Innovative Systems Design and Engineering
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.4, No.12, 2013

Enhancing Facility Layout via Ant Colony Technique (Act)

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ABSTRACT

Cellular manufacturing systems optimization is investigated and manipulated using artificial intelligent (AI) approach combining facility layout and group technology scope. This research applied the ANT COLONY technique (ACT) optimization where this process was inspired by the real ants and how they move and build colonies by avoiding obstacle and simulate the process to get a procedure that can be adopted on this optimization process. In this research the problem goes in two way first the theory that take account the positions of machines inside the plant and its equations of controlling and second is the routing of part during product life cycle then execute results and applying it on factory configuration. The application of Ants system was carried out on industrial factory of electrical motor where all data was taken from the factory depending on the position and sequence of operations took place. Results were carried out in a way that depending on the showing site plan configurations for each stage and studying the iteration curve response to the parameters changes while testing the system during different environments. The results show high flexibility in ACS (Ant colony system) with fast response and high reduction in the distance crossed by the product part that reached 500m. The ratio of the reduction is 0.625.

Keyword: Artificial intelligent (AI), Ant colony (AC), pheromone, genetic algorithm, facility layout, cell manufacturing (CM).

INTRODUCTION

Facility layout refers to the physical arrangement of production facilities. It is the configuration of departments, work centers and equipment in the conversion process. It is a floor plan of the physical facilities, which are used in production. Facility Layout Design is one of the most important ways to get real time tracking and it give more flexible and free space to firm and plant [1]. Facility layout influenced by many factors that can change the layout periodically if it wasn't understand properly, it could be a problem that complicates the operation instead of make it flexible and easier. This concept firstly should classify the layout into Function layout, Product layout, Combination layout, fixed position layout, and Cellular layout. [2]. Over the last three decades considerable research effort has gone into studying various aspects of designing a CMS. The importance of a good design is underscored by the fact that a properly designed structure is the basis for other tactical decisions related to managing the manufacturing system in the short run. Moreover, redesigning the system often is prohibitively costly and often not feasible. An assessment of the similarity among the parts that are manufactured or among the machines (or more generally the resources) required for manufacturing forms are the predominant basis for cell design. The similarity could be based on the requirement of machines, the process sequence, the design attributes such as shape. [3].

The most popular technique used with (CMS) is first the genetic algorithms, which is computerized search, and optimization algorithms based on mechanics of natural genetics and natural selection. It operate on the principle of “The survival of the fittest”, where weak individuals die before reproducing, while stronger ones live longer that inherit the qualities and enabled their parents to survive, the reproduced items are in most cases stronger than their parents, second the TABU searches which motivated by the observation of human behavior appears to operate with a random element that leads to inconsistent behavior. The Tabu method operates in this way with the exception that new courses are not chosen randomly, instead the Tabu Search proceeds according to the supposition that there is no point in accepting a new (poor) solution unless it is to avoid a path already investigated, third is particle swarm optimization (PSO) algorithms as one of the latest algorithms inspired from the nature, was introduced in the mid-1990s and since then, it has been utilized as an optimization tool in various applications, fourth is ant colony optimization as a population-based general search technique for the solution of difficult combinatorial problems, which is inspired by the pheromone trail laying behavior of real ant colonies. To apply ACO, the optimization problem is transformed into the problem of finding the best path on a weighted graph. The artificial ants incrementally build solutions by moving on the graph. The solution construction process is stochastic and is biased by a pheromone model, that is, a set of parameters associated with graph components (either nodes or edges) whose values are modified at runtime by the ants [4].

