A HYBRID CRITICAL PATH METHODOLOGY – ABCP (AS BUILT CRITICAL PATH); ITS IMPLEMENTATION AND ANALYSIS WITH ACO FOR MEDICAL IMAGE EDGE DETECTION

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ABSTRACT

The edge detection in an image has become an imminent process, with the edge of an image containing the important information related to a particular image such as the pixel intensity value, minimal path deciding factors, etc. This requires a specific methodology to guide in the detection of the edges, assign a Critical Path with a minimal path set and their respective energy partitions. The basis for this approach is the Optimized Ant Colony Algorithm [2], guiding through the various optimized structure in the edge detection of an image. Here we have considered the scenario with respect to a Medical Image, as the information contained in the obtained medical image is of high value and requires a redundant loss in information pertaining to the medical image obtained through various modalities. A proper plan with a minimal set as Critical Path, analysis with respect to the Power partitions or the Energy partitions with the minimal set, computation of the total time taken by the algorithm to detect an edge and retrieve the data with respect to the edge of a medical image, cumulatively considering the cliques, trade-offs in the intensity and the number of iterations required to detect an edge in an image, with or without the presence of suitable noise factors in the image are the necessary aspects being addressed in this paper. This paper includes an efficient hybrid approach to address the edge detection within an image and the consideration of various other factors, including the Shortest path out of the all the paths being produced during the traversing of the ants within a medical image, evaluation of the time duration empirically produced by the ants in traversing the entire image. We also construct a hybrid mechanism called ABCP (As Built Critical Path) factor to show the deviation produced by the algorithm in covering the entire medical image, for the metrics such as the shortest paths, computation time stamps obtained eventually and the planned schedules.

This paper addresses the meta-heuristic process of ant colony optimization which is self-adaptive and adds onto the parallelism with the addressing of the hard problem offering many practical ways of subduing the effect of Critical analysis aspects as such.

KEYWORDS

Critical Path, ABCP (As Built critical Path), Energy and Power Partitions, Edge detection, ACO (Ant Colony Optimization)

1. INTRODUCTION

The various image processing techniques such as Image Segmentation, Image Enhancement and Restoration involves many images as inputs to the algorithmic machine and outputs a processed image or a set of parameters or characteristics pertaining to the image. The information contained within a medical image is of great importance and any compromise in the same is non-tolerant. A very low level processing of an image is the Edge Detection of an image. These Edges contain important information and the data redundancy is expected to be low in this regard. The Edges within an image shows sudden variations and thus are required to be synthesized for the data integrity. The extraction of such information is necessary and a requirement for higher extraction efficiency order is required with higher quality values. Such a varsity of image segmentation is required in Medical Image segmentation and has got great importance value, being a key part in the medical applications and development of clinical medicines. There appears to difficulties in the quantitative analysis, image diagnosis without proper image segmentation or degradation in the edge detection of the medical image, as this requires proper ROI (Region-Of-Interest) highlight and a proper segmentation methodology for the detection of the edge in a medical image. These methodologies wavier as the combinatorial logics with the optimization required at early stages. Such combinatorial logic synthesis requires algorithms that ease the image segmentation reducing the complexities, such as intrinsic noise, lower resolution and contrast.

A well established history of such methodologies that provide a source of potentiality in adhering and resolving the medical image edge detection algorithms have been provided in Ant Colony Optimization (ACO)[3], Modified Ant Colony Algorithm(MACA)[4],etc. An algorithm inspired by the natural behavior of the population- based, with pheromone deposition phenomenon, ants and bees, which deposit pheromone in their path of traversal for their followers to have a favorable path. These algorithms are inspired by the real ant colonies. These natural habitants try to find the shortest path between their source and destinations. These paths are rendered by the pheromone deposition made by the former ants in the path, while the latter choose the shortest path with a strong pheromone concentration.

In this paper, we have used the same methodology followed by the ants in traversing from source to destination, and back to their nests all along, based on the pheromone deposition concentrations, as described in the Ant Colony Optimization algorithm (ACO)[3], with the shortest path criteria as one of the Critical Path Methodologies metric, along with various factors such as, computation time, cliques, Energy Partitions and Power factors in describing our hybrid algorithm. We also have proposed an algorithm that clearly specifies the deviations from the planned schedules with that of the obtained from the previous works. We also propose a pre-defined shortest path, ABCP (As Built Critical Path), obtained from the algorithmic schedules that utilizes the best possible computation time, shortest path/best possible path, better energy definition & partition, evaporation rate of the pheromone deposition and provides with the details of the edge of the medical image.

