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Load Optimization Using Genetic Algorithm and Decision Support System

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Abstract: The global trade supply chain consists of container shipment of hundreds of millions of metric tons of deadweight. With the ever-increasing demand for a freight shipment, the need of the hour is optimized freight loading pattern and plan. This scholarly paper aims to optimize the loading pattern within a container to make space for more cargo making underutilization of space inside a container almost near to obsolete. In this paper, we have surveyed research papers that the existing system uses. The proposed way out to overcome the flaws is a model which is an amalgamation of Decision Support System (DSS) and Genetic Algorithm (GA). This hybrid algorithm is first fed the container size and the number of different sizes of cargo individually. The input data will then run GA against a certain set of predefined target parameters. Upon multiple iterations, GA will generate multiple near-optimal solutions. This pool of solutions will be processed with the help of DSS to decide the optimal loading pattern. The optimal solution is fed in the form of coordinates to the Unity engine. The Unity engine will use the given coordinates to simulate a 3D optimized loading pattern inside a container. The user can see a step-by-step simulation of loading the cargo into the container where the cargo will be color-coded. This result can be stored to refer to and transport a similar cargo.

Keywords: Genetic Algorithm Optimization, Cutting and packing problems, Load optimization, cargo load planning

I. INTRODUCTION

Container freight being the major means of transporting goods around the world, in 2019 alone 266 million metric tons of dead-weight was transported around the world (Statista, 2020). Load optimization aims to eliminate the guesswork involved in the freight loading pattern planning. This also helps get rid of pallet storage of cargo which adds extra weight and consumes space in the container. Our conjecture about the project is that it will help when the load has optimized the percentage of underutilization is brought down, it will reduce the requirement of containers to transport goods. This enables an eco-friendly chain reaction i.e., decreased consumption of fuel and environmental pollution with the reduced number of trips. Apart from this, the capital spent on that saved fuel consumption will amount to a lot too. The cargo to be optimized inside a container will be performed considering a list or various parameters. These parameters will be based on and not limited to safety standards, international freight shipment protocols, dimensions, and weight of the individual packages in the cargo shipment. Based on these parameters which will be passed through the GA which is metaheuristic in nature and populates data points with the strongest traits. This will be further fed into the DSS which makes the model decide if the solution provided by the GA is optimal. After the generation of the plan, it will be used in the 3D modeling engine to produce an optimized loading plan. The remainder of the survey is structured as follows: Section 2 gives an overview and review of various load optimization algorithms that have been applied previously to solve the problem. Section 3 describes the proposed methodology where we discuss the employment of GA and DSS to solve the container loading problem, and Section 4 of this paper compares the results of the papers surveyed. Section 5 discusses the results and concludes.

II. LITERATURE SURVEY

The main goal in cargo or freight loading is optimal positioning of the product with the maximum utilization of space & volume without damaging the container/truck and product.

A new Load Balance Methodology for Container Loading Problem in Road Transportation [1]: In loading, the load balance element of the container is either taken loosely or the geometric center of the container is presumed to be the best position, which does not follow transport regulations in the literature until now. This approach takes the load balance aspect into account as a hard constraint for optimizing the load. It uses a hybrid GA which takes static stability, load balance, and weight into consideration simultaneously while also maintaining the optimal volume usage of the container.

Practical constraints in the container loading problem: Comprehensive formulations and exact algorithm, Computers & Operations Research [2]: The problem with container loading is solved with the help of an integer linear programming model that takes into consideration only a single container. For real-world applications to be achieved, the model, along with the relaxed packing feasibility restrictions, also uses 12 other real-world criteria. The drawback of this technique is that there is a lot of memory and extra work involved when formulating complex functional constraints if the constraints are increased.

Output maximization container loading problem with time availability constraints [3]: Based on a timeline for the arrival of boxes, the authors considered the three-dimensional geometry of the problem and proposed a stochastic dynamic programming system. The problem associated with this method is when there is a fluctuation in production, the number of boxes loaded satisfies the minimum volume utilization of the truck/container, thereby increasing the number of trips required to transport.