Azadeh et al.[5]. The researchers minimize inter-cellular movements. Inspired by the rational called grouping genetic algorithm (GGA), this paper proposes a grouping version of differential evolution (GDE) algorithm and its hybridized version with a local search algorithm to solve benchmarked instances of cell formation problem posing as a grouping problem. To evaluate the effectiveness of this approach, the researchers borrow a set of 40 problem instances from literature and compare the performance of GGA and GDE. They also compare the performance of both algorithms when they are tailored with a local search algorithm. Their computations reveal that the proposed algorithm performs well on all test problems. .Bouazza et al.[6]. Introduce a local search procedure to solve the cell formation problem where each cell includes at least one machine and one part. The procedure applies sequentially an intensification strategy to improve locally the solution. To search more extensively the feasible domain, a hybrid method is specified where the local search procedure is used to improve each offspring solution generated with a steady state genetic algorithm. Yang et al.[7]. The researches formulated the bottleneck station scheduling in semiconductor ATM into an optimization problem. The objective is to minimize the total unsupported demands and machine conversion time. The constraints are defined by the ATM business rules. The optimization problem was mapped to an undirected multipartite network and solved using an ACO technique. They also designed and conducted numerical experiments to tune the system parameters using a real-world benchmarking problem. The ACO-based scheduling system was successfully implemented and verified in an Intel ATM factory. Mehdi and Zaki [8]. Presents a useful tool for simulating the behavior of random FMSs. Their simulator is used for real time alternative routing selection based on a group of meta-heuristics principles which include in particular simulated annealing (SA), genetic algorithm (GA), tabu search (TS), ant colony algorithms (ACO), particle swarm optimization (PSO) and electromagnetism like method (EM). This software can also be used for performance and sensitivity analysis of the techniques jugged by the production rate, machines and material handling utilization rate, the cycle time and the work in process. Kato et al. [9]. Proposed an Ant Colony optimization approach for production scheduling problem in a flexible manufacturing system. The problem was treated with two perspectives, based on the modeling and the search method. The problem modeling was characterized by a high-level problem description, using the production routes as a way to represent the states of the solution space. The collaboration concept applied a search method based on Max-Min Ant System algorithm. According to the results achieved, the proposed approach was effective for the problem considered, with quality solutions in a short time processing. Lale et al. [10]. A novel multiple-colony ant algorithm is developed for balancing bi-objective parallel assembly lines. The proposed algorithm is also one of the first attempts in modeling and solving the present problem with swarm intelligence based meta-heuristics. The proposed approach is extensively tested on the benchmark problems and the performance of the approach is compared with existing algorithms.

This current research present the idea and concept of facility layout design of firm using advance intelligent technique of ant colony system (ACS) to modify its production process.

METHODOLOGY AND IMPLEMENTATION OF CELL FORMATION VIA ANT COLONY SYSTEM (ACS)

In classical Cellular Manufacturing Systems (CMSs), machines belonging to each cell are normally used to be close to each other to minimize the material handling costs and setup times. In such systems, by reconfiguring machine cells the physical location of machines must be changed on the shop floor layout. Therefore, rearrangement costs may occur to systems and also process cycle must be taken. In addition, doing reconfiguration very frequently may become impractical or even infeasible. A cellular layout simplifies workflow and reduces material handling efforts in dynamic environments with fluctuating demands and unpredictable parts-mix compositions in implementation of CMSs are difficult. A configuration developed for one product-mix may be inefficient in another environment and frequent cell redesigns would be required or significant and inter cell flows must be allowed. To minimize inter cell flows, resource duplication leads to higher investment costs and unbalances in utilization among resources duplicated. To reduce the negative implications of CMSs while keeping the positive effects, companies have been encouraged to use artificial or virtual cellular manufacturing systems (VCMSs). These systems keep the dynamic nature of systems without any need to physical rearrangement of machines against new arrived orders.

Normally, problems concerning the distance that the parts crosses in the plant is done by using part-machine incidence matrix also it is desired to form groups of machines according to “distances” between them which is one of group technology type. The manufacturing cells are then adjusted completely through distributing each part to the group where it induces. To formulate the assumption, let [11]:

$A=\lambda_{pi}$

Where

$$\lambda_{pi} = \begin{cases} t, \text{if part p visits machine i at step t } (1 \le t \le n) \\ 0, \text{if not} \end{cases} \quad \text{........ (1)}$$

For each part, p visit machines i , j Sequentially :

$$\mu_{ip} = \begin{cases} 1 \text{ if } \mu_{ip} * \mu_{ip} \ne 0 \text{ and } |\mu_{ip} - \mu_{ip}| = 1 \\ 0 \text{ if not} \end{cases} \quad \text{.......................(2)}$$

