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PATH OPTIMIZATION OF SMALL TRACTOR FOR REMOVAL WEEDING SYSTEM IN OIL PALM PLANTATION

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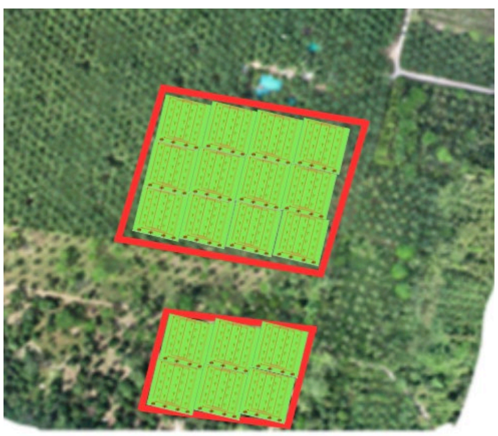
Graphical abstract



Abstract

This research presents a path optimization based on genetic algorithm suitable for small tractor in order to mow or remove weeds in oil palm plantations. Fuel is the most important budget or cost for cutting weeds by tractor. Hence, the aim is to design an optimized path and calculation model for saving the cost of fuel of a tractor that can save the fix cost of oil palm farmers. Genetic algorithm is applied to find an optimized path of tractor for removal weeds compared with the conventional path of native oil palm farmers. Modified greedy genetic algorithm is introduced by using the greedy algorithm and ranking selection in the conventional GA. For the cutting machine, a Kubota weed cutter is installed at the tail of Kubota tractor. These experiments are tested at the Agricultural Learning Center, Mueang District, Ranong Province in the South of Thailand. Basic types of paths for removal weeding around the oil palm trees are line, rectangle and zig-zag. All three patterns of path driving of two small tractors for removal of weed are tested and evaluated. Pattern A is the round-trip in the same row, Pattern B is the U-typed trip in the next row and Pattern C is the spiral trip. Experimental results achieve in accordance with the energy savings and budget. After calculation, it found that Pattern C is the best way to save budget. Experiments on two types of tractors with Pattern C spent 7.44 min./0.41L and 14.89 min./0.53L of gasoline. Practical results in path optimization for driving tractors by native farmers are similar to the proposed calculation model.

Keywords: Path optimization, genetic algorithm, small tractor, removal weeding, oil palm plantation

1.0 INTRODUCTION

1.1 Background

The path optimization algorithms are intensively studied problems, which have a lot of applications such as: the scheduling in heterogeneous distributed embedded system [1], the decisioning system for Wi-Fi access point installation in network system [2], the task scheduling of vehicle sensors for internet of things [3], and so on. Genetic algorithm is within an optimization algorithm which is widely used such as palm oil price prediction [4], scheduling for cloud computing [5], botnet attack solutions [6], and optimized mass damper parameters [7]. The ideal stopping pattern for the Bangkok Mass Transit (BTS) system in Bangkok, Thailand was determined by using a genetic algorithm [8]. Genetic algorithm is convenient for improvement or optimization.

Modern agriculture in Thailand uses tractors such as weeding, hormone spraying, tilling the soil, chopping sugarcane leaves, and amending the soil. Small tractors used by Thai farmers include Kubota, John Deere, Yanmar, and Mitsubishi. Kubota small tractors have under 40 horsepower (HP) with the diesel engines [9]. The educational and research data from the Agricultural learning center (ALC) in Ranong province in the South of Thailand [10] presents three guidelines for the development of agricultural production efficiency enhancement. These are 1) proper management of palm plantations,

2) reduction of production costs, and 3) increase of income in the oil palm plantations. The production cost reduction is an important factor for farmers' operations. For example, reducing costs for various activities in order to increase productivity. Therefore, the increase in profits is due to lower farm costs such as saving cost for fuel.

Oil palm business is one of the major factors for improving the economy of Southeast Asian countries [11] such as Malaysia and Indonesia. Nowadays, research on oil palm is being done in various fields [12, 13, 14]. Thailand has a few than one percent of farmers able to grow sustainable oil palm. Most oil palm growers in Thailand still do not know how to manage budget about lack knowledge of sustainable palm plantations [15].

