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Applying PSO Algorithm to Determine the Scan Plan for the PA Ultrasonic Probe carried Robot in Testing the Corrosion of Fuel Tanks

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ABSTRACT

The paper shows an approach to determine the scanning plan (the shortest path) using the PSO algorithm based on the operating characteristics of the PA ultrasonic probe carryied robot, testing environment of fuel tanks and the requirements for collected ultrasonic images. The solution of the PSO problem has proposed an optimal scanning plan with shortest scanning time. Thescan plan has also been verifiedby robot movement on an area of 1000×1000 mm^2.Experimental results showed that the simulation time is almost within 97% confidential limits of actual movement time. This means the PSO algorithm can be applied effectively into corrosion mapping for fuel tanks.

Key words: Corrosion testing,fuel tank,PSO (Particle Swarm Optimization), scan plan.

1. INTRODUCTION

Ultrasonic technique is an useful for mapping the corrosion level offuel tanks, and the corrosion images ofspecific areasare collected and evaluated.The corrosion images are collected and transferred to a computer to merging images and build a corrosion map. Currently, the corrosion images are scanned in subdivided areas manually[1], which is depending on the skills of technicians; or byusing self-propelled robots with ultrasonic probes to run horizontally/vertically in the area to be scanned [2], which is called one-line scanning. These may result to a low accuracy or overlapping (reducing the economic efficiency) or lack of full surface scanning.

During the scanning, the robot carrying a phased-array (PA) ultrasonic probe is controlled according to a pre-determined scanning plan tocollect the images [2], [3].Beside collecting high-quality images with less influences from the external environment, the scanning plan must have straight boundary for ease of image merging process and have lowest scanning time, thus shortest traveling path length.

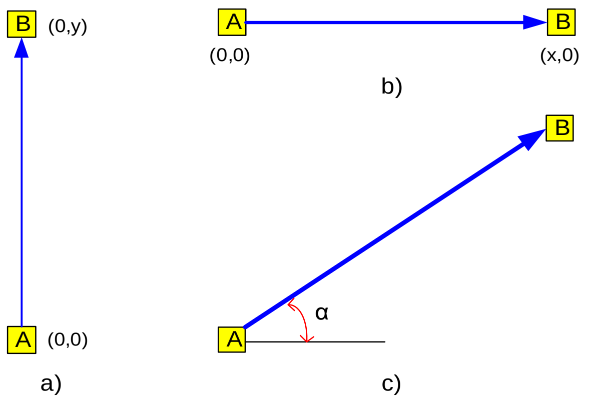
To match the requirements such as the corrosion image must be a straight profile (ease of identifying, easeof merging together).When the robot moves according to the scanning plan, it is less affected by the environment affecting image quality, etc. it must also get the shortest move distance, in other words, the scanning time is the smallest. This way the tank corrosion scanning time will be short and allowsaving for cost testing as well as recoveringquickly investment costs of equipment.

Recent scientific studyby Yang Xue and Jian-Qiao Sun (2018) shows that have built a specific mathematical model to plan obstructed paths when it has known the starting point and target point to apply theMulti-Objective Evolutionary Algorithm (MOEA) [4]. HaiyanWang, Zhiyu Zhou(2019)[5] introduced how to develop A* mathematical model to find the shortest path length on the basing on PSO algorithm for MT-R robot with a diameter of 50cm with maximum speed of 2,5 m/s in the indoors environment with flat moving path. Firas A. Raheem andassociates (2018) [6] proposed the way to improve the method of finding the D* path applying PSO in a dynamic environment to anticipate obstacles on the way to the target point.

Many researches have conducted on the shortest path length,howeverthey only limitswithin theoretical and simulation research. Some studies have applied the PSO and GA algorithms [7],[8] to simulate the optimal movement plan to find the shortest path planning or avoid obstacles, without comparison with real model.In Vietnam, there is still no study on the testing and evaluation of corrosion level of fuel tank regarding to the scanning plan with the shortest path length.Manual movementof probes is commonly used to collect corrosion images. This paper proposes an approach to determine the shortest movement path for robot carrying the PA ultrasonic probeapplying the PSO algorithm.