2. IMAGE EDGE DETECTION

A boundary or a contour at which there is a significant change in the physical factors of a medical image such as normality of the surface, depth of the image, surface color & reflectance, illumination or the visible surface distances. The changes can also be manifested in the metrics such as texture, gradient, color, or the intensity values of all the pixels in an image. During underlying major task of object detection in a medical image, requiring precision segmentation, with respect to various objects being detected in the image is very much essential. Similarly during the application development for the production of a low bit rate image requiring the coding of the edges within an image, with respect to the intensity values in an image, making it a highly intelligible concept for the edge detection. Definition and the identification of the boundaries or the contours in a medical image representing significant image details are required for the edge detection. This substantially defines that the edge of an image is highly constrained with the application requiring the task of edge detection. These edges were earlier termed as edgels, the short linear edge segments, which are collectively called as the edges, with the detection of the same. One such factor for the image edge is the image gradient, with the derivative having a maximum magnitude, or the 2^{nd} order derivative bearing the value zero, The image gradient is monitored by the equation;

$$\nabla f = [\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}]$$

The rapid change in the intensity factor points out to the gradient points, with the direction of the gradient given by;

$$\theta = \tan^{-1}(\frac{\frac{\partial f}{\partial y}}{\frac{\partial f}{\partial x}})$$

The shapes of the objects convey high amount of semantic information about the image. The gradient variation as given and monitored by the above equations is one of the methods of image edge detection, where in the image considered is represented with an analog factor *f(x)*, representing a typical 1-dimensional edge within an image. The methodology follows an episodic procedure in the detection of such edges where there happens to be a zero-crossing in the image considered. The variation in the intensity of the pixels contained within an image is considered as an essential factor in one of the methods for the detection of the edges in an image, known as the Laplacian method. Here the general 2-dimensional localization factor *f(x,y)* with the intensity variation is considered suitably for the image edge detection. The formula for the Laplacian of a function *f(x,y)* is given by;

$$\nabla^2 f = {\partial^2 f}/{\partial x^2} + {\partial^2 f}/{\partial y^2}$$

The main focus shift with the image edge detection is to convert a 2-dimensional image into a set of curves, with the extraction of the salient features associated with the scene, proving more efficient and compact than the pixels.

3. RELATED WORK

The process of processing an image pixel by pixel and the application of these modifications in the pixel neighbourhood, with the noise removal, enhancing the image contours and the edges, using a MATLAB interactive, high level graphical user interface eliminating the high level language for coding defining an architecture of filtering images for edge detection with the help of Video and Image Processing block-set was defined by Amandeep Kamboj et al.(2012). Edge Detection in a Medical Image remains to be a key in the medical image research and other diagnosis applications. The contours in these medical images are obtained through the work established using the standard GVF Snake model, for the image segmentation. Convergence speed to an optimized solution, processing the concavity, and the precision with which the segmentation of the image is being done are some of the metrics that needs to be taken care of with the adopted GVF Snake algorithm as it deviates from these local optimization factors. With the crowded degree function adherent to the Ant Colony algorithm was developed by Xiangpu Gong et al. (2008), which enhanced the overall traversability and the capacity to converge at an optimal solution. The natural behaviour of the ant species that deposit the pheromone in the path traversed by thou for foraging with the representation of the pheromone matrix with respect to each pixel position of the image under consideration, based upon the finite amount of ants allowed to traverse on an image, whose movements are defined by the variations in the intensity values of the presenting pixels of the image were provided by Shengli Xie et al.(2008) to demonstrate the superior behaviour of the proposed algorithm. Alberto Coloroni et al. (2008) were the first to come up with the algorithm based on the behaviour of the ants and their simulation known as the Ant Colony System (ACS)[5], for the well-known Travelling Salesperson Problem (TSP), a combinatorial optimization problem.

In this paper we discuss the methodology revolving around the actual proposed work, wherein a medical image is subjected to noise removal with the application of various filters, and approximate it to a set of continuous functions from which the image samples were taken, allowing for the computation of the edge to a sub-pixel precision. Then we apply the Optimized Ant Colony algorithm to model the image neighbourhood as a bi-cubic polynomial followed by equation:

$$f(x,y) = k_1 + k_2x + k_3y + k_4x^2 + k_5xy + k_6y^2 + k_7x^3 + k_8x^2y + k_9xy^2 + k_{10}y^3$$

The image thus obtained is subject to Critical Path operators for the computation of shortest path for within the images obtained from the ACO algorithm vector machine, along with the deviations pertaining to the computation time for the detection of the edge within the image. Our hybrid algorithm computes the shortest path with the application of the approximation vectors, at suitable time intervals with the polynomials and suitably enhances the computation time in detecting the edge of the image.

