An improved ant based algorithm and its implementation for the Broken Edge Linking Problem

Md. Bakash Ahamed, Suchintya Sarkar, Dibyendu Barman

***Abstract:** As a robust image processing technique, the broken edge linking technique is considered to be the complementary one to the edge detection technique. Here in case of the edge linking problem, we form closed contours by linking the broken edges. This action indeed needed to split the areas in the image into different parts known as segment. However the traditional edge linking technique is always succeeded by the traditional edge detection technique.*

The traditional edge linking technique, for all time, neglects some significant part of the boundaries to consider, as a result, appropriate and perfect solutions to the edge related linking problem cannot be reached always. With this article, we presented an improved method (technique) for the edge related linking difficulty (problem), which is actually the expansion of the original old Ant System (AS) algorithm. Here in the experiment, we mainly consider the two decisive and significant factors: first one is the length of the linking edge as well as second one is the grayscale visibility of the pixels, apart from an sobel edge binary image , so that the effective solution evaluation and enhancement of the overall performance can be achieved. The experiment showed the expected result, are presented herewith this to ensure the successfulness of the projected improved technique /algorithm.

***Keywords_:** Ant System, Algorithm, edge detection technique, Edge linking technique, Grayscale Visibility. Sobel Edge Operator.*

I. INTRODUCTION

Recently, with advancement of the modern technology, image processing techniques are so often applying to the existing transportation model, business/commercial model, medical diagnostic related applications, chemical/civil engineering, scientific application, military research related application, robotic application and developed industry related applications etc. Recently, the genetic algorithms, artificial_ neural networks (ANN) technique, fuzzy logic and ant colony optimization approach, all are the types of the soft computing approaches, have chosen as the extra advantageous in the study ,as well as practices of the digital color or gray images. Ant _Colony_ Optimization approach has been applied to the diverse digital color/gray image processing applications. Few of them are the edge detection technique, edge linking technique, feature related extraction, segmentation and digital image compression technique. However, practically it is a very difficult task to tackle with the broken edges found in images, where a missing i.e. lost edge part is requisite between the two given endpoints (pixels) , that is, these are points (pixels)on the image, from where the image edges are vanished i.e. broken. There are some effective methods with respect to the computational cost and other considered factors, developed in the past by developers, researchers to find out the suitable solution to the ongoing linking crisis, as well as for better edge detection. However, the proposed well improvement in our algorithm that originated from the original ant system based approach, for has the lower functional cost and gives us satisfactory results.

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II. LITERATURE REVIEW.

A set of associated pixels laying in between the boundaries of two different regions forms an edge. The various attributes in Edge etc provide important information about the digital image. In case of Edge detection, we spot as well as locate all the sharp discontinuities of an image whether, brightness, colour, gray intensity level, texture etc changes sharply or not. We try to identify pixels with high intensity and extract edges accordingly. In this way, we get the sketch of an image object, as well as, the borders between the background in the image, and objects are detected. There are so many number of techniques have been there in the literature for detecting the edges of different objects .They are the statistical technique, difference technique and technique based on curve fitting [2-3].In Classical technique, we are to consider here the first directional derivative to decide the position of the image edges. The second derivatives as well as the zero-crossing edge detectors included along with the Laplacia n operator present enhanced accuracy than ,the previously discussed first derivati ve operator s [8]. We make use of Gaussian detectors technique in case of frequently used edge detectors ,the Canny edge_ detector technique [9] give enhanced performance .But this technique is computationally more expensive than the classical technique s. specific formulas are applied to extract edges in all these techniques. But, most of the conventional techniques for performing edge discovery come with their restriction; some of them have several disadvantages also. Some of these conventional techniques are costly (not cheap) with respect to computational cost.

In case of the simple Ant based edge detection technique, the technique adopt is very simple and effectively extract the related edges of the digital gray images. Here as the first step, a definite quantity of ants are distributed randomly on the selected pixels of the digital gray image [5]. The ant randomly moves from one pixel to nearby another pixel on the digital image by leaving pheromone trail in their route. A pheromone matrix is formed accordingly based on these combination all these pheromone trails. Each and every assigned entry value in the pheromone matrix contains the desired data (information) about the edge at any given pixel (i, j) .At end of each and every iteration phase, the pheromone intensities are restructured and refreshed (i.e. updated).