2. SCANNING AND COLLECTING CORROSION IMAGE

When using the robot carrying the PA ultrasound probe to check corrosion of fuel tank and based on the characteristics of the Olympus OMNIScan MX2 ultrasound system, corrosion images are collected as a rectangular dimension. The image width and length are the width and movement length of the probe. Thus, robot can move to collect images in vertical-horizontal or inclination direction.



a) Vertical direction; b) Horizontal direction; c) Inclination direction

Figure 1: Robot movement direction

Mathematically, it is clear that robots moving in vertically or horizontally are the same, excepting in the coordinate system. However, when the robot moves horizontally direction, under the influence of gravity force, the deviation of the robot will be larger. On the other hand, when the robot moves in theinclination direction, beside the disadvantages horizontal movement, the control of robot in the X and Y axes simultaneously will affect the movement speed. Therefore, the vertical movement will be selected.

A corrosion map is built by merging adjacent images of the determined scanning area. Therefore, when the scan of the scanned image data collection of the scan line i^{th} is completed, the robot move back to the starting position of the scan line $(i+1)^{th}$. Thus, beside the scanning movement to obtain theimages, the robot must move without scanning to bring the probe to the starting position of the next scan line. The path of no-scanning movement is also known as sub-movement path and the robot will be able to move in many different ways, as shown in Figure 3.

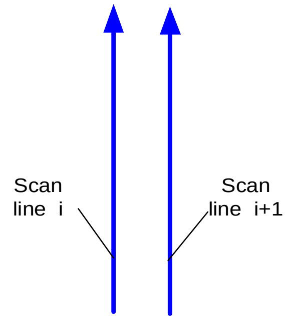
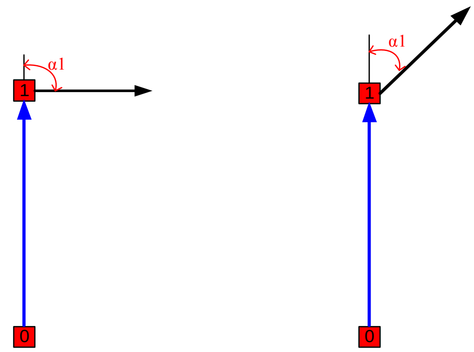


Figure 2: Scanning lines collect corrosion images



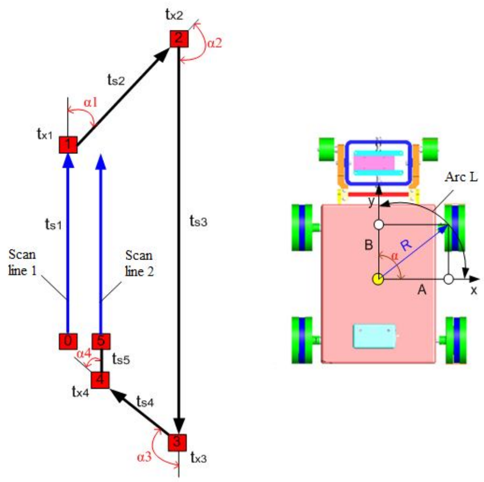
a) Straight movement *b) Straight movement*

Figure 3: Sub-movement path

3. MATHEMATIC MODELLING FOR THE SHORTNEST PATH

The aim is to determine the path planing having the shortest distance, in other words, the movement time of the robot during scanning operation to collect corrosionimagesis shortest. The process of scanning operations to collect an image for a scan line and the movement from the starting point to the end point and movement to the starting point of the next scan line, is called scanning cycle. Therefore, the scanning operation collects corrosion images for a pre-determined area will include the multiple scan cycles.