Where μ_{ip} represent the condition if the part visit machines i & j in two stages successively or not. For all parts in all cell traffic between sections and machine, it is

$c_{ij} = \sum_{p=1}^{p} \mu_{ip}$ ……….. (3)

where $i = 1$ to $n - 1$

And $j = 1 + i$ to n

In the consideration of cost (distance) matrix $C = (c_{ij})$ and logically it can be represented by using integer programing formulation for cellular system and that means the objective function Z will be:

$z = \min \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} c_{ij}\, d_{ij}$ ………………….….(4)

Where d_{ij} is logically; equal to $(1 - x_{ij})$ and that satisfying and represents the objective function under these constraints [12].

c_{ij} = Cost (distance) matrix

$\sum_{i=1}^{k-1} x_{ij} + \sum_{j=k+1}^{n} x_{kj} \leq \quad M - 1$ where $k = 1$ to n ………..(5)

$$\left.\begin{aligned} & x_{ij} + x_{jk} - x_{jk} =\leq 1 \text{ where } i = 1 \text{ to } n-1 \\ & x_{ij} - x_{jk} - x_{jk} =\leq 1 \text{ where } j = i+1 \text{ to } n-1 \\ & -x_{ij} + x_{ik} + x_{jk} =\leq 1 \text{ where } k = j+1 \text{ to } n-1 \quad \text{….(6)} \\ & x_{ij} = \begin{cases} 1 & \text{if machines } i, j \text{ in the same cell } i = 1 \text{ to } n-1 \\ 0 & \text{if not} \qquad j = i+1 \text{ to } n \end{cases} \quad \text{……(7)} \end{aligned}\right\}$$

Constraint (5) prevents confusing between machines when there is more than one machine (M) at the same cell and it also keeps correct operations sequences (K). And for triangular constraints in (6), it enforces the integrity of cells. The above formulation considers most important parameters, processing sequences of the parts routings and the maximum allowed size for cell. In our case the modification of any revisiting part to its same machine could not take more than zero but there are some parameters that should be taken in consideration just like volume weighting in the routings. For problem if the cell sizes are fixed it can be formulated as quadratic assignment transportation or matrix norm minimization problem. If there are k cells of pre-specified sizes $m_1, \dots \dots m_k$ and y_{ik} where i=1 to n & and k=1 to k these binary variable ensure that the machines m are allocated to cell k and could be connected in relations with (7) as :

$x_{ij} = \max \sum_{k=1}^{k} y_{ik}\, y_{jk}$ where $i = 1$ to $n - 1$, $j = i + 1$ to n …… (8)

According to optimization problem and by subtracting (8) from (4), the following is obtained:

$z = \max \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} c_{ij} - \max \sum_{i=1}^{n-1} \sum_{j=1+1}^{n} \sum_{k=1}^{k} c_{ij} y_{ik} y_{jk}$ …….(9)

With formulation (9) max term shows the intercellular movement under constraints:

$\sum_{k=1}^{k} y_{ik} = 1 \quad i = 1$ to n ……………(10)

$\sum_{i=1}^{n} y_{ik} = m \quad k = 1$ to k …………(11)

$y_{ik} \in \{0|1\} \quad i = 1$ to n & $k = 1$ to k ……..(12)

Where (10),(11),(12) ensured that each machine is at one place only and no confuse on happens at pre-specified size.

The formulation for current site plant is shown in Figure (1) and its matrix cell table (1).