Edge linking technique succeeded by Edge detection technique has some certain drawbacks .This may include the false image edge detection, missing true image edges, or when the input image is noisy or blurred. [14].

It is a difficult task to connecting the broken image edges perfectly. The original gray image has some significant data (information), which is generally exploited to link (fix) these wrecked (broken) or missing edges. In order to connect these broken or missing edges, so as to, get better of the edge detection, a very simple method has been suggested in [15]. The end points of edges of the image, are the very noteworthy parts which hold the vital data (information) so that, to connect the broken edges, we draw the direct lines between these image points where broken points found. The methodology succeeds such as, that each and every pixel in a image is allied with its 8(eight) neighboring .pixels. But when different ants search the same area may lead to a redundancy. To overcome from such type of problems different labels are assigned different group of ants and labeled accordingly. These groups of ants assigned with different labels try to fix the breaks in the edges. There are large numbers of strategies coded as well as projected, enhanced and developed in the past for the linkage of the broken or missing edges, as well as for the upgrading of the image edge detection approaches (techniques). Somewhere the other approaches such as the Hough's strategy of transformation is applied where specific figure(shape) is then taken out for the linkage of the broken or missing edges, for the reason that, the edges are for eternity are associated with dissimilar size and shapes. Some other technique exercise the hybrid strategies for the same purpose s mentioned. The morphological image enhancement method was applied by Jiang *et a_* to spot as well as project thin-edge quality in the case of the stumpy contrast area of an image. The Sequential_ edge_ linking (SEL) process applied by Wei *et al.* to entirely link the image edges. [17]. Lu *et al* envisaged the ultimate enhancement and upgradation to the traditional Ant based algorithm for the linkage of broken or missing (lost) edge, so that, the performance may be better as well as the working out cost may not be so higher..*[18].*

III. ANT SYSTEM ALGORITHM

Italian scholar M.Dorigo et al. in the 1990s projected the first ant based algorithm (ACO), known as the Ant System (AS). Thereafter, numerous ACO strategy based algorithms have been proposed by different researchers, scholars, developers, such as, the Max_Min ant algorithm etc. Then the various composite combinatorial problems, such as the quadratic assignment related problem, image retrieval, image thresholding and image segmentation problem etc. have been solved by the ACO algorithms. [1, 4]. Ant System (AS) algo take advantage of the sorting out nature of the real ant colonies and their rummaging conduct successfully resolve numerous complex, discrete optimization n problems, such as such as, data mining, data_clustering, TSP etc .

The foraging (searching for food) behavior of ants from the ant (nest) colonies is basis of the AS algorithm. Unlike its organic counterpart s, the artificial ants move randomly in the discrete surroundings from one node (destination or source) to another node for the food. Artificial ants are not absolutely blind and they have memory. They survive in a distinct time surroundings. The paths with enhanced quantity of pheromone deposited are actually chosen by them for their movement. While in movement, pheromone trail leaved by them on their paths to draw the attention of the other ants. In this way, pheromone trail deposited and thereby accumulated in their path of movement. The shorter visited paths should have the higher and better rate of deposition in the percentage of pheromone e trails. The percentage of quantity of chemical pheromonic trails laid on each and every direction helps the ants to communicate to each other, while they are in the movement. The ants restrain themselves from taking the same path, when the non positive response perceived by them through pheromone vanishing on the path [11].

The Ant (based) System (AS) approach begins with the variables setting to their permissible initial values. This first step is then, chased by another next allowed step: iterative construction of the new solutions, which is then followed by the next step: the pheromone updating. There are mainly four steps involved in the Ant System (AS) algorithm [8].

1) FIRST STEP- INITIALIZATION [ANTS, NODES]: randomly, certain quantities of ants from the ant colony are positioned on selected nodes.

2) SECOND STEP- TRANSITION RULE FOR INTER NODES: Probabilistically, T^{th} Ants' movement from source node (say l) to destination node (say q) is determined with the following equation:

$$P^t_{(l,q)}=[(\tau_{lq})^\alpha * (\eta_{lq})^\beta] / [\sum (\tau_{lh})^\alpha * (\eta_{lh})^\beta]$$

(If, when q, h $\notin$ tabu^t)

$$=0 \text{ (if q, h } \in \text{ tabu}^t) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, τ_{lq} implies to the intensity value of the chemical pheromone trail on the edge (linked by *l, q*).