Supposingthat the robot moves as shown in Figure 4a.When the robot moves from the node 0 to the nodes 1, 2, 3, 4, 5, it is called the first scan cycle and the node point of number 5 will be the start of the second scan cycle. The nodes 1, 2, 3 and 4 are unknown and may change during the sub-movement depending on the angle of rotation α.



a) A scan cycle b) Robot rotates an angle α

Figure 4: Time for a scan cycle

Considering the node of point p_i having coordinates (x_i, y_i), the path planning from node of point p_i to point p_{i+1} will have the following parameters:

+ Path lengths$_i$ (mm)
+ Movement velocityv_i (mm/s)
+ Scan time $t_{s1} = s_i/v_i$ (s)

Thus, the path s_i between two adjacent points is computed as:

$$s_i = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2} \quad (1)$$

So, the total length of path needs to move the robot in a scan cycle is:

$$s = s_1 + \dots + s_n = \sum_{i=1}^{n} s_i \quad (i = 1,\dots, n = 5) \quad (2)$$

During the movement, the robotswill rotate an angle $\alpha_i$at the nodes 1, 2, 3, 4, respectively. The rotation angle α_i is a multiple of the basic rotation angle (α_{cb}) of the robot (its value is dependent of the design characteristics of the robot).We have:

$$\alpha_i = a.\alpha_{cb} \quad (3)$$

where$a$is an integer (a = 1, 2, 3,…)

The average velocity of a robot moving in a straight line is computed as

$$v_i = (v_t + v_o + v_g)/3 \text{ (mm/s)} \quad (4)$$

where$v_t$isaccelerating stage (m/s), $v_o$is stable velocity stage, (m/s) and $v_g$isdecelerating stage, (m/s).

The rotating time of robot around a point is determined by the radius from the center of the robot to the center of the front wheel as

$$R^2 = A^2 + B^2 \text{ (mm)} \quad (5)$$

where A and B distances from the center to the front wheel vertically and horizontally. When the robot rotates an angle α, the arc length L is

$$L = \frac{2\pi.R.\alpha}{360} \text{ (mm)} \quad (6)$$

Thus, rotating time of the robot t_x at any angle α_i (without moving) will be:

$$t_{x_i} = \frac{2\pi.R.\alpha_i}{v_{xi}.360} = \frac{2\pi.R.a.\alpha_{cb}}{v_{xi}.360} \quad (7)$$

The total time for a movement cycle is calculated by the following equation:

$$t = \Sigma t_s + \Sigma t_x \quad (8)$$

where

$\Sigma t_s = t_{s1} + t_{s2} + t_{s3} + t_{s4} + t_{s5}$; $\Sigma t_x = t_{x1} + t_{x2} + t_{x3} + t_{x4} + t_{x5}$

$t$isthe total moving time; $\Sigma t_s$is the total moving time of robot through adjacent points over the path s; $\Sigma t_x$is the total rotating time.

4. APPLYING PSO ALGORITHM

PSO is initialized by a random group which it is the positions of the nodes, and then it will find the optimal solution by updating the generations, each generation at each node is updated by two values [9]:

- *Pbest*: is the best solution obtained upon the current time.
- *Gbest*: is the best solution that this neighboring node has obtained upon the current time.

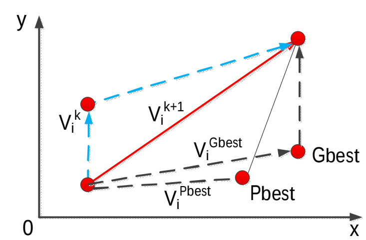


Figure 5: Change searching point of PSO [9]

where

+ k: number of iterations
+ $V_{i,j}^k$: velocity of node i at iteration$k$
+ w: inertial weight
+ c_1, c_2: acceleration coefficient
+ rand (): random real numbers in the range (cluster size, problem size)
+ $X_{i,j}^k$: position of node $i$at iteration k
+ $Pbest_{i,j}^k$: the best position of node i
+ $Gbest_{i,j}^k$: the best position of the node in the path planning

The motion of each particle is the sum of 3 movements, so the velocity function has the following [10], [11], [13], [14]:

$$V_{i,m} = w.V_{i,m} + c_1 * rand() * (Pbest_{i,m} - x_{i,m}) + c_2 * rand() * (Gbest_{i,m} - x_{i,m})$$

The position function would be[10], [11], [13], [14]:

$$X_{i,m} = X_{i,m} + V_{i,m}$$

4.1Objective function determination

The objective function $f(X)$ is a function describing the problem and is used to evaluate the solution of the problem. By evaluating and comparing the current solution with the best solution, the particles will determine the next step. The best three solutions (positions) arebest individual (P_{best}), best global (G_{best})and the best local (L_{best}).

