An Efficient Strategy of Shape Assignment for Block Division

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Abstract

This paper presents the strategies of bestfit Bottom-Left by Right first (BL-Rf) and Bottom-Left by Top first (BL-Tf) (BL-Rf/BL-Tf) for block division selection. The block solution inspires from Space Allocation Problems (SAPs) and Packing Problems (PPs), however the huge number of possible solutions the heuristic with guided strategies required for the satisfied results. The mathematical expression was formulated to represent this problem. The independent strategy by BL-Rf or BL-Tf has inconsistent result and led to fail to promote optimal solution. Therefore, BL-Rf/BL-Tf attempts to improve the result performance. The strategies applied in GA, the generated numbers of optimal solutions were stated for the purpose of analysis. The BL-Rf/BL-Tf promotes more solutions number than the independent strategies and indicates that result quality and time efficiency are better.

Keywords: *Genetic Algorithm, Space Allocation Problems, Block Division. Shape Assignment*

1. Introduction

Some papers related of block division for Lining Layout Planning (LLP) have been published [13, 14]. These papers discussed how we organized genetic algorithm (GA) to decide optimal combined blocks intelligently with the intention of optimizing tree planting land areas. Block division by shape assignment strategy is to reach an optimal result of combined block with referring to zero unused (unfilled) space of area. This optimal result has tendency to promote maximum number of trees. The factors of block number and shapes used that represent blocks influence the analysis time. Thus, block division is Non-Deterministic Polynomial (NP) problem since it requires the exponential time for optimal solution. In order to decide the possible blocks combination in an area relates to the associated ideas of space allocation problems (SAPs) by packing problems (PPs).

The objective of SAPs is to optimize the space usage in order to maximize the total profit [21], while PPs is to maximize the utilization and hence to minimize the "wasted" material [11]. Some literatures in SAPs and PPs that devoted on various fields using Genetic Algorithm (GA) such as architecture [20], retail [18], fashion industry [17], computer graphic [1] and others to handle their problems have given an inspiration to solve this domain issue.

Packing problems (PPs) is a class of space allocation problems (SAPs). PPs is encountered in many areas of business and industry is forms part of the combinatorial problems found in operational research. Optimization problems are concerned with finding a *good* arrangement of multiple *items* in larger containing regions (*objects*) [11]. The usual objective of the allocation process is to maximize the utilization and hence to minimize the "wasted" material. Rectangular object layout aim is to put rectangular shapes of different sizes in definite stock sheets and get the higher using ratio of material sheets with no interference and not beyond the boundary [23]. The ambiguity solution to determine the appropriate shapes to be fitted into an area is considered as a type of optimizations problems. The aim is to minimize unused space so that the area could be optimized.

The searching processes to meet the objective function, however, promote many possible solutions to be analyzed in accordance with the available constraints and consequently led to high computational time. They noted

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that the rectangular object layout is not a simple optimization problem [6]. Moreover, in complex solutions in SAP that involve different shape combination to be examined is high time-consuming. Therefore, SAPs are considered as NP problem that requires exponential time to solve such related problems in the worst-case. Packing problem is class of SAPs and has been shown to be NP hard [9, 15]. The complexity to find the optimal solution has led this bin packing problem is considered as a combinatorial NP hard problem [19].

Heuristic techniques have been used since the mid 70's and one approach sorts the shapes into some order (for example, ascending order of area) and then packs the shapes as near to the bottom left of the bin as possible [5]. The more extensive and detailed descriptions for packing problems are given [2, 3, 19]. The importance of these problems, various heuristic algorithms based on different strategies have been presented [16]. These algorithms can be categorized into two groups: the traditional heuristic algorithms and the metaheuristic algorithms. The traditional heuristic algorithms use the heuristic information to guide the search process such as bestfit Bottom-Left (BL) [4] and recursive algorithm [24, 10].