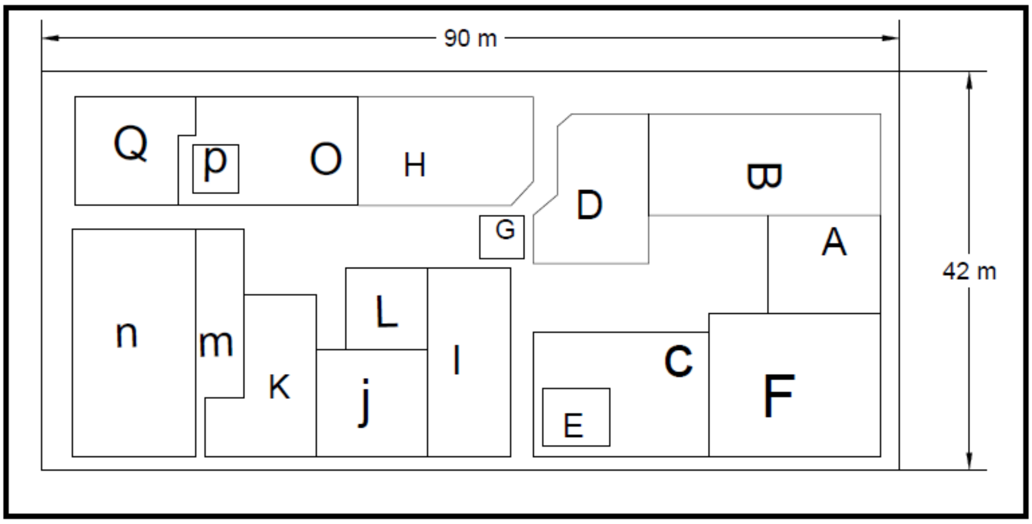


Figure (1) the plant sections.

Table (1)-incidence matrix machine – cell

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
M1														X			
M2														X			
M3														X			
M4											X						
M5											X						
M6											X						
M7											X						
M8										X							
M9										X							
M10									X	X							
M11																	
M12										X							
M13	X																
M14	X																
M15																	X
M16																	X
M17																	X
M18												X					
M19																	
M20															X		
M21															X		
M22								X									
M23								X									
M24								X									
M25								X									
M26							X										
M27	X																
M28	X																
M29						X											
M30						X											
M31				X													
M32				X													
M33				X													
M34				X													
M35				X													
M36							X										
M37							X										

Assuming the routes from dependent-type units (where the operation of a specific part that took place neglected the other part in the same combination that was not needed for this operation) to independent-type units are straight lines and through constructing two- dimension coordinate system in such case, the total intercellular moves take into account the impact of the sequence of operations and the layout of cells as follows:

First: The movement: -

$$total\ moves = \sum_{i=1}^{p}\sum_{i=1}^{k-1}|c_k - c_{k-1}| \ \ldots\ldots\ldots\ldots(13)$$

Where

C_k = Cell number in which operation k is performed on part i, considering the sequence of operations;

C_{k-1} = Cell number in which operation k-1 is performed on part i, considering the sequence of operations;

k_i = Total number of operations to be performed on part i to complete its processing requirements;

C = number of cells;

p = number of parts to be processed

And the total cell load variation aids the smooth flow of materials inside each cell and reduces the work-in-progress (WIP) within each cell.

The variation cell load was calculated as the difference between the workload on the machine and average load on the cell.

Second: The loading: -

$$load\ variation = \sum_{i=1}^{p}\sum_{l=1}^{c} x_{il} \sum_{j=1}^{p}(w_{ij} - m_{ij})^2 \ \ldots\ldots\ldots(14) \quad \text{and}$$

$$w_{ij} = \left(\frac{t_{ij} \times N_j}{T_i}\right) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

$$m_{ij} = \frac{\sum_{i=1}^{m}(x_{ij} \times w_{ij})}{\sum_{i=1}^{m} x_{il}} \ \ldots\ldots\ldots\ldots\ldots\ldots(16)$$

Where

m = total number of machines .

c = total number of cells .

p = total number of parts .

t_{ij}= processing time (hours/piece) of part j on machine i .

T_i = available time on machine i in a given time period .

N_j= production requirement of part j in a given time period .

[w_{ij}] = an m × p workload matrix .

[x_{il}] = an m×c cell membership matrix, where xil = 1 if the i-th machine is in cell 1, and 0 otherwise .

[m_{lj}] = a c× p matrix of average cell load .

