INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 2 ISSUE 2 (2016) PAGES 538-546
RECEIVED : 04/03/2016. PUBLISHED : 15/03/2016
March 15, 2016

HEURISTIC GENETIC ALGORITHM FOR PACKING ARBITRARY SIZED BIN PACKING PROBLEM

Jaisree.A.D, PG Scholar, Mahendra engineering college, Namakkal,
Umagowri.R, Asst prof, Dept of CSE, Mahendra Engineering College, Namakkal.

Abstract:

Generally, the containers used for bin packing problem are rectangular in shape. But literatures also used variable sized containers, which cannot be suitable for cargo packing. Similarly, from the literatures it was found that most of the solutions were provided for cubical and rectangular prismatic bins. This situation cannot exist all the time in the logistic industries. In many situations, bins are heterogeneous in nature and very few literatures had dealt with heterogeneous bins. Literatures proved that the simple mathematical methods cannot be more appropriate for multi-objective and multi-constrained problems. The researchers had also succeeded in using genetic approach for problems involved with discrete and continuous variables. None of the literature concentrated on weight constraint, load bearing constraint, placement constraint, stability constraint, boundary crossing constraint, orientation constraint all together. The researchers compared the developed algorithm with the lower bound values and have not considered much on the output format. The bin packing problem is to pack arbitrary sized and heterogeneous bins into a container leaving as little empty space as possible by considering major constraints namely boundary crossing constraint, overlapping constraint, stability constraint, orientation constraint, weight constraint and load bearing constraint using genetic approach.

Keywords – Cargo, Genetic approach, Overelapping.

1. INTRODUCTION

Storage system for physical goods are a necessary and important part of most manufacturing and distribution enterprises. In manufacturing, an automated storage andretrieval system (AS/RS) can be a space-effective way to storecomponents, subassemblies, or work-in-process inventory.

In distribution centers, AS/RSs can be the centerpiece of fullyautomated unit-load delivery systems, or they can be used toreplenish case or broken-case order picking areas. Tote-basedsystems are often used to bring small items to an order pickingworkstation, where workers assemble orders. Such systemshave become essential parts of modern logistics systems,where replenishment quantities are typically small and productvelocity is high.

Despite their potential to reduce the costs ofmaterial handlinglabor, automated storage systems face significant obstacles toadoption. One of the most significant is the perception that such systems are inflexible; that is, that they are incapable of accommodatingchanges in storage capacity, throughput capacity, ortypes of material stored and handled. For example, retail distributionis highly seasonal, so companies are reluctant to buysufficient automation to handle products during the busy seasonbecause utilization of the system would be so low during off seasons.

Third-party logistics providers (3PLs) also struggle to justifyautomation, because their contracts are rarely long enoughto ensure payback for such a large capital expenditure.For our purposes, flexibility in material handling systems embodiestwo traits, scalability and reconfigurability. For example,a traditional, aisle-based AS/RS is somewhat scalable becauseone can add or remove racks, aisles, and cranes, but it is difficultand expensive to reconfigure because adding an additional craneor aisle involves significant changes to mechanical and electricalsystems. Another contributor to inflexibility is centralizedcontrol, in which making a simple change to the system requireschanges to control logic and software. For changes to most automatedmaterial handling systems, there is a need to employthe services of technicians from multiple supporting firms.Furmans et al. [1] proffer an alternative approach called plugand-work material handling, which is based on conveyor modulesthat can be plugged together to form networks or, as wedescribe here, high density storage systems. Changing the configurationrequires only that modules be unplugged, rearranged,and plugged together again. Modules self-discover the new networkthrough a message passing scheme. A primary featureof plug-and-work systems is decentralized control. Eachmodulein a plug-and-work system contains the same control logic, andconveyance by a module at each time step is based solely onlocal conditions and on the results of message passing betweenmodules.