For example, methods for removal weed or mowing the grass grows around oil palm trees consist of 1) hiring human workers, 2) shoulder-mounted mowers machine 3) diesel or gasoline for the cutting machine. Moreover, small tractors can be used to reduce human workers and save the cost of mowing grass. Therefore, removing weeds by small tractor effectively reduces the production costs for the large oil palm plantation areas.

The application of genetic algorithms for solving problems related to oil palm in many researches such as, the optimization of yield models in oil palm production [16]. The oil palm fresh fruit bunches transportation problem [17], and prediction of Indonesian oil palm production [18].

We propose how to design a path optimization of small tractor for low-cost removal weeding system. It will help reduce and save the cost of fuel on the small tractor. There are 3 objectives of the research as follows: 1) To design path optimization of small tractor for low-cost removal weeding system. 2) To create a path optimization system model for processing. 3) To evaluate approaches of path optimization of small tractor for low-cost removal weeding system.

1.2 Theory

In this section, we present theories of oil palm plantations and weed control in oil palm plantations as follows.

1) The taxonomy of oil palm is classified as follows: Family: Palmae or Arecaceae, Genus: Elaeis, Species: guineensis, and scientific name: Elaeis guineensis Jacq. Oil palm is a monocotyledon and mature palms are single-stemmed and grow to 20 meters tall. The leaves are pinnate and reach 3–5 meters long. A young oil palm produces about 30 leaves a year. Established oil palms over 10 years produce about 20 leaves a year. The flowers are produced in dense clusters; each individual flower is small, with three sepals and three petals. Rows are lines of oil palms in parallel to the maintenance paths as shown in Figure 1.

2) Weed control in oil palm plantations is to reduce the amount of weed density to a level below the critical point. This will reduce the competition for nutrients between weeds and oil palm trees. Weed control does not need to be completely eradicated. Because it may cost a lot, resulting in increased costs. There are several methods for controlling weeds in oil palm plantations such as soil preparation, weed control in nurseries, weed control in seedlings and planting plots. Weed control can be divided into two methods: weeding around the base of oil palm trees and weeding between rows of oil palm trees that will be applied for cutting weed path of tractor.

Figure 1 Rows of oil palms' line in parallel to the maintenance paths

Weed control around the base oil palm trees method is used to prevent weeds from snatching the fertilizer applied to the oil palm plant, reducing the competition between weeds and the oil palm plant, and helping to solve the problem of oil palm fruit drop. The radius around the base of the oil palm tree must be weeded according to the age of the oil palm tree as shown in Table 1.

Table 1 Radius around the base and age of the oil palm tree must be weeded

Radius (meter)	Age of the oil palm tree (month)
0.50 - 0.75	0 - 6
0.75 - 1.00	6 - 12
0.75 - 1.25	12 - 24
1.25- 2.25	24 - 30
2.25– 2.75	> 30

Weed control between rows of oil palm trees approach is convenient for maintenance such as reducing weed growth competition with oil palm trees, preventing oil palm plantation fires, and also preventing hiding of pests. There are a variety of methods, including mechanical eradication of weed cutting and grafting, mulching, herbicide protection, and combination methods.

2.0 METHODOLOGY

This research presents a path optimization based on modified greedy genetic algorithm (MGGA) on the most suitable method of driving a mini tractor for mowing or removal weed in oil palm plantation. The problem is simple because farmers must use this algorithm to evaluate the efficiency of calculations using conventional methods. Once the farmer is convinced that the algorithm can be extended to solve complex problems in his work. The research roadmap as shown in Figure 2 consists of survey the area, discussion with the native farmer, design path optimization algorithm, proposed MGGA, algorithm simulation in MacBook Pro personal computer and the KR260 Robotics Starter Kit, design web application, practical experiments at the agricultural learning center (ALC), Ranong province in Thailand, and comparison and evaluation of three methods.