The description of problem including the criteria of work and choosing better ant colony technique to implement it into the problem and taking shortcut steps to get artificial control algorithms was inspired by ants and its ability to move in the shortest route using some kind of pheromone. To deal with such problem in programing by knowing input parameter, process attitude to get the output results is needed to achieve best route. The input parameters should include the shop floor site plan of electrical motor industrial plant. The plant area is (3780) square meter (90m*42m) and it produces electric motor for air cooler .The total production about (1000) pieces in a month and each piece should cross over 800 m to get to the final product assembly production. The code of the machine in the plant used numbers from 1 to 37 showed in table (2) .The production process happens in five phases, which are:

I. Production of the stator. This operation take the following sequence
27-28-14-36-26-37-25-24-23-22-21-20-15-16-17

II. Frame and base manufacturing. This operation takes the following route.
27-34-32-33-35-24-23-22-21-20-15-16-17

III. Front and rear cover.
29-30-1-2-3-20-15-16-17

IV. Manufacturing of rotor.
27-13-11-12.

V. Shaft route.

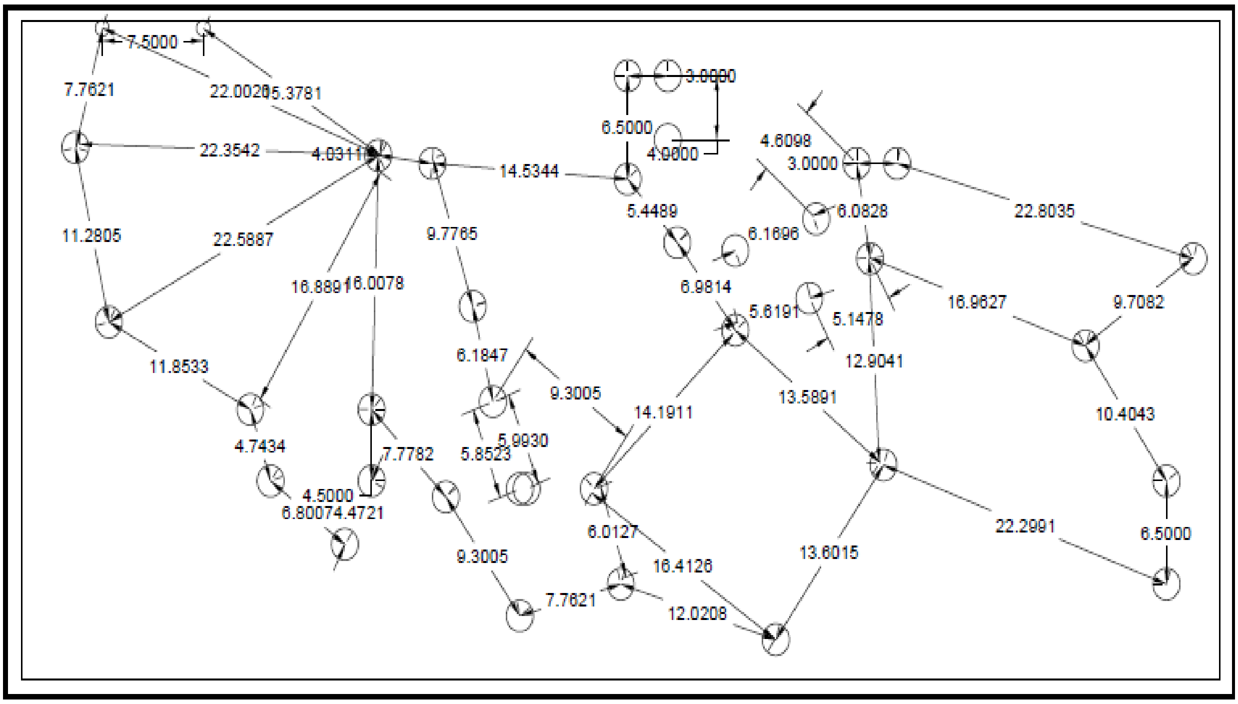


Figure (2) Distance between machines inside plant

Table (2) the iterations of codes given to the machine

Code	Process
1	Front and rear cover turning machine
2	Washing front and rear cover machine
3	Painting section
4	Shaft grinding machine
5	Shaft turning machine
6	Shaft sleeve turning machine
7	Blacking the shafts
8	Immersing in acid
9	Immersing in acid
10	Washing
11	Rotor core turning machine
12	Heating and coupling center
13	Rotor die casting
14	Annealing center
15	Painting
16	Adding condenser
17	Packaging
18	Quality control center
19	Shaft raw material store
20	Assembly
21	Immersing insulators
22	Electrical field testing
23	Connecting wires and welding
