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Smart Container Stacking in the Yard

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Abstract

The workloads at seaport container terminals are increasing; thus, to enhance performance, the focus on improving container stacking is argued to be an integral factor that should be studied. The main problem is the number of unproductive moves of handling containers. A well-planned stacking area is argued to be a key requirement in order to increase the performance of the terminal operations and assist in maximum utilization of existing resources. In this work, we investigated and then propose the best possible solution by evaluating GAs in order to minimize the unproductive moves often witnessed in terminal operations. A discrete-event simulation CSS model has been developed to study the inbound container stacking that considers in the model the following: the working of the yard crane, Automated Guided Vehicles, delivery trucks and obtain the simulation-based results of GA. We propose a mathematical model to minimize the container handling costs during stacking and retrieval operations in the container terminal yard.

Keywords: Container Terminal; Automated guided vehicle (AGV); Genetic Algorithm (GA); Container stacking

1. Introduction

A container terminal has three main areas. One is quayside where the ships come and dock, a quay crane load and unload the container from ship and load on AGVs or lifting vehicles on another side, other is landside where a railway system for transferring the containers and truck stand where trucks wait for the turn to load container for delivery and the third one is yard where containers are stacked and retrieved. Yang J. H. and Kim, K. H. (2006) said that the increasing demand of global transportation necessitates the concern of productivity of container yards. The operational efficiency of seaport container terminal is influenced by the performance of its sub-systems. It is necessary to investigate all sub-systems but mainly focus on the most important part of the system which is the container yard. If that part is working well, then it means we achieve maximum efficiency in the form of time and cost reduction of a container terminal because container handling in the yard is very expensive and especially in the case of re-handling or unproductive moves in stacking system. There are many operational rules to achieve the operational efficiency at the terminal.

The container yard plays a vital role in the terminal in that it affects the overall performance of seaport container terminal. According to Miguel A. Salido et al. (2009), a container stack is a type of temporary store where containers await further transport by truck, train or vessel. The container yard is a storage area where containers stacked and retrieved for further delivery. Gamal Abd El-Nasser A. Said and El-Sayed M. El-Horbaty (2015) stated that the container yard serves as a buffer for loading, unloading, and transshipping containers. Ceyhun Guven et al. (2014) stated that the yard is a temporary storage area where containers remain until transported to their next location by truck, train or vessel. According to Phatchara Sriphrabu et al. (2013), container stacking is a major problem at a container terminal because the container location assignment affects the operating time of the container terminal. Chuanyu Chen et al. said that the decisions on the storage locations of containers directly affect the allocation and scheduling of yard cranes, the dispatching of the prime movers and indirectly affect the efficiency of Quay cranes. We need to focus on this part of seaport container terminal and to make it more efficient and intelligent to save time and money both. According to Riadh Moussi et al. (2011), to increase the efficiency of a container terminal, containers are optimally stacked in the storage areas in the form of stacks.

The major problems in container stacking system are the number of container's reshuffling/unproductive moves which occur due to not properly arranged stacking system. According to Ceyhun Guven et al. (2014), an unproductive move of a container required to access another container stored underneath and has a negative effect on the operational efficiency of the container terminal in terms of cranes and operators' workloads. Wei Jiang et al. (2011) stated that the additional movement which assigns the position of a blocking container is called a reshuffle or unproductive move. Amir Hossein Gharehgozli et al. (2014) said that the containers' reshuffles at a container terminal is time-consuming and increases a ship's berthing time. This is the main reason of other problems which occur like delay in operational time at the terminal, cost increases and late container's delivery etc. Phatchara Sriphrabu et al. (2013) stated that a relocation is most important to storage and pickup operation in block stacking because it affects the handling cost. According to Niraj Ramesh Dayama et al. (2014), the total cost incurred in container handling operations is the sum of the (vertical) stack rearrangement costs and the (horizontal) crane movement cost. Yang J. H. and Kim, K. H. (2006) said that the block stacking is an efficient way for usage of storage space in the container yard. A block size is a storage space unit in the container yard at seaport terminal. Phatchara Sriphrabu et al. (2013) said that the block size affects yard crane operation and productivity. According to Gamal Abd El-Nasser A. Said and El-Sayed M. El-Horbaty (2015), the container yard is divided into blocks: each container block is served by one or more-yard cranes (YC). A block is the product of a bay, row, and tier (express as Tone Equivalent Unit/TEU). Tao Chen (1999) said that higher container stacking in the yard will inevitably influence most of the operations carried out in the terminal. Miguel A. Salido et al. (2009) stated that the main efficiency problem for an individual stack is to ensure easy access to containers at the expected time of transfer. According to Jose M. Vidal and Nathan Huynh (2010), Import containers are typically stored in the available designated blocks.