4. PROPOSED METHODOLOGY

In this paper we have proposed an efficient approach for the detection of the edge in a medical image. The medical image considered in our scenario is necessary to be a square image with a resolution factor of either 128X128, or 256X256, or 512X512. The medical image considered is normalized and the noise is filtered using a suitable filter such as Gaussian, Laplacian, Fourier or Sine filters as given by the equations in the ACO algorithm as:

$$f(x) = \lambda x$$
$$f(x) = \lambda x^2$$
$$f(x) = \sin(\pi x/2\lambda)$$
$$f(x) = (\pi x \sin(\pi x/\lambda))/\lambda$$

Where λ in the above equation adjusts the clique shape function in the above equations. The above equations mentioned determines the function that monitors the pixel of clique's *c* given by the equation;

$$V_c(I_{i,j}) = f(neighbourhood\ pixel\ values\ within\ an\ image)$$

These equations are proportionally guided in the ACO algorithm which considers the meta-heuristic features of the foraging behaviour of the ants. The same has been modified with the application of the structured format of initiating the Asynchronous movement of Real Ants and the synchronous movement of the Virtual Ants in providing some sort of implicit solutions in finding the edge of an image. The below given flow depicts the actual process flow involved in the proposed methodology which is the basis for our work:

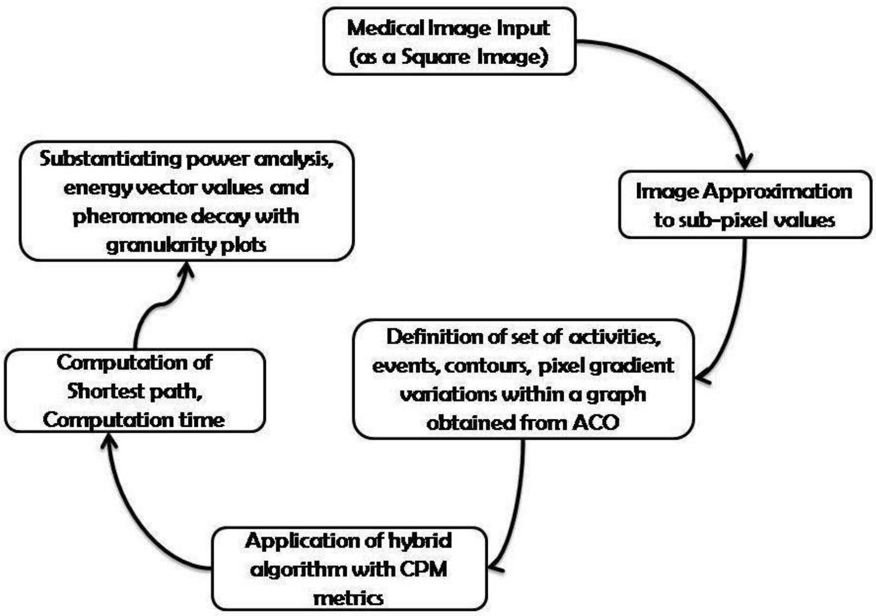


Figure 1. Proposed Methodology Workflow

The proposed algorithm takes the input in the form of a .bmp (Bitmap Image format), grayscale image, into the vector machine. Later the image is approximated to the sub-pixel values using the image approximation methodology. Thus approximated image is defined and synthesized by the algorithmic vector machine into an acyclic graph, represented with series of arcs(activities) defined by the movement of the ants and the events during the pheromone deposition, definition of the contours and the gradient or the intensity variations obtained from approximating the image with the application of the Hybrid ACO algorithm, which considers a probability to define the correct(shortest) path and the elimination of the spurious edge detection within a medical image. The algorithm also takes into consideration the Daemonic Actions for the foraging behaviour of the ants and their traversal in an image. Then the structure of the Critical Path is applied to find the shortest path between the source and destination as specified by the algorithm. We also calculate the computation time and verify the deviation magnitude with the manually calculated values. This forms the basis for the proposal of the ABCP (As Built critical Path) and an active involvement of the active metrics in the calculation the deviation produced in the real terms, as metrics.

5. IMAGE APPROXIMATION

The image approximation procedure with reference to the scenario presented in our proposed work accepts the input as an array of sample functions in the form of an image. This is helpful in the estimation of the continuous functions which represent the image properties, to sub-pixel precisions followed by the equation considered as;

$$z = f(x,y)$$

This function z, is considered to be a continuous image intensity function. During the reconstruction of the image from all these sub-pixel values, we consider the piecewise analytical functions, similar to facets. Here we try finding the intensity values of each pixel from the local neighbourhood pixels. This continuous function is approximated locally at every pixel in the image.