In this paper, we describe a high-density storage system forphysical goods called GRIDSTORE, which features a scalable,modular structure and decentralized control. We show that theunderlying control rules for GRIDSTORE guarantee deadlockfreeoperation, and we describe the performance of the systemfor several sizes and configurations.

2. RELATED WORK

Gueret C, N Jussien, O Lhomme, C Pavageau and C Prins developed the module for optimizing the packing of the bins into the aircraft compactly and they took the military application for the experimentation purpose. In military context, force projection means fast and massive transportation of military equipment (vehicles, troops, ammunitions, etc) from a set of bases to a set of destinations, with the objective of minimizing both the total transportation time and the number of required vectors (aircraft, boats, trains, etc).The authors consider only the 2D problem for solving, but the real time problem is 3D in nature.

The work carried out for the military transportation and the items considered were in prismatic shapes, but in the domestic packing, the items might not be in prismatic shapes all the time. Because most of the military items are packed in the boxes and that that boxes will be packed into the container or the cargo for transporting.

Kevin R. Gue, Kai Furmans, ZäziliaSeibold, and OnurUludağ used the 2D grid based puzzle system has used to store and retrieval with multiple objective. They describe a high-density storage system for physical goods in which identical conveyor modules can be plugged together to store and retrieve unit-loads or small containers. Material movement conforms to the “puzzle architecture” found in popular board games such as the 15-puzzle and Rush Hour. Control of the system is decentralized, meaning that each module contains identical operating logic that directs its behavior based on local conditions and message passing. They also proved the system deadlock-free and show its performance under a wide variety of operating configurations.Developed for 2D bins and not for 3D bins.i.e the algorithm was developed to pack the 2D objects into a larger 2D rectangular item and assumed that can be extended for the 3D space.

Developed decentralized system of packing. This was concentrating only on the bins associated with the container and not considering the other bins and the containers.Grid based arrangement or packing consumes more computational time for larger problems. Grid based system can be best suitable for the simple mathematical problems with finite number of solutions.

Yusen Li, Xueyan Tang and WentongCaiconsidered the concept of dynamic bin packing. Dynamic Bin Packing (DBP) is a variant of classical bin packing, which assumes that items may arrive and depart at arbitrary times. Existing works on DBP generally aim to minimize the maximum number of bins ever used in the packing. In this paper, the authors considered a new version of the DBP problem, namely, the MinTotal DBP problem which targets at minimizing the total cost of the bins used over time. It is motivated by the request dispatching problem arising from cloud gaming systems. We analyze the competitive ratios of the modified versions of the commonly used First Fit, Best Fit, and Any Fit packing (the family of packing algorithms that open a new bin only when no currently open bin can accommodate the item to be packed) algorithms for the MinTotal DBP problem.

Xiaofan Zhao and Hong Shenconsidered the packing of cubes into the standard are container. The authors defined the bin packing problem is one of the oldest classical problems in both computer science and combinatorial optimization. Since it has been studied for over 30 years, many variants of this problem have also been well studied. In this paper, they consider the 2-space bounded online cubes and hypercube packing problem, which is formulated as follows: Input to the problem is the list L of items, Eachitem li is a 2-dimensional variable i.e. the length and the width.

There is also an infinite number of unit-capacity bins T , each of which is a 2-dimensional.Md. Rashid Chowdhury, Md. RaihanMahmud, and Rashedur M Rahmanstudied the performance of the placement strategy of the bins inside the container. In this model, infrastructure requests are mainly served by allocating the VMs to cloud users. Successful live migration of VMs among hosts to hosts without a significant interruption of service results in dynamic consolidation of VMs to minimum number of physical hosts thus consumption of less electrical energy. However, high variable workloads can cause performance degradation when an application requires increasing demand of resources. Beside power consumption the need to also keep in mind about performance, as it puts Quality of services (QoS) which is defined via Service Level Agreement (SLAs) into jeopardy. It is clear that maintenance of cloud computing is an energy performance trade-off – we have to minimize the energy consumption while meeting the QoS. In order to address the problem, in this work, multiple VM placement algorithms are proposed based on the solution of bin packing problem.