η_{lq} implies the visibility value of the source node *q* from the source node *l*..

(Provided that, τ_{lq} , η_{lq} >0;and τ_{lq}, τ_{lq} ∈R, for the all l, q).

α and β are the user managed control factors, where α, β are all with always positive value(+,and >0);and α, β∈ R).

The importance of the pheromone trail is controlled by α.

The importance of the visibility is controlled by β.

tabu^t is the list of all visited nodes by the T^{th} ant.

3) THIRD STEP- UPDATE RULES FOR PHEROMONE: the pheromone update is applied at this point, as soon as all the performing ants come with the development which destination node (food source) to travel subsequently, and is specified with the following probabilistic equation.

$$\tau_{lq(NEW)}= (1-\rho)\tau_{lq(OLD)}+\sum\Delta(\tau_{lq})^t; \text{ for } t=1,2,3\ldots.k-1, k \quad \ldots (2)$$

Where the pheromone evaporation rate is ρ and (0 <ρ and ρ <1; and ρ ∈R). The quantity (amount of chemical) pheromone trail deposited on the preferred edge (l, q) by the T^{th} ant is given by $\Delta(\tau_{lq})^t$. and the following equation:

$\Delta(\tau_{lq})^t=F_k/W$,

if preferred edge (path, connected by source and destination nodes: l, q) is visited (travelled) by the T^{th} ant at the recent round.

= 0 otherwise ……………… (3)

Here, the fitness value = F_k, for the desired solution. and W is an invariable non zero quantity.

4) LAST STEP- CONDITION OF STOPPING: The above two noted phases come after the first initialization phase, are repetitive in a conditional loop. The whole procedure described in the above phases discontinues its execution, while an acceptable reasonable solution is established there, in either case; the larger number of iterations is achieved.

The pheromone trail matrix resulted in this way ultimately classifies each pixel is either on an edge or non_edge. This selection is normally done by pertaining a threshold T_{final} on this final matrix. This value (of threshold) is calculated by the strategy given in the Otsu thresholding technique [7].

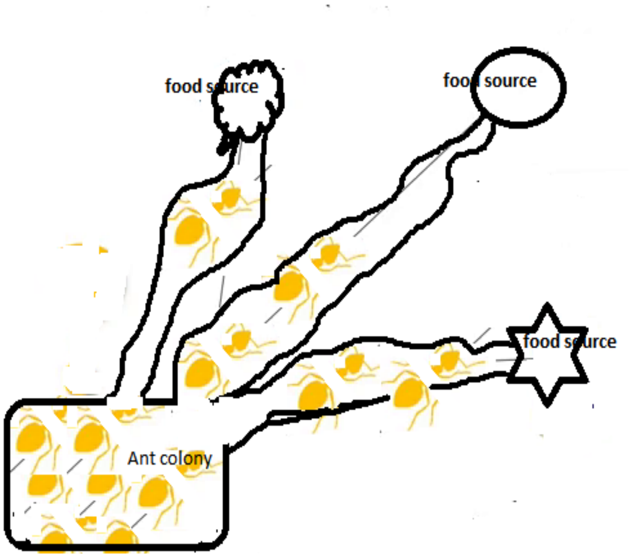

Fig.1 ants searching food

IV. PROPOSED ANT SYSTEM METHOD

The foraging (searching for food) behavior of ants from the ant (nest) colonies is basis of our proposed Ant System (AS) algorithm. Ants move through discrete surroundings within the nodes for food and chemical pheromone trails leaved by these ants in order to draw attention of the other ants of ant colony, so some of other ants can chase their paths. The best possible paths followed by the ants, are the edges of the objects, where the nodes are represented by the image pixels for the broken edge linking problem,

Here two images are as input for this proposed strategy: one is the original clean noise free grayscale image and, other one is the noise free sobel edge image. The implantation of sobel edge operator to the original grayscale image generates the Sobel edge images which is actually a binary image. The endpoints from this image are extracted and they are the significant pixels, from where the detected edges were broken. We use these endpoints as the preliminary pixels on the ants' paths. The *grayscale visibility* matrix is developed from the original input grayscale image.