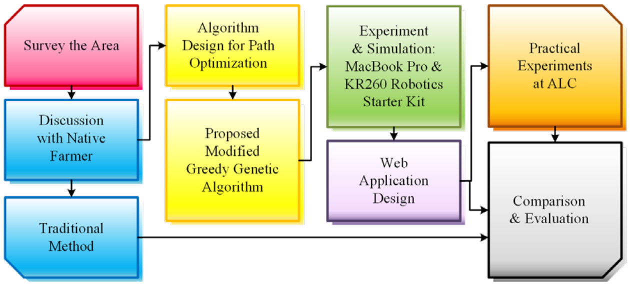


Figure 2 Research roadmap

Figure 3 Top view of survey area that is located at the agricultural learning center (ALC), Ranong province in south of Thailand

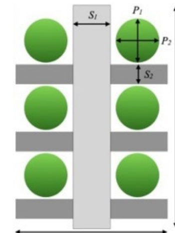
Figure 3 shows the top view of survey area that is located at the Agricultural Learning Center, District of Ranong, Ranong Province in South of Thailand. The survey area of oil palm plantation is of 130m of width and 270m of length, respectively. Figure 4a and Figure 4b show the diameter and height of example oil palm tree. The traditional method of removal weeding around the oil palm tree with small tractors. A small tractor specification that is an engineering vehicle used to deliver a high tractive effort at slow speeds, for the purposes of hauling a trailer applied in agriculture.

(a) Diameter of canopy is 69cm

(b) Height of oil palm tree is 3.42m

Figure 4 Sizes of oil palm tree

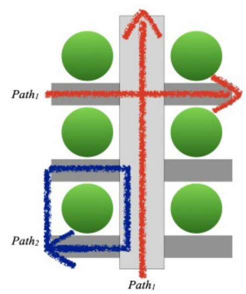
(a) Discussion with native farmers



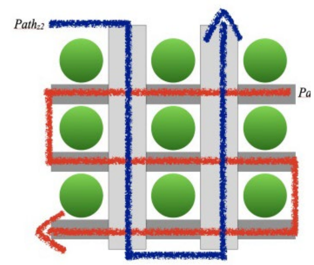
(b) Parameters used

Figure 5 Parameters concerned by discussion

Parameters concerned are defined by discussion with the native farmers for oil palm plantations used to calculate for path optimization as shown in Figure 5a. The parameter *P1* and *P2* are the diameter of green canopy of oil palm in meter. *S1* and *S2* are the distance between each oil palm tree as depicted in Figure 5b. Applied optimization algorithm is used to find an optimized path for removal weeding around the oil palm tree with straight line, rectangle and zig-zag types as depicted in Figure 6a and Figure 6b respectively. The design path optimization algorithm describes in the next section.

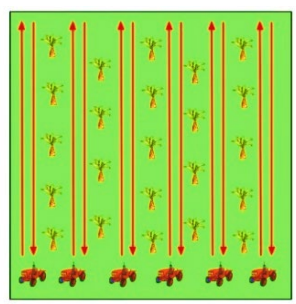


(a) Line and rectangle

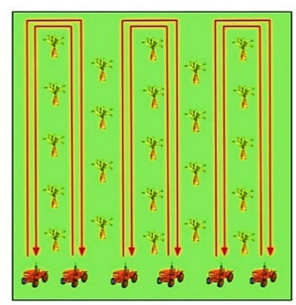


(b) Zig-zag

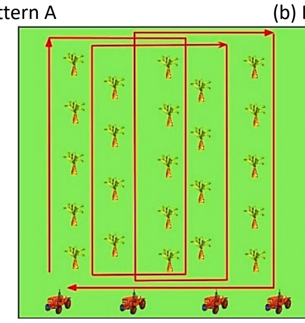
Figure 6 Type of Path for removal weeding around the oil palm tree