A beam search algorithm for the bi-objective container loading problem [4]: This approach is based on reporting some of the best results for the single-objective container loading problem tree search method. This investigates the search tree one level at a time, searching for the best successors to expand using a heuristic evaluation function. The limitation in this algorithm is continuous re-checking of the tree at each level, which increases the time to find a new successor

Optimization of Heterogeneous Container Loading Problem with Adaptive Genetic Algorithm [5]: Intending to optimize the use of 3D space, the subject of optimized container loading is studied in this paper. A dedicated heuristic positioning based on the mathematical loading model's characteristics, integrated with a new dynamic space division method that enables the adaptive GA to be constructed to maximize the use of loading space. To test proposed algorithms, we use both weakly and strongly heterogeneous loading data.

Mathematical models for Multi Container Loading Problems with practical constraints [6]: By placing the goods on pallets and then loading the pallets into trucks, the freight loading here is tackled. They address the issue by developing and solving integer linear models. For the models, a wide variety of real cases involving up to 44 trucks have been confirmed. They achieve optimal solutions in some situations, with very tiny gaps where optimality cannot be verified. Extensions of the models are also considered in the case of large loads, requiring a special arrangement of the pallets in the truck.

III. METHODOLOGY

The application built over Unity’s game engine helps in determining the efficient loading pattern of putting boxes into a truck/container. It does so by considering an array of parameters like dimensions of the truck, varying dimensions of the cargo to be loaded into the container, the load-bearing capacity of the truck/ container, the center of gravity of the container/truck along with the standard rules and regulations of the transport industry. This as a chain reaction ensures the longevity of the important components of the truck like engines, tyres, and in turn increase in fuel efficiency and road safety.

The user first provides the dimension, quantity & weight of the boxes, and selects the truck/container from an array of templated truck/container types to load the boxes into. This data is fed to the DSS employed along with the GA. The DSS decides the best loading pattern from the different patterns generated by the GA. The results will be the 3D visualization placement of the individual box in a truck/container. A step-by-step procedure of placing the boxes is displayed to the user.

The process begins with a set of random sets of x,y,z coordinates of all boxes generated to form a population. The individual set of x,y,z coordinates along with the orientation is a gene. A chromosome is a specific collection of these coordinates. The fitness function examines whether the maximum container/carriage volume is used. The GA is a meta-heuristic in nature. It mimics the natural selection process of biological evolution. It works by selecting the best solution, then introducing random mutations to the selected solution. The process is repeated until the best solution is found. The advantage of the GA is that it is capable of finding the optimal solution. However, as it is a meta-heuristic, it is not as easily explainable as other algorithms. Some of the coordinates must be flipped. The entire iteration forms a generation and is sent to DSS.

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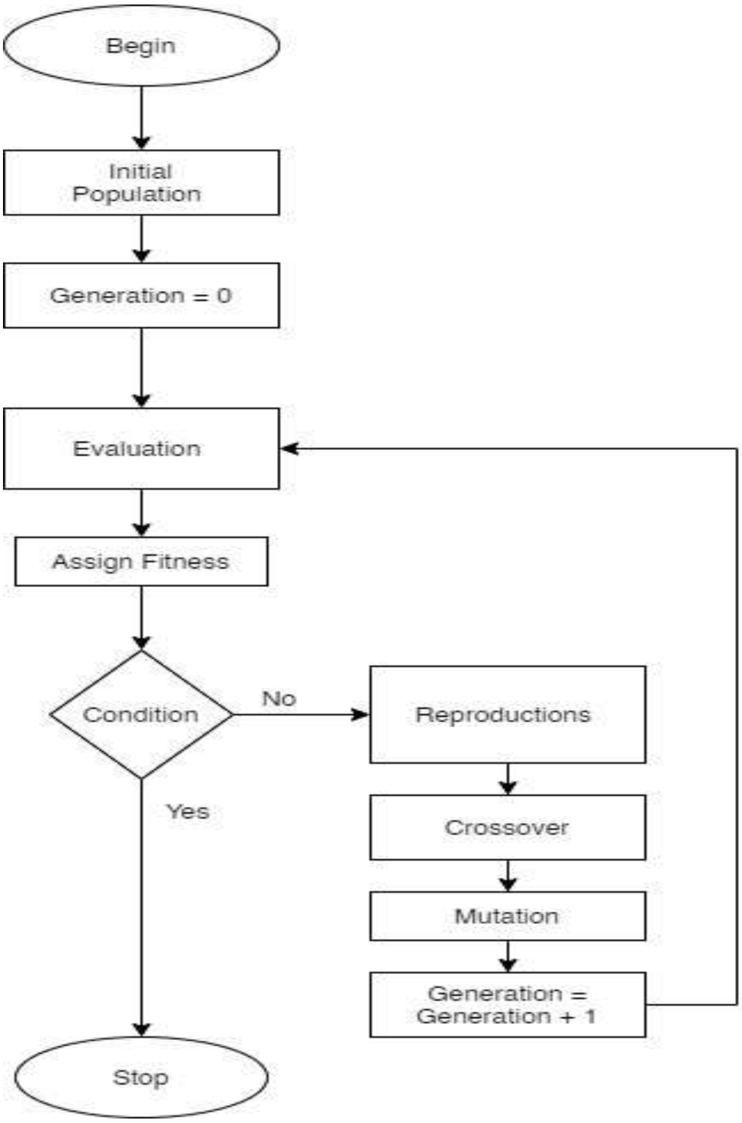

