Novel Genetic Algorithm towards Implementing a Lining-Layout Optimization Strategy

Ismadi Md Badarudin[1], Abu Bakar Md Sultan[2],
Md Nasir Sulaiman[2], Ali Mamat[2], Mahmud Tengku Muda Mohamed [3]

[1]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA
Shah Alam, Selangor, Malaysia

[2]Faculty of Computer Science and Information Technology, Universiti Putra Malaysia
Serdang, Selangor, Malaysia

[3]Faculty of Crop Science, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

Abstract

This paper presents the strategies for optimizing planting areas. The three strategies considered for preparing field lining; 1) 60^0 line-direction 2) selecting the best line-direction for single block and 3) selecting the best line-directions for many separate blocks, might lead to different numbers of trees. Thus, an application named *Lining-Layout Planning by Intelligent Computerized System* (*LLP-ICS*) is introduced to choose the best strategy. Because there are many possible solutions with ambiguous results, a novelty of Genetic Algorithm (GA) for lining-layout with focusing on the two approaches which are 1) assigning the determined random values to the genes of chromosome, 2) avoiding the same solution of optimal blocks occurs, was applied to suggest the optimal solution intelligently. The aim of this study was to suggest the best strategy among the various area coordinates tested. In addition, the capability of the application by novel GA was also examined. The results indicated that the LLP-ICS produces a consistent solution with feasible results and less number of repetition processes led to reduce the computation time.

Keywords: Optimization, Genetic algorithm, Lining-layout, Optimal solution

1. Introduction

In implementing the strategy of lining layout planning (LLP) planting area optimization as discussed in section 2, the four criteria in land used planning as describe by Steward [2], involvement of the stakeholder, complexity of the problem, use of a geographical information system and use of an interactive support system are considered as part of the challenge. In LLP optimization, the decisions of the managerial department depend on the demands for tree quality and the ease of managing the field; consequently the optimal solution is not simply the one with the maximum number of trees. However, a huge number of possible solutions are generated for both determining the location of the blocks and selecting the best line-direction. Moreover choosing among several proposed optimal solutions requires an algorithm that capable of producing a feasible solution with acceptable computational time. The complexity of the problem is increased by a variety of area coordinates besides the assignment of blocks and line-direction, which might have some constraints making them much more difficult to solve. The choice of coordinate-based system from a GIS application makes the required coordinates of selected planting area easy to stored and presented as geo-referenced information. However, the large areas represented by a high number of coordinates might require a scale representation of the coordinates to show the significant representation in a graphic view. The interactive support system focuses on the quality of the result and on computational time. The LLP strategy relies on the input of area coordinates and number of blocks, and determining the appropriate parameters is vital to make the system produce a feasible result within the result in acceptable time.

A number of area optimization techniques have been proposed for computation of the optimal allocation within an area [5, 6, 7]. The enormous increase in the number of decision has led to applying heuristic algorithms such as genetic algorithm [2], simulated annealing approach [8, 9], tabu search heuristic [10] to be to overcome site allocation problems. According to Theodor J. Stewart [2] the four mentioned criteria to evaluate the result with implementing a grid-based system by Genetic Algorithm (GA), which showed feasible results with certain numbers of grids; however enlarging problem will result in tediously increased computational time. In contrast, for our LLP solution, we analyze the use of coordinate-based for analyzing the assignment of blocks and line-direction by GA. In contrast, for our LLP solution, we analyze the use of coordinate-based for analyzing the assignment of blocks and line-direction by GA.

The LLP strategy is to suggest the optimal result in term of tree number. The inconsistency of tree density in a planting area makes the number of trees difficult to predict. An analysis by Jusoh [3] stated that maximum income could be obtained at 148 palms/ha, contrary to the conventional practice of 136-148. Moreover, on peat soil, tree density can be increased to 200 palms/ha. In the certain circumstances with the common spacing, 9 m x 9 m triangular planting distance, yields varied between 128 to 148 palms/ha depending on planting material, soil and climate [4]. However, in another perspective, the tree is uncertain because it depends on the factors of different line-directions and various areas coordinate [1a].