Here, the problemis to determine the coordinates of four intermediate points [1(x_1,y_1), 2(x_2,y_2), 3(x_3,y_3), 4(x_4,y_4)] such that themoving time from the first coordinate 0 (x_0,y_0) to the end coordinate5(x_5,y_5) be the shortest with the binding angle of the robot rotation angle being an integer a of 45^0, in a scan line.

So, the objective function $y=f(X)$ of the scanning cycle is determined for the moving of robot is as follows:

$$f(X)=\sum_{i=1}^{5} t_s(i)+\sum_{i=1}^{4} t_x(i);\ X=[x_1,y_1,x_2,y_2,x_3,y_3,x_4,y_4] \qquad (9)$$

$$f(X) = t_{s1} + t_{s2} + t_{s3} + t_{s4} + t_{s5} + t_{x1} + t_{x2} + t_{x3} + t_{x4}$$

$$f(X)=\frac{s_1}{v_1}+\frac{s_2}{v_2}+\frac{s_3}{v_3}+\frac{s_4}{v_4}+\frac{s_5}{v_5}+\frac{2\pi.R.a.\alpha_{cb}}{v_{x1}.360}+\frac{2\pi.R.a.\alpha_{cb}}{v_{x2}.360}+\frac{2\pi.R.a.\alpha_{cb}}{v_{x3}.360}+\frac{2\pi.R.a.\alpha_{cb}}{v_{x4}.360}$$

Thus, the problem model for robot moving in the shortest time is determined as follows:

(1) $y=f(t)=\sum_{i=1}^{n} t_{si}+\sum_{i=1}^{n} t_{xi} \rightarrow$ Min

(2) $t_{s_i}=\frac{s_i}{v_i}$; $\quad t_{x_i}=\frac{2\pi.R.a.\alpha_{cb}}{v_{xi}.360}$;

$\alpha_i = a.\alpha_{cb}$

(3) a = 1, 2, 3, 4, 5, 6, 7 ; $\alpha_{cb} = 45^0$

4.2PSO optimization algorithm

The population size is N and each particle has a characteristic D and$D$ is the coordinates of four intermediate points.

Initialization solution is:$\boldsymbol{X} = [\boldsymbol{X}_1,\ldots,\boldsymbol{X}_i,\ldots,\boldsymbol{X}_N]$; $i = 1, 2,..., N$.

Characteristics of each particle:$X_i= [X_{i,1},\ldots, X_{i,j},\ldots., X_{i,D}]$; j = 1, 2, …, D = 8.

The PSO algorithm performs searching behavior basing on the best position it has achieved at the present time (P_{best}) and the best position in all searches of the population up to present time (G_{best}), which determines their next position in searchingarea. In addition, the new position depends on the acceleration coefficients(c_1 and c_2) and the inertial weight$w$. In which, c_1 and c_2 are selected randomly in the range [0, 2] and w is selected in the range [$w_{\min}$, $w_{\max}$].

The initial velocity of the population is denoted $V = [V_1, V_2,\ldots,V_N]$. Therefore, the velocity of each particles X_i (i = 1, 2,..., N) is $V_i= [V_{i,1}, V_{i,2},\ldots, V_{i,D}]$. The steps for PSO are as follows[12], [13]:

- Step 1: Set the initial values of w_{min}, w_{max}, $c_1$and$c_2$of PSO algorithm.
- Step 2: Initializing population of particles to have positions X and velocities V.
- Step 3: Set up theiteration k = 1.
- Step 4: Calculating fitness of particles.

$$F_i^k = f(X_i^k), \forall i$$

and finding the index of the best particle b.