Fig. 1 Genetic algorithm workflow

The DSS is used to support determinations, judgments, and courses of action in positioning the boxes in a truck/container. DSS tends to be aimed at the less well structured, underspecified problem we typically face in this case. It attempts to combine the use of models or analytic techniques with traditional data access and retrieval functions. DSS specifically focuses on features which make them easy to use by non-computer-proficient people in an interactive mode; and it emphasizes flexibility and adaptability to accommodate changes in the environment and the decision making approach of the user. The DSS sifts through and analyzes massive amounts of data generated by the GA, compiling comprehensive information that can be used in decision-making at a quicker pace.

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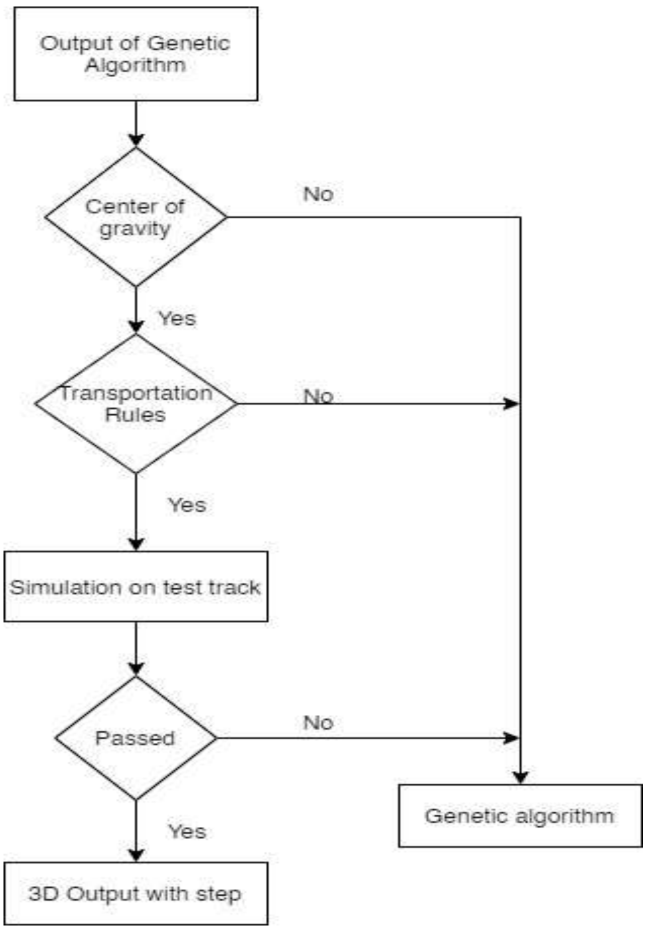

Fig. 2 Decision support system workflow

The system is built using Unity3D which is used for the simulation and displaying the results in a 3D view, Unity ML for the training part and Firebase as the primary database. The main feature of the system is the generation of the location of each box with a few clicks. The application stores all the different loading solutions so that, when the input given by the user is similar to the existing input, the system does not perform computation all over again but loads the existing solution from the database thus reducing loading time. Even with the most efficient pattern generated by the system, if the user finds space to fit a box, it can be communicated to the system as feedback where the system learns to generate a better pattern for future computation.