The ultimate objective of this study is to determine the capability of the application called *Lining Layout Planning by Intelligent Computerized System (LPP-ICS)* by GA in handling proposed optimization strategy. To discuss this, the remainder of this paper is organized as follows. An optimization strategy that is able to improve tree density is discussed in section 2. The development of a computerized system for designing LPP intelligently is discussed in section 3. A GA method is our main approach to solving this issue; we discussed the strategies for reducing computation time in section 4. The LPP-ICS application is briefly discussed in section 5 and followed by empirical analysis and discussion in chapter 6. Finally section 7 contains our conclusions and future directions for this work.

2. Optimization Strategy

A strategy called *Lining Layout Planning (LLP*) attempts to optimize land use by dividing an area into blocks and then assigning line-direction within the determined blocks. Figure 1 shows that the two main tasks in the LLP strategy are determining blocks division and followed by identifying the best line-direction for every determined block. The unpredictable tree density in an area produced by the different line-directions, various areas coordinates and variety of shapes coordinates make requires a computerized system to find the best lining layout.

Preliminary observation revealed that the current practice (CP) of 60^0 line-direction in preparing field lining does not necessarily produce the optimal number of trees. The optimization strategy in figure 1 shows an area that could be one block or many blocks. The block division requires GA to find optimal combination of blocks with no unused spaces of area as discussed in section 3.1. The divisions with both one and many blocks will be assigned with the best line-direction that the calculation process is initially derived from the line representation technique as discussed in section 3.2. 90 line-directions, between 0^0 and 90^0 from the base line are tested. The line that produces the highest number of trees is considered the best. The number of trees in an area depends on several factors such as area coordinates, block number, shape coordinates, planting distance, base line and line-direction. The evaluation process must fulfill the condition that the use of many blocks (LLP result) must produce at least as many trees as one block (LP result) to be considered optimal strategy, otherwise the repetition process of determining other combinations of blocks will be repeated. The repetition process will occurs until the number of evaluation higher than set value by user and it indicates that the LP strategy will be selected as optimal strategy. These processes are shown as a flowchart in figure 2.

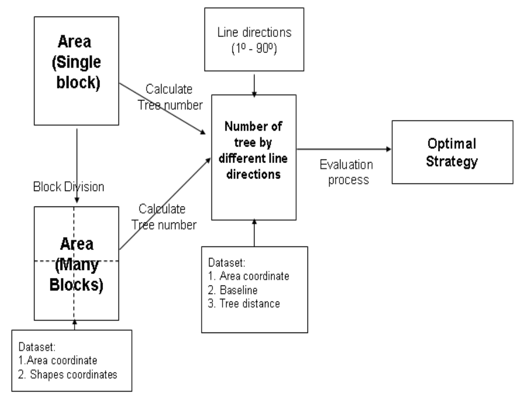

Fig.1. Lining-Layout Optimization Strategy

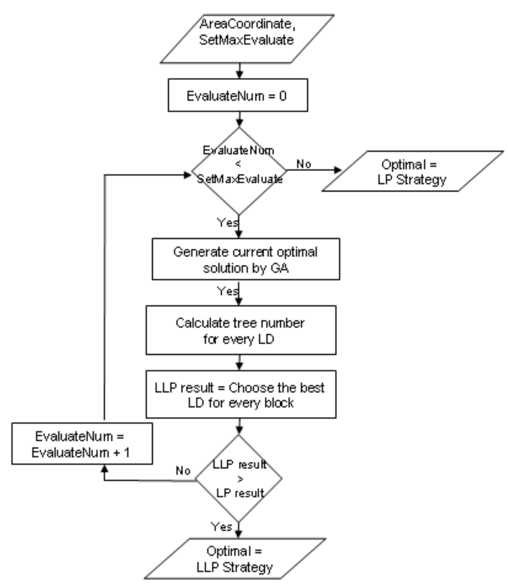

Fig.2. Processes to find the Best Strategy

3. Solution Techniques for LLP

In obtaining the optimal result, the assigning blocks are assigned first, followed by choosing line-direction. This section discusses the techniques for selecting block division and line-direction selection.