1.1. Research Contributions

The main contribution in this work is discrete-event simulation model for inbound container stacking in the yard and applying Genetic Algorithms(GA)with high fitness value parameters to determine the appropriate location for inbound container stacking so as to minimize the container's reshuffle. The results from the simulation experiments using GA have been compared to Tabu Search's results. This design is based on the delivery date of the container. The integration between the fitness value and handling cost has been shown by using GA.

2. Literature Review

The literature on container reshuffling and stacking problems in the yard area at seaport container terminal has been reviewed. For this purpose, a literature review has been conducted. We have used keywords and search strings related to the problem via online databases to find the articles. The classified data from these studies according to KPI's is mention at the end of this paper.

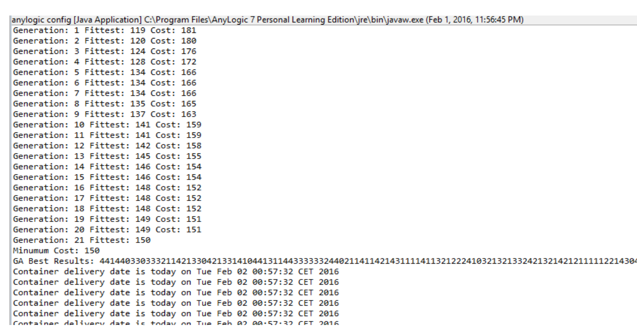
Phatchara Sriphrabu et al. (2013) said that the container stacking problem in container terminal is an important part of port management. The simulated results based on GA are more efficient than FIFS (First-in First serve) solution for containers' location assignment with minimized total lifting time. The given solution is a comparison of two simulation models and results that showed the best one model is using GA. Amir Hossein Gharehgozli et al. (2014) proposed a decision-tree heuristic approach to minimize the expected number of reshuffles when containers should be stacked in a block. They used a heuristic algorithm that uses the results of a stochastic dynamic programming model built on work of Kim, Park and Ryu (2000). The proposed approach-based model's results are same but much faster to solve the small-scale problem as compared to other DT heuristic approach. For large scale problems, proposed approach performed better than common heuristic [Gharehgozli, A.H., et al. 2014). Chuanyu Chen et al. 2003, presented a comprehensive survey of the operations in container terminals and their simulation and optimization issues from a hierarchy point of view. They discussed the management of automated terminals by decomposing it into separate types of decision-making to solve the problems (Chuanyu Chen et al. 2003). In Wei Jiang et al. (2011) they had done a simulation study on reshuffling problem in logistics operations of a container terminal yard. Their simulation model for container stacking, reshuffling and retrieving in one bay for static and dynamic environments are evaluated. Their model is highly extensible and well-suited for the stacking and retrieving operations in container terminals. Ndeye