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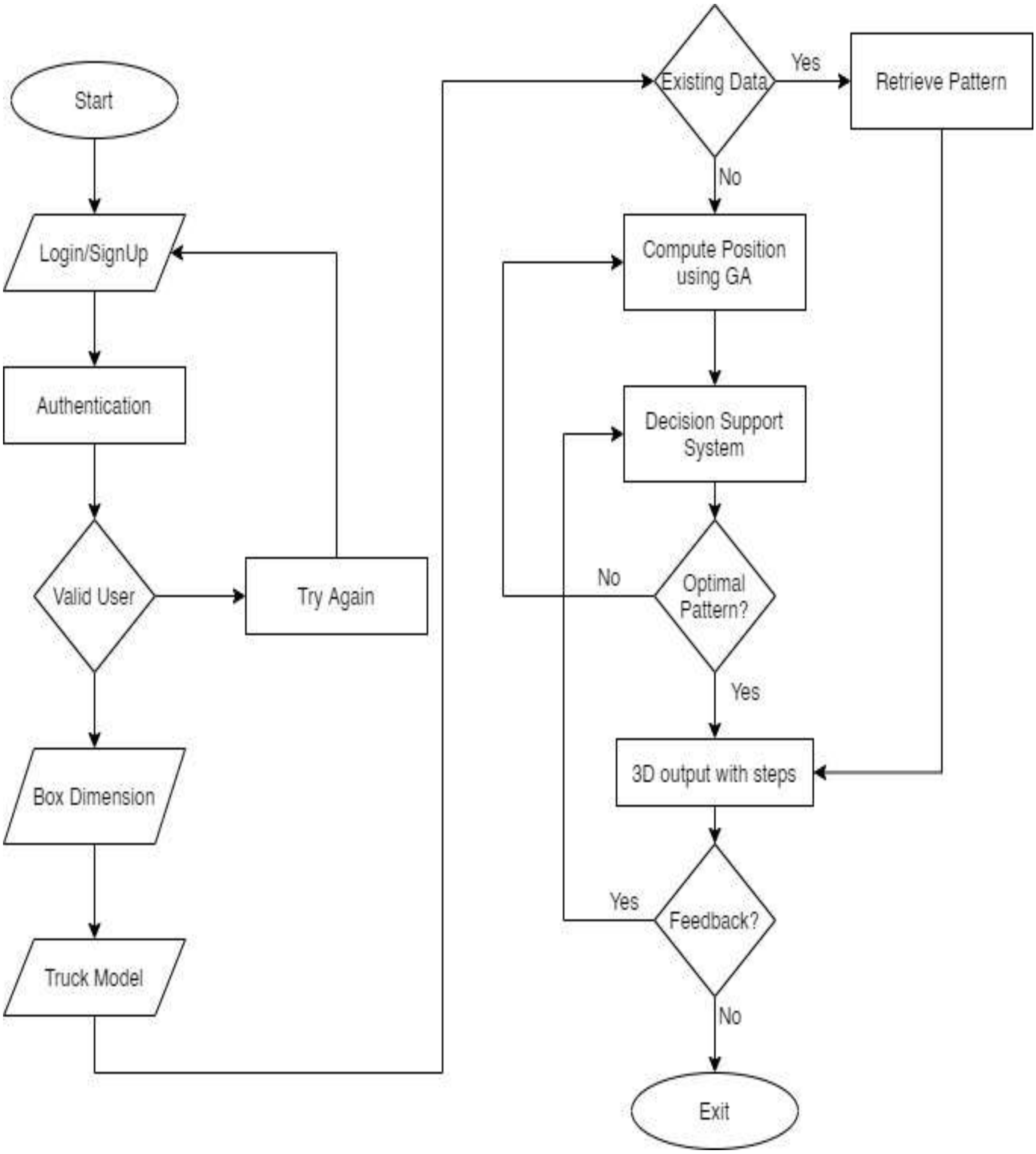

Fig. 3 Application workflow

IV. RESULT

The tests are conducted on 15 sets of Loh and Nee test data[7]. All freight containers in the other 13 test sets can be loaded into the container with LN02 and LN06. The LN02 contains 200 goods, of which 162 can be placed into the container following optimization of loading. The percentage of use of space was 95.41 percent. In LN06 200 cargos are supplied, 181 of them after loading optimization can be loaded into the container. The usage of space is 93.98 per cent in this scenario.;

Table and Figure provide the findings of the performance comparison. As can be observed, our algorithm's average space usage is 70.62 percent, which is the highest of all the methods.