3.1 Shape Assignment

LLP strategy aims to obtain the optimal number of trees that can be planted into an area based on the two management requirements of 1. ease of managing the field and 2. cost or benefit. For the first requirement, the block division should be in a straight, which is assumed to be a field road. Second, the process of determining line-directions that produces the highest number within in area with different coordinates is desired. Consequently the optimal value is only reach if the total number of trees in the determined blocks is higher than with a single block.

To accomplish this, we identify the possible shapes coordinates that can be assigned subject to the area coordinates. Suppose a rectangular area with 4, 5 coordinates has 1,1; 1,2; …; 4,4; 4,5 shape coordinates with potential to be used. We assume that area and shape coordinates should be in square or rectangular form so as to fully fit the shape with no unused space.

To find the optimal blocks in an area, a shape assignment technique has been introduced to represent blocks in an area [1b]. The use of shapes depends on the number of blocks and the possible number of shapes used will be larger when the number of blocks increases. One important issue to be highlighted is that different combinations of shapes lead to different numbers of trees. Therefore, the purpose of assigning blocks into an area is to create different combinations of shape for each suggested solution. However, the combination of shapes is stated without taking into account the possibility of different arrangement of the shapes because the tree number will remain the same. Figure 3 shows the combination of shapes to be assigned into a (4, 5) coordinate of area using three blocks. By computerized system implementation, the procedure of assigning shape technique is described below:

1. The total size of the shape combination must equal to the size of the area.
2. The largest shape size should be assigned first.
3. No repetition of shapes coordinates. Repetition of shapes will reduce the number of blocks required.

The X or Y shape coordinate should be two times the X or Y area coordinate, respectively, to determine either the row or the column side to be assigned after the first shape assignment.

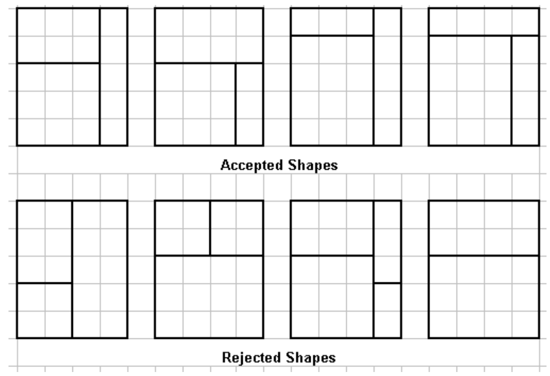

Fig.3. Example of the Accepted and Rejected Shapes According to the Shape Assignment Strategy

3.2 Line Representation

The line representation technique with calculating the line length for each assignment has three possible conditions as shown in figure 4. First, the line in range is within the range of the area coordinates; second, the line has its L2 coordinate beyond the y4 coordinate; third, the line has its L1 coordinate beyond the y1 coordinate. The line lengths are calculated by trigonometric function because the angle of line-direction was initially determined. Then, the number of trees is derived by dividing the sum of the line lengths by the determined planting distance.

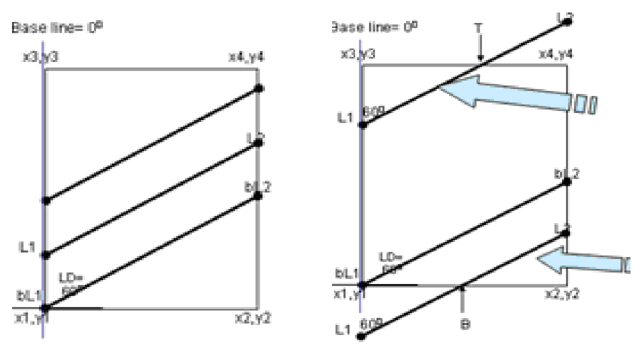

Fig.4. Line length with the three different conditions

The process of putting every tree into an area was analyzed but it produced a very large number of iterations. This was also shown in performance computerized analysis by Steward [2], deciding the suitable items to be assigned into cells represented by 20 x 20 and 40 x 40 problems required very high computational time because of the numerous iterations in the process.