(a) Pattern A



(b) Pattern B



(c) Pattern C

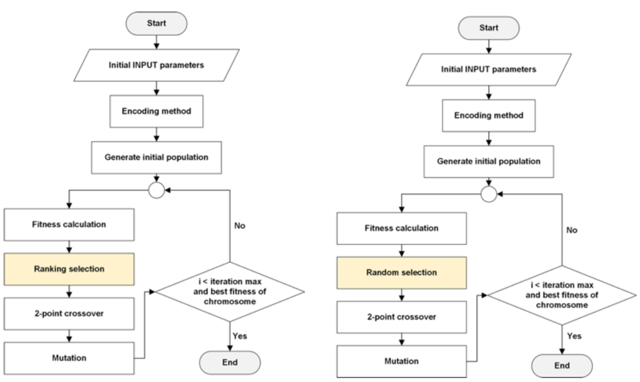
Figure 7 Three main patterns for running path of removal weeding around the oil palm trees

2.1 Patterns Design For Running Path Of Removal Weeding Around Oil Palm Trees

There are three main patterns of experiments for running tractor path of removal weeding around the oil palm tree with two tractors. The pattern is the size of an oil palm plantation consisting of 24 oil palm trees divided into 5 rows. Pattern A is shown in Figure 7a that the tractor will drive through in the vertical line. Meanwhile, Pattern B in Figure 7b will drive in U-type starting from the first row to next row. And Pattern C will drive in rectangular line as shown in Figure 7c.

2.2 Modified Greedy Genetic Algorithm

The modified greedy genetic algorithm (MGGA) based on genetic algorithm (GA) with greedy algorithm and ranking selection. The GA is a bio-inspired method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution [19]. For traditional GA, we notice from previous work that if their fitness calculation is sorted by ranking selection instead of the random selection step, then the result from GA is performed well. Figure 8 shows the flowchart of path optimization algorithm based on GA with ranking selection in Figure 8a and traditional GA in Figure 8b. For ranking selection function is replaced on the random selection function. The crossover probability is 100% of GA with ranking selection setting.



(a) GA with ranking selection (b) Traditional GA

Figure 8 Path optimization algorithms

In Figure 9, every chromosome represents a parameter group. Encoded chromosomes are divided into 4 groups. Each group consists of PATTERN, ROTARY, WEEDS HIGH, and OBSTACLES. All parameters related to oil consumption, such as the distance of movement in the pattern. Large rotary reduces the number of cutting passes. The height of the weeds must be cut several times. And there are no obstacles that need to be moved. PATTERN is encoded in characters: A, B, and C. ROTARY is encoded as a decimal point number: 0.9 and 1.3. WEEDS HIGH is encoded as numbers: 10, 20, 30, 40, and 50. And the OBSTACLES is encoded as numbers: 0 – 6. Fitness value is the oil consumption of a small tractor (Litter) as $Gas_{palmplants}$. The fitness calculation Equation 1 as follows.

$$Gas_{palmplants} = Area_{palm}((GasArea_{cutting} * Weeds_{high}) - Gas_{obs}), \quad (1)$$

where $Area_{palm}$ is the total number of oil palm plantations, $GasArea_{cutting}$ is the average oil cost used for a small tractor to weed 24 oil palm trees per oil palm plantation. It depends on the patterns and the size of the rotary. $Weeds_{high}$ is the height of the weeds. Gas_{obs} is the average amount of unused gasoline per row with obstructions in the oil palm plantation.

Chromosome N	PATTERN [A, B, C]	ROTARY [0.9, 1.3]	WEEDS HIGH [10 - 50]	OBSTACLES [0 - 6]
Chromosome A	PATTERN [A]	ROTARY [1.3]	WEEDS HIGH [10]	OBSTACLES [2]
Chromosome B	PATTERN [B]	ROTARY [0.9]	WEEDS HIGH [40]	OBSTACLES [0]

Figure 9 Permutation encoding

Table 2 Pseudocode of modified greedy genetic algorithm (MGGA)

```
1:  Initial input parameters: iterations, oil palm plantations,
    obstacles in each oil palm plantation, height of weeds,
    cutting rotary size;
2:  Encoding method: Permutation encoding
3:  Generate initial population
4:  While i < iterations and best fitness of chromosome do
5:      Fitness calculation
6:      Ranking selection
7:      2-point crossover
8:      5% mutation rate
9:      Greedy algorithm
10: End while
11: Output: iteration no., best fitness of chromosome
```

