Genetic Algorithm to Dry Dock Block Placement Arrangement Considering Subsequent Ships

Chen Chen[1], Chua Kim Huat[2], Yang Li Guo[3]

Abstract

In this paper, a genetic algorithm (GA) is presented in order to optimize dry dock block placement arrangement on consideration of subsequent ships. Dry dock is mathematically expressed by grid model. GA chromosome is to represent dock blocks placement pattern based on the grid model. The chromosomes are filtered through selection criteria, those satisfying all constraints further form up chromosome clusters. A chromosome cluster represents dock blocks placement arrangement for a single dock to a series of ships. Fitness function is designed to choose out the best chromosome cluster which corresponds to the minimum dock blocks placement changing requirements. The approach is justified by an experimental case.

Keywords: block arrangement, dock operation, genetic algorithm, subsequent ships.

Introduction

Docking operation is one of most frequent activities in shipyard. However, the existing dry dock arrangement practice heavily relies on dockmaster's experience. It lacks an optimized dock arrangement from a telescopic view. A comprehensive description of the procedure doing docking operation analysis is given in reference [1-9].

In dock planning, dock block arrangement is a major focus. Dock blocks are to support the deadweight of the ship and generally by far the greater portion of it is carried on the center line or keel blocks. Dock blocks arrangement requires dock dry up and dewatering a dock takes one or two days, but if the preparation work for the next ship can be paralleled processed during the current docked ship's repairing time, then the necessity of dock dry up can be significantly reduced, thus shortens ship docking time.

Genetic Algorithm (GA) has received considerable attention regarding their potential as novel optimization technique, moreover, GA is very effective and efficient to deal with inherently intractable problems called NP-hard problems. Chen and etc. [10,11] have successfully applied GA on nesting problem. So GA is also selected for this problem, since it is not likely that an efficient exact solution procedure exists, leading an optimal solution in bounded computation time. GA is like a heuristic method in that the optimality of the answers cannot be determined. They work on the principle of evolving a population of trial solutions over a number of iterations, to adapt them to the fitness landscape expressed in the objective function.

The solution procedure for dock block placement arrangement problem is first to express the dock mathematically by grid model, then to apply GA for optimum block arrangement solution. The GA chromosome is binary coded with 1 indicates the existence of dock block

[1] Engineer, Sembcorp marine Technology Pte. Ltd, part-time PhD student in National University of Singapore, cchen@smtpl.com.sg
[2] Associate Professor, National University of Singapore, ceedavid@nus.edu.sg
[3] Dock Section Senior Manager, Jurong Shipyard, lgyang.dkd@jspl.com.sg

and 0 indicates empty and the size of it is the total number of the grid nodes in the dock's mathematical model, so that a whole dock block placement pattern can be represented. A single dock's block placement arrangement for a series of ships is represented by a chromosome cluster. A chromosome cluster is a group of chromosomes satisfying all constraints. So, before forming up a chromosome cluster, the chromosomes have to be filtered through selection criteria. The fitness function is designed to search for minimum block placement changing needs. Finally, a best chromosome cluster is screened out through evolution of several generations.

The application of this approach is illustrated in an experimental case. Below gives detail explanation.

The solution procedure

Dock model

The dry dock should be expressed in a mathematical model, based on which numerical calculation can be realized. The dock space is thus separated into small grids, and the grid nodes are represented in numbers. The node of each grid is the location going to place the dock block. Fig.1 shows a dock grid model, and Fig.2 shows a dock block placement pattern.