In our approach, the line representation which is every line length in range of the area coordinates is divided by planting distance to calculate the number of trees. This technique will significantly reduce the number of iterations in an analysis process. For example, using the three blocks, 90 types of line-direction, 900m of area size, 9m of planting distance, 10 m line length requires 27,000 (*(((area size / planting distance) * block number) * line-direction types)*)iterations. This is because of the number of iterations increments one for each assigned tree. However, using line representation the algorithm produces significantly fewer iteration only 2,700 (*((((area size / planting distance) / line length) * block number) * line-direction types)*) because the iteration process refers to a number of lines that is assigned into the area.

4. Genetic Algorithm (GA)

4.1 Genetic Algorithm Overview

Optimizing layout by defining suitable rectangular shapes has been employed by many researchers in areas in areas such as computer aided design [12], the fashion industry [13], architecture [14], retail shelving [15] and others. Moreover, several studies in proposing optimal solution to packing problems have been done [16, 17, 18]. Taking inspiration from the works mentioned, we began by deciding the shape combination and then appropriate size to maximize the number of items. Due to the ambiguity of the result of shape assignment, the GA technique was employed, whereas the exact method was sufficient for choosing the best line-direction.

GA is classified as nature inspired because it is derived from the biological process of evolution. GA is one of the preferred algorithms in solving the optimization problems using 1. genetic operators capable to propose new individuals in the next generation that are most probably better solutions, and 2. a mutation operator acting to avoid traps in local optimal. By random searching, finding a solution is uncertain; using short term or long term memory to store the history of movement and current solutions might be helpful. According to Blum [20], more advanced approach uses search experience (embodied in some form of memory) to guide the search. This approach is to quickly identify regions in the search space with high quality solutions and on the other side to waste too much time in regions of the search space which are already explored. Other strategies that might improve the performance of GA in terms of time and solution quality need to be applied. Determining population size, chromosome, problem representation, rate of crossover and mutation all play role in improving the searching process. How these strategies constitute to the shape assignment technique has been discussed in the previous paper [1b]. Shape assignment for area block requires GA to decide for optimal solution since ambiguous solution. Several method to make sure the space is fully utilized without having unused space by referring space allocation problem.

GA implementation begins with population initialization and followed by the three genetic operators. The parameter of problems is represented by combination of genes. A scheme represents a set of individual and it is characterized by the two parameters of defining length and order. The genes develop a chromosome ad the chromosomes are manipulated by selection, crossover and mutation to build the new offspring. This process will be iteratively done with each offspring is analyzed to produce better result. The basic implementation of GA is illustrated by flowchart as shown in figure 5.

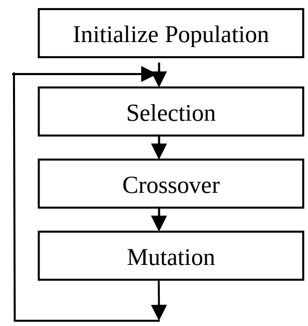

Fig.5. Flowchart for Basic GA Implementation

GA works by probabilistically introducing random values into the chromosome, and it is usually guided by determined constraints. The time spent to find an optimal solution is difficult to predict. Computation time typically refers to the number of iterations in the process. Less iteration reduces computation time.

4.2 Novel GA for Lining Layout Strategy

Classical GA means the basic works of GA that discussed in section 4.1. The classical GA is typically able to solve some optimization problems; however the computational time is always questionable. Some efforts to improve the classical GA [21, 22, 22] have been deployed in the field of problems. In implementing Lining Layout strategy, the two novelties of GA were introduced.

4.2.1 Code Representation

The process of encoding in a chromosome to represent the problems is the factor of the GA performance. Different representation schemes might cause different performance in terms of accuracy and length time [11]. The coding decides not only the arrangement form of an individual chromosome, but also the decoding form genotype to individual performance type in search space, and the designing genetic operators [16].