24	Compounding the frame with stator
25	Adding coil to the stator
26	Stator turning machine
27	Raw materials
28	Lamination punch machine
29	Die casting for the front cover
30	Die casting for the rear cover
31	Frame and base punch machine
32	Welding frame and base machine
33	Turing machine
34	Turing frame and base machine
35	Quality control
36	Grouping lamination
37	Compounding the insulator

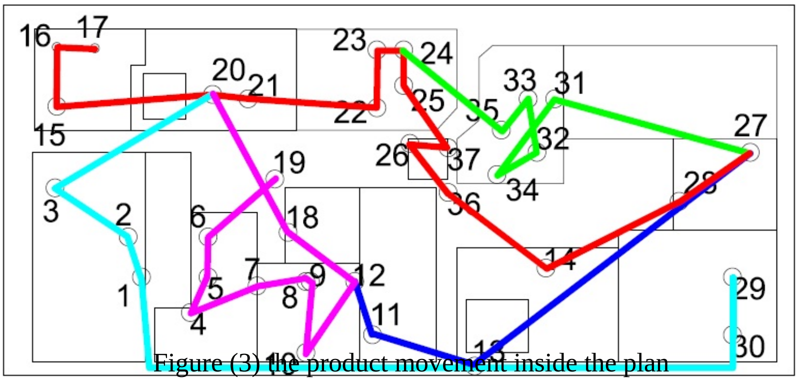


Figure (3) the product movement inside the plan

Some function is used and evaluated in the optimization process during Ant technique system as follows. X and Y using symbol to representing the coordination of the nodes or products fabrication section location at a matrix grid that are distributed on the area of the shop floor where each node should be allocated exactly in the site plan configuration, D is the symbol to generate matrix that represents the distance between nodes, t is the primary ants tracing of ant around all nodes following the pheromone and Iteration. as Ant great system builder, so it keeps moving on for building the system and get the best tour and that can only be limited by keeping iteration for specific value figure (3). The iteration should reflect the algorithm coming with the specific case. This process is iterated until the tour counter reaches the maximum (predefined) number of cycles or all ants (parts) make the same tour.

RESULTS AND DISCUSSIONS

By applying ACS to specific plant and using the existing plant configurations as a primary state of starting point. The ACS dealt with past physical distributions of the plant as initial state figure (4). Implementation start by fixing the Ants numbers that represent the number of machines to be re-allocate and changing the iteration times from 50 by increasing until it reaches to 500, after that there is a changing in the iteration to 500 each time until to get 3000. Notes that for shorten, just few figures were shows.

