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Cargo Loading Using Dynamic Programming and Comparative Software Study

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***Abstract*— Dynamic Programming is one of the elegant algorithm design standards and is powerful tool which yields classic algorithms for a variety of combinatorial optimization problems. Current load planning studies fail to consider numerous practical requirements, such as visualized data presentation, cargo-loading prioritization, complexity of mathematical models, and no-cost analysis. Cargo load planning is critical to transport carriers, especially for an industry heavily influenced by increasing fuel prices and costs. Therefore, from a practical viewpoint, simple parameter settings, optimized computations, easily understandable results, and the generation of relevant work reports are essential for the logistic industry. The softwares like AutoLoad Pro to assist transport carriers in planning their cargo loading operations.**

***Index Terms*—AutoLoad, Cargo, Optimization, Prioritization,**

I. Introduction

Some well-devised algorithm design standards - such as Divide and Conquer, Greedy Methods, Graph Exploration, etc, yield classic algorithms for a range of optimization problems. However, a major drawback of these tools is that they can only be applied to very specific kinds of problems . E.g. certain problems have recursive solutions that are very natural but simultaneously are inefficient too. This inefficiency is due to many identical recursive calls made during any given computation. This property, termed overlapping sub problems, is characteristic of many important problems. Therefore, we must turn to the sledgehammer of the algorithms craft – dynamic programming. It is the most powerful scheme and is an alternative way of looking at these discrete optimization problems that could be solved and is invoked in very broad applicability when more specialized methods fail. Predictably, this generality often moves towards with an optimal cost . Problems having the overlapping sub problems property are almost always solved using dynamic programming. In transportation operations, attempts to shorten transportation distance and maximize cargo loading are essential activities by logistic companies planning for the ideal approach to fulfill transportation objectives before the execution of any actual transporting activities.

In particular, in an industry environment where fuel costs are rising, improving cargo loading efficiency can help achieve several benefits: (1) reduce the number of transportation trips; (2) lower the cost of transportation; (3) increase energy efficiency; and (4) raise customer satisfaction. Therefore, for third party logistics service providers, improving cargo loading efficiency can reduce costs and raise service standards. Yet, the factors that must be considered in cargo loading plans are many, including cargo size, cargo weight, compartment space, and loading and unloading sequence. They must be considered when using a mathematical planning model of multi-restriction, making the NP-hard problem even more difficult to solve. Regarding logistic operator practices, load planning primarily involves planning for manual activities and direct cargo stacking, which is prone to errors that can lead to an increased number of transportation vehicles, an increased number of transportation trips, and delayed delivery schedules. These mistakes are damaging because of higher costs and lower customer satisfaction.

This paper chiefly focused on a decision support system specifically designed for transport load planning of sea and air transport containers, trucks, boxes, and pallets, and is optimized with full auto loading capability. A smart load stacking engine with 3D visualized presentation capability that is driven by an optimized computing core is used to provide a two stages loading solution technique from the process of packing to container loading. The engine can automatically determine the best loading pattern. During packing and container loading of various sized goods, constraints must be considered, such as load stacking direction, heavy-to-the-bottom ,light-to-the-top goods stacking rule, loading / unloading sequence, and grouping similar goods [2], [4]. They help to calculate the number of pallets, crates, and containers required, and quickly develop a practical planning solution. They can simultaneously meet the practical demands of businesses under limiting conditions. 3D visualized presentations of cargo stacking sequences can drastically reduce freight costs and loading time [1].

Loading cargos of different sizes is a highly complex and difficult task. Currently, logistics companies with many years of cumulative practical experience manage such tasks. However, due to different sizes and cargo types, loading workers often spend many hours arranging and stacking cargoes based on trial and error methods or rules of thumb. To fit the cargo into the same container, the direction and position of cargoes must often be changed numerous times, even when cargoes that are originally in place would

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have to be removed and repositioned. Such a practice is certainly a timely burden with no financial benefits, and it cannot guarantee that the objective of a secure, stable, and optimized use of space is achieved each time. Therefore, the scientific method of AutoLoad Pro was used in place of manual labor during load planning operations, which helped to develop a set of criteria for cargo loading [2]. Speedy and efficient numerical analyses of computers are used to automatically calculate the "best" and "near optimal" cargo arranging and stacking method, which is provided as a reference to practical cargo load planning and transport vehicle scheduling operations for management decision-making solutions.