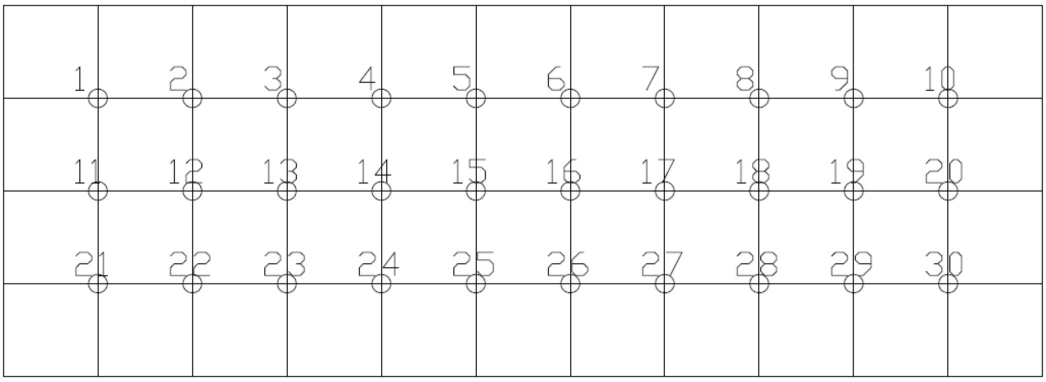


Fig.1. Dock model

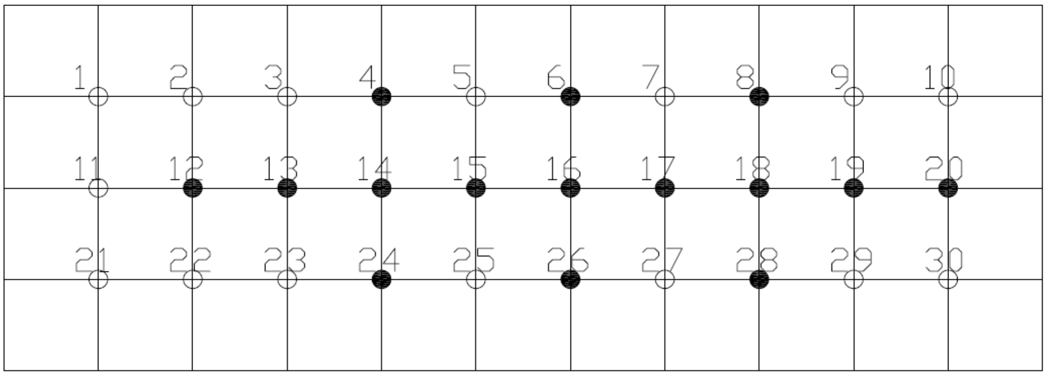


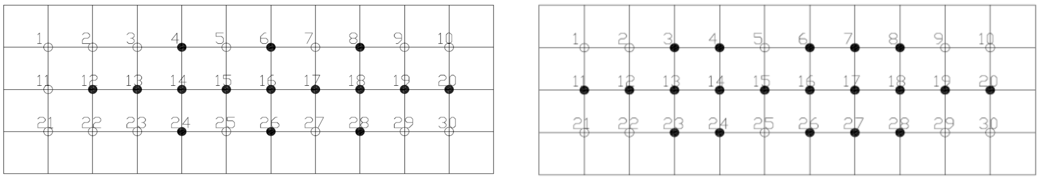
Fig.2. Dock block placement pattern

Genetic Algorithm (GA)

Chromosome and chromosome cluster

GA chromosome is binary coded, with 1 represents the existence of dock block and 0 represents empty. The size of GA chromosome is the number of grid nodes in the dock model. For example, a chromosome {0,0,0,1,0,1,0,1,0,0,0,1,1,1,1,1,1,1,1,1,0,0,0,1,0,1,0,1,0,0}, with the property {S,S,S,S,S,S,S,S,S,S,K,K,K,K,K,K,K,K,K,K,S,S,S,S,S,S,S,S,S,S} can represent the dock block placement pattern described in Fig.2. The property is predefined when defining the dock model, S indicates side block, and K indicates keel block.

Taking into account subsequent ships, chromosome cluster is used to represent dock block placement arrangement for a single dock accommodating to a sequence of ships. A chromosome cluster is a combination of chromosomes which satisfy constraints. Fig.3 shows a chromosome cluster for a two ship case. Because of symmetry of the placement pattern, the chromosomes are expressed in short.



1st docking ship   2nd docking ship

Fig.3. Block arrangement for two ships

{0,0,0,1,0,1,0,1,0,0,0,1,1,1,1,1,1,1,1,1 || 0,0,1,1,0,1,1,1,0,0,1,1,1,1,1,1,1,1,1,1}

{S,S,S,S,S,S,S,S,S,S,K,K,K,K,K,K,K,K,K,K || S,S,S,S,S,S,S,S,S,S,K,K,K,K,K,K,K,K,K,K}

GA operators

The GA operators are acting on these chromosome clusters. The operators of GA include: selection, cross-over, rotation, mutation, and fitness function.

Selection

The next generation is formed from two parts: 1) elitists selected from the current generation on a rank-based fashion, and 2) offspring which are evolved from parents selected from current generation by cross-over, rotation and mutation operators.