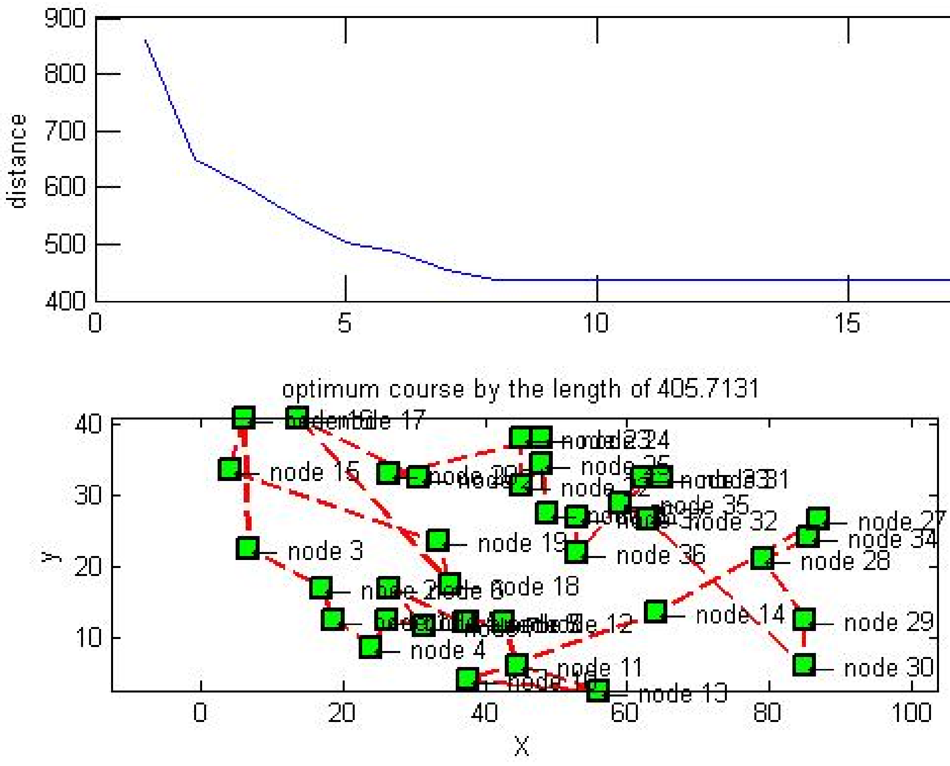
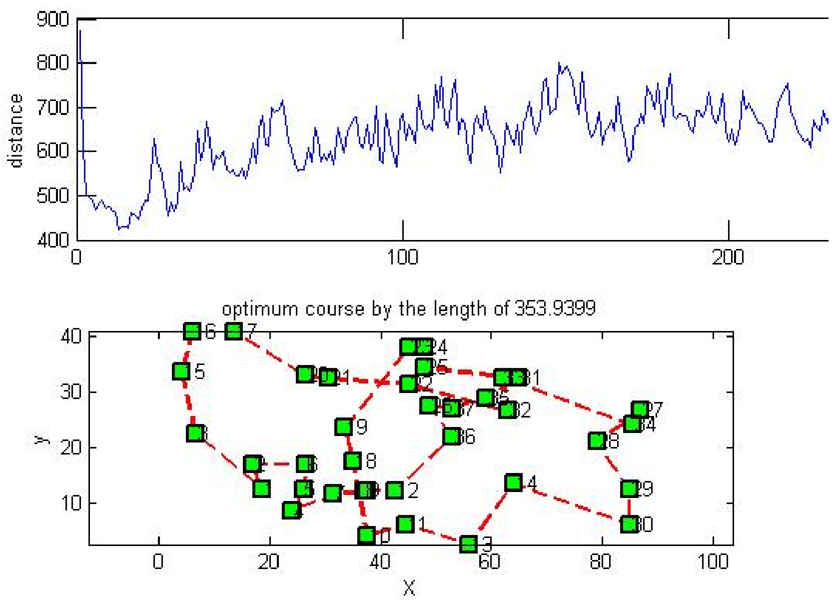


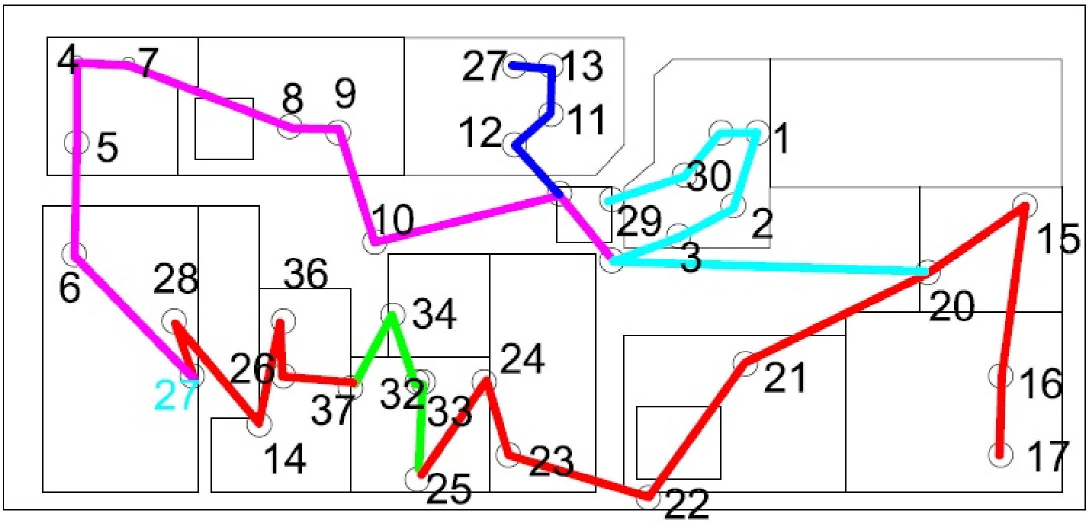
Figure (4) site plan at 50 iteration and 37 ants

