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SOLVING PRACTICAL PROBLEMS IN SHIPPING BY USING MATHEMATICAL MODELS

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Abstract:*The purpose of this paper is to highlight how using mathematical algorithms, some practical problems on board can be more easily solved.*
Keywords:*mathematical model, Yu Chen algorithm, Bellman algorithm.*

INTRODUCTION

Currently, one of the biggest ships in the world, which is in service, is Maersk Mc-Kinney Moller– Figure 1 and it is the first of the Maersk Triple-E class ships[3]. This ship has been designed to set leadingstandards in the container vessel industry.

Figure 1[2]

We have considered that could be important, to point out that only 14 ports are capable of accommodating the biggest ship in the world and those are located only in Northern Europe (6 ports) and in Asia (8 ports). Maersk Mc-Kinney Moller can’t traverse the expanded Panama Canal but it is able to sail in the Suez Canal [2]. Because Maersk Mc-Kinney Moller has an energy-efficient engine, an U-shape hull – Figure 2 and a special system of recovering the waste, it can sail 184 km using 1kwh of energy per ton of cargo [2].

Figure 2[2]

In the paper „Solving concrete problems in naval framework through canonical mathematical models” [5] we already mentioned that the purpose of the ship Maersk Mc-Kinney Moller is to serve the trade route between Asia and Europe and bring in the ports of Europe millions of products manufactured in China, Malaysia, Taiwan and Korea. Taking into account this we present below a possible route that could be developed by this large container vessel.

PRESENTATION OF THE PROBLEM

In order to improve costs for Maersk-Mc-Kinney Moller, we thinkthat we can apply two mathematical modelsto determine the shortest path, that can be traveled, so that the delivery time of goods to be optimal. More precisely, we consider that the ship starts from South Korea and will finish the route in Hamburg. We use the following notation

X_1 = South Korea,
X_2 = Hong Kong,
X_3 = Taiwan,
X_4 = Malaysia,
X_5 = Port Elisabet,
X_6 = Algeciras,
X_7 = Marseille,
X_8 = Rotterdam,
X_9 = Hamburg.

Figure 3[4]

We will treat the problem as one of graph theory using mapes provided by [4] and for this we want to remember that in many practical problems we are faced with attaching to each arc of the graph, associated to these problems, a number(arc lenght, capacity, transport costs along the arc, benefits, etc), in such circumstances as travel time along the arc or distance in time. The time required to navigate between intermediate ports considered is:

$X_1 \rightarrow X_2$ = 7 days, $X_1 \rightarrow X_3$ = 5 days, $X_2 \rightarrow X_3$ = 3 days,
$X_3 \rightarrow X_2$ = 3 days, $X_2 \rightarrow X_4$ = 4 days, $X_3 \rightarrow X_4$ = 7 days,
$X_4 \rightarrow X_5$ = 17 days, $X_5 \rightarrow X_6$ = 20 days, $X_6 \rightarrow X_7$ = 3 days, $X_6 \rightarrow X_8$ = 4 days, $X_7 \rightarrow X_8$ = 7 days, $X_8 \rightarrow X_9$ = 1 day.
In terms of graph theory this reverts to the finding of Hamiltonian path in the graph associated to the application of the above stated problem; for this it is necessary to recall that a Hamiltonian path is a path of a graph that passes throgh all the node once[1].
To make the things to be easier we want to recall Yu Chen algorithm[1] for graphs with circuits which has the following steps:

Step 1. Determine the tough components of the graph(Asia, Europe) denoted by C_1, C_2,...

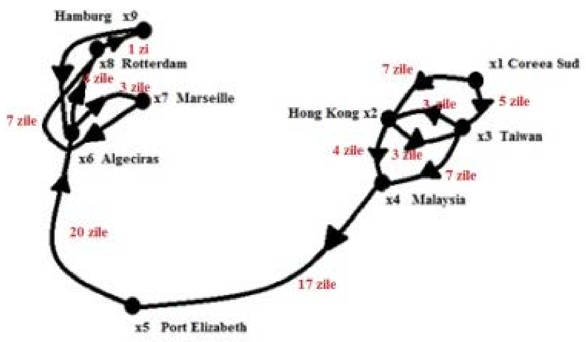
Step 2. Determine the condensed graph associated to the graph (Asia, Europe) which is a graph without circuits.

Step 3. Determine the Hamiltonian path in the condensed graph when this exists.

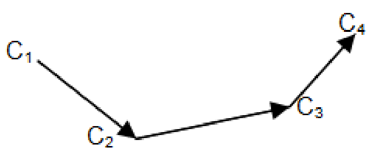
Step 4. Arrange tough components related to the order given by the Hamiltonian path determined in step 3.