Cross-over

If the crossover point is chosen at 5 (indicate by "||") then examples of two parents could be:

P1: {0,0,0,1,0,|| 1,0,1,0,0,0,1,1,1,1,1,1,1,1,1}
P2: {0,0,0,1,1,|| 1,1,1,0,0,0,1,1,1,1,1,1,1,1,1}

then the two offspring would look as follows:

O1: {0,0,0,1,0,|| 1,1,1,0,0,0,1,1,1,1,1,1,1,1,1}
O2: {0,0,0,1,1,|| 1,0,1,0,0,0,1,1,1,1,1,1,1,1,1}

Rotation

If the rotation point is chosen at 5 (indicate by "||") then example could be:

P: {0,0,0,1,0,|| 1,0,1,0,0,0,1,1,1,1,1,1,1,1,1}

O: {1,0,1,0,0,0,1,1,1,1,1,1,1,1,0,0,0,1,0}

Mutation

If the mutation point is chosen at 5, then example could be:

P: {0,0,0,1,0,**1**,0,1,0,0,0,1,1,1,1,1,1,1,1,1}

O: {0,0,0,1,0,**0**,0,1,0,0,0,1,1,1,1,1,1,1,1,1}

Fitness function

The fitness function is designed to find out the chromosome cluster which has the minimum dock block changing requirement. For a chromosome cluster given above:

{0,0,0,1,0,1,0,1,0,0,0,1,1,1,1,1,1,1,1,1 || 0,0,1,1,0,1,1,1,0,0,1,1,1,1,1,1,1,1,1,1}

Compare the first chromosome with the second chromosome, and count when genes are different. The example gives 5, means we need to make 5 changes in the first ship's block arrangement layout pattern to accommodate to the docking requirement of the second ship.

Finally, select the least changing block placement pattern as the best one.

Selection criteria

Before forming up chromosome clusters, the chromosomes are filtered through selection criteria. The criteria include geometric constraint and strength constraint.

Geometric constraint

The geometric constraint include ship position in the dock, ship's flat bottom boundary, location of internal major structural members, and other constraint such as dock space accessibility and so on.

Dock block capacity and stress constraint

The block should support ship weight plus potential overloading caused by wind and the exertion of excessive pressure due to ship overhang at prow and stern.

Experimental Case

Consider a three ships' case, suppose the block layout for each ship should comply with below criteria:

Ship 1	There must have no block on node 1 and node 2, and there must have block on the last node. Number of keel blocks >=3, number of side blocks =4
Ship 2	There must have block on node 1, node 2 and the last node. Number of keel blocks = 4, number of side blocks =4

Ship 3	There must have no block on node 1, and there must have blocks on node 2 and the last node. Number of keel blocks >=3, number of side blocks =4

The dock space is assumed to be a rectangle, and its dimensions are as below:

Dock Length	20 meter
Dock Width	10 meter

Then the dock space is built into a 5×4 grid model, totally 12 grid nodes. The grid nodes are labeled with serial numbers. If coordinate origin is set on the bottom left corner of the dock space, then the coordinates of grid nodes are obtained. Fig.4 gives a dock model, in which keel blocks are designed to be placed in the regime from node 5 to node 8.

Node Code	X (meter)	Y (meter)	Keel / Side Blok?
1	4	2.5	S
2	8	2.5	S
3	12	2.5	S
4	16	2.5	S
5	4	5	K
6	8	5	K
7	12	5	K
8	16	5	K
9	4	7.5	S
10	8	7.5	S
11	12	7.5	S
12	16	7.5	S

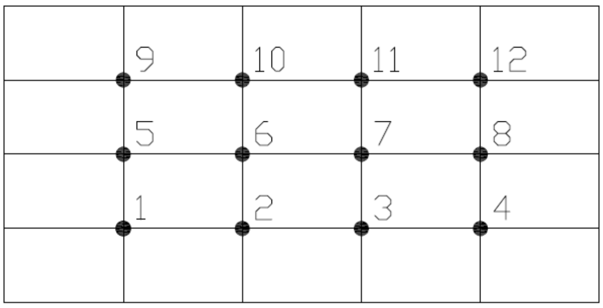
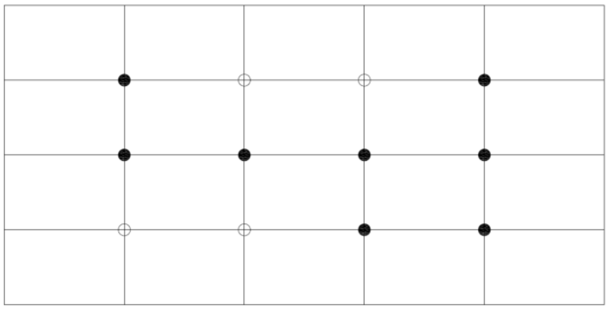


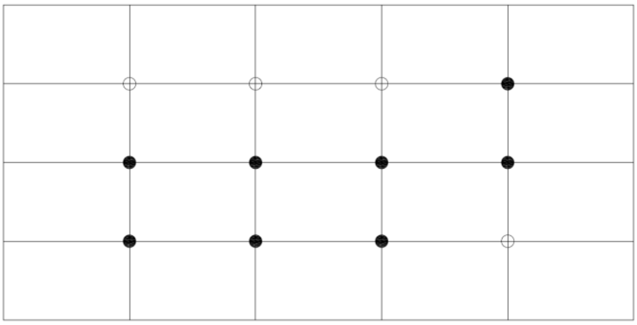
Fig.4. Dock model for the experimental case

Optimum dock block arrangement plan can be reached as illustrated in Fig.5.