The iteration curve is drops from over than 800 meters and gets slow down where it looks smooth and becomes stable at 392.580 m with no change. But the physical configuration of the machine distributions in the plant look complex to the machine route and also deadlock and bottleneck problems may occurs.

By monitoring the iteration curve, has sharp drop from 900 m little distraction to minimum distance of 356 m. But the physical distributions of the machine or the plant configuration still need more flexibility to prevent the traffic choking. For 700 iteration and 37 Ants (number of part) the iteration curve has three regions until getting to stability at 401.2527 m. which is, the beginning of distraction, the iteration curve looks far away from the stability and starts new age of distraction with optimum tour made by parts of 336 m. At iteration 1000 and Ant 37, the distraction in the curve will become more obvious and it increases as the iteration increase until reaching to 3000. It will be noisy and it cannot be read with different plant configurations. The purpose of increasing the iteration is to make sure from the robust design of the ACS, if there is any weak point in the system or in the application that will appear in situations of iteration with different time from 50 to 3000. By fixing the iteration at 600 and achieved flexible plant configuration, this represents the medium between iteration, distraction in the curve will be noisy, complex and unreadable, which is mean small number of ants in the ACS cannot meet with the criteria and the requirement of the problem. The minimum Ant (number of part) should be no -less than 30 Ant where there is 37 sections or machine to be visited. At 600 and 35 Ant, the distraction will be little noisy and then get to be unreadable. This is given a notification that there is a response from the ACS to reduce the distraction. At iteration 600 and 50 Ant the iteration curve shows sharp drop in operation stability and then starts distraction but there is an increasing in the flexibility and this shows reduction in bottle neck and traffic chock of parts. At iteration 600 and 55 Ant, there is a sharp drop in curve iteration but there is no stability region and the distraction can be readable, but the traffic problem needs to be solved. the (ACS) still responding to the increasing of the Ant. The increasing of Ant is critical because of the amount of pheromone deposited in the route by given Ant number. Which represents the processing time and amount of part to be processed at specific machine. The best tours are given by using 600 iterations and 60 Ant. The distance curve or (iteration curve) shows sharp drop and near to stability when it achieves about 301.378 m. figure (5)



From the results it is observed that the ACS approach can achieved the best in specific iteration and number of Ant via applying these issues to the plant layout; the factory landscape is improved as shown in Figure (6).



CONCLUSIONS AND FUTUREWORK

According to the results of work, the total distance should the products travel is more than 800 meter inside the plant, saving this area could be use to increase the factory ability in order to increase throughput time for the existing plant. The best iteration is at 600 and 60 ant that means its should be a proper selection between Iteration and ant number with corresponding to products parts number. The increase with ant number will increase the defect of the optimization process. Ant algorithms include an evaporation feature for integrating a time factor when incrementally creating solutions. The proposed research may also be utilized in resolving common routing problems and other combinatorial optimization problems once the adjustment has been put in place. The number of general iterations and the stochastic descent process are parameters of the algorithm that need to be tuned according to the size of the problem. The contributions of this research may be further developed in several ways. Promising directions for future in by enriching the algorithms with neural network and making a union algorithms work independently to extract the best solution. Also improved to be implement on submarine to get the best route under high seas. Rebuilding ant algorithms dependent on genetic algorithm in such a way of genetically restructuring the ant and swarm algorithms.

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