The grayscale visibility value of the node (pixel) at (i, j) is determined as per the equation follows:

$$\xi_{ij}=1/I_{max}(\text{MAX}[|I(i+1,j-1)\text{-}I(i-1,j-1)|, |I(i+1,j+1)\text{-}I(i-1,j+1)|, |I(i,j+1)\text{-}I(i,j-1)|, |I(i+1,j)\text{-}I(i-1,j)|]) \quad ……….\ ……..(4)$$

Here, I_{max} =the maximum gray value obtained for the input image, and the value of ξ_{ij} will be normalized ($0 \le \xi_{ij} \le 1$).

For the pixels (of the digital image) in the locale of the discrete gray influences (intensities) are speckled, the better tolerable values are established.

E_1(X-1, Y-1)	E_1(x-1, y)	E_1(X-1, Y+1)
E_1(X, Y-1)	E_1(x , y)	E_1(X, Y+1)
E_1(X+1, Y-1)	E_1(x+1, y)	E_1(X+1, Y+1)

Fig.2 the Pixel E1(x, y) and its eight neighbors.

The grayscale visibility matrix, obtained after applying the above mentioned equation, will be known as the initial pheromone trail matrix to estimate the fitness value of a path preferred by ants from the ant colony. The benefit of doing this is to improve the possibility of getting better result.

The pixels fitted with the right edges are preferred by the some ants on their starting paths (routes), which enhance the performance. The consequential produced image will hold the paths (the linking edges) whose having the higher fitness values. And these paths will be treated as the most favorable paths between the endpoints of the image. The non favorable paths can be rejected by applying a suitable fitness threshold value. Eventually, the resultant enhanced, modified image is the amalgamation of the sobel edge image and the connecting edges.

The concise modification in the working Algorithm:

For the messed up (broken) edge connecting (linking) issue, the discrete position for the artificial (fake) ants is on a computerized grayscale picture (image). The first grayscale picture (image) is characterized as:

$0 \le I(i, j) \le I_{max}$,

Where $1 \le i \le N$,,*and* $1 \le j \le M$, .

$N \rightarrow$ the row number and $M \rightarrow$ column number.

Where, I(i, j) $\rightarrow$ the gray_value of the pixel at position (i, j).

($0 < I(i, j)$ and $I(i, j)$ <255,as well as $I(i, j)$ belongs to R..)

The modified ant approach applies an iterative strategy and includes mainly the following four steps:

1) First step-initialization of approach [Ants, Pixels]: The quantity of ants equivalent to the quantity of endpoints (pixels) exist in the participated sobel- edged image, and each of such pixels will be a preliminary starting- pixel of the individual ant of the ant colony. Initial pheromone trail for such each and every pixel is assigned to a value equal to the grayscale- visibility.

2) Second step- transition rule of the pixel: the Possibility of ant move to the nearest pixels is characterized by model as shown in Fig.3:

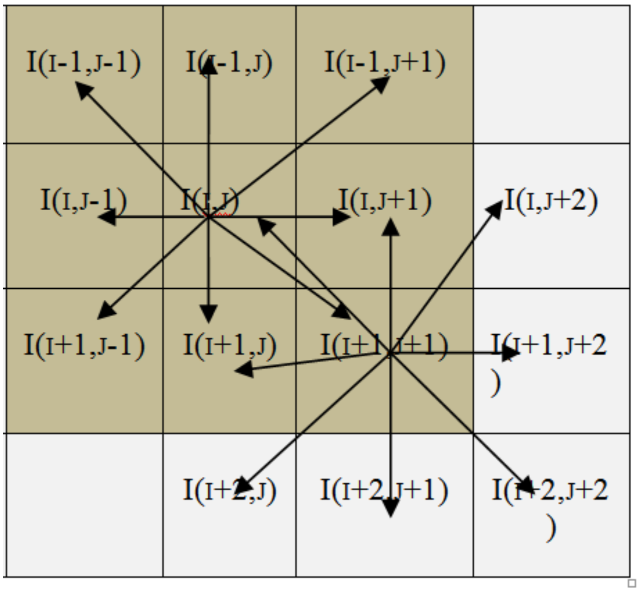

Fig. 3: the 8(Eight) Connected Pixels

The permitted adjacent pixels for the k^{th} ant of the ant colony to move to are the ones whose do not belong to the list of $tabu^k$. The movement of the k^{th} ant within the pixel (r, s) to pixel (i, j) is determined probabilistically as by the equation as follows:

$P_{(r,s)(i,j)}^{k} = (\tau_{ij})^{\alpha} * (\eta_{ij})^{\beta} / \sum(\tau_{uv})^{\alpha} * (\eta_{uv})^{\beta}$ …………..(5)

When, (i, j), (u, v) $\notin tabu^k$ and

$0<r-1 \leq i,\ 0<u \leq r+1$, and $0<s-1 \leq j,\ 0<v \leq s+1$

= 0 ,otherwise

Where, τ_{ij} -> the intensity value of the pheromonic trail and η_{ij} -> the visibility value of the pixel at point (i, j).