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TABLE I COMPARATIVE ANALYSIS OF EFFICIENCY

Data	E[1]	M[2]	L[3]	W[4]	D[5]	LM[6]	This paper
LN01	62.5%	62.5%	62.5%	62.5%	62.5%	62.5%	62.5%
LN02	90.8%	92.6%	80.4%	90.7%	86.3%	96.4%	95.41%
LN03	53.4%	53.4%	53.4%	53.4%	53.4%	53.4%	53.43%
LN04	54.9%	55%	55%	55%	55%	55%	54.96%
LN05	77.2%	77.2%	77.2%	77.2%	77.2%	77.2%	77.19%
LN06	87.9%	91.7%	84.8%	92.9%	89.2%	93.5%	93.98%
LN07	84.7%	84.7%	77%	84.7%	83.2%	84.7%	84.66%
LN08	59.4%	59.4%	59.4%	59.4%	59.4%	59.4%	59.42%
LN09	61.9%	61.9%	61.9%	61.9%	61.9%	61.9%	61.89%
LN10	67.3%	67.3%	67.3%	67.3%	67.3%	67.3%	67.29%
LN11	62.2%	62.2%	62.2%	62.2%	62.2%	62.2%	62.16%
LN12	78.5%	78.5%	69.5%	78.5%	78.5%	78.5%	78.52%
LN13	85.6%	68%	73.3%	85.6%	85.6%	84.9%	85.61%
LN14	62.8%	62.8%	62.8%	62.8%	62.8%	62.8%	62.81%
LN15	59.5%	59.5%	59.5%	59.5%	59.5%	59.5%	59.46%
Average	69.91%	69.11%	67.08%	70.24%	69.60%	70.61%	70.62%

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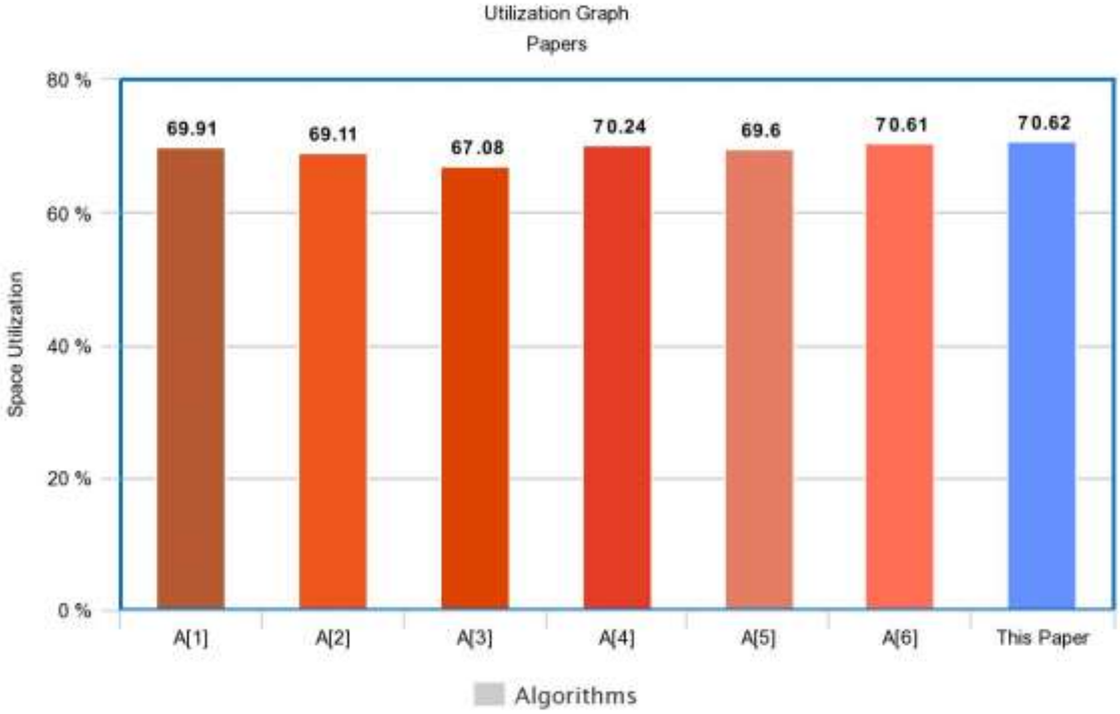

FIG. 4 PACKING EFFICENCY

The below images are the 3D rendered loading patterns over Unity3D with Loh and Nee datasets. The varying type of cargo in regards with dimensions and orientation are represented here in a color coded format. The user seeking the loading pattern for the cargo is provided with the step-by-step loading pattern screenshots in the application. The previous outputs that were acquired can be accessed again on the application.
The container chosen in the figures is an LCV open Body container having dimensions 10ft in length with 6ft in width and a height of 6ft. The volume utilized by the displayed arrangement is 83.33%.