- Step 5: Select values $\quad Pbest_i^k = X_i^k, \forall i$

$$Gbest^k = X_b^k$$

- Step 6: Determine

$$w = w_{\max} - k \times (w_{\max} - w_{\min})/Maxite$$

- Step 7: Update the velocity $V$and position $X$of particles[13], [14].

$$V_{i,j}^{k+1} = w \times V_{i,j}^k + c_1 \times rand() \times (Pbest_{i,j}^k - X_{i,j}^k)$$
$$+ c_2 \times rand() \times (Gbest_j^k - X_{i,j}^k); \quad \forall j \text{ and } \forall i$$
$$X_{i,j}^{k+1} = X_{i,j}^k + V_{i,j}^{k+1}; \quad \forall j \text{ and } \forall i$$

- Step 8: Evaluating fitness $F_i^{k+1} = f(X_i^{k+1}), \forall i$ and finding the index of the best particle b_1.
- Step 9: Updates$Pbest$of population$\forall i$

+ If $F_i^{k+1} < F_i^k$ then $Pbest_i^{k+1} = X_i^{k+1}$ else $Pbest_i^{k+1} = Pbest_i^k$

+ If $F_i^{k+1} < F_i^k$ then $Pbest_i^{k+1} = X_i^{k+1}$ else $Pbest_i^{k+1} = Pbest_i^k$

- Step 10: UpdatesGbestof population

  + If $F_{b_1}^{k+1} < F_b^k$ then $Gbest^{k+1} = Pbest_{b_1}^{k+1}$ and $b = b_1$else $Gbest^{k+1} = Gbest^k$

- Step 11: Ifk<$Maxite$then$k = k$ +1and go to step 6 else go to step 12.
- Step 12: Print optimum solution as $Gbest^k$.

From the steps of PSO algorithm here above, the PSO algorithm flowchart is summarized as shown in Figure 6.

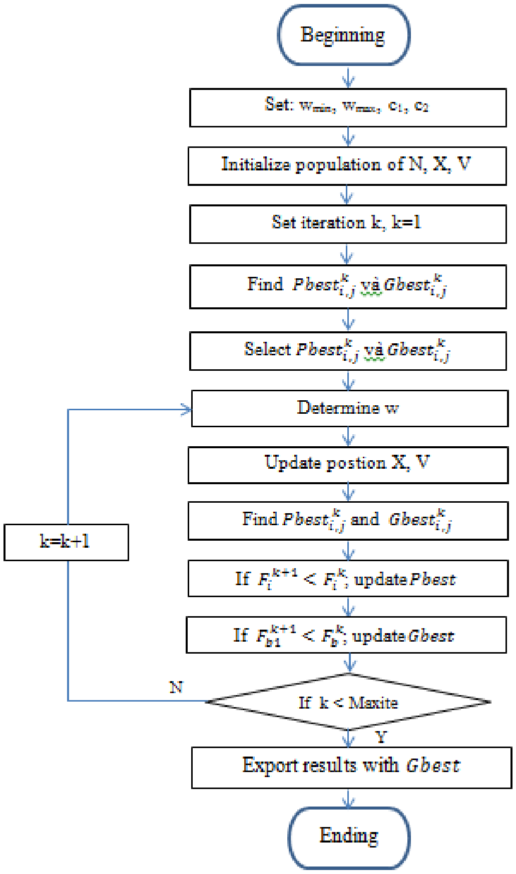


Figure 6: Flowchart of PSO algorithm

5. SIMULATIONS AND EXPERIMENTS

5.1 Simulation of PSO algorithm

To determine the optimal values for the objective function, which is also the shortest moving time for a scan cycle, the objective function depends on parameters such as*w*, c_1, c_1 and size of population *N*. For the problem of finding the shortest moving distance mentioned above, the values of the optimal parameters have been investigated are*w* = 0.4 to 0.9; c_1 = 1 to 2; c_1 = 1 to 2 [6], [15]. Table 1 is presented the results of surveying the parameters value of applying PSO algorithm with the program written in Matlab.

Table 1: Valuesof the PSO algorithm coefficient

Cases	*w*	c_1	c_2	*f(X)*
1	0.4	1.5	1.5	159.8846
2	0.5	2	2	159.8183
3	0.6	1.8	1.8	159.8143
4	0.7	2	2	159.8248
5	**0.6**	**2**	**2**	**159.8045**
6	0.9	1.8	1.5	159.8941
7	0.8	2	2	159.8440
8	0.6	2	1.8	159.8142
9	0.7	1	2	159.8346
10	0.5	1	2	159.8243

From Table 1, case 5 gives the minimum objective value, so the parameters selected to simulate the objective function will be *w* = 0.6, c_1 = 2, c_2 = 2.