α , β : two control parameters ($\alpha>0$, $\beta>0$; and $\alpha \in$ R, $\beta \in$ R).

For the pixel at end (i, j), the visibility value of the pixel defined as:

$\eta_{ij}=1/d_{ij}$ …………(6)

Where d_{ij} is the Euclidean _distance of the pixel at (i, j) from the nearest pixel.

Euclidean distance (two- dimensional vector) of any pixels from Xi to Xj is calculated as:

$d_{ij} = \sqrt{(Xi1 - Xj1)^2 + (Xi2 - Xj2)^2}$ ……….(7)

3) Third step - Pheromone update rule: Non positive feedback is established with the pheromone trails disappearance according to the equation:-

$\tau_{ij} = (1-\rho)\tau_{ij}(old) + \Delta\tau_{ij}$ ……..…(8)

Where, ρ is known as the evaporation rate of the chemical pheromone.

($0 < \rho$ and $\rho < 1$;ρ belongs to R), and ,

$\Delta\tau_{ij} = \sum\tau_{ij}^{k}$ Where k=1 to m

Where, $\Delta (\tau_{ij})^t = F_k/W$. if ,k^{th} ant move to the destination at (i, j)

=0 otherwise

F_k, is defined by the following equation:

F_k= mean value/ standard deviation*total no of pixels in the root.

The chemical Pheromone evaporation prevents the ongoing algorithm stagnation. The value ρ is set 0.05.

4. Fourth step- principle behind for discontinuation of the process: The second and third steps are recurring in a while loop and the whole procedure described in the above phases suspend its execution, while an acceptable and reasonable solution is established there, in either case; the larger figure of iterations is achieved. Iteration over, when all the ants do not the look for the endpoints, by either finding desired one or getting extremely wedged or being very incapable to move ahead to any nearby pixel.

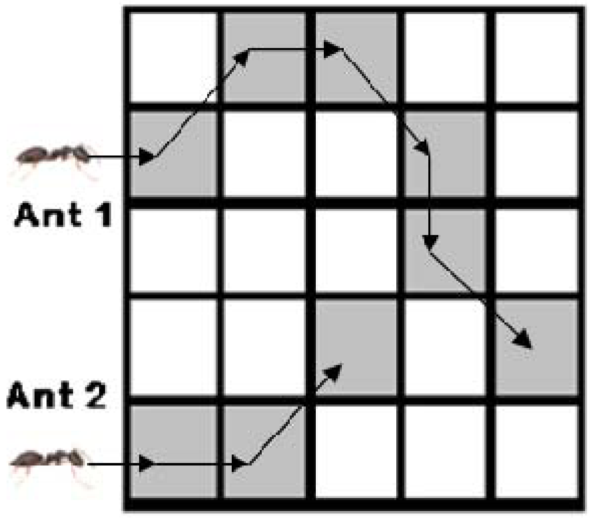

Fig.4 Movement of two Ants: 1, 2 within the pixels.

V. IMPLEMENTED MODIFIED ALGORITHM

1) Input a noise free and non blurred digital image.
2) Transform noise free and non blurred digital image into a colorless grayscale digital image.
3) Sobel edge image formation, applying sobel edge operator.
4) Extract end points from the generated sobel edge image.
5) Apply the formula as per the equation (4) to get the grayscale visibility matrix.

Where maximum gray value in the image is I_{max}.

6. Pixel visibility matrix (η_{ij}) is constructed according to the rule as specified in equation (6)
7. Initialization of the iteration cycle:

Set the parameter t as well as value of CC to 0.