Table 2 shows the pseudocode of MGGA used for path optimization. Line 1 shows the initial input parameters such as iterations, oil palm plantations, obstacles in each oil palm plantation, height of weeds, and cutting rotary size. Line 2 shows the encoding method using permutation encoding. Line 3 describes the generate initial population from the chromosome encoding. Line 4-10 describe the condition of finding the best fitness of chromosome. There are four functions including the fitness calculation, the ranking selection function, selection, 2-point crossover, 5% of mutation rate, and greedy algorithm [1]. Line 11 shows the output of the best fitness of chromosome and iteration number of MGGA.

Table 3 Pseudocode of greedy algorithm

```
1: Initial: greedy value
2: If best fitness of chromosome < greedy value then
3:     Best greedy = best fitness of chromosome
4: End if
5: Output: best greedy
```

Table 3 shows the pseudocode of greedy algorithm. Line 1 shows the initial input greedy value. Line 2-4 show the decision instead of the solutions to find the best greedy for the next iteration. And Line 5 shows the best greedy of MGGA output. The simulation result of the proposed MGGA have been used to create a web application for ease of use. Web application design will be presented in the next section.

2.3 Web Application Design

Web application functionality design of finding mowing paths presents on web applications (https://optimzestudy.web. app) using programmatic calculations as shown in Figure 10. The web application design process consists of 5 steps as follows: 1) web application draft, 2) evaluate the web application draft from relevant people, 3) to improve the web application draft, 4) to build a web application, and 5) to test the web application by people involved.

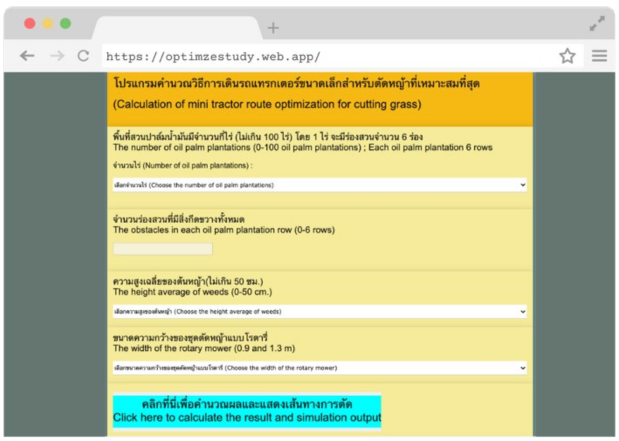


Figure 10 Welcome page of web application

Input and output parts of web applications are as: The input part is divided into 4 parts: the number of oil palm plantations (0-100), the obstacles in each oil palm plantation row (0-6 rows), the height of weeds (0-50cm.), and the width of the rotary mower (0.9 and 1.3m). The output is generated by pressing the calculate button, which is divided into 5 parts. Distance used by small tractors to mow weeds (km), oil used by small tractors (litters), time used by a small tractor (hours/minutes/seconds), and the cycle that the small tractor uses (cycles).

The final output is a simulation of the optimal weeding path with the mower as shown in Figure 11, which shows the detail of calculation for path optimization of small tractor for removal weeding. Results from calculation are including with the distance used in km, the fuel in litters (L) and the spent time in minute (min)

Figure 11 Output simulation of the optimal weeding path

3.0 RESULTS AND DISCUSSION

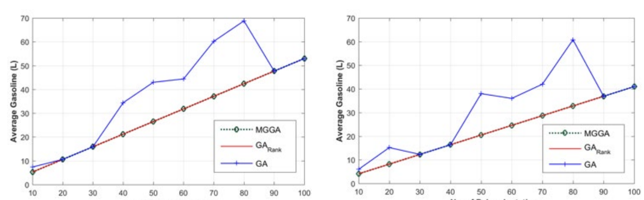
The section of the results and discission was divided into three sections: experiments and simulation results from path optimization algorithm, experiments from web application calculation, and practical experiments at Agriculture Learning Center (ALC) in Ranong Province, Thailand respectively.

