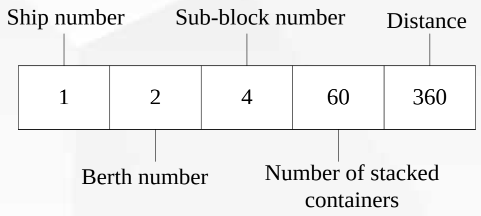
- Initial population
- Crossover and mutation
- Tabu selection
- The number of iterations

Algorithm design



Hybrid tabu genetic algorithm

- Initial population

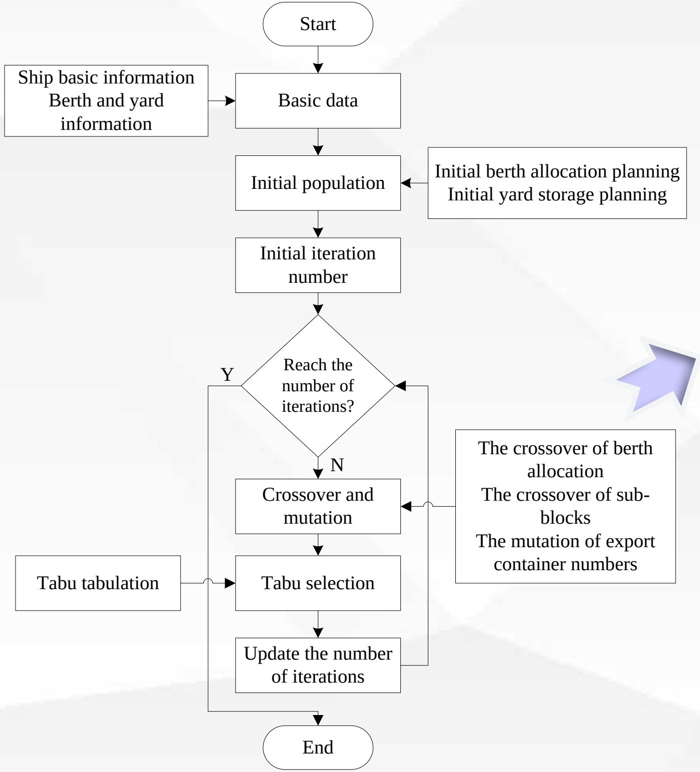


- Coded in real numbers

- Genetic elements

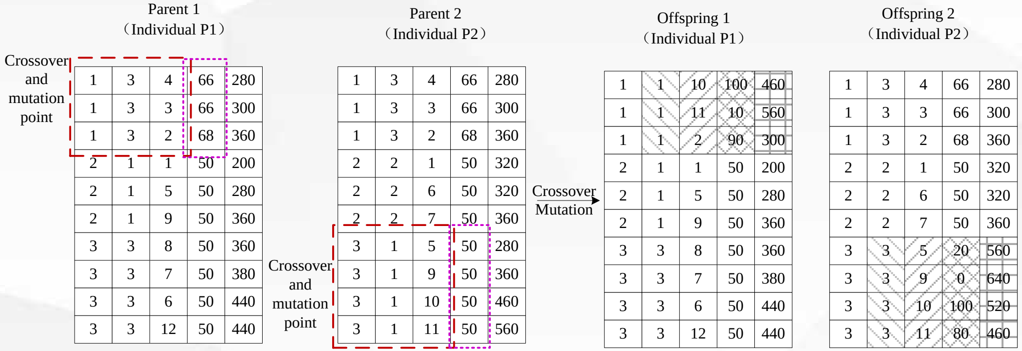
✓ The ship number
✓ The berth number
✓ The selected sub-block number of the export containers to be loaded on the ship
✓ The number of export containers to be stacked in the sub-block
✓ The distance from the berth to the sub-block

Algorithm design



Hybrid tabu genetic algorithm

- Crossover and mutation



Parent 1 (Individual P1)

1	3	4	66	280
1	3	3	66	300
1	3	2	68	360
2	1	1	50	200
2	1	5	50	280
2	1	9	50	360
3	3	8	50	360
3	3	7	50	380
3	3	6	50	440
3	3	12	50	440

Parent 2 (Individual P2)

1	3	4	66	280
1	3	3	66	300
1	3	2	68	360
2	2	1	50	320
2	2	6	50	320
2	2	7	50	360
3	1	5	50	280
3	1	9	50	360
3	1	10	50	460
3	1	11	50	560

Offspring 1 (Individual P1)