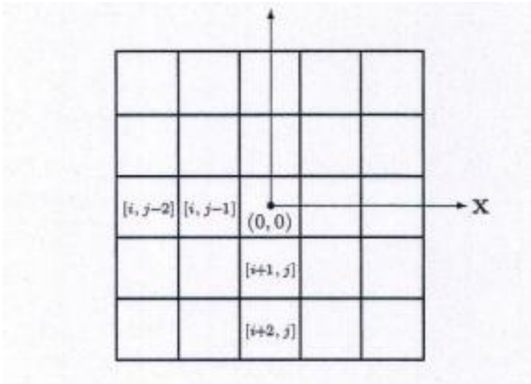


Figure 2. Co-ordinate System for the approximation of the facet value in the neighbourhood

The edge points that occur at a relative maximum point from the pixel of consideration, in the first directional derivative of the continuous function are approximated with the image intensity in the neighbourhood of a pixel. These first order derivative results in the zero crossing for the second order derivative whose equations are given as:

$$f'_\theta(x,y) = \frac{\partial f}{\partial x} \cos\theta + \frac{\partial f}{\partial y} \sin\theta$$

And the second order derivative in the direction θ given by,

$$f''_\theta(x,y) = \frac{\partial^2 f}{\partial x^2} \cos^2\theta + 2\frac{\partial^2 f}{\partial x \partial y} \cos\theta \sin\theta + \frac{\partial^2 f}{\partial y^2} \sin^2\theta$$

Where the intensity of the local image was approximated with by the cubic polynomial,

$$f(x,y) = k_1 + k_2 x + k_3 y + k_4 x^2 + k_5 xy + k_6 y^2 + k_7 x^3 + k_8 x^2 y + k_9 xy^2 + k_{10} y^3$$

With the angle θ, the angle of the approximation plane resulting in ,

$$\sin\theta = \frac{k_3}{\sqrt{k_2^2 + k_3^2}}$$

$$\cos\theta = \frac{k_2}{\sqrt{k_2^2 + k_3^2}}$$

At some point considering the direction θ and the line of its intersection being made in the same direction, $x_0 = \rho\cos\theta$ and $y_0 = \rho\sin\theta$, the continuous function follows the equation,

$$f_\theta''(x_0, y_0) = A\rho + B$$

There exists an edge at the point (x_0, y_0), in the image for some ρ, where ρ_0 is the length of the side of a pixel. For our case study we have considered a medical image as given in Figure 3, which is an X-ray of human indicating the fracture. The original considered for this scenario is of the resolution 128X128, and is grayscale, bitmap image file.

Figure 3. Original Medical Image; X-ray image of the Nose Fracture

The original image is then subjected to the approximation and the approximated values are plotted on a graph for the analysis. The Figure 4 depicts the plot for the sum of pixel values with respect to the radius of the curve in the considered image.

For the image considered in the above scenario, the bi-cubic polynomial varies in accordance with the specific values of the constants as follows:

$$k_1 = \frac{1}{175} \qquad k_8 = k_9 = \frac{1}{140} \qquad k_4 = \frac{1}{70}$$

$$k_2 = k_3 = k_6 = \frac{1}{420} \qquad k_7 = k_{10} = \frac{1}{60}$$

These constants occur from the pixel values with the neighbourhood pixels, with pixel selection can be made either in the 8 bit clique mode or the 4 bit clique mode, from which these constant matrices are constructed.

We can also observe from the below plots that the maximum value of the pixel value is achieved for a sum of the pixel value of 0.8 in Figure 4 while that in Figure 5 it is 0.4. The approximated value is inversely proportional to the pixel value, varying with the radius of the image, in terms of pixels.