Metaheuristic approaches have been applied since the mid 80's. These include genetic algorithm (GA), tabu search and simulated annealing and neural network [5]. A variety of packing problems have been tackled using genetic algorithms. The first researcher to apply GA to packing problems was Smith [22] in a bin-packing problem. At the same time Davis [7] summarized the techniques for the application of GA using the example of two-dimensional bin-packing. The GA manipulates the encoded solutions, which are then evaluated by a decoding algorithm, which transforms the packing sequence into the corresponding physical layout [11].

2. Application: Block Division Selection for Area Optimization

Block division focuses the strategy to assign the determined number of shapes into an area. This strategy is applied for determining the broken land area down into the blocks, so that promoting the optimal number of trees (item). Block represented by shape which is the attempt of assigning shapes into a rectangular or square area with the intention to fully occupy the area.

The area and assigned shapes represented by coordinates that are acquired from the top-right of *x4, y4* coordinate. By coordinate-based representation of area and shapes be able to determine their sizes and patterns. For example, figure 1 shows an area or a shape of (8, 4) coordinate produces 32 square meter (x4 x y4) size and consider horizontal rectangular pattern.

Fig.1. Horizontal Rectangular Pattern with (8, 4) Coordinate

While the solution of shape assignment is certain, the number of items produced by shapes is uncertainty number. We found that the different arrangement of items by line directions in shape yields distinct numbers as shown in figure 2. In addition, the use of shapes which are same size with different pattern may produce a different number as shown in figure 3.

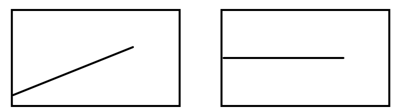

Fig.2. Shapes with different line direction produce various item numbers.

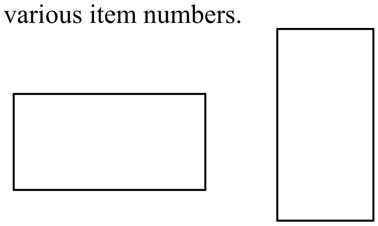

Fig.3. Same shape size with different pattern produce different item number.

On top of the uncertainty, the item number from shape combination in area is difficult to expect. Therefore, in determining the highest item number in an area requires series of iteration in analysis process, as a consequence, the high computational time is needed.

3. GA for Block Division

Block division is to find the combination of the determined number of shapes in an area with intention two constraints. First, combined shapes according to the determined block number must be fully utilized. Second, prevents possible shapes from overlapping. The overlapping shapes share same planting direction, so that the shapes have possible to be merged will eventually fail to find the required number of blocks.

Based on the above constraints and strategies, we attempt to assign to the number of shapes that have been priory determined into the given area. Therefore GA was used to

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propose solutions after considering the constraints for the optimal solution of block division. For the discussion of how the GA works refers to the three shapes to be assigned into an area.

Figure 4 represents the successful solution with chromosome of 3, 3, 1, 4, 3, 1 when it fulfils all constraints as discussed above, all shapes were fully located into the area with no unused space. However, the figure 5 with 3, 3, 3, 2, 2, 2, can only be fitted one shape and it remains an unsuccessful solution.

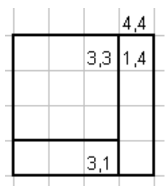

Fig.4. Successful Solution

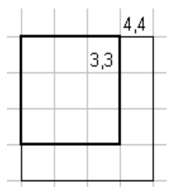

Fig.5. Unsuccessful Solution

The processes of shape assignment by GA begin with assigning value to genes of a chromosome (genome) that represents individual. The chromosome of population consists of shapes will be assigned into an area as figure 6. The chromosome that has fulfilled the constraints is considered as a successful individual; in contrast fail to find the successful individual new generation will be produced. GA guides the search process in which the first two genes of chromosome (first shape) from the Bottom-Left as shown in figure 6. Then to fill in the others shapes a combination strategies of Bottom-Left by Right first (BL-Rf) and Bottom-Left by Top first (BL-Tf) was introduced.