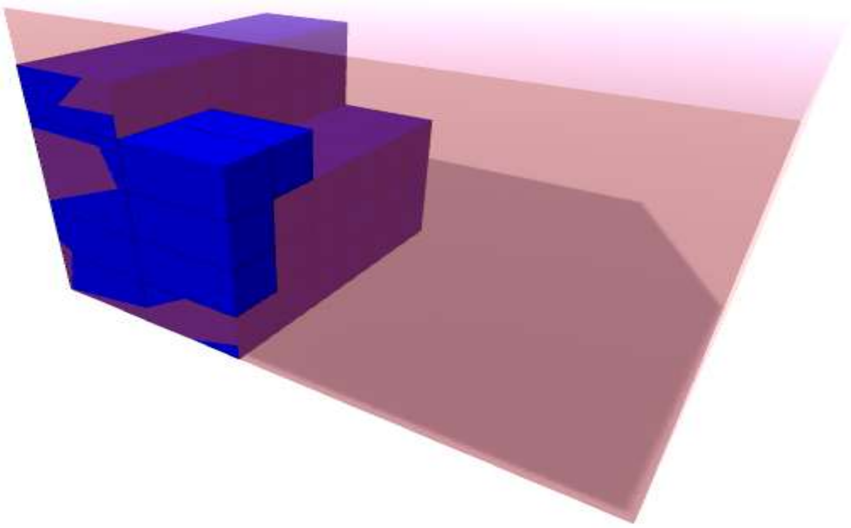

Fig. 5 Represents the position of boxes at iteration 72

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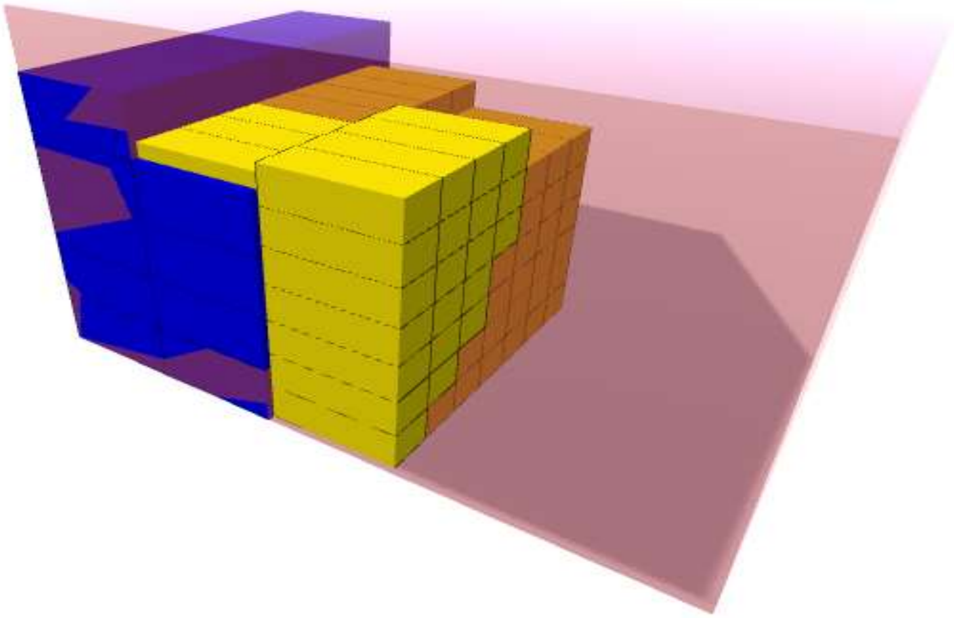