II. PRINCIPLE OF OPTIMIZATION

Dynamic programming was the brainchild of an American mathematician, Richard Bellman, who described the way of solving problems where you need to find the best decisions one after another. The word Programming in the name has nothing to do with writing any code or computer programs. Mathematicians use this speech to illustrate a set of rules which anyone can follow to solve a problem. They do not have to be written even in a computer programming language . The word "programming" in "dynamic programming" is a synonym for optimization and is meant as "planning or a tabular method". It is basically a stage wise search method of optimization problems whose solutions may be viewed as the result of a sequence of decisions[2], [3] .

General working methodology for achieving solution using this approach is given as:

Divide into Sub problems – The main problem is divided into a number of smaller, similar sub problems. The solution to main problem is expressed in terms of the solution for the smaller sub problems. Stage wise solutions start with the smallest sub problems .

ii. Construction of Table for Storage - The underlying idea of dynamic programming is to avoid calculating the same stuff twice and usually a table of known results of sub problems is constructed for the purpose. Dynamic programming thus takes advantage of the duplication and arranges to solve each sub problem only once, saving the solution in table for later use . The key to competence of a dynamic programming algorithm is that once it computes the solution to a constrained version of the problem, it stores that solution in a table until the solution is no longer needed by any future computation. The initial solution is trivial . This tells us that we trade space for time to avoid repeating the computation of a sub problem.

iii. Combining using Bottom-up means - Combining solutions of smallest sub problems obtain the solutions to sub problems of increasing size. The process is continued until we arrive at the solution of the original problem . Dynamic programming involves selection of optimal decision rules that optimizes a certain performance criterion

i. The Principle of Optimality – An optimal sequence of decisions is obtained if each subsequence must be optimal. That means if the initial state and decisions are optimal then the remaining decisions must constitute an optimal sequence with respect to the state resulting from the first decision. Combinatorial problems may have this property but may exploit too much memory and/or time towards efficiency.

ii. Polynomial Break up - The original problem is divided into several sub problems. The division is done in such a way that the total number of sub problems to be solved should be a polynomial or almost a polynomial number. This is done for efficient performance of dynamic programming. Using the top-down view of dynamic programming, the first property mentioned above corresponds to be able to write down a recursive procedure for the problem that we want to solve. The second property makes clear in our mind that this recursive procedure builds only a polynomial number of different recursive calls.

III. CONTAINER LOADING PROBLEM

Chan et al. (2006) proposed a two-stage decision support system for a two stage air cargo loading plan. Since air pallets have different shape and size specifications, they belong to a three-dimensional bin-packing problem. Thus, the first stage involved the use of linear planning to determine the lower limit for the overall cost of the pallet relative to weight and quantity. The second stage involved the creation of a loading plan for each pallet. Yan et al. (2008) developed a stochastic demand cargo container loading plan model for the air express industry. The model belongs to a class of non-linear mixed integer programming problems designed to minimize total operation costs of pallet management under associated operational limits. The aforementioned studies reveal that practical programming or algorithm based mathematical models used to solve loading problems when considering realistic load limits yield results that are often difficult for operators to understand during stacking prioritization, due to calculations being too complex. Moreover, few studies have used information software systems to address practical loading problems, resulting in loading problems remaining at the academic research stage. This study focused on AutoLoad Pro software with a simulated annealing algorithm and tabu search technique designed to support truck loading plans, sea and air container loading plans, wooden box and carton box loading plans, pallets, containers, and air pallets stacking plans.

Suppose we have to load a vessel with 3 items. The maximum allowable weight is 7 tones. It is required to find the loading which maximizes the values of the vessel without exceeding the weight constrains in tones. The details of items to load are shown below.

ITEM	WEIGHT/UNIT	PROFIT/UNIT
1	1	20
2	3	90
3	2	70

(Table I)

Let's find out solution for above situation by successive optimization stages as shown.