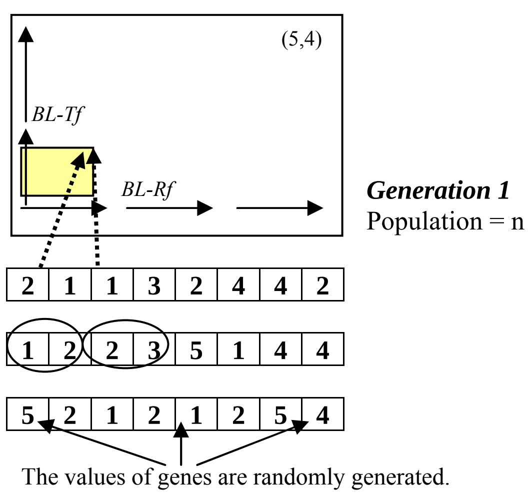

Fig.6. Shape Assignment Strategy

4. Strategy of Bottom-Left by Right first and Bottom-Left by Top first (BL-Rf/BL-Tf)

A chromosome with the pair of genes values represent shapes that to be assigned into an area. Therefore, every chromosome is evaluated by a proposed strategy named BL-Rf/BL-Tf. The BL-Rf/BL-Tf guides for the search of optimal solution in which chromosomes that fulfill the given constraints are successful. This strategy acquired from the two independent strategies of BL-Rf and BL-Tf. Both share the same goal to find optimal result in shape assignment but implement different strategy of assigning shapes.

In BL-Rf implementation each shape to be assigned into *W*, *H* of area represented by coordinate of x_i, y_i. First step is to assign the first shape starting from bottom-left where the origin coordinates is (0, 0) of *W*, *H* of area which is considered as first level of row *H*. Second step, the next shape is assigned at the right side of *W* with condition of $x <= W$ where x is value derived from the sum of total x and current shape of x_i ($x = x + x_i$). Failure to meet the condition, the shape will be moved to the next level of *H* in which shape placement based on the highest y of assigned shapes at previous level, and x back to 0. As illustrated in figure 7, shape 1, 2 and 3 can be fitted at same level of *W* and shape 4 was placed to next level of *H* at $x = 0$ and $y = y_i$ of shape 3. For others shapes this process will be repeated to second step until $y > H$ (shape beyond *H* area) or all shapes have been assigned.

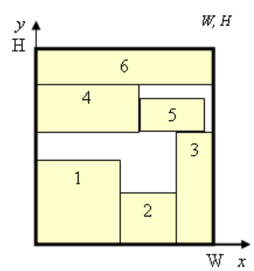

Fig.7. BL-Rf Result

In BL-Tf implementation each shape to be assigned in *W*, *H* area represented by coordinate of x_i, y_i. First step is to assign the first shape starting from bottom-left where the origin coordinates is (0, 0) of *W*, *H* area which is considered as first level of column *W*. Second step, the next shape is assigned at the right side of *H* with condition of $y <= H$ where y is value derived from the sum of total y and current shape of y_i ($y = y + y_i$). Failure to meet the condition, the shape will be moved to the next level of *W* in which shape placement based on the highest x of assigned shapes at previous level, and y back to 0. As illustrated in figure 8, shape 1 and 2 can be fitted at same level of *H* and shape 3 was placed to next level of *W* at y =

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0 and $x = x_i$ of shape 1. For others shapes this process will be repeated to second step until $x > W$ (shape beyond H area) or all shapes have been assigned.