Fatma Ndiaye et al. (2014) proposed a linear mathematical model for operational constraints and minimizing the total distance traveled by straddle carriers between the quays and the container yard, and determined the exact location assigned to each container without causing reshuffle. They proposed also a hybrid ant colony and genetic algorithm (HAC/GA) to solve the container storage problem at port terminal and made a comparison to CPLEX, the experiment showed that the HAC/GA's results are better than CPLEX's results (Ndeye Fatma Ndiaye et al. (2014). Kun-Chih Wu et al. (2009) proposed a tabu search algorithm to solve the container handling the static problem (arriving container is not allowed during the period of retrievals). Make a comparison with depth-first branch and bound (B&B) to check the efficiency. The results show that the average gap between tabu search and B&B is 0.4% and computational time is effective. Shuding Kang and Weimin Wu (2015) designed a GA to solve the container's location allocation problem (CLAP). They took 20ft normal containers and ignore the weight of containers. The proposed GA can provide the solution of the minimum number of reshuffles and the balance between the bays (Kang and Wu, 2015). In work by Jana Ries et al. (2014) they introduced the fuzzy logic approach for import-dry containers with regards to minimizing relocation moves and distance traveled of the yard equipment. The experimental results show that the proposed fuzzy logic approach is a good strategy to assign any incoming container to a preferable location in the yard. Mazen Hussein et al. (2012) identified that the reshuffling of containers according to weight has minimized the energy consumption by using GA and Global Retrieval Heuristic approach. This solution is reducing the cost just 5% only but for real world problem, the delivery time of the container is one of the most important factors to cost reduction. Xiaoming Yang et al. (2015) developed a GA to minimize the unbalance workload and unnecessary movement of yard crane in stacking area. The results of the experiment show the effectiveness and robustness of the GA (Xiaoming Yang et al. (2015). I.Ayachi et al. (2010) presented a GA to determine an optimal containers arrangement which respects customers' delivery deadlines, reduces the re-handling of containers and minimizes the stop time of the container ship. The GA can solve the problem with different container's types (dry, open side, open top, tank, empty and refrigerated). The proposed approach was compared to Last in First out (LIFO) algorithm and has recorded good results [18]. Mohammad Bazzazi et al. (2009) proposed an effective GA to solve an extended storage space allocation problem to balance the workload between blocks in order to minimize the storage/retrieval times of containers. The obtained results from the extended model and proposed GA showed a relative gap about 5% between GA and optimum solution in term of the objective function value. Luiz Antonio Carraro and Leandro Nunes de Castro (2012) proposed MRCLONALG (Metaheuristic Clonal Selection Algorithm) to minimize the number of reshuffles in container stacking operations involving piles of containers. The performance of proposed model was evaluated through simulation and compared the results with MRIP model. The MRIP model may always give an optimal solution but its computing time for large instances is too high. The proposed algorithm can give a competitive performance with a low computational cost in time. In work byt Jonas Ahmt et al. (2015) they proposed a new Mixed Integer Programming (MIP) model for the container positioning problem. They said that this model together with the rolling time horizon-based solution is to date the most efficient mathematical programming model to solve this problem. This approach can better reflect the real application as to plan for containers for which the information about arrival or departure times is known with certainty. Shell Ying Huang et al. (2014) proposed several algorithms for yard crane deployment among the rows of yard blocks in a container storage yard to minimize vehicle waiting times and the number of overflow jobs. They showed an experiment in two situations. (1) When the number of cranes is less than the number of yard blocks, deploying YCs in the proposition to the number of jobs in each row (3L-Pro-Jobs) is the best. (2) When the number of yard cranes is equal to or more than the number of yard blocks using the apparent workload approach, (3L-AW) will be performed best [22]. Kun-Chih Wu and Ching-Jung Ting (2012) identified two novel heuristic approaches for reducing container reshuffle operations at container yard. The first heuristic, Lowest Absolute Difference (LAD), relocates containers based on the difference of retrieval priorities between a reshuffled container and other containers. The second heuristic is Group Assignment Heuristic (GAH), addresses a group of reshuffled containers simultaneously according to their retrieval priorities. They compared proposed approaches with 02 other heuristic approaches including Reshuffle Index (RI) and expected number of additional relocations (ENAR). The result showed that the GAH outperforms other heuristics. Kap Hwan Kim and Hong Bae Kim (1998) developed a cost model for the determination of the space requirement and the number of transfer cranes in import container yard to include the space cost, the fixed cost of transfer cranes which correspond to the investment cost, the variable cost of transfer cranes and outside truck which is related to the time spent for the transfer of containers. The experimental results showed that the optimal space amount decreases as the space cost increases but the optimal number of transfer cranes is insensitive to the change of the space cost. The optimal number of transfer cranes and the optimal space amount increase as the cost of outside trucks increases. Xuan Qiu and Jasmine Siu Lee Lam (2014) proposed a Stackelberg game theoretic approach model for storage pricing-pickup problem in a dry port system for inbound containers to minimize its total cost. This model is solved analytically. After analyzing the proposed game model, the Stackelberg equilibrium solutions are obtained in closed-formed. Radh Moussi et al. (2011) identified a new algorithm using a GA called GALUO (Genetic algorithm for loading and unloading operation) to minimize the total travel time of lifting vehicles. Through this approach, they tried to minimize the container handling time at seaport terminal. Azizi AB. Aziz & Azzizi Zakariya (2003) proposed a GA technique to solve the container stacking problem where a prototype has been developed. The average optimal stacking result obtained range between 78-83%. Nature adaptation in GA gives a better way to solve container stacking and allocation problem. The simulation results provide further insight in predicting possible container arrangement and movement. Best optimization rate 85.6% is achieved. Yan, L. et al. (2010) proposed a fuzzy optimization model of storage space allocation and rolling-planning method is derived. The model took into account the uncertainty of departure time of import containers and arrival time of export container. For planning horizon, the problem is divided into two levels: the first level minimizes the unbalanced workloads among blocks using hybrid intelligence algorithm, the second level minimizes the number of blocks to which the same grouped containers are split. The results showed that the model reduced workload imbalance and speed up the vessel loading and discharging process. Xie et al. (2015) proposed a GA for scheduling of cranes and minimize the reshuffling of products in the warehouse. The experimental results show that the GA is much effective than other heuristic algorithm and generates a good solution within a short time if problem size is up to 100. Tang, L. et al. (2015) improved the existing static reshuffling model, developed five effective heuristics and analyzed the performance of these algorithms. A discrete-event simulation model was developed to animate the stacking, retrieving and reshuffling operations and to test the performance of the proposed heuristics and their extended versions in the dynamic environment with arrivals and retrievals of containers. For static & dynamic both problems, the results showed that the improved model can obtain optimal or feasible solutions more quickly than the existing model and proposed extended five heuristics are superior to existing ones and consume very little time. Hu, W. et al. (2012) proposed a ship loading scheduling model to make the whole container ship loading plan by using the heuristic greedy algorithm to choose the container having least cost in the yard during every loading. Many experiments verified the utility of the heuristic greedy algorithm. A mathematical model was constructed to minimize container reshuffle rate on board, the center of gravity of the ship, holding appropriate trim and ensuring that the heavy containers stacking in the middle of the ship. The GA with group coding and stacking strategy in the bay was taken as the resolution of the model. The results showed that the proposed model and the algorithm have a good performance. Miguel A. Salido et al. (2009) developed a domain-independent planning tool for finding the best configuration of containers in a bay. The proposed tool minimized the number of relocations of containers in order to allocate all selected containers in an appropriate order to avoid further reshuffles.