Zhang De-Fu Chen, Sheng-Da, and Liu Yan-Juan [8] introduced recursive based heuristic GA for rectangular strip packing problem. First, the algorithm checks for similar rectangular pieces to form strips, strips have been arranged in ascending order and then packs them in sequence, thereby the waste space between rectangles were avoided. Remaining available empty space has been found using recursive algorithm and that empty space has been filled with the help of GA and found that the methodology performs better for larger benchmark problems. For packing, they used bottom left fill method.

The literature survey reveals various strategies and methodologies applied by the researchers in the field of bin packing problems. Generally, the containers used for bin packing problem are rectangular in shape. But literatures also used variable sized containers, which cannot be suitable for cargo packing. Similarly, from the literatures it was found that most of the solutions were provided for cubical and rectangular prismatic bins. This situation cannot exist all the time in the logistic industries. In many situations, bins are heterogeneous in nature and very few literatures had dealt with heterogeneous bins. Literatures proved that the simple mathematical methods cannot be more appropriate for multi-objective and multi-constrained problems. The researchers had also succeeded in using genetic approach for problems involved with discrete and continuous variables. None of the literature concentrated on weight constraint, load bearing constraint, placement constraint, stability constraint, boundary crossing constraint, orientation constraint all together. The researchers compared the developed algorithm with the lower bound values and have not considered much on the output format i.e. the format which the practitioners can easily understand and implement the model.

Hence in this work, an attempt had been made to develop a conceptual framework for solving the problem in the field of bin packing. The framework could aid in developing an optimal solution for multi-objective problem by satisfying the major packing constraints.

3. SYSTEM MODEL

The main objective is to minimize the empty space inside a container while packing arbitrary sized and heterogeneous bins. Generally, optimization problems are classified either as maximization or minimization function. The first function helps to maximize the number of bins to be packed into the container, while the second one helps to minimize the empty space or unpacked space inside the container, thereby resulting in the transportation cost reduction. The above mentioned objectives should be achieved by satisfying the constraints in packing of bins into a container.

In this project, placement constraints considered are boundary crossing constraint, container capacity constraint and bin placement constraint. All the packed bins should be placed within a container boundary. Bins to be unloaded first should be placed near the door and so on. These placement constraints should be checked at eachand every bin placement inside the container. Functional constraints did not have direct influence on the optimization of bin packing, but they will add to the complexity while loading and unloading of bins and also affects the ease of packing.Overlapping constraint : This constraint needs to be checked at each and every bin placement for overlapping among them and with the container boundary.Stability constraint: The bins to be packed should be stable inside the container. Because instability results in collision and damage the bins, the profile and the surface area of the packed bins and the bins to be packed are to be taken care. Orientationconstraint: The position andorientation of the bins play a major role in space optimization. In other words, items namely fragile materials, liquid/gas containers and glass items should not be tilted. Weight constraint:Each container has the pay load capacity. The cumulative weight of all the packed bins should be less than the pay load capacity of the container. Load bearing constraint: This requires that items that arelighter in weight and are fragile should be kept at the top layers of a container and heavier bins should be packed at the bottom layers of the container.

Thus the obtained solution by satisfying the above mentioned constraints will be the optimal and the feasible solution for the bin packing problems of arbitrary sizes and of heterogeneous shapes.Input data to the bin packing problem is the bin specification (length, breadth and height), container specification and the constraints involved in packing. The output should be the optimal bin packing sequence which satisfies the constraints. The entire project is divided into six stages and is as follows.

i) Input Module
ii) Encoding Module
iii) Genetic Algorithm Module
iv) Decoding Module
v) Tuning Algorithm Module
vi) Output Module

Input Module

To collect the required data namely bin types, number of bins, its dimensions along with other constraints.