For best image quality using the experimental conditions of PA ultrasonic testing and the robot characteristics, the parameters such as the average velocity of the robot is selected as *v* = 35 mm/s and the rotation speed of the robot is *v* = 20 mm/s.

The results were simulate for a scan cycle on the scanning area of 1000 x 1000 mm, the simulated population values of *N* were 50, 100, 150, 200, and 250 replicates for each population is 50 times. The results are presented in table 2.

Table 2: Results of presenting survey *N* value of PSO algorithm

No.	*N*	Repetition *k*	*f*(*X*) average
1	50	50	1.0007e+05
2	100	50	1.4007e+05
3	150	50	4.0079e+04
4	200	50	6.0076e+04
5	250	50	2.0080e+04

From Table 2, it is shown that the best objective function value has the values N = 250 and *f*(*X*) = 2.0080e+4. The converging characteristic curve when implementing different population numbers is shown in Figure 7.

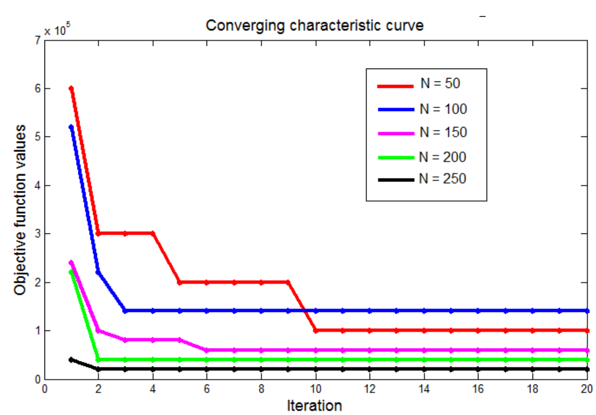
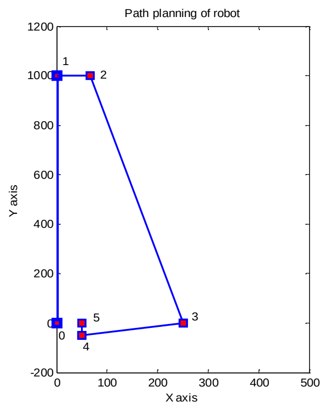


Figure 7: Average convergent characteristic curve of PSO algorithm

Figure 8 show the simulation results of path planning for various values of coefficient a using the values of coefficients *w*, c_1, c_2, and the population size *N*.In the case of low *a*-value (*a* = 1, 2) in Fig. 8(b), the moving time is shortest of *f* (*X*) = 115.9411 seconds and the path is smoother than in the case of Fig. 8 (a) and (c). Therefore, the path planning is selected through the survey and simulation of coefficients, we choose the path plan presented in Figure 8 (b).

Position	x	y
0	0	0
1	0	1000
2	50	1000
3	250	0
4	50	-50
5	50	0

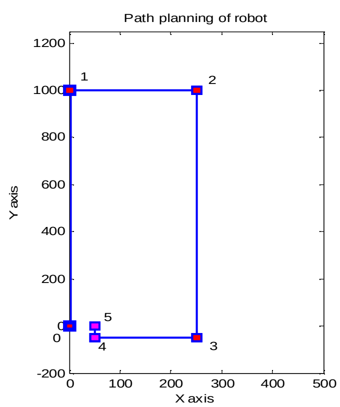
Coefficient	Value
w	0.6
c_1	2
c_2	2
N	250
$f(X)_{min}$	159.8045



