Optimizing a container-ship stowage plan using genetic algorithms

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Abstract

Short sea shipping is prone to be one of the areas of development for the transportation policy of the European Union in the near future. Nevertheless, in order to be able to make its stand on the market, there are several problems that have to addressed, namely its safety and economic viability. To study the second, a genetic algorithm may be applied to the optimization of the stowage plan of a small container-ship that visits several ports, aiming to reduce the period of call on each port, but not neglecting the vessel’s stability and safety.

Keywords: genetic algorithms, short sea shipping, container stowage problem, master bay plan

1-Introduction

Today, according to the European Transport Commission, short sea shipping represents 40\% of the intra-EU exchanges in terms of ton-kilometers. Nonetheless, there are still funding programs, such as Marco Polo, that intend to fund projects which shift freight transport from the road to the sea, rail and inland waterways. In truth, it is estimated that for Euro of Marco Polo funding generates social and environmental benefits worth six or more times as much. It is believed that the short sea shipping concept could be applied to the Portuguese internal trade, if a small enough containership with good seakeeping and stability characteristics would visit several cities from North to South of the littoral, where most population is concentrated.
On the other hand, the economical viability of such model, in comparison with road transport, can only be ensured by reducing the loading and unloading time of containers and by considering ship designs with good seakeeping performance, in order to maintain the vessel running for as much time as possible, even in unfavorable environmental conditions. Therefore, it is necessary to develop a tool that can be used in the viability analysis of the logistic system of freight transportation by sea and to define the containership design concept.

2. Available methods

The Container Stowage Problem (CSP) can be explained as the problem of assigning several containers of various types and weights, to slots on a containership with limited space and stability characteristics, meaning the heavier containers should be stacked below the lighter ones. During its journey, the containership visits several ports of call and at each one some containers are unloaded and others are brought on board. During this procedure, the aim is to spend as little time as possible and to move as little containers as possible, commonly known as overstows, bearing in mind the previously mentioned stability requirements, which ensure the safety of personnel and cargo.

In the literature several approaches to this problem may be found. One of the first was presented by Wilson and Roach (1999), who proposed a method based on Tabu search within the cargo-space of a container ship until each container is specifically allocated to a stowage location. More recently Gümüş et al. (2008) made a review of the several methods dividing them into simulation based approaches, combining simple loading heuristics with simulation methods, rule-based systems, using the methods of artificial intelligence and metaheuristics, and mathematical-programming based approaches, using the methods of mathematical programming with relaxations of difficult constraints.

Nonetheless, it is believed that for a viability study such as the one being proposed, the method presented in Nobre, Martins, et al. (2007) can be used, where genetic algorithms are
applied to solve the problem.

2. Genetic Algorithms Implementation Method

As explained before, the CSP is an optimization problem that aims to minimize the overstowage and the time of loading and unloading containers each time the ship visits a port, and therefore the definition of the objective function is trivial, if the time to move any container is considered to be constant, bearing in mind that to move one container, all other containers stack above it must be moved also.

As far as the stacking characteristics and the number of containers to be transported for each port, this may be considered as a set of “quantity” restrictions that limit the number of containers stowed at each row and column, reducing the problem to two dimensions of determining the position of each container in a matrix of “rows x columns”, where each stack (column) can be placed anywhere on the ship, as long as its longitudinal and transverse positions are known.

These restrictions are complemented by another group of “stability” restrictions which ensure navigation safety. In fact, they are implemented by limiting the ship’s vertical position of the center of gravity, the angle of trim (bow - stern) and the angle of heel (port – starboard), that change due to container distribution, since each one has its own weight.

Once all the restrictions are defined, a set of possible solutions, the “initial population”, is evaluated, attributing each distribution of containers a penalty if any of the restrictions are not verified, and selecting the ones with less penalties. The selected ones are than changed by pre-defined “crossover” and “mutation” functions, obtaining a “new generation” of possible solutions. Once again, this new set of different containers distribution is evaluated and changed, starting an iteration process that will end after a predefined number of “generations”, i.e. loops.
All in all, this method was validated in Nobre, Martins, et al (2007), when the genetic algorithm solution for the CSP problem of 12 containers was compared with the “Microsoft Excel Solver” solution, ensuring that for a larger problem the same method can be used to obtain good solutions.

4. Conclusion

It was proven that the CSP problem could be solved using genetic algorithms. Consequently, there is an easy enough tool to be used in the study of the design of small containerships and short-sea-shipping routes to be applied between several Portuguese ports.

References