Fig. 6 Represents the position of 2 different types boxes at iteration 102

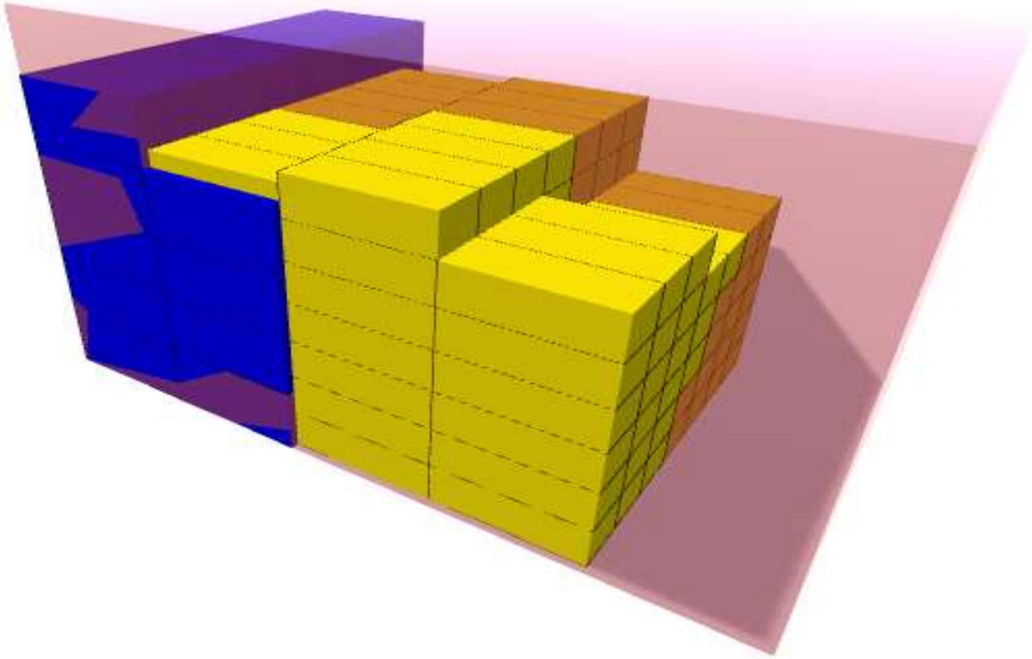

Fig. 7 represents the position of 2 different types boxes at iteration 193

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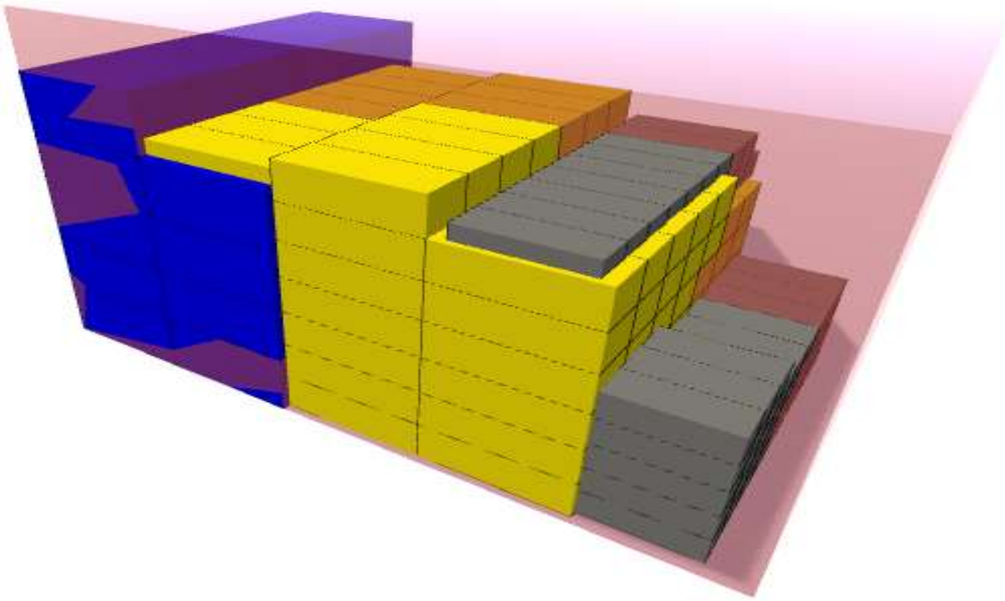