Step 5. Write all Hamiltonian paths from each tough component connection.

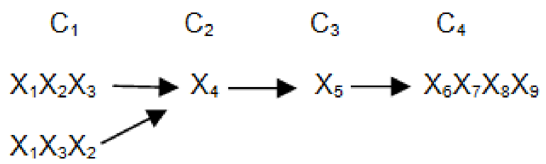
Step 6. Establish communication from one component to another, depending on the arcs of incidence(link) of the given graph, then reading all the Hamiltonian paths.



Let's find the Hamiltonian paths of the graph above. The tough connected components are: C_1= {X_1,X_2,X_3}, C_2={X_4}, C_3={X_5}, C_4={X_6,X_7,X_8,X_9} and the corresponding condensed graph is given by the figure below



It is noted in the condensed graph we have the Hamiltonian pathd_{CH}={C_1,C_2,C_3,C_4}.Now we write the connected tough components following the order from d_{CH}pathand bellow them we write all the Hamiltonian paths from each component:



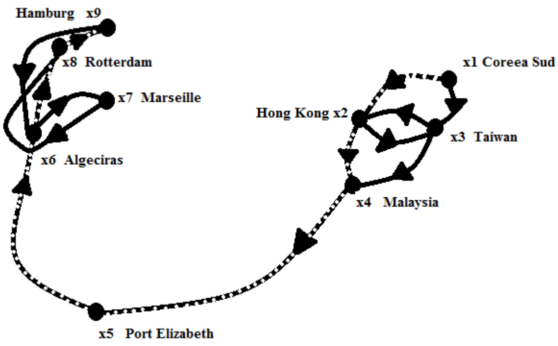
Then we link the last elements of the paths with the next one. We obtain Hamiltonian paths:

d_{1H}={ X_1,X_2,X_3,X_4,X_5, X_6,X_7,X_8,X_9}
d_{2H}={ X_1,X_3,X_2,X_4,X_5, X_6,X_7,X_8,X_9}

and we can easily determine that for the first Hamiltonian path 65 days are necessary and for the second path, 60 days.
In the problem stated above, we calculate the distance in time by using the algorithm of Bellman[1]. It is based on Bellman's principle of optimality: any optimal policy consists of optimal subpolitics. By this algorithm to each node X_i, a number $d_i$is attached, representing the minimum length of paths from X_1 to X_i measured as distance in time(time delay).
We consider d_1 = 0. Now, suppose we want to find d_l, where the node X_l is following X_i, X_j and X_k to which have already been calculated the numbers d_i, d_j, d_k. Then the minimum length d_l from X_1 to X_l is determined by the formula $d_l = \min(d_i + c_{il}, d_j+c_{jl}, d_k +c_{kl})$ where c_{il}, c_{jl} and c_{kl} are the corresponding capacities arcs (X_i, X_l), (X_j, X_l) and (X_k, X_l). When we determine de distance from $X_1$to X_l, we use the formula of d_l, where we choose the outline node value for which the minimum is reached. Once all the numbers d_1, d_2,…,d_n are determined, the value of d_n is the minimum length of the path from the X_1 to X_n, and starting to read from theX_n to X_1all the underlined nodes for which we have obtained the minimum length.
For the graph in the figures above we will find the minimum path length thus:

$d_1 = 0$, $d_3 = \{ d_1+5 \} = 5$,
$d_2 = \min \{d_1+7, d_3+3 \} = \min \{7,8\} = 7$,
$d_4 = \min \{d_2+4, d_3+7 \} = \min \{11,12\} = 11$,
$d_5 = \min \{d_4+17\} = 28$,
$d_6 = \min \{ d_5+20\} = 48$,
$d_7 = \min \{ d_6+3\} = 51$,
$d_8 = \min \{d_6+ 4, d_7+7\} = \min \{52,58\} = 52$,
$d_9 = \min \{d_8+1\} = 53$,
d_{min} = { X_1,X_2,X_4,X_5,X_6,X_8,X_9}.
Therefore, the minimum length of time is 53 days, and the path which has this length is

d_{min} = { X_1,X_2,X_4,X_5,X_6,X_8,X_9}. In the figure below, the minimum path arcs are represented by a dotted line.



CONCLUSION

We conclude that using Hamiltonian path and applying Bellman algorithm we could obtain an optimal solution for this kind of problem that can lead once again to the confirmation of the fact that mathematical methods could be used more ingenious in practice in shipping.

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