3. Methodology

The methodology use in this paper is a discrete-event simulation that consist of a simulation method for modelling to stack the containers in the yard and to avoid the further reshuffles. A GA is used to calculate the maximum fitness of 150 containers to store at the best possible location in the yard. The delivery date is assigned to each container before stacking in the yard. The tier level of stack is 3. So, our solution will be based on the groups of 3 values. On that basis, we shall find the best possible location to store a container in the stack. The containers with early delivery date will be stacked on upper tier and the late delivery container will be stacked on lower tier 1 or 2 in the yard or all container with same delivery date will be stacked in same stack. A mathematical model is purposed to show the relationship between the number of unproductive moves and container handling cost.

According to Lixin Tang et al. (2015), Simulation is a suitable tool for evaluating the algorithms or rules [33]. Hartmann, S. (2004) said that the simulation models as tools to evaluate the dynamic processes in a container terminal that allow generating and analyzing statistics such as average productivity, waiting time, the number of re-shuffles moves in the stack and provide a testing environment for optimization algorithms. There are two most common types of simulation, one is a discrete-event simulation, and another is a continuous simulation those are used. In discrete event simulation, the state variables change instantaneously at specific points within the specific simulated time. These types of problems are solved by discrete-event simulation. Gamal Abd El-Nasser A. Said et al. (2015) stated that the discrete-event systems are well suited to represent various activities performed in container terminals and to optimize the solution for storage space allocation problem. According to Sgouris P. Sgouridis et al. (2002), the simulation of incoming container handling in stacking is a discrete event problem.