{Here t is the time counter, CC is the cycle counter}

For the trail intensity, for each and every edge with (i,j) there ,an preliminary preferred value $\tau_{ij}(t)=c$ is set and preliminary preferred value of $\Delta\tau_{ij}$ set to 0.

[Initialization of the pheromone matrix]

Distribute the m quantity ants on the n number of pixels.

8. Put s:=1 [Here, the tabu(which maintain the trace of all visited pixels)list indexed by s]

For k:=1 to m do

Keep the preferred k^{th} ant in the $tabu^k(s)$

[Initialization of $Tabu^k$ (ant's memory):]

9. Input all the required parameters:

ρ: the pheromone_ evaporation _rate.

α: controls the degree of the pheromone_ trail.

β: control the degree of the visibility.

n: Number of iterations.

10. Keep repeating until the tabu list is finally full

{The quantity of replication of this phase will be (n-1) times}

Reset s:=s+1.

For ant

k:=1 to m do

Select the pixel, j, to move to, with the probability $P^k_{(i,j)}(t)$, which can be obtained from the equation (1).
{At time come to t, the k^{th} ant(not yet positioned in the tabu) is relocated on the pixel i equivalent to $tabu^k(s-1)$}
The k^{th} ant move, the pixel j is moved and place it in the $tabu^k(s)$.
11. For k:=1 to m do

The marked k^{th} ant is shifted to the $tabu^k(1)$ from the $tabu^k(n)$.
The length equal to L_k of the journey passed through by the marked k^{th} ant is calculated.
The shortest visit established here is updated.
Now for each and every edge (i,j),

For k:=1 to m do

Calculate $\Delta\tau_{ij}=\sum\tau_{ij}^k$ .where
$\Delta(\tau_{ij})^k = F_k/W$,if in case the particular edge (i,j) is visited by the k^{th} ant during the recent round.
= 0, otherwise.
Where the desired fitness value of the probable solution established by k^{th} ant= F_k and W = a constant value.
12. For each and every edge (between I and j) evaluate $\tau_{ij}(t+n)$ as per the below equation
$\tau_{ij}(t+n)-\rho .\tau_{ij}(t)=\Delta\tau_i$
13.Set t:=t+n and Set CC:=CC+1.
For each and every edge (i,j), set $\Delta\tau_{ij}= 0$.
14. If (CC < CC_{MAX}) and
(No continuing stagnation activities there)
Then
Vacant all the tabu lists
Goto step 8,
Else
Print shortest path travelled by the ants
end
[The stopping rules are applied to confirmed whether the ant can move to the next position or not, if it is not, stop the ant]
The utmost probability of transition is calculated according to the transition rule and the ant is moved for that reason.
The optimal path is chosen by applying a favorable fitness threshold. As a final point, a binary conclusion is prepared at each and every pixel position to conclude whether it can be a preferred edge or not, by consulting with a threshold T_{sh} on the final concluding pheromone matrix. In this article, we exercise the thresholding based way as depicted in [15] as follows:
(i) Pick an opening approximation for T_{sh} (the standard average of the values for the preferred points).
(ii) Construct two collections of values: C1 holding of all the values< T_{sh} and C2 holding of all values > T_{sh}.
(iii) Calculate the average normal values μ_{01}, μ_{02} for the values found in collections: C1, C2.
(iv) Calculate a fresh threshold value:
$T_{sh}(new) = (\mu_{01}+\mu_{02})/2$.
Continue with the (ii) to (iv) steps until the variation in T_{sh} in repeated iterations is lesser than a predefined (user defined) constant parameter say £.