NO/ WEGHT	1	2	3	4	5	6	7	PROFIT
0								0
1	20							20
2	20	40						40
3	20	40	60					60
4	20	40	60	80				80
5	20	40	60	80	100			100
6	20	40	60	80	100	120		120
7	20	40	60	80	100	120	140	140

(Table II)

NO/ WEGHT	1	2	PROFIT
0			0
1			0
2			0
3	90+0		90
4	90+20		110
5	90+40		130
6	90+60	180+0	180
7	90+80	180+20	200

(Table III)

NO/ WEGHT	1	2	3	PROFIT
0				0
1				0
2	70+0			70
3	70+0			70
4	70+0	140+0		140
5	70+90	140+0		160
6	70+110	140+0	210+0	210
7	70+130	140+90	210+0	230

(Table IV)

Maximum profit=230 Lakh;
Item 1=0, Item 2=1, Item 3=2

IV. LOAD PLANNER SOFTWARE COMPARATIVE STUDY

This paper also aims to make a comparative study of industry available software for Cargo Load optimization and planning and study the available algorithm for Cargo Loading optimization. There is a very long list of available commercial software that performs cargo load optimization and planning with full visualization via graphical representation. Following is brief list of some of the best in industry.

3D Load Packer (3DLP) is the unique space optimizer designed to help you plan quickly and easily the best compact arrangement of a number of different size 3D rectangular objects (hereafter called "Boxes") within one or more rectangular enclosures (hereafter "Containers"). 3DLP is based on the truly three-dimensional, most dense and quick original packing algorithms. The program may be used to optimize multi-product load plans for any rectangular containers, trucks, trailers, railcars, crates, pallets and boxes, as well as be applied to any other 3D-space optimization problem. 3D Load Packer can optimize over multiple containers in multiple sizes at the same time, taking into account overall box set considered and allowed box space orientations, specified for each box separately or for all boxes together. An overall load weight limit and truck axle weight limits may be taken into account as additional constraints or actual optimization factors. Full control on the allowed box overhang is also available. The program has a facility for specifying the associated cost for each box / container item in order to calculate totals and affect upon optimization as additional priority factors. Optimizer goal and other main settings are adjustable. Typically, optimizer reduces volume waste by a factor of 1.5 - 2 with respect to load planning.

The Cube-IQ Load Planning system is built around the best Loading Engine on the market and will give optimal volume/weight utilization. (Needed – sidebars and quotes from the industry)Cube-IQ optimizes the loading of items in one or more containers, optionally of different sizes. The system can help to cube-out loads on PC, and also in the actual loading through its clear, 3-D diagram based loading instructions. Cube-IQ has a state-of-the-art load optimization engine. Cube-IQ's database allows to pre-define containers and boxes, and to store and retrieve any number of complete loading cases. The system has full data import and export facilities and can both read and write Excel, XML and other formats.

AutoLoad Pro integrated 3D graphic technology, visual effects and excellent computing speed help to work out how to load varied shape of goods into varied sizes of containers efficiently with considering delivery safety of goods, utilization of space, move convenience and etc. AutoLoad Pro can work out the minimum containers, trucks and cartons quickly to complete a loading plan.

CubeMaster is a versatile, cost-effective software solution to optimize the cargo load on your trucks, air & sea containers and pallets quickly and efficiently. It reduces shipping and transport costs through intelligent loading and optimal space utilization. CubeMaster supports in planning order picking, loading and capacity requirements. The system delivers clear instructions regarding the work preparation in seconds.

The Packer3d Online Service calculates optimal plans for loading different types of boxes, cylinders, and pallets into containers, trucks, and railroad freight cars.

PackVol is an Optimization Software for Load Planning, designed to plan the best space utilization inside containers and trucks, to help to reduce transportation costs. It is an innovative software for MS Windows, which has some unique features not found in other container loading software products. It is truly tri dimensional; the program allows managing efficiently complex load planning problems.

PalletStacking allow users to find the best arrangement of boxes on loading pallets to warehousing or transportation. This software reduce the costs of palletizing boxes and calculate the most optimal dimensions of boxes. PalletStaking Solution calculate the best arrangement of products in a box, calculate box dimensions and show 3D graphics of the solution. It could be exported to Microsoft Excel to generate reports.

LoadPlanner is the first system that offers comprehensive load planning and optimization solution. The heart of LoadPlanner is its sophisticated 3D loading algorithm, the result of many years of intensive research and cooperation with leading logistics providers. But what makes us different is that LoadPlanner is an advanced rule-based system.

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