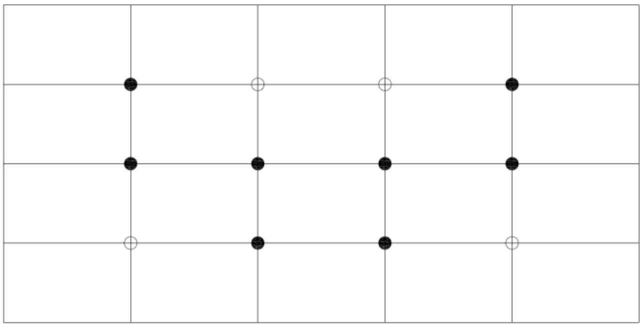
Node Code	Ship 1	Ship 2	Ship 3
1	0	1	0
2	0	1	1
3	1	1	1
4	1	0	0
5	1	1	1
6	1	1	1
7	1	1	1
8	1	1	1
9	1	0	1
10	0	0	0
11	0	0	0
12	1	1	1



Ship 1



Ship 2



Ship 3

Fig.5. Optimum block layout pattern

To prepare the dock block arrangement for ship 1 to ship 3, the minimum changes is 6 steps.

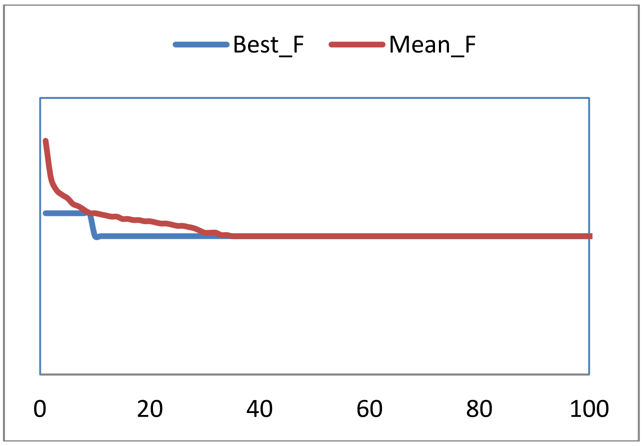


Fig 6. Convergence line

The optimum block layout arrangement can be reached quickly within 100 iterations.

Conclusion

In this paper, an approach to find the optimum dock block placement arrangement for several ships in queue is illustrated. An experimental case is shown to justify the approach. The experimental case shows the great potential of this approach working on the real cases. In our future work, we will explore the approach for practical application.

Reference

1. Yang Li Guo, 2006. *Study of dry-dock operation*, MSC thesis, School of Marine Science & Technology University of Newcastle Upon Tyne.

2. Henry F. Cornick, 1958. Doc*k and harbor engineering Volume 1 – the design of docks – Chapter 5*, Charles Griffin & Company Limited.

3. Henry F. Cornick, 1962. *Dock and harbor engineering Volume 4 – Construction – Chapter 22*, Charles Griffin & Company Limited.

4. B. K. Mazurkiewicz, 1980. *Design and construction of dry docks*, Trans Tech Publications.

5. Gregory P. Tsinker, 1986. *Floating ports – design and construction practices*, Gulf Publishing Company.

6. Gregory P. Tsinker, 1995. *Marine structures engineering – specialized applications*, Chapman & Hallm.

7. Gregory P. Tsinker, 2004. *Port engineering-planning, construction, maintenance, and security*, John Wiley & Sons Inc.

8. John W. Gaythwaite, 2004. *Design of marine facilities for the berthing mooring, and repair of vessels*, 2nd edition, American Society of Civil Engineers.

9. David J. House, 2003. *Dry docking and shipboard maintenance – a guide for industry first edition*, Witherby & Co. Ltd.

10. Chen Chen, Chua Kim Huat, Wee Keng Hwee, 2011. *Polygon Nesting Using Genetic Algorithm*, Proceedings of the 5th ABB Cup National Automation Thesis Contest, China.

11. Chen Chen, Chua Kim Huat, 2011. *Optimized Shipyard Steel Plate Cutting Plan Based on Genetic Algorithm*. The 2nd International Conference on Engineering, Project, and Production Management, Singapore.