Encoding Module

The user entered data should be checked for the feasibility and converted to the genetic chromosomal format.

Genetic Algorithm Module

GA has been employed in this research to optimize the solution to the bin packing problem. The various stages of GA like initial parent generation, crossover, mutation, fitness function calculation and termination.

Initial population generation

In this stage, 'n' number of parents with 'm' numbers of strings have to be generated randomly. Various experiments will be conducted for the parent size of 75, 100, 135, 150, 175 and 200.

Crossover

Crossover site is the position in the parent chromosome at which the interchanging of strings occurs. So that the generated child will inherit the properties from both sets of parent. The sample image of the crossover is shown in the figure 1.

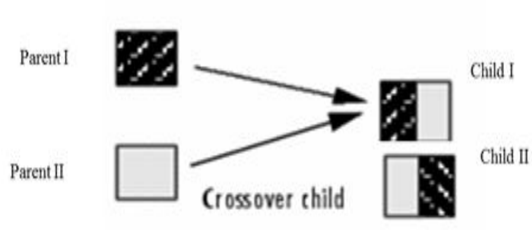

Figure 1 : Crossover

Mutation

Mutation is the operation of swapping an individual string from a parent by selecting the position of string randomly. Figure 2 explains the mutation overloading operation with a sample parent.

Figure 2: Mutation Operation

Fitness function

Fitness function is also called as objective function, which is used to identify the best parent from the generated population.

Termination conditions

A set of termination conditions used to identify the optimal solution are Minimum criterion condition, Max. no. of generations, Stagnation condition, etc.

Decoding Module

Decoding is the reverse of encoding process. Decoding process converts genetic chromosomal output into user understandable format.

Output Module

The output module utilized the decoded data and generated the coordinate points of the bins, its position inside the container, volume occupied and empty space inside the container.

Algorithm Simplification

Simplification of 3D problem into 2D or 1D problems inorder to reduce the problem complexity is called as algorithm simplification. Assuming that the heights of all the bins are equal will reduce the 3D problem to 2D problem. But, the result obtained by simplifying the algorithm cannot be feasible for all the bin packing problems. Kun and

Bin Packing Assumptions

Bin packing assumptions are a set of specific conditions for specific instance which will yield maximum container volume utilization. These assumptions cannot be universal for all the bin packing problems and can result in infeasible packing pattern. Inorder to obtain a feasible bin packing pattern, packing constraints need to be satisfied without any assumptions. In practice, number of assumptions made should be as least as possible to generate a feasible bin packing pattern.

Thus a multi-objective andmulti-constrained model is required to generate an optimal bin packing pattern which considers all the major packing problems discussed above. This can be achieved by means of Genetic algorithm

Genetic Algorithm

Recent revolutions in molecular genetics made clear that the modular organization of genes is highly important for evolution of complexity. Evolutionary concept of Genetic Algorithm (GA) was introduced by John Holland in 1975 at the University of Michigan. First stage in using Genetic Algorithm is initial population generation randomly based on probability logics and each individual in the randomly generated population is represented by chromosomes in biology. The method of random generation may vary from researcher to researcher. Chromosomes have many segments and 'n' number of strings depends on the complexity of the given problem.

The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.

Genetic algorithms find application in bioinformatics, phylogenetics, computational science, engineering, economics, chemistry, manufacturing, mathematics, physics and other fields.

A typical genetic algorithm requires:

1. A genetic representation of the solution domain,
2. A fitness function to evaluate the solution domain.

A standard representation of the solution is as an array of bits. Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations may also be used, but crossover implementation is more complex in this case. Tree-like representations are explored in genetic programming and graph-form representations are explored in evolutionary programming.