Fig. 8 represents the position of 3 different types boxes at iteration 320

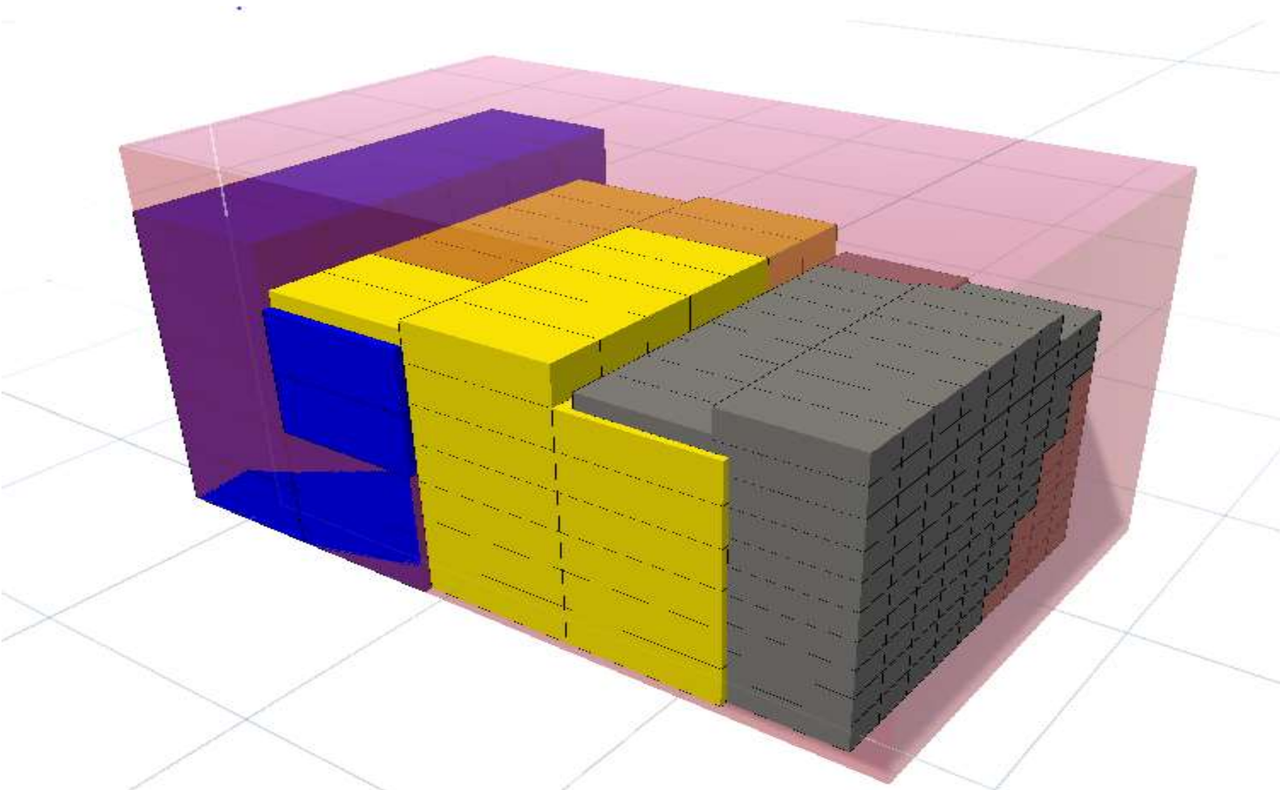

Fig. 9 represents final set of position with 4 different boxes at iteration 364

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V. CONCLUSION

It is feasible to address the growing need for high-quality solutions for complicated loading challenges that require many containers or vehicles and take into account a variety of practical limits in a variety of ways. In this research, we have examined the different methods of container loading. In order to reach optimal or near optimal solutions, we discussed first the modelling of the corresponding limits and then solving them in a reasonable time. The dynamic stability requirements for a loading plan to be usable in service, including limits relating to overall weight, maximum axle-supported weight, and centre of gravity location, have been thoroughly investigated. The method used in this paper improves the loading pattern optimization with greater precision and gives solutions in real time. The integration of two algorithms, GA and DSS, in this model aids in the making of better decisions that are not only theoretical but also practical. On any device connected to the internet, the aforementioned approach combining these factors will be used to generate a comprehensible step-by-step load plan with just a few taps, thus decreasing the loading time.

ACKNOWLEDGMENT

A new model of truck has been developed that can load different types of products, such as other than tyres, to make it more efficient. It will allow the driver to be in a more upright position for irregular shaped products or loading different type of products.

FUTURE ENCHANCEMENTS

Further training of the model to provide an efficient solution that utilizes more volume of the truck. Computing position for irregular shaped products, or loading different types of products other than boxes like tyres.

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