4. Simulation Experimentation

We have generated a discrete event simulation model for a single container stacking block in the yard of a seaport terminal. For this purpose, we have used AnyLogic 7.2 simulator.

In this model, we the AGV's transporting containers and land the containers outside of the yard. The yard crane picks up the containers and stores in the yard. The delivery truck retrieves the containers from yard for further delivery. We have integrated our model with GAs. In this model, the number of containers depend on the population size of GA which is 150. If we shall increase or decrease the population size of GA then the number of containers will also be increased or decreased. The delivery trucks retrieve only those containers from the yard for further delivery whose delivery date is today according to GA results.

- AGV: Are resources those travel within the terminal area. To move the containers from one place to another place within the terminal. For this purpose, we have 5 AGV's in this model just to assume the environment of the terminal. These are used to load the container and move from the seaside to yard area.
- Yard Crane: A single yard crane is taken as a resource unit in this model, and it will pick up the containers from outside of yard to store in the yard. The storage process will continue up to 150 containers. After this, the crane will be stopped in the yard.
- Delivery truck: Are resources in the terminal. The waiting place to retrieve the containers for delivery is the truck stand. When the container retrieval time will be started then they will go into the yard, load the container and delivered it. For this purpose, we have used 3 trucks in this model to show the delivery process.
- Container: Number of containers depends on population size of GA. There are 150 containers stacked outside of the yard to show the in-out flow process of containers in the yard. The containers are taken as agents in this model. The AGV's come with containers outside of the yard. The crane picks up the container and stored in the yard. The containers whose today delivery date according to GA result will be delivered by trucks for further delivery.

4.1. Run Experiment

In this experiment, when we run the GA to obtain best fitness results, the best fitness value will increase gradually and get maximum value before the 25th generation. The results will be mentioned in the form of table and graph. The tournament size of GA affect the better results on the number of generations. If tournament size is small, then best fitness will be gradually increased and achieved on later generations but if the tournament size will be 4 to 6 then results are good else not. The resources used in simulation model have performed their tasks at above mentioned time and mean time. The yard crane has minimum mean time to handle a container in the yard that is 2.582 seconds. The AGV's required maximum time to complete the task that is more than 8 seconds. In the figure 1, we have showed the simulation-based results of GA. The fitness values and cost versus the number of generations has also been shown in the figure. The fitness value of GA is increasing gradually, and the cost is decreasing gradually until the best results for container stacking problem has been achieved.

Figure 1. Simulation based results of GA

The number of 0's in GA results has been shown that the container has today delivery date. The 13 containers have today delivery date, and the 137 containers will be remained in the yard. The number of containers in the discrete-event CSS simulation model depend on population size of GA, which is 150, so the maximum fitness value will be 150 as shown in figure 2. If we increase or decrease the population size of GA, then the number of containers will also be increased or decreased. we have achieved maximum fitness value 150 out of 150 (100%) at 21st generation. This value is showing the high accuracy and efficiency of the GA to solve this problem in a good way and give a best optimal solution. In this problem, we have 150 containers for storage and 50 stacks with 3 tiers. This solution showed that all stacks are correctly stacked the containers without reshuffles.

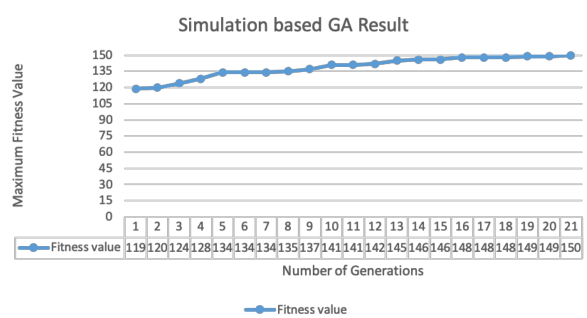


Figure 2. GA fitness value versus generations

In figure 3 a comparison of fitness value of GA and accuracy value of Tabu Search for container stacking problem to find best possible location is presented. The experiment has been performed upto 50 generations. The GA has obtained maximum fitness value 150 out of 150 at 21st generation. Tabu Search has obtained maximum accuracy level 120 out of 150 at 16th iteration. We have performed experiment runs of up to 10000 iterations to check the maximum accuracy of Tabu Search but maximum accuracy level 150 has not been achieved. The accuracy of TS is low as compared to fitness value of GA. The GA has obtained maximum fitness value before the 25th generation. The results are shown that the GA has performed better than TS for the container stacking problem in this scenario.