The fitness function is defined over the genetic representation and measures the *quality* of the represented solution. The fitness function is always problem dependent. For instance, in the knapsack problem one wants to maximize the total value of objects that can be put in a knapsack of some fixed capacity. A representation of a solution might be an array of bits, where each bit represents a different object, and the value of the bit (0 or 1) represents whether or not the object is in the knapsack. Not every such representation is valid, as the size of objects may exceed the capacity of the knapsack. The *fitness* of the solution is the sum of values of all objects in the knapsack if the representation is valid or 0 otherwise. In some problems, it is hard or even impossible to define the fitness expression; in these cases, interactive genetic algorithms are used.

During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a *fitness-based* process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected. Certain selection methods rate the fitness of each solution and preferentially select the best solutions. Other methods rate only a random sample of the population, as this process may be very time-consuming.

Most functions are stochastic and designed so that a small proportion of less fit solutions are selected. This helps keep the diversity of the population large, preventing premature convergence on poor solutions. Popular and well-studied selection methods include roulette wheel selection and tournament selection. In this project work, each segment in the chromosomes represents a bin and may contain constraints in the form of strings. Generally population size should be fixed based on the complexity of the problem. So there should be a tradeoff between computational time and number of chromosomes in the population.

CONCLUSION

The GRIDSTORE system offers high storage density and highthroughput, which previously have been considered conflicting objectives in material handling systems design. Because storage locations are themselves conveyors capable of transport, the system can deliver items at almost any required rate. In order to achieve high density in the third dimension, multiple levelsof GRIDSTORE could work simultaneously in cooperation with vertical lifts. We have modeled throughput in GRIDSTORE with a constant work-in-process policy in which the number of active requests in the system is constant. For low to medium levels of WIP,throughput increases at an *increasing* rate, in contrast with many vehicle-based material handling systems in which additional requestslead to congestion and increases in throughput at a decreasingrate (or even to decreasing throughput). The major contribution of our work is to introduce to the materialhandling community a new way of thinking about material movement on a grid. The GRIDSTORE system extends existingresearch on puzzle-based storage systems by allowing simultaneous retrieval of an arbitrary number of requests. Future research might develop systems that can deliver items to anyexterior boundary, rather than to a single side, as GRIDSTOR Erequires.The complex behavior of GRIDSTORE is made possible bya relatively simple decentralized control scheme, which is a second contribution of our work. Decentralized control allows for complex system operations and conflict resolution through electronic negotiation. Effective and, we believe, interesting behaviour of the system emerges as a result of these rules.

REFERENCES

1. C Gueret, N Jussien, O Lhomme, C Pavageau and C Prins, "Loading aircraft for military operations", Journal of the Operational Research Society (2003), Issue 54, pp. 458–465.
2. Kevin R. Gue, Kai Furmans, ZäziliaSeibold, and OnurUludağ, "GridStore: A Puzzle-Based Storage System With Decentralized Control", IEEE Transactions On Automation Science And Engineering, Vol. 11, No. 2, April 2014.
3. Yusen Li, Xueyan Tang, WentongCai, " Dynamic Bin Packing for On-Demand Cloud Resource Allocation", IEEE Transactions on Parallel and Distributed Systems, Vol 1045-9219, June 2015, pp. 1-14.
4. Xiaofan Zhao and Hong Shen, "2-Space Bounded Online Cube and Hypercube Packing", TSINGHUA Science And Technology, ISSN 1007-0214 04, Volume 20, Number 3, June 2015, 10 pp255-263.
5. Mohammed Rashid Chowdhury, Mohammad Raihan Mahmud, Rashedur M Rahman, "Study and Performance Analysis of Various VM Placement Strategies", IEEE SNPD 2015, June 1-3 2015, Takamatsu, Japan, 978-1-4799-8676-7/15, pp. 30-36.
6. Lau, H.C.W., Chan, T.M., Tsui, W.T., Ho, G.T.S. and Choy, K.L. "An AI approach for optimizing multi-pallet loading operations", Journal of Expert System with Applications, Vol.36, No.3, pp.4296-4312, 2009.