4.1 Simulation Results from Path Optimization Algorithm

The path optimization algorithm divided the experiment into two parts: MacBook Pro and the KR260 Robotics Starter Kit. Features of a MacBook Pro 2019 include 2.4GHz quad-core Intel Core i5 processor, Intel Iris Plus 655 graphic processor, 8GB of LPDDR3 memory, using the MacOS Ventura 13.2, and uses power 61W. Specifications of the KR260 Robotics Starter Kit [20] include 1.5GHz quad-core Arm Cortex-A53 processor in Zynq UltraScale+ MPSoC EV processor, Arm Mali-400 MP2 graphic processor, 4GB of DDR4 memory, programmable logic, using the Linux OS Ubuntu 22.04, and uses power 36W as shown in Figure 12.

Figure 12 KR260 Robotics Starter Kit

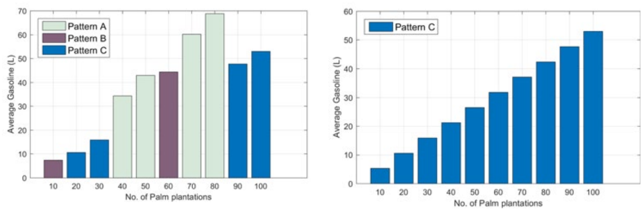
The path optimization algorithm simulation results on MacBook Pro for finding path optimization with a MGGA, the GA with ranking selection (GA_{Rank}), and traditional GA (GA) are shown in Figures 13 – 14.



(a) 0.9m of cutting rotary (b) 1.3m of cutting rotary

Figure 13 Average gasoline simulation results

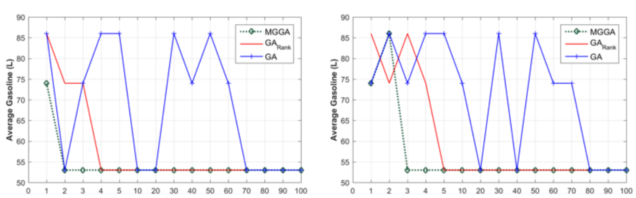
Figure 13 shows the 100 iterations result of average gasoline used and the number of oil palm plantations from the three algorithms with the different size of cutting rotary, where Figure 13a and Figure 13b present the result from 0.9 m and 1.3m of cutting rotaries, respectively. The height of the weeds is 20 cm and 10 cm, respectively, without obstacles. It was found that the graph of MGGA and GA_{Rank} has a constant increase rate than traditional GA. Because the results of MGGA and GA_{Rank} can choose that Pattern C is the most suitable path. 53 litters and 41 litters of gasoline per 100 oil palm plantation per size of rotary cutter respectively. The best path optimization depends on the smallest gasoline average. Figure 14a and Figure 14b are examples for comparing the pattern selection results of the three algorithms, where MGGA and GA_{Rank} select only Pattern C. It can be concluded as the best path optimization.



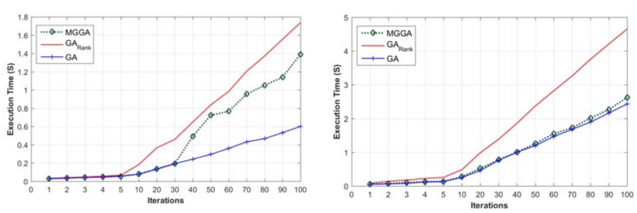
(a) Traditional GA (b) GA_{Rank} & MGGA

Figure 14 Average gasoline of simulation results in 0.9 m of cutting rotary

Figure 15 shows the iteration of 100-palm plantations simulation results of 0.9 m of cutting rotary of the MGGA, GA_{Rank}, and GA. Figure 15a and Figure 15b show the number of iterations of the three algorithms on a MacBook Pro to find the answer as the gasoline. The MGGA algorithm found the best answer before another algorithms. Figure 15c and Figure 15d show the execution time per iteration of the three algorithms on the MacBook Pro and KR260 Robotics Starter Kit to find the answer. The GA takes the least execution time. But MGGA gave a more accurate answer than the GA. Additionally, the KR260 Robotics Starter Kit takes only 1.89 times longer to run than a MacBook Pro and uses 1.79 times less energy.