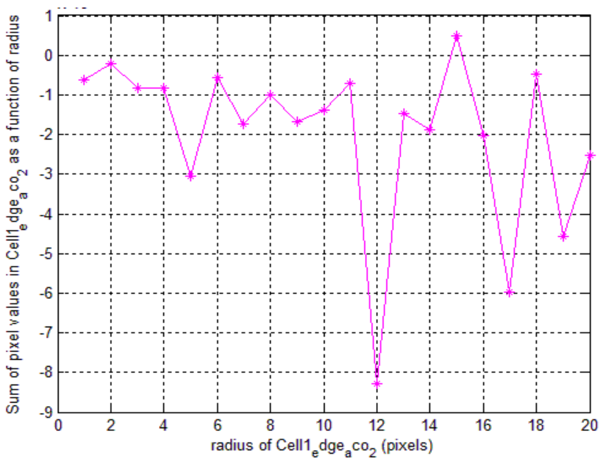


Figure 4. Image Approximation Plot with $\rho_0 = 0.8$

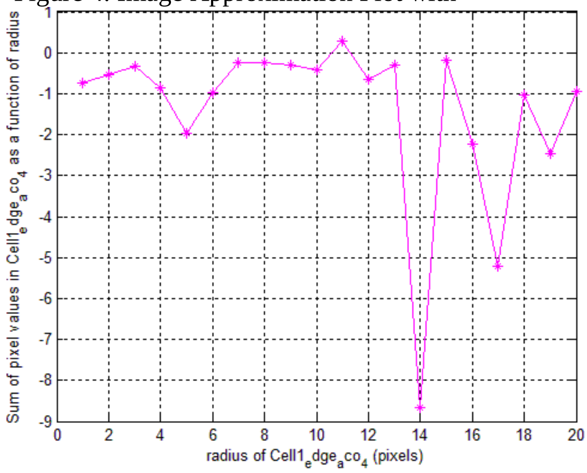


Figure 5. Image Approximation Plot with $\rho_0 = 0.4$

6. ALGORITHM

The hybrid ACO algorithm proposed in this paper depends on the basic structure defined in the ACO meta-heuristic procedure, which includes the major 3 steps as a part of their schedule activities:

i. Construction of ant solution
ii. Updating of the pheromone depositions in the form of a matrix
iii. Daemonic Actions/activities

The algorithmic flow clearly specifies the categories and the steps involved in the execution procedure of the algorithm vector machine, which output specific data values at proper intervals of time, substantiating the proof for the algorithm implementation,

