

“A STUDY THE EDGE DETECTION USING ACO AND HYBRID IMPLEMENTATIONS OF SOBEL AND CANNY”

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ABSTRACT: *The process of detecting edges in an image is essential to many areas of computer vision & image processing, such as object recognition and scene analysis. This research proposes a new method for detecting edges by utilizing a hybrid version of the Sobel & Canny algorithms with Ant Colony Optimization (ACO). In order to calculate gradient information, the suggested technique first preprocesses the input image by converting it to grayscale and applying the Sobel operator. By viewing edge selection as a combinatorial optimization problem, ACO is used to achieve optimal results. Taking into account both edge strength as measured by the Sobel operator and pheromone levels on the edge map, an objective function is created to evaluate edge relevance. Iteratively moving based on pheromone concentration and edge strength, ant agents are initially placed at random locations on the edge map. The pheromone concentrations are adjusted accordingly. There will be an infinite number of iterations until convergence is reached. The results prove that a combination of ACO and Sobel-Canny edge detection efficiently pinpoints important boundaries within images. The use of ACO enables adaptive edge selection, which has the potential to increase the precision & durability of edge detection over standard approaches.*

Index Terms: ACO, Sobel, Canny, Edge Detection, MSE, PSNR

I. INTRODUCTION

Edge detection in images is the process of identifying and removing unwanted parts of a picture [1]. The purpose of this procedure is to locate areas in an image where there are abrupt changes in brightness or color. This technique is used in image analysis & machine vision, both of which rely on it to decipher a picture's meaning. It is commonly used in the introductory phases of computer-vision projects. Many image analysis & machine vision applications rely on edge detection's ability to pinpoint the borders of objects in an image. Because each pixel has its own unique set of computations, traditional methods of edge detection are computationally intensive. The computation time in traditional methods grows exponentially with the image size. Traditional methods may be improved upon by adopting an ACO-based strategy. In addition, the approach may be easily parallelized, making it a good fit for distributed computing environments.

ACO is inspired by ant species' natural foraging behavior [P. Xiao, J. Li et al. 2010]. Ants use pheromone trails to communicate to other ants which routes to take when returning to the colony from foraging. Pheromones lose their effectiveness after a while. Pheromones are less effective because of the time it takes for an ant to go down the trail & back again. Shorter, more advantageous routes are trampled more quickly & compensated for pheromone loss more generously. Shorter routes maintain higher pheromone densities because more pheromone may be laid down in a shorter amount of time. The ants' decision to take the shorter routes is reinforced by a positive feedback loop. The ACO metaheuristic was motivated by this observed phenomenon in nature. The first ACO algorithm, ant system (AS), was proposed by Dorigo et al. [2004] [Jing Tian, et al. 2008]. There have been enhancements to AS since then. Numerous optimization issues have been addressed by employing ACO. This research presents an ACO-based approach to detecting edges in images [2].

FUNDAMENTALS OF EDGE DETECTION

The term "edge detection" describes the method used to locate & identify distinct image boundaries [3]. Discontinuities are the sharp transitions in brightness between neighboring pixels that define the edges of objects in a scene. The phrase "edge detection" describes a class of image processing methods designed to locate and analyze visual boundaries. It appears in Computer Vision when dealing with feature selection & feature extraction [4]. To create an edge map, a digital image is fed into an edge detector. Some detectors' edge maps specifically detail edge location, edge strength, and edge orientation. Traditional edge detection techniques (Wen and Zhong, 2008) often include convolving the image with an operator (2-D filter) designed to be sensitive to big gradients while returning zero in uniform regions. There is a plethora of edge detection operators [5], each optimized to identify a particular class of edge. Some of the factors to consider while deciding on an edge detection operator are:

- **Edge orientation:** A direction in which the operator is especially sensitive to edges is determined by its geometry. Edges can be searched for in a variety of directions, including horizontally, vertically, and diagonally.
- **Noisy environment:** It's challenging to detect edges [6] in noisy photos because both the noise and the edges have high-frequency information. When noise is

reduced, sharp edges fade and become deformed. Noise reduction in photos often requires more comprehensive operators that can average enough data to ignore individual noisy pixels. This causes the detected edges to be less precisely localized.

- **Edge structure:** An abrupt shift in strength is not a feature of all edges. Objects with edges defined by a gradual change in intensity may be the consequence of refraction or blurred focus. In such situations, picking an operator who can adapt to subtle shifts is essential. In order to differentiate, say, hair edges from face edges, modern wavelet-based algorithms actually characterize the nature of the transition for each edge.