(a) Gasoline of MacBook Pro (b) Gasoline of KR260 Robotics Starter Kit

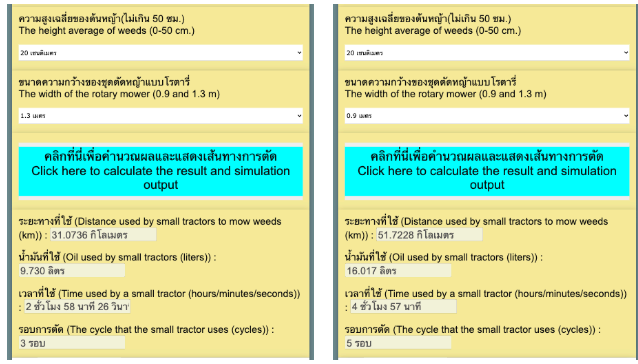


(c) Execution time of MacBook Pro (d) Execution time of KR260 Robotics Starter Kit

Figure 15 Iteration of 100-palm plantations simulation results of 0.9 m of cutting rotary

4.2 Results from Web Application Calculation

The web application is developed from the computational method of Equation 1 and parameterization based on the proposed MGGA. It is easy to use by entering various parameters. Start the experiment from fill all parameters need for path optimization of two tractors for removal weeding in the web application. Figure 16a shows the details for Kubota L3218SP with 1.3m of cutting rotary and Kubota L3608SP tractor with 0.9m of cutting rotary is shown in Figure 16b.



(a) Kubota L3218SP tractor with 1.3m of cutting rotary (b) Kubota L3608SP tractor with 0.9m of cutting rotary

Figure 16 Detail of calculation for path optimization

Results from web application calculations were used for experiments at the agricultural learning center (ALC), Ranong province in south of Thailand as shown in Figure 17. Configure input parameters in the web application include 20 oil palm plantations, there are no obstacles in each row of oil palm plantations, weeds are 20cm high, and the width of the rotary mower is 0.9m following the KUBOTA L3608SP.

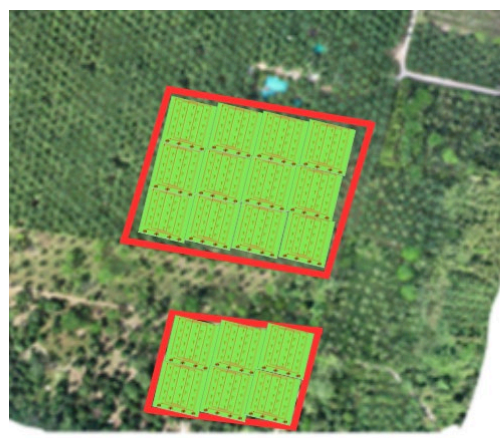


Figure 17 Top view of path optimization area with pattern#3 that is located at the agricultural learning center (ALC), Ranong province in south of Thailand

The results of web application include the distance used by small tractors to mow weeds is 51.72km, oil used by small tractors 16 litters, time used by a small tractor is 4 hours 57 minutes, and the cycle that the small tractor uses is 5 cycles. The final output of the optimal weeding path with the mower is Pattern#3. Thus, Pattern#3 is a size 1 palm oil plantation that will fill the area to be tested. The farmer drives the tractor according to a Pattern#3 to compare the measured values in the next section.

4.3 Practical Results at ALC in Ranong Province

Kubota small tractor is limited with less than 40 horsepower (HP) which are full-fledged workhorses utilizing a variety of implements or attachments [9]. In these experiments, there are two Kubota tractors with the different type as Kubota L3608SP and L3218SP for practical tests. A Kubota weed cutter is used for cutting weed installed at the tail of tractor.