The common assignment of value 0 to 9 to the genes produces a huge possible solution. For example, if the 8 genes can be assigned random values from 0 to 9, the possible solutions of the worse case will be 10^8 = 100,000,000. Our strategy is to assign possible shapes into the area randomly, and we developed an approach of assigning the coordinate into the genes depending on the *x* and *y* coordinates of the determined area. For example, if the *x* and *y* of area represented by 4 and 5 respectively, the odd genes of the chromosome can be assigned numbers between 1 and 4 numbers, and in the even genes, a number between 1 and 5 is allowed.

2	5	1	2	1	2	4	5

Fig. 6: One set of possible values assigned randomly into genes when the area coordinate is (4, 5)

We manage this strategy using the equation of $x\ \text{AreaCoordinate}^{\text{chromosomeLength}/2} * y\ \text{AreaCoordinate}^{\text{chromosomeLength}/2}$. The area coordinate of (4, 5) requires $4^4 * 5^4$ = 160,000, which significantly reduces the possible results and eventually reduces the number of iterations in the analysis process.

4.2.2 A Control Mechanism towards Avoiding the Occurrence of Same Solutions

To obtain the optimal blocks division is certain but the optimal strategy does not necessarily belong to LLP if the LLP result less than LP result. The repetition process of GA will be continuously run while the condition is not found. However, this repetition process causes the tendency of the same optimal blocks occur. As a consequence, the process of selecting and the best line-direction and calculating tree number in which the lack of significant results lead to wasted time.

GA is based on probabilistic selection and to decide the solution is usually guided by basic knowledge. There are two possible matters will occurs in generating optimal blocks which are 1) the same current result with previous results 2) The block combination of genes in current result and previous results is same but different location place. The same shape solution refers to combination of shapes that has been expected to produce the same number of item. Let us say that the optimal assigned shapes represented by chromosome is 351114 of the 4, 5 area coordinate. This means the three assigned shapes have coordinates by sequence of 3, 5; 1,1 and 1,4, respectively. By changing the shapes order, the combination of shapes can be 3,5; 1,4; 1,1 or 1,1; 3,5; 1,4 or 1,1; 1,4; 3,5 …; 1,4; 1,1; 3,5. These all combined shapes certainly produce a same number of items.

To avoid the same optimal shape results occur, a control mechanism by storing the same shape solutions into a database. The process of comparing the current result and historical result from database to keep track the similar results, so that the flow will be repeated for generating another optimal solution. A control in GA by exploration approach was employed. The creation of database is to collect all history of optimal block. Every result of optimal block is stored into database. The current optimal block will be compared with available optimal block in database. The existence of same shapes combination in the comparison process as a result the process repeat to determine another optimal block. This control will protect from a wasted time since the processes of the best line-direction and calculating tree number can be skipped. In contrast, dissimilar shapes combination, the process of finding the best line-direction process and then calculating will be implemented. The processes by flowchart are shown as figure 7.