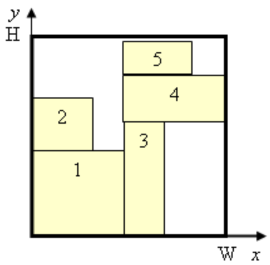
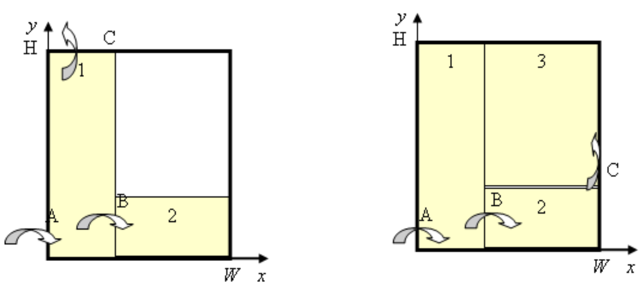


Fig.8. BL-Tf Result

In this situation BL-Rf looks better than BL-Tf in term of the number of assigned shapes and minimizes unused space; however in other situation the result might be different. Figure 9 for instances illustrates that BL-Rf fails to assign shape 3 because it exceed the *H* of area, and then implement BL-Tf shows the success of assigning all shape 3 into the area.



BL-Rf fails to assign shape 3 because it exceed (*H, W*)

BL-Tf succeed to assign all shapes

Fig.9. Shapes Placement by BL-Rf/BL-Tf

On top of the inconsistent results, the choice of either BL-Rf or BL-Tf may fail to find the solution. The flawed strategies therefore, the combination of BL-Rf and BL-Tf (BL-Rf/BL-Tf) was introduced. By BL-Rf /BL-Tf the shapes to be assigned will evaluated by BL-Rf and if it fails to reach the solution; the BL-Tf will be implemented. Otherwise the only BL-Rf will be performed. Thus with evaluating both strategies in BL-Rf/BL-Tf has possible to improve the quality of solution.

4.1 Mathematical Solution for Block Division Strategy

BL-Rf/BL-Tf implemented in shape assignment strategy is to optimise land area in lining layout planning (LLP) is Space Allocation Problems (SAPs) matter. SAPs by taking the inspiration of packing problems solution were investigated to overcome this issue. We formulate the block division in area based on the basic idea of bin packing problem and knapsack problem.

Let each shape i is derived from a set of the n shape number $I = \{1, 2, 3, \dots n\}$, thus is i subset of I as $i \in I$. We are given a set that a x_i and a y_i for each shape i and an area A represented by W and H. We design bottom-left side of area A as the origin x and y coordinate for the first shape i is assigned referring x-axis and y-axis are the direction of the width and of height respectively. We represent each shape i to be assigned in area A by coordinate (x_i, y_i) where x_i, y_i refers to top-right side of shape (*see figure 1*). Each assigned shape i is summed to a w for x_i and an h for y_i. We consider the perfect block division that requires a determination of whether all given shapes can be placed into an area A with a fixed (x_i, y_i) without overlap and no rotations, so that minimize wasted space in area A is our consent however utilize area A with zero wasted space is our main aim. The mathematical solution for this problem can be formulates as follow:

Minimize $A = (\sum_{i=1}^{n} w_i h_i S_i)$

Subject to $\sum_{i=1}^{n} h_i w_i \leq W * H$ $\quad c1\{0, 1\}$, --- (1)

$h + y_i \leq H$ $\quad c2\{0, 1\}$, --- (2)

$w + x_i \leq W$ $\quad c3\{0, 1\}$, --- (3)

$x_i,\ y_i >= 0$ $\quad c4\{0, 1\}$, --- (4)

$x_i < x_{i-1}$ or $x_i > x_{i-1}$ or

$y_i < y_{i-1}$ or $y_i > y_{i-1}$ $\quad c5\{0, 1\}$, --- (5)

$c1 \cap c2 \cap c3 \cap c4 \cap c5 \qquad S_i\ \{0, 1\}$

The constraint 1 has possibility to assign all shapes i in area A but violence this constraint means at least one shape is certainly failed to be placed. The constraints of 2, 3 and 4 are to ensure that all shapes within the area. The constraint 5 prevents rectangles from overlapping. The success of each constraint of 1, 2, 3, 4 or 5 is given 1 otherwise is 0. While all the constraints are fulfilled, the S_i will be 1, otherwise is 0. The shape i will be placed according to $S_i = 1$.