Test procedure and rule of experiments are consisting of 5 steps as follows:

1) To check the amount of fuel use.

2) The height of weed is of 10-50cm. and the amount of oil palm tree is around 24 trees. Each tree has the 69cm of diameter of canopy of oil palm used for experiment and height of oil palm is of 3.42m. as shown in Figure 4.

3) Driver who drives the tractor that must be the same person for all tests.

4) Tractor route for each path is closed to 3 cycles.

5) Timer is to start when cutting the weed shown in Figure 18.

(a) Kubota L3218SP (b) Kubota L3608SP

Figure 18 Kubota tractor is cutting weed while driving

Table 4 Specification of KUBOTA L3608SP and L3218SP

Type:	Wheel Tractor
Usage:	Farm Tractor
Drive Wheel:	4 Wheel Drive (4WD)
Fuel:	Gasoline

Table 5 Experimental results from two tractors driving in ALC, Ranong Province

	KUBOTA L3218SP			KUBOTA L3608SP		
Pattern	**A**	**B**	**C**	**A**	**B**	**C**
Time (min)	14.00	11.20	7.44	20.00	16.03	14.89
Cycle	3	3	3	5	5	5
Number of Oil tree	24	24	24	24	24	24
Height of weed (cm) (before)	10	20	20	10	20	20
Height of weed (cm) (after)	5	5	5	5	5	5
Gasoline (L)	0.76	0.60	0.41	0.86	0.74	0.53
Cutting rotary (m)	1.3	1.3	1.3	0.9	0.9	0.9
Fuel consumption rate (%)	12.2	9.6	6.56	13.07	11.24	8.05

Table 4 shows the specification of KUBOTA L3608SP and L3218SP. Experimental results from two tractors driving in the oil palm area in Ranong Province show in Table 5 compared to Kubota L3218SP and L3608SP with the different size of cutting rotary.

4.4 Discussion

The experimental results presented from the research. Table 6 shows the comparison of Web application, experimental results of KUBOTA L3608SP Pattern C, and traditional scheme. The values of the web application are similar to the experimental results. The time, cycles, gasoline of the web application and the experimental results were less than traditional weeding method.

Farmers can use the web application to pre-weed planning in oil palm plantations. The web application calculation results are taken from the MGGA that selects the Pattern C for small tractor mowing. In the future, an embedded board and sensors with this system can be installed on a small tractor. For more accurate and real-time experimental results.

Table 6 Comparisons of web application, experimental results, and traditional method

	Web Application	KUBOTA L3608SP Pattern C	Traditional Method
Time (min)	14.53	14.89	22.5
Cycle	5	5	5-6
Number of Oil tree	24	24	24
Height of weed (cm) (before)	20	20	20
Height of weed (cm) (after)	5	5	5
Gasoline (L)	0.80	0.53	1.07
Cutting rotary (m)	0.9	0.9	0.9

4.0 CONCLUSION

The proposed calculation model is based on genetic algorithm to find an optimized path for removal weed. Modified genetic algorithm is proposed by using the ranking selection compared to the random selection in the conventional GA. Path driving of two small tractors for removal of weed are tested and evaluated in the oil palm plantation, where Pattern A is the round-trip in the same row, Pattern B is the U-typed trip in the next row and Pattern C is the spiral trip with the basic types of paths as: line, rectangle and zig-zag around the oil palm trees. For the cutting machine, two sizes of Kubota weed cutting rotaries are 0.9m and 1.3m used for cutting weed installed at the tail of Kubota tractor. The experiments are tested at the Agricultural Learning Center, Mueang District, Ranong Province in Thailand. Experimental results can be achieved in accordance with the saving energy and budget of native farmer. After calculation, it found that Pattern C is the best to save cost. Then, the practical experiments by two types of tractors are spent 7.44 min./0.41L and 14.89 min./0.53L of gasoline. Practical results in path optimization for driving tractor by native farmer are similar to the proposed calculation model, according to Philosophy of Sufficiency Economy [21].

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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