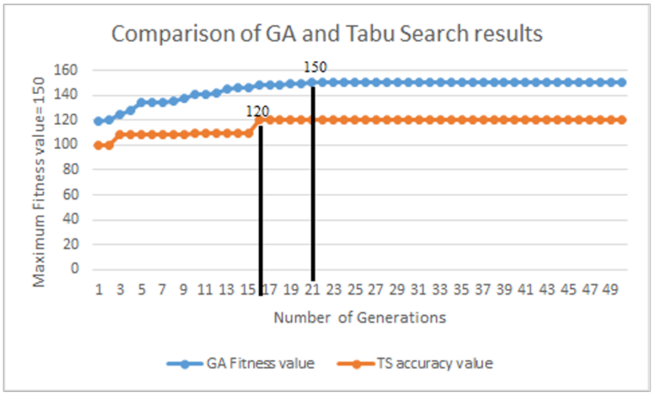


Figure 3. Comparison of GA and Tabu Search results

5. Conclusions

The purpose of this work was to investigate and propose a solution for container stacking system in the yard of seaport container terminal to minimize the unproductive moves and facilitate the yard area management to reduce the container handling cost and save the time. In attempting to integrate such scheduling has been identified to be an NP-hard problem. As GA is a type of meta-heuristic algorithms, it is able to locate near optimal solutions for this type of problem. We have considered a single yard crane within a single block area of 150 inbound containers and 180 storage positions. The yard area of Helsingborg port, Sweden has been visited to investigate the problem and collect the information. To explore the key challenges for container stacking and suggested solutions in the literature, we have conducted a literature review. In this literature review, we have found 4 main KPI's (Time, Cost, Workload, and Reshuffles). All these KPI's are interrelated to each other and in most of the cases, 3 KPI's depend on the most important one, which is unproductive moves/reshuffles. Different optimization techniques like LP, MIP, GA, TS and SA has been used to optimize the solutions. The 21 out of 35 selected articles for literature review have focused on minimization of container reshuffles and indicate the importance of the problem and need to solve it. A few articles have focused on cost, which is important for the port or terminal and their customers. So, we have focused on both unproductive moves and cost in this work. To investigate the impact of GA in order to minimize the unproductive moves it is necessary to conduct such research via simulation experiments. The GA was tested on different parametric values and then the best of them was chosen to obtain a high fitness of the population. The highest fitness is achieved before the 25^{th} generation. These results can save on the time and memory utilization of the system. A discrete-event simulation model has been developed and integrated with the GA. The number of containers depend on the population size of GA which is 150. If we shall increase or decrease the population size of GA then the number of containers will also increase or decrease. The GA has achieved the maximum fitness value up to 100% to enhance the accuracy in container stacking system. The delivery trucks retrieve only those containers from the yard for further delivery whose delivery date is today according to GA results.

The simulation-based GA's results have indicated that the GA has an impact on unproductive moves minimization and the high accuracy in delivery dates of containers is achieved. The cost and time both factors are affected due to the inefficiency of this stacking system. We can take a control on these factors indirectly through the improvement of the third factor, which is unproductive moves. We have made a comparison between the results of GA and Tabu Search on the same problem to test the performance and to identify which is best to solve this type of problem. This comparison indicated that the GA has performed quite well to solve the container stacking problem and provides an optimal solution.

The future work in this field on the basis of present information is to expand the model for whole yard area so that we can handle the outbound and transshipment containers with inbound containers and containers having different properties. The second option for future work is to consider time as a key factor to be taken considered in attempting to minimize it. We believe to the proposed mathematical model for cost management can also be further improved. In this work, we had used the port of Helsingborg, Sweden as a reference in developing the simulation model. The container operations handle 350,000 TEU per annum. A larger terminal, e.g., handling more than 1 million TEU, would be an interesting study to conduct in order to evaluate the robustness of the proposed solution by attempting to solve the yard problems with such large volumes of containers to be stacked and handled.

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