4.2 Algorithm for BL-Rf/BL-Tf

The above principle discussion of BL-Rf/BL-Tf is to find a successful chromosome for optimal solution. The algorithm in figure 6 shows how this strategy works. The algorithm evaluates the chromosomes by BL-Rf or both BL-Rf and BL-Tf according to the given constraints. The chromosome that fulfils the constraints is successful..

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```
call ShpAssgByBL-Rf( ){
StatusBL-Rf ← 0
if fulfill all constraints (refer section 3)
        StatusBL-Rf ← 1 }

if StatusBL-Rf = 1 {
        Info ← "Optimal Block Division was found at BL-Rf
        strategy"
else
        call ShpAssgByBL-Tf( ) {
        if fulfill all constraints (refer section 4.4.2 of chapter 4)
                StatusBL-Tf ← 1 }
        if StatusBL-Tf = 1 {
                Info ← "Optimal Block Division was found at
                        BL-Tf strategy"
        else
                Info ← "Fail to find Optimal Block Division
                solution at this type chromosome" }
```

Fig.6. Algorithm of BL-Rf/BL-Tf Strategy

5. Experiment Result and Discussion

A comparative performance of BL-Rf, BL-Tf and BL-Rf/BL-Tf was conducted. In order to find as much as possible of optimal solution, we set population size is 200. The number of successful chromosomes was taken for analysis purposes based on the last number before the analysis is terminated. The process of termination occurs when no promoting other optimal result leads to the repetitive results. Table 1 shows detail results by three shapes to be assigned into 4, 4 coordinates of area. The successful chromosomes, the number that chromosome reach optimal and processing time of the three strategies were stated.

	BL-Rf		**BL-Tf**		**BL-Rf / BL-Tf**	
	Successful chromosome	reach optimaat	successful chromosome	reach optimaat	successful chromosome	reach optimaat
1	123224	20	314311	43	111334	17
2	321242	72	124232	139	224124	22
3	224124	84	111334	193	114331	70
4					113413	72
5					224124	83
6					423212	119
7					331341	151
8					314311	167
	Processing Time	**0.026 sec**		**0.043 sec**		**0.064 sec**

Table 1. Comparison of the Three Strategies

The optimal solution refers to the successful chromosome. The result shows that BL-Rf and BL-Tf obtained three optimal solutions, while BL-Rf/BL-Tf was eight optimal solutions. This result shows that BL-Rf/BL-Tf is able to determine more solutions numbers; therefore the comparison of results is wider as a result has high tendency to achieve better result compared with the two strategies.

BL-Rf/BL-Tf promotes eight solutions of chromosome leads to the earliest reach the first solution. The overall time taken for all successful chromosomes as stated show BL-Rf is 0.026 second, BL-Tf is 0.043 second and BL-Rf/BL-Tf is 0.064 second. The average time of successful chromosomes to find optimal solution for BL-Tf is 0.00867 (0.026/3) sec, BL-Tf is 0.0143 (0.043/3) sec and BL-Rf/BL-Tf is 0.008 (0.064/8) sec. Hence, BL-TF is the slowest to retrieve optimal solution, while BL-Rf/BL-Tf is the fastest. Based on this situation, BL-Rf/BL-Tf strategy requires fewer analysis as a result this strategy is most efficient than others. We conclude that by BL-Rf/BL-Tf strategy has possibility to find more number of optimal solutions, therefore it has tendency to promote less time.

6. Conclusion

The strategy of BL-Rf/BL-Tf improves the result quality and time efficiency. As conclusion, this strategy promotes a promising solution of shape assignment and will give a significant contribution of the overall solution in LLP for tree planting optimization. The generated results by GA application, BL-Rf/BL-Tf is usually better but somehow at certain circumstances BL-Rf or BL-Tf outperforms BL-Rf/BL-Tf. This is a challenge to make the result consistent and should be for further work.

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