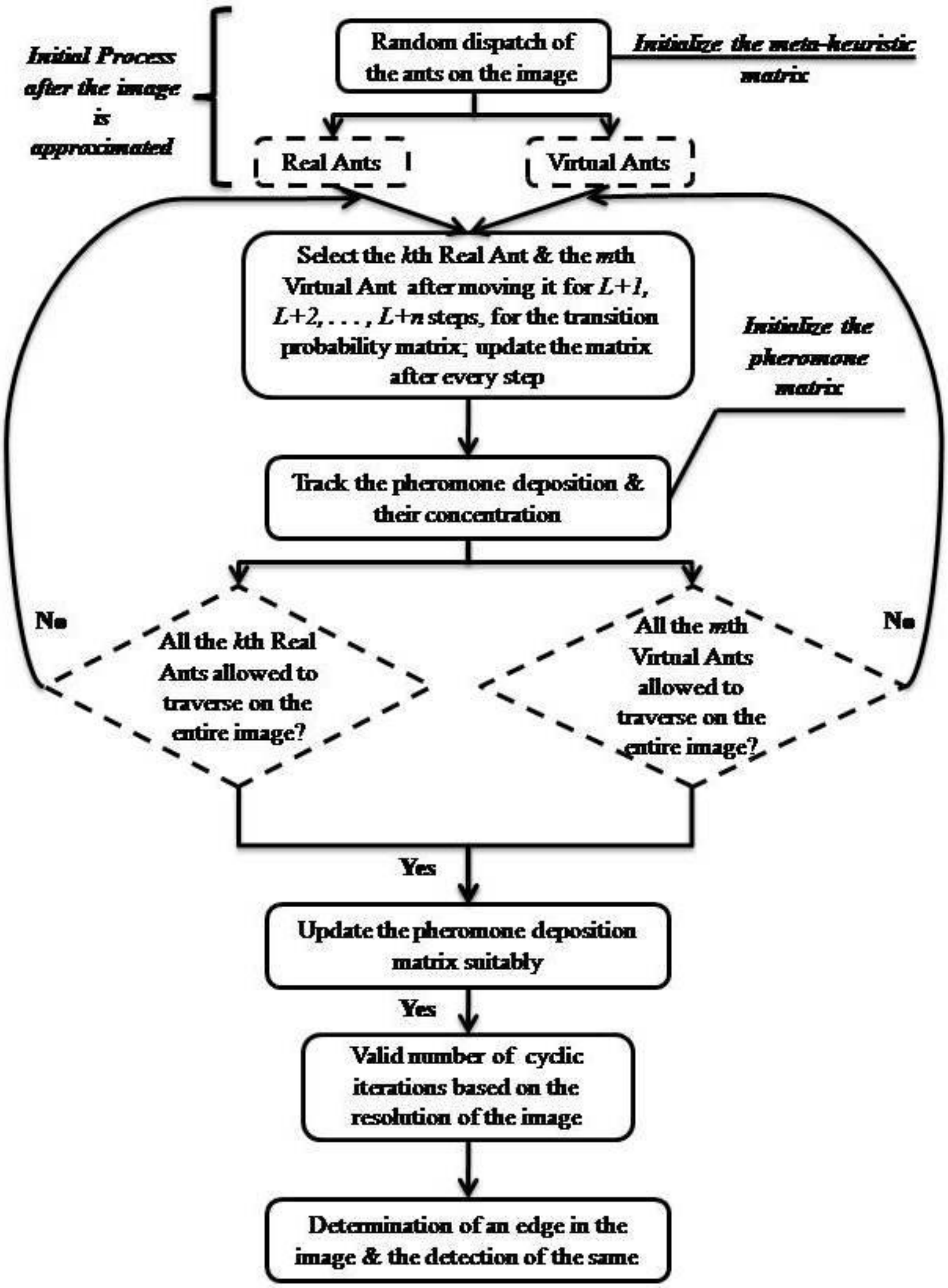


Figure 6. Algorithmic Flow for the modified ACO Approach

The same is referred in our algorithm vector machine with an addition done in the inclusion of the Virtual ant concept which works around with the pre-defined set of Critical Path parameters defined in the algorithm. The major deviations, which occur in the exclusive ACO algorithm that lead to the definition of the hybrid algorithm, are:

i. Detection of erroneous edges within an image
ii. Delay in the execution and the detection of the edges
iii. Complex path traversal by the ant initialized to traverse within an image.
iv. Proper clique/curve definition
v.

The general steps in this process can be summarized as follows:

i. Parameter setting and its initialization wit reference to both the Real Ant and the Virtual Ant quality
ii. The initialized metrics are to be stepped over for a cycle of *L*+*n* steps, with an incremental process along with their value updation provided in the form of a matrix
iii. All the Real and the Virtual Ants are allowed to traverse on the considered medical image, with a suitable concentration of pheromone deposition being done in the process, to highlight the path from the initialized vector point to the destined point.
iv. Update the pheromone matrix so obtained with the localization machine detecting the edge in the image.

The ant traversed images after the algorithmic vector machine runs for the required number of iterations, and a specific approximation values, is as shown in the Figure 7 and Figure 8.

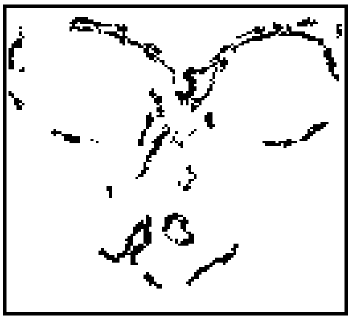
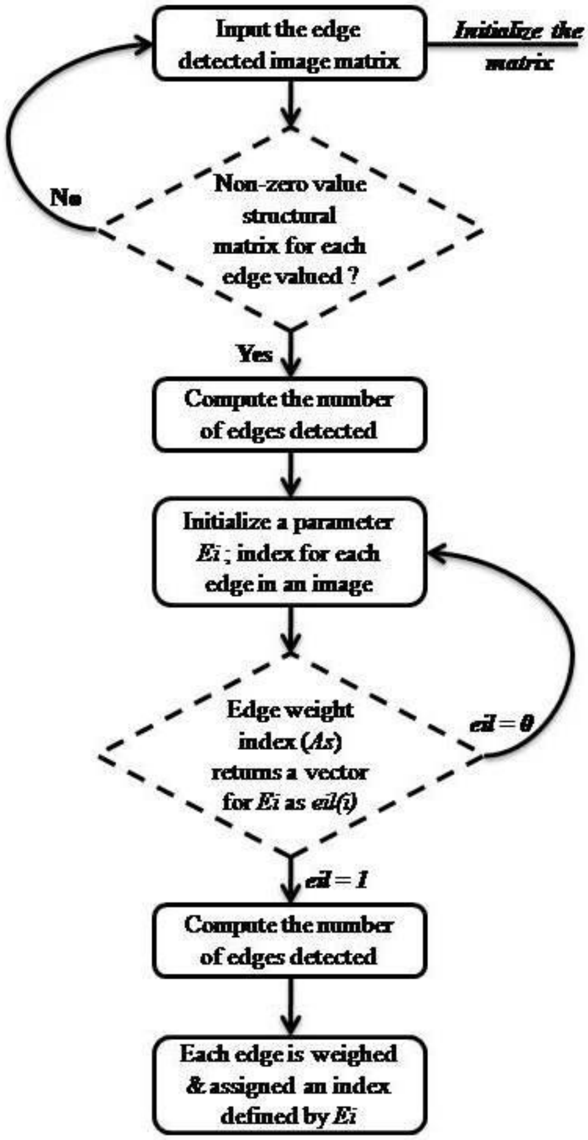