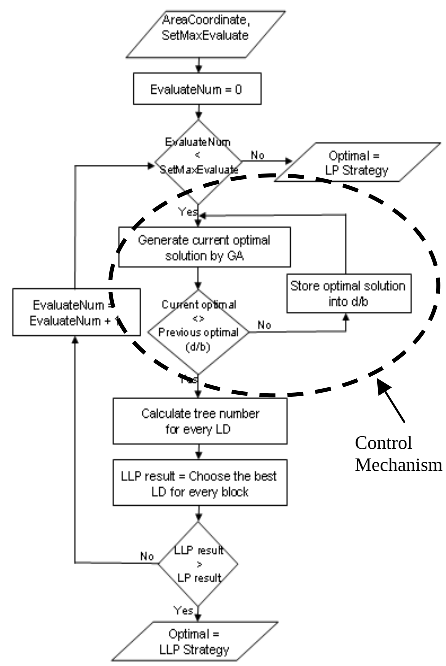

Fig.7. A control mechanism towards protecting the same shape coordinates

5. Implementation of the LPP-ICS Application

An intelligent automated approach to deciding the combination of shapes and the best line-direction will certainly assist planners who have previously used a manual approach. The LLP-ICS application is intelligent software that produces a lining design with reference to the optimal number of trees to be planted. It uses shape assignment and line representation techniques with GA implementation to generate the acceptable shape combinations and then determine the best line-direction for every selected shape. The total number that produced by the LLP-ICS application is considered the optimal number of trees that can be planted in the selected area. Figure 8 and figure 9 shows the optimal of shapes combination and line-direction, respectively, with number of trees.

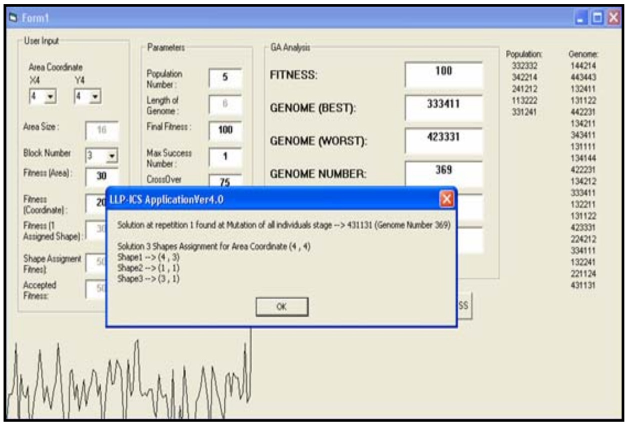

Fig.8. Shapes Assignment Interface

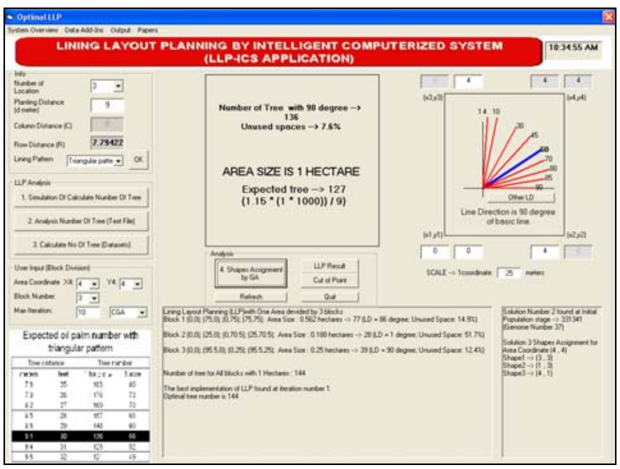

Fig.9. Line-direction with Tree Number Interface

6. Empirical Analysis and Discussion

To gauge the capability of GA to find the optimal solution, we conducted a laboratory test by running LLP-ICS with different sets of area coordinates. Table 1 shows the four experiments and their results in Table 2. The datasets consisted of area coordinate, scale and number of blocks defined by user. Area size, CP and LP were automatically generated by LLP-ICS. The CP means C*urrent Practice* and works on one block with 60^0 line-direction and the LP is *tree-Lining Planning* which handles one block with the best line-direction implementation. The *LLP* result is derived from the implementation of many blocks with the best line-directions. Table 2 shows the optimal solution comprising selected shapes and their coordinates, number of trees, taken time and number of iterations to reach the optimal solution. For analysis purposes we use the same number of block and variety of area coordinates and scales.

Table 1. Datasets for 5 Experiments

Exp num	Area coordinate (x4, y4)	Scale (m)	Area size (Hect)	Number of blocks	Number of trees	
					(CP)	(LP)
1	4, 4	25	1	3	133	138
2	4, 4	50	4	3	550	567
3	7, 7	50	12.25	3	1695	1747
4	7, 8	30	5.04	3	690	718
5	7, 8	100	56	3	7876	8054