a) a = 1, 2, 3, 4, 5, 6, 7

Position	x	y
0	0	0
1	0	1000
2	250	1000
3	250	-50
4	50	-50
5	50	0

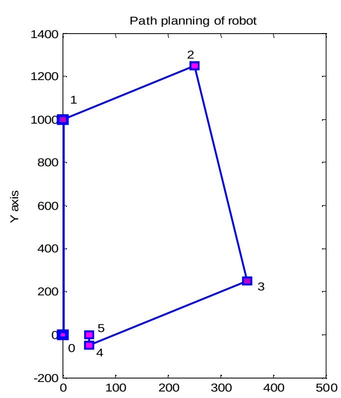
Coefficient	Value
w	0.6
c_1	2
c_2	2
N	250
$f(X)_{min}$	115.9411



b) a = 1, 2

Position	x	Y
0	0	0
1	0	1000
2	250	1250
3	350	250
4	50	-50
5	50	0

Coefficient	Value
w	0.6
c_1	2
c_2	2
N	250
$f(X)_{min}$	165.7082

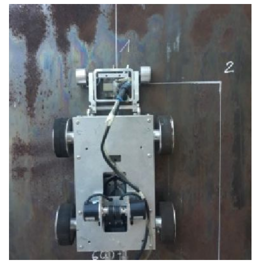


c) *a* = 1, 2, 3, 4, 5, 6

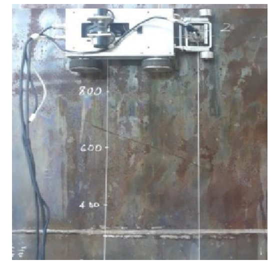
Figure 8: Path planningfor various *a* coefficient values

5.2Experiments

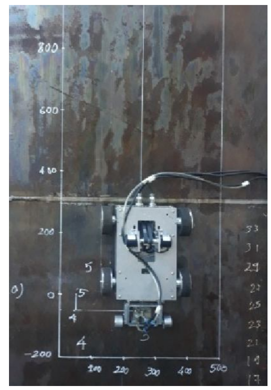
From the path planning determined from PSO algorithm in Section 5.1, the moving time of robot is experimentally measured, as shown in Figure 9. Table 3 represents the values of simulation time and actual moving time for a cycle. The 97% of confidential limits of the actual movement time are also computed from the standard deviation of experimental timeσ=0.86 (s). In comparison to the simuation time, a very slight difference of 0.217% shows that the PSO algorithm gave very accurate path planning for robot to scan the tank.



a) From 0 to 1

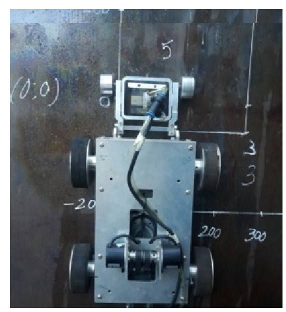


b) From1 to 2



*c) From*2 to 3

*d) From*3 to 4



e) From4 to 5

Figure 9: Robot movementalong the path planning of PSO algorithm

Table 3: The results are tested on the tank models

Testing		Simulatedtime $f(X)$	Actual moving time t(s)
No.	Iteration		
1	1	115.941	116.541
	2	115.941	117.962
	3	115.941	118.981
2	1	115.941	117.975
	2	115.941	117.983
	3	115.941	118.941
3	1	115.941	116.843
	2	115.941	118.765
	3	115.941	117.996
Average		**115.941**	**117.9989 ± 1.806**

6. CONCLUSIONS

The following conclusions are made:

i. The problem of finding the shortest path planning has been built in accordance with the PA ultrasonic testing method, working conditions of the robot, selected coefficient s such as*w*, c_1, c_2, size of population *N*, coefficient *a* to obtain the optimal results.

ii. The simulation results show that the application of PSO algorithm on Matlab software has found the shortest route plan when the robot moves a scan cycle. The simulation process also finds cases where there are solutions nearly together to give analysis and find the optimal solution for better testing.

iii. Experimental results of movement time showed that the proposed path planning has a time had very small difference of about 0.217% in comparison to simulation value, showing that the PSO algorithm can be accurately applied for corrosion mapping of fuel tanks.