Figure 7 Real and Virtual Ants Traversed Image **with** $\rho_0 = 0.8$

Figure 8 Real and Virtual Ants Traversed Image **with** $\rho_0 = 0.4$

The edge detected image is then converted to a matrix format containing the information about the edges detected by the hybrid algorithm. Here we have considered the fact that, the image be in a compact connected domain in the plane and $x,y \in \Omega$, with a path from *x* to *y* designated as an injective function;

$$\gamma : [0, L] \rightarrow \Omega \text{, such that}$$
$$\gamma(0) = x \text{ and } \gamma(L) = y$$


Input the edge detected image matrix
Initialize the matrix
No
Non-zero value structural matrix for each edge valued ?
Yes
Compute the number of edges detected
Initialize a parameter Ei ; index for each edge in an image
Edge weight index (As) returns a vector for Ei as eil(i)
eil = 0
eil = 1
Compute the number of edges detected
Each edge is weighed & assigned an index defined by Ei

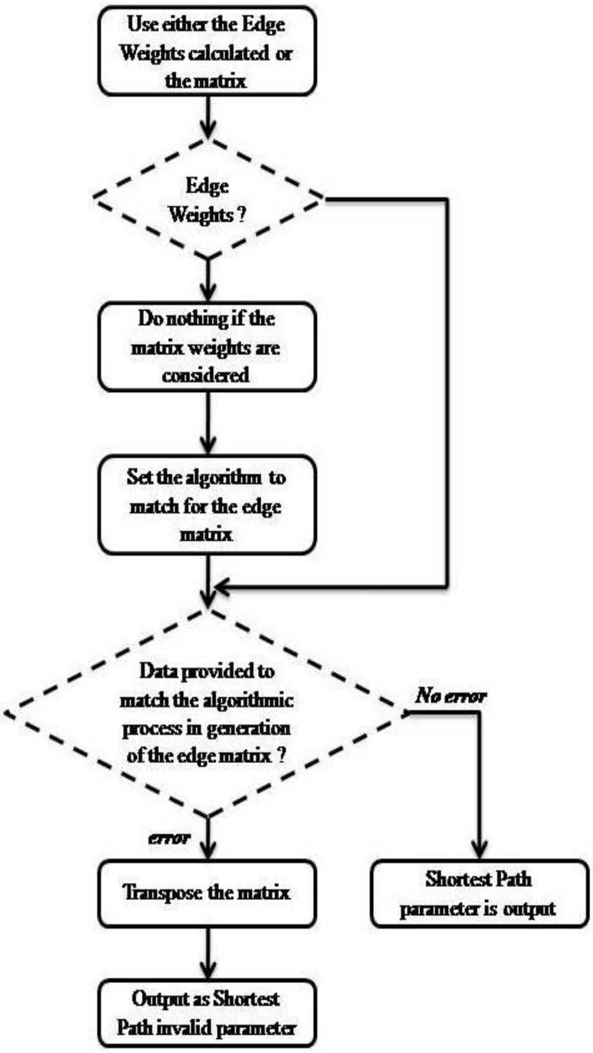


Figure 8. Flow representing the detection of Edge Weight index used in the determination of the shortest path parameter for Critical Path

With this concept of the relational minimal path and the surface of action or the energy, of a potential function given by,

$$P : \Omega\, X\, S^1 \rightarrow \mathbb{R}^+$$

This potential function defined with respect to a source point $x_0 \in \Omega$, evaluated at the source point *x* as defined in,