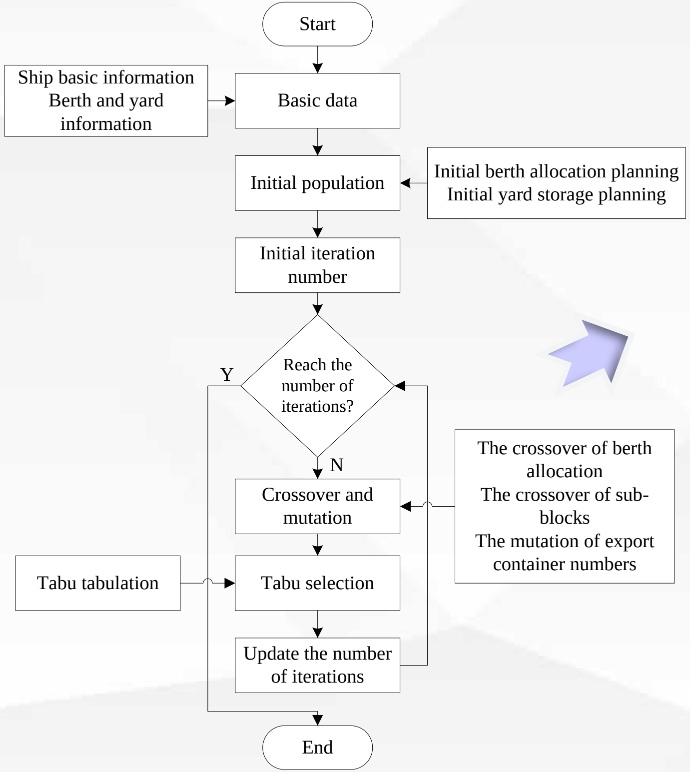
1	1	10	100	460
1	1	11	10	560
1	1	2	90	300
2	1	1	50	200
2	1	5	50	280
2	1	9	50	360
3	3	8	50	360
3	3	7	50	380
3	3	6	50	440
3	3	12	50	440

Offspring 2 (Individual P2)

1	3	4	66	280
1	3	3	66	300
1	3	2	68	360
2	2	1	50	320
2	2	6	50	320
2	2	7	50	360
3	3	5	20	560
3	3	9	0	640
3	3	10	100	520
3	3	11	80	460

- ✓ The crossover is mainly aimed at the berths where the ship docks and the sub-blocks where the export containers are stacked
- ✓ The mutation is mainly aimed at the number of export containers in each sub-block

Algorithm design



Hybrid tabu genetic algorithm

- Tabu selection

1	2	3	4	5	6	······	np-2	np-1	np

  - ✓ Arrange the individuals in order from large to small
  - ✓ Compare the fitness function of new individuals with initial individuals

- The number of iterations

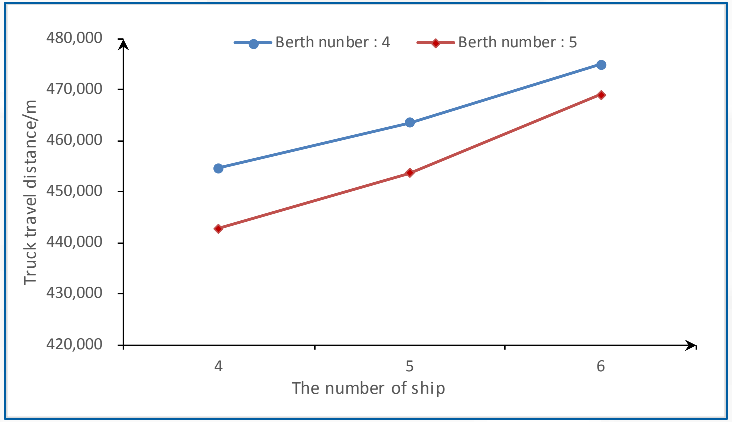
  - ✓ Set the maximum number of iterations
  - ✓ Record the shortest truck travel distance and the corresponding berth number, sub-block number and the number of export containers stacked in each sub-block

Numerical experiments

Examples analysis

The same berth scene

- ✓ The types and numbers of berth are the same
- ✓ When the number of berth is 4, the berth 1 is the small berth, the berth 2 and 3 are the middle berth, and the berth 4 is the big berth
- ✓ When the number of berth is 5, the berth 1 is the small berth, the berth 2 and 3 are the middle berth, and the berth 4 and 5 are the big berth.