Table 2. Analysis of Optimal Block Solution

Exp Num	Shape Coordinate	Block Coordinate	Number of Tree (LLP)	Time (sec)	Repetition Num / Iteration Num
1	3, 4	75, 100	427		
	1, 1	25, 25	31		
	1, 3	25, 75	106		
			138X	**0.58**	**1 / 1515**
	3, 3	75, 75	77		
	3, 1	75, 25	27		
	1, 4	25, 100	32		
			136 X	**0.46**	**2 / 1122**
	3, 3	75, 75	33		
	1, 3	25, 75	28		
	4, 1	100, 25	39		
			144 √	**1.2**	**3 / 3282**
2	3, 4	150, 200	427		
	1, 1	50, 50	31		
	1, 3	50, 150	106		
			564 X	**2.56**	**1 / 2601**
	4, 2	200, 100	229		
	1, 2	50, 100	70		
	3, 2	150, 100	203		
			552 X	**0.22**	**2 / 142**
	4, 3	200, 150			
	3, 1	150, 50	429		
	1, 1	50, 50	108		
			31		
			268 √	**0.12**	**3 / 154**
3	6, 5	300, 250	1072		
	6, 2	300, 100	416		
	1, 7	50, 350	243		
			1731 X	**6.46**	**1 / 7406**

	6, 6	300, 300	1287		
	6, 1	300, 50	223		
	1, 7	50, 350	243	**4.28**	**2 / 1753**
			1753 √		
4	7, 4	210, 120	359		
	6, 4	180, 120	303		
	1, 4	30, 120	48		
			710 X	**2.42**	**1 / 2378**
	7, 6	210, 180	467		
	2, 2	60, 60	175		
	5, 2	150, 60	75		
			717 X	**1.9**	**2 / 2112**
	7, 7	210, 210	624		
	6, 1	180, 30	75		
	1,1	30, 30	10		
			709 X	**2.18**	**3 / 4809**
	4, 6	120, 180	306		
	3, 6	90, 180	222		
	7, 2	210,60	**175 X**		
				6.34	**4/ 7242**
	6, 6	180, 180	467		
	6, 2	180, 60	151		
	1, 8	30, 240	101		
			719 √	**4.5**	**5 / 4325**
5	6, 8	600, 800	6917		
	1, 1	100, 100	133		
	1, 7	100, 700	1001		
			8051 X	**6.2**	**1 / 16053**
	7, 4	700, 400	4003		
	4, 4	400, 400	2262		
	3, 4	300, 400	1700		
			7965 X	**5.6**	**2/ 14586**
	.	.	.		
	.	.	.		
	.	.	.		
	7, 7	700, 700	7031		
	6, 1	600, 100	851		
	1, 1	100, 100	133		
			8015 X	**2.6**	**50 / 9012**

6.1 Solution Quality

The analysis shows that LLP-ICS was able to propose an optimal blocks combination of blocks that produced no unused spaces. In experiments 1, and 2, the number of repetitions was three, whereas the experiments 3 and 4 required two and five repetitions, respectively, fulfill the condition of *LLP result > LP result.* Experiment 5, however, failed to meet the condition after 50 times of repetition (we set the maximum evaluation is 50).

Based on the results above, we compared LLP, LP and CP. We found that the strategy of LLP consistently produced a better number of trees than CP. The LLP strategy also showed better numbers than LP result when the area size was small. When the size increases to certain point, the unsuccessful solution means that the LP strategy is better.

We also conducted other series of experiments (not described in this paper). The use of fewer than 20 populations sometimes might fail to find an optimal solution because of the overflow problem existence in which a huge computing process that cannot be accommodated by the database. This is because fewer populations require a higher number of generations, but the diversity and exploration processes will be limited [19]. Therefore, we increased the number of populations to 100 and the result as consistent achievement of an optimal solution. We conclude that LLP-ICS by novel GA is able to propose an optimal result in which the combination of blocks produces no unused spaces without the premature convergence problem.

6.2 Computational Time

Basically, the larger area coordinates will produce higher number of possible solutions. For example, the area coordinates of experiment 1 and 3 generated possible results with 65,536 ($4^3 * 4^3$) and 5,764,801 ($7^3 * 7^3$) respectively, as a result experiment 3 required more analysis time.