$$E_0(x) = inf_{\gamma \epsilon \Gamma_x} \int_0^L P\,(\gamma(s))\,ds$$

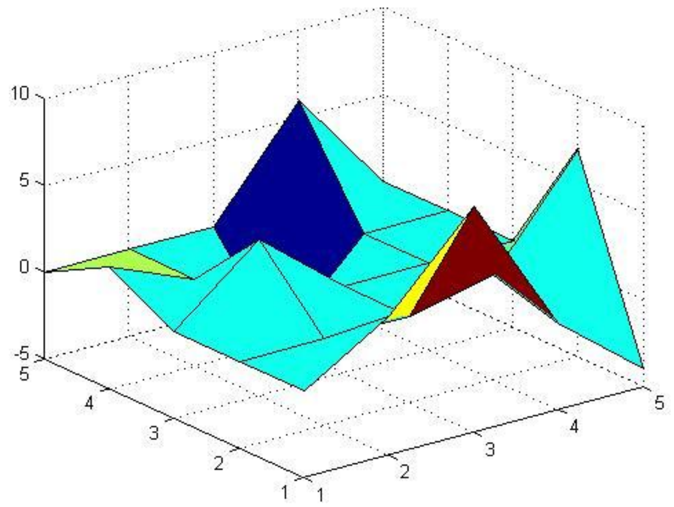


Figure 9. Shortest Path plot by the algorithm

Table 1. Shortest Path as a Critical Path metric in ABCP and their deviation

ρ_0	**Expected Value for the Shortest Path**	**Obtained Result**	**Deviation (%)**
0.4	6.1	6.3	20
0.8	7.4	6.9	50

In the above equation *P* depends on the position of $\gamma(s)$ and this value will be strictly positive. The energy partition is done with respect to the a set of sources $S = \{x_i\}_{i \epsilon j}$ defined by the function as the minimal individual energy, given as,

$$E_s(x) = inf_{i\epsilon j}\, E_i(x)$$

The source is a medical image; while the partition within this image is done based on the neighbourhood image pixel values based on their intensity values. The power factor analysis provides us with the magnitude of the intensity value with respect to the neighbourhood pixels in the image. As we can in Figure 7 & 8 that the concentration of the pheromone deposition is more at certain regions, leading to the segregation of large group of ants around that region, resembling the sharp change in the intensity providing an edge at that particular point. The intensity variations are provided in the energy partitions with their magnitudes in terms of the pheromone deposition around the edge in the image.

Table 2 Power Factor Analysis as a Critical Path metric in ABCP and their deviation

ρ_0	**Expected Energy Value**	**Obtained Result**	**Deviation (%)**
0.4	81	93	12
0.8	77	85	8

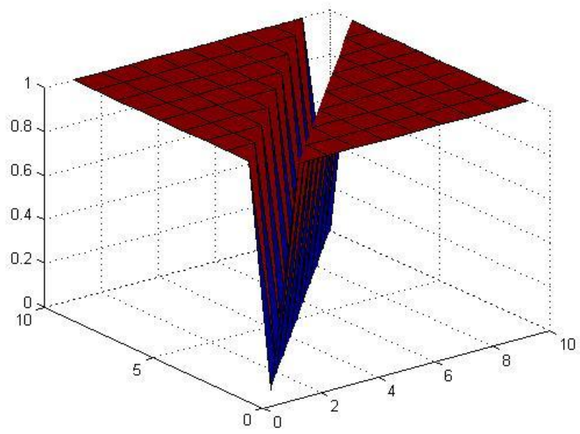


Figure 10. Power Factor Analysis

7. CONCLUSIONS

The information contained in the edges in an image and detection of these edges are highly required for various image processing, also in various critical applications such as medical diagnosis and clinical research. With this importance value, substantial algorithms, structured operators, etc. have been developed and a lot of research is being done for decades. The algorithm developed in this work is also a meta-heuristic methodology which addresses the critical metrics and provides a description and describes their deviation from the pre-defined As Built Critical Path metrics. This also addresses the most in-evitable NP Hard problems. This paper proposes usage of traditional Ant Colony Optimized edge detectors with Daemonic actions including both the Real as well as Virtual Ants, pheromone depositions and distribution matrixes that validates the shortest path, edge weights, edge weight indices, energy partitions, and power analysis. The adaptivity provided by this algorithm is that it is trained to accept a variety of inputs dependant on application. Image size constraint and the grayscale factors along with the reduction is introduced as a really effective method to noise reduction compared to previous method of image smoothness. Death escape opportunity is provided randomly for some ants to increase the edge length. In pheromone update process, a few parameters such as diameter and area of travelled path are converted into rules and rules are normalized to compute the final update value through averaging. Results are obtained by modifying certain aspects related with the normalized ACO algorithm and the Critical Path metrics on the same image and also they are more reliable.

ACKNOWLEDGEMENTS

The authors would like to thank the Management, Panchajanya Vidya Peetha Welfare Trust (Regd), Dr. C. Nanjundaswamy our beloved Principal, Dr. G V Jayaramaiah our beloved HOD, Dr. R.Murali, Dr M V Mandi and Dr S Ramesh of Dr. Ambedkar Institute of Technology, Bengaluru for their assistance, suggestions, insight and valuable discussion over the course of this research work. The authors also thankful to the Jain University, Bengaluru for providing an opportunity to pursue this research work.

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