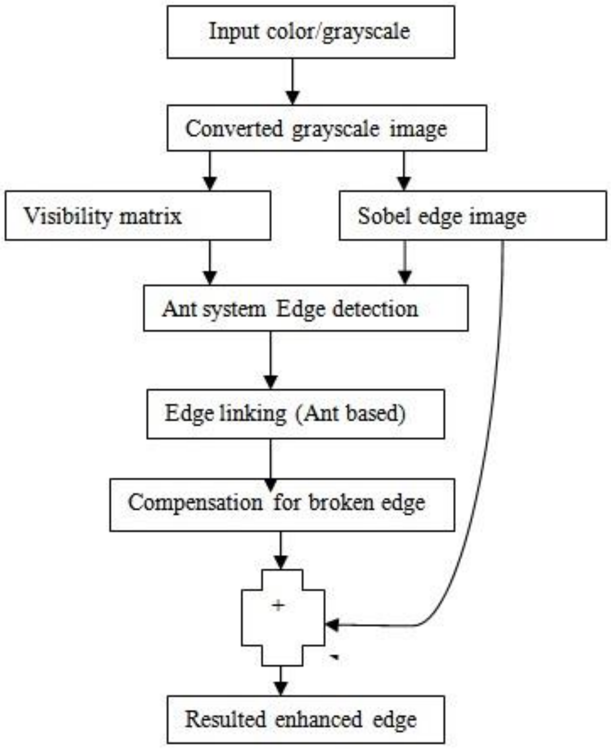

Fig. 5.Block_Diagram of the implemented edge _linking_ method

VI. RESULT OF THE IMPLEMENTED METHOD

The outcome of the proposed approach applied to the peppers image of size 128x128 pixels is shown below.
1. Input digital Image: modified edge linking algorithm is being applied on this original digital image.

Fig.6 Original input grayscale image

2. Sobel Edge Image: Sobel edge operator generated edge.

Fig. 7: Sobel Edge Image

3. Resulted Image: the resulted image after applying the improved Ant System Algorithm.

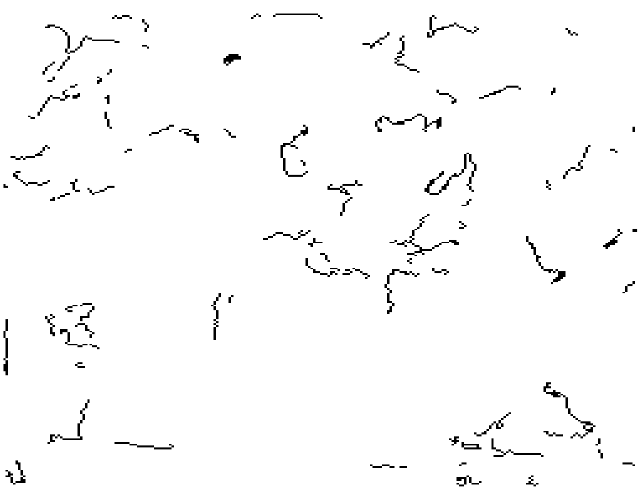

Fig.8 Resulting Edges

4. Improved Edge Image: Sobel edge image and resulting edges are combined to reproduce the improved edge image.

Fig.9 Improved Image

VII. ANALYSIS OF THE RESULT

The proposed method has been put into practice with a real digital color noise free image of size 128x128as well as coded in the MATLAB(2018).The implemented Ant System (AS) algorithm effectively detects all the broken (lost or missing) exact edge in case of the input digital image of peppers of size 128x128. A grayscale visibility value was set to individual pixel of the initial pheromone trail so that the ants can prefer their preliminary direction (path) when the pixels discovered on the true edges with better probability. This helps algorithm taking minimum the time to find an acceptable solution and enhance the result found for a preset number of iterations. The fact is that there only 80 iterations were as much as necessary to find the results presented here. The value of the control parameter α *is* set to 8 and β set to 1 on the trial and error basis. The ants select the strongest edges for a higher value of α/β ratio but being of β control parameter is vital for the inclination of the ant's visiting route headed for the nearby endpoint of the image. If the value β to be 0, then, to find the endpoints each ant require more moves. The practical solution always may not be there, for a rational number of iterations. We set value 12 to the memory length of each ant, i.e. value 12 is the length _of_ the_ tabu_ list. Higher value of the memory length, such value as 20 or 30 or 40 can produce the better quality of the resulting binary image, but this can lengthen the overall computation time. The visited paths with higher grayscale visibility mean stronger image edges as the gray level dissimilarity of their neighboring pixels of the image is higher. Lastly, we retain the entire amount of pixels in the path lesser so as to get the privileged fitness values.
With the proposed method, the outcome of our experiment on the basis on the probabilistic trials and error presented is: clear and continuous edges.

VIII. CONCLUSION

The proposed well improvement in our algorithm with lower functional cost gives us pleasing results.
The proposed technique can be applied on a set of different test noise free digital images and the investigational results established its expected performance to that of the existing edge linking algorithm. It is difficult to find out edges in the noisy image as the amount of noise is greater than data as well as some time the edges detected and linked as faulty when images are blurred.

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