However, the small areas coordinates have higher tendency to occurrence of the repetitive optimal block solution. In experiment 2, for example, there were three same solutions as shown in table 3. As a comparison, by classical GA, the process of calculating tree number and determining the best line-direction and required 15,575 ($\sum_{bS=1}^{bS=N}(trLD * OS)_{bS}$) iterations, while novel GA required only 9,203 ($\sum_{bS=1}^{bS=N} trLD_{bS}$) iterations.

Table 3. Analysis of the Same Optimal Block Solution

Optimal Block Solution (*bS*)	Shape Coordinates (*Genes*)	Tree Number and Line-Direction Iteration (*trLD*)	Repetition of Same Optimal Solution (*OS*)
1	341113	2842	1
2	333114	3186	3
3	331341	3175	1

The computational time increased consistently when the iteration number to reach optimal blocks increased. The overall time taken is based on the accumulation of time in all repetition processes. Thus, more repetitions require more computational time. However, we found the taken time for each experiment was inconsistent. This is because of the GA method is based on a probabilistic algorithm with a randomness strategy, the uncertainty in number of repetitions and iterations and consequently in the computational time is hardly expected.

In conclusion, the computational time and optimal solution generated by LPP-ICS are relatively acceptable. However, this application should be a better impact in terms of the result improvement by focusing on genetic operator modification in GA. Moreover, a strategy that guides the search process might give a good indication of expecting the computational time.

7. Conclusion

The Novel GA is capable of reducing computational time in analyzing the optimal strategy of lining-layout. This Novel GA can be a basic algorithmic approach for optimizing the other industries of planting areas. The decision of land optimization in lining-layout planning strategy is not always easily reconciled with users' perceptions. For this reason, the LLP-ICS for implementation lining-layout optimization developed here will create extensive use of coordinates represent an area as an interface between the computer model and the users. Therefore, this study promotes several contributions as follows:

1. The LLP-ICS is the first attempt at application development to facilitate tree-planting planners. The LLP-ICS assists planners in deciding the best implementation quickly.
2. Promoting a new optimization strategy by focusing on blocks division and line-direction.
3. The proposed strategy gives an indicator to improve number of trees.

This study refers to the square and rectangular shape areas, but the task becomes more complicated for trapezoidal areas in which a variety of areas coordinates must be determined early in the process. Thus, a study on this matter should be conducted incorporating mathematical formulation and area coordinates representation, so that the use of the various types of land area will give a more significant contribution.

To provide a strategy for genetic operators of GA in this domain issues towards improving the better result consistently when the new generations are generated is the challenge for the future. The algorithmic refinement is being conducted and the results will be revealed in the next paper.

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Ismadi Md Badarudin is attached as lecturer to the Computer and Mathematical Sciences Faculty at UiTM, Malaysia. He started as a lecturer in 2001 and was appointed as a senior lecturer in 2008. He obtained a Master's Degree in 2002 in Metaheuristic Approaches in Timetabling. He is currently on leave as a lecturer and pursuing a PhD in Computational Intelligence at UPM, Malaysia, under the supervision of Abu Bakar.

Abu Bakar Md Sultan is a senior lecturer holding a doctorate in the faculty of Computer Science and Information Technology, UPM. His fields of expertise are Metaheuristic and Evolutionary Computing. He has published several journal papers regarding metaheuristic approaches since 2004.

Md Nasir Sulaiman and **Ali Mamat** are Associate Professors holding doctorates in the faculty of Computer Science and Information Technology, UPM. Nasir has expertise in Intelligent Computing, Intelligent Software Agents and Data Mining, and Ali is expert in Databases and XML.

Mahmud Tengku Muda Mohamed is a doctorate holder in Plant Physiology/ Post Harvest Physiology and an Associate Professor in the faculty of Crop Sciences. His areas of expertise are Agricultural Sciences, Plant Physiology and Post Harvest Physiology. Currently, he is a Director of University Agriculture Park, UPM, Malaysia.