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REFERENCES

1. Thanh TuanTo, Thien NgonDang, Duy AnhNguyen.**The study of proposal structure and control robot with ultrasonic probe for testing storage oil tank**, *National Conference on Machines and Mechanisms 2015 (NCOMM 2015) Ho Chi Minh*, VN, pp. 220-231, 2015.
2. S. G. Pierce, C. N. Macleod, G. Dobie, R. Summan.**Path planning & measurement registration for robotic structural asset monitoring**, *7th European Workshop on Structural Health Monitoring*, La Cité, Nantes, France,pp. 1–9, July 8-11,2014.
3. Silverwing.**Scorpion, Document number BRO-SCO Rev 1.2**, Silverwing UK Ltd, pp.1–4, 2018.
4. Yang Xue, Jian-Qiao Sun.**Solving the Path Planning Problem in Mobile Robotics with the Multi-Objective Evolutionary Algorithm**,*Appl. Sci. 2018, 8, 1425,*MPDI journal, Switzerland, 21 pages, 2018.
5. WangH., Zhou Z. **A Heuristic Elastic Particle Swarm Optimization Algorithm for Robot Path Planning**,Information 2019, 10, 99. https://doi.org/10.3390/info10030099
6. Firas A. Raheem, Umniah I. Hameed.**Path Planning Algorithm using D* Heuristic Method Based on PSO in Dynamic Environment**, *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS),* Volume 49, No. 1, pp 257-271, 2018.
7. Patience I. Adamu, IAENG, Member, Joshua T. Jegede, Hilary I. Okagbue and Pelumi E. Oguntunde.**Shortest Path Planning Algorithm – A Particle Swarm Optimization (PSO) Approach,***Proceedings of the World Congress on Engineering 2018 Vol. I*, WCE 2018, July 4-6, 2018, London, U.K.
8. Imen Hassani, Imen Maalej, and Chokri Rekik.**Robot Path Planning with Avoiding Obstacles in Known Environment Using Free Segments and Turning Points Algorithm**,*Mathematical Problems in Engineering Volume 2018*, Article ID 2163278, 13 pages, 2018.
9. Duy Hung Pham, Minh Trien Pham and Quang VinhTran.**Multi-robot Searching System in a disaster area using Particle Swarm Optimization Algorithm**,*National Conference on Control and Automation*, VCCA 2011, University of Technology, Hanoi National University, pp. 56-59, 2011.
10. Yong Zhang, Dun-wei Gong, Jian-hua Zhang.**Robot path planning in uncertain environment using multi-objective particle swarm optimization**, *Neuro-computing,* Volume 103, 2013, pp. 172-185, 2013. https://doi.org/10.1016/j.neucom.2012.09.019
11. HarshalS. Dewang, Prases K. Mohanty, Shubhasri Kundu.**A Robust Path Planning For Mobile Robot Using Smart Particle Swarm Optimization**,*International Conference on Robotics and Smart Manufacturing (RoSMa2018),* Procedia Computer Science 133 (2018), pp.290–297, 2018.
12. Maryam Yarmohamadi, H. Haj Seyyed Javadi, Hossein Erfani.**Improvement of Robot Path Planning Using Particle Swarm Optimization in Dynamic**, 2011 *Environments with Mobile Obstacles and Target, Advanced Studies in Biology*, Vol. 3, No. 1, 2011, pp.43–53, 2011.
13. IMaria Zemzami, Aicha Koulou, Norelislam Elhami, Mhamed Itmi, Nabil Hmina.**Interoperability Optimization using a modified PSO algorithm**, International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE), Volume 8, No.2, March - April 2019, pp.101-107. https://doi.org/10.30534/ijatcse/2019/01822019
14. Suraya Mubeen. **Synthesis of Circular Array Antennas Using Accelerated Particle Swarm Optimization**, International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE), Volume 8, No.5, Sep.–Oct. 2019, pp.2121-2125. https://doi.org/10.30534/ijatcse/2019/41852019
15. T. A Badmos, P. O. Omolaye, J. Mebawondu, H. A. Aliyu.**Robot Path Planning Performance Evaluation of a Dynamic Environment**,*IOSR Journal of Electronics and Communication Engineering (IOSR-JECE),* Volume 13, Issue 6, Ver. I (Nov.-Dec. 2018), pp. 19-26, 2018.