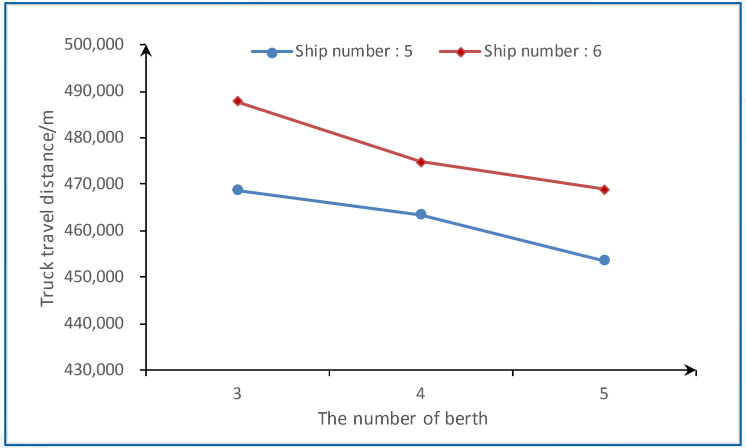
concl usion

- We can obtain the optimal solution quickly, which implies that the model is valid and the algorithm is reasonable.
- When the number of berth is the same, the more the number of ship is, the greater the truck travel distance. Because the export containers loaded on the different ships must stack in different sub-blocks. When the number of ships becomes more and more, there are fewer valid sub-blocks with shortest distance to choose. Therefore, the total truck travel distance becomes greater.

Numerical experiments

The same ship scene

- ✓ The types and numbers of ship are the same in different examples
- ✓ When the number of ship is 5, the ship 1 and 2 are the small ship, the ship 3 and 4 are the middle ship, and the ship 5 is the big ship
- ✓ When the number of ship is 6, the ship 1 and 2 are the small ship, the ship 3 and 4 are the middle ship, and the ship 5 and 6 are the big ship



conclusion

- We can obtain the optimal solution quickly, which implies that the model is valid and the algorithm is reasonable.
- When the number of ship is the same, the more the number of berth is, the shorter the truck travel distance. Because the number of export container and the ship are the same, if the selected berth is more, the ship can select the berth with the shorter distance from berth to sub-block.

Conclusion

01

With the increase of the ship number and the decrease of the berth number, the truck travel distance becomes greater

02

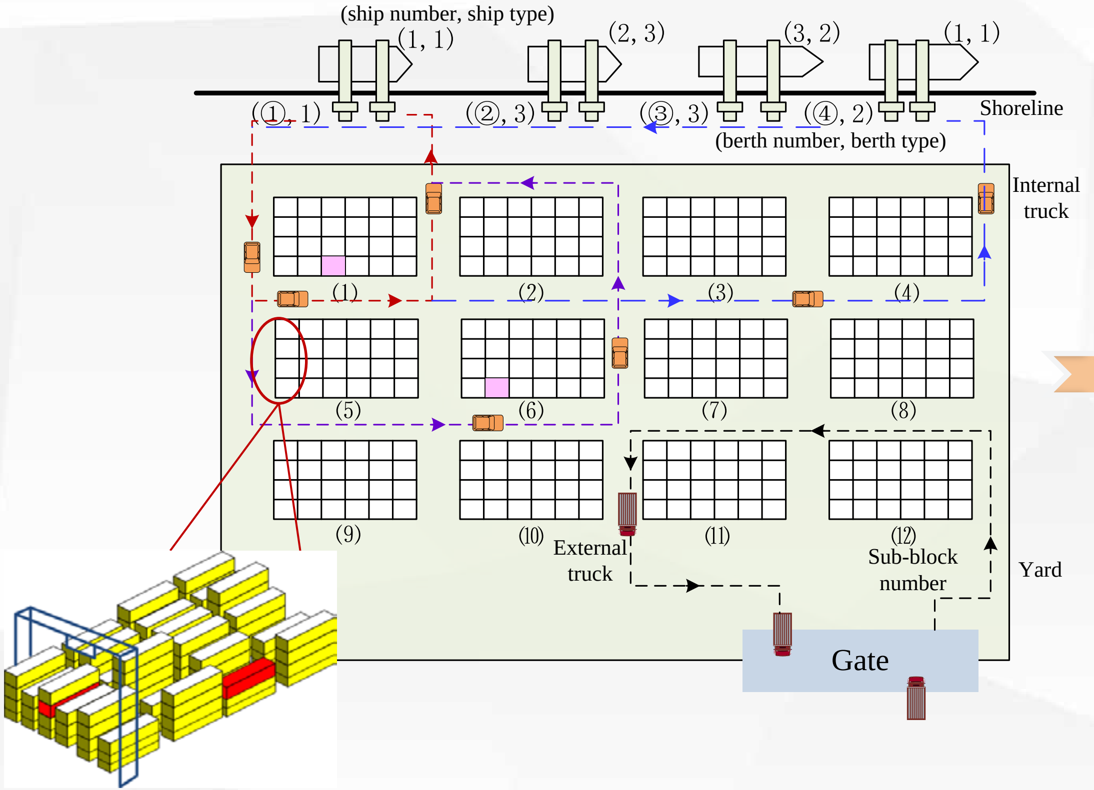
The collaborative optimization of berth and yard can minimize the truck travel distance

03

Provides the decision support for terminal operators

Outlook

Berth type + Ship type + Time window



- Berthing position
- Yard stacking
- Loading sequence

interaction

Truck travel distance+ rehandles

- Berth allocation
- Yard storage
- Loading sequence

Conclusion

Thank you!

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