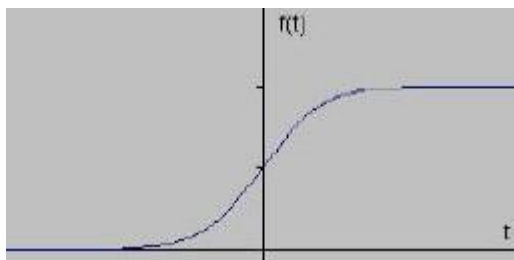


Figure 1. Increased intensity shows edge

In one dimension, the gradient of this signal is the first derivative with respect to t , as illustrated in figure2.

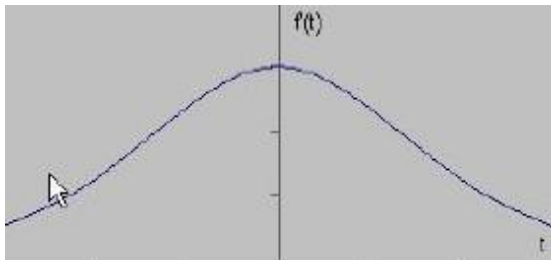


Figure 2. First derivatives with respect to t

The derivative clearly reveals a maximum in the exact middle of the edge in the original signal. The Sobel method is one of a larger family of edge detection filters known as "gradient filters" that use this technique. If the gradient value for a given pixel exceeds a predetermined threshold, the pixel is labeled as an edge. As was previously said, edges will have more intense colors than their surroundings. Once a threshold is established, the gradient value can be compared to it to identify edges whenever they are larger. As an added bonus, the second derivative is always zero when the first derivative is maximal. Therefore, determining the zeros of the second derivative provides an alternative method to pinpointing the position of an edge. The second derivative of the signal, calculated using the Laplacian approach, is depicted in Figure 3 below.

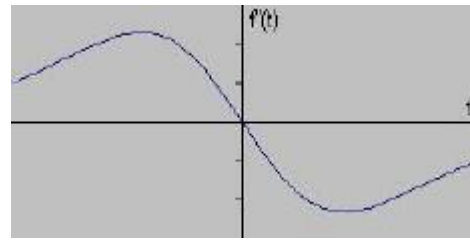


Figure 3: image Second derivative

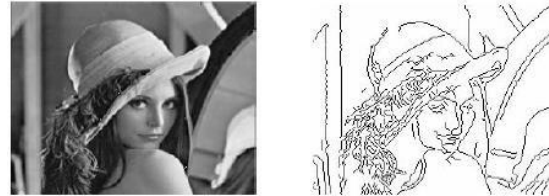
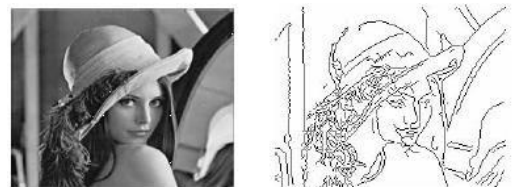


Figure 4: Displays Lena Image edge detection

DIFFICULTIES IN EDGE DETECTION

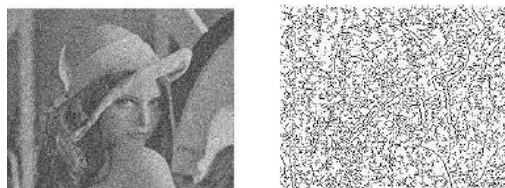
Image edge detection [7] locates sharp discontinuities. The scene's object borders are defined by abrupt pixel intensity changes. Traditional edge detection algorithms convolve the image using a 2-D filter that is sensitive to big gradients and zero in uniform regions. The number of edge detection operators responsive to specific edges is huge. Edge orientation, noise environment, and structure affect edge detection operator selection. The operator's geometry defines its edge-sensitive direction. Optimize operators to find horizontal, vertical, or diagonal edges. Since noise & edges include high-frequency content, edge recognition in noisy images is difficult (Li et al., 2007). Trying to decrease noise blurs edges. Operators on noisy images are usually larger to average enough data to discount localized noisy pixels. This reduces edge localization accuracy.

Edges don't always vary intensity. Refraction or inadequate focus can cause objects with progressive intensity boundaries. In certain instances, the operator must be attentive to progressive change. These include erroneous edge detection, missing true edges, edge localization, excessive computational time, and noise issues.



(a) Lena image

(b) Edges using Canny detector



(c) Lena image with noise

(d) Edges from the image with noise

Figure 5: Comparison of edge detection results from two identical photos, with white noise in the latter.

EDGE DETECTORS APPLICATION

Although edge detectors [8] have a wide variety of uses, recent years have seen the adoption of GUI-based implementations of some real-time applications that make use of many edge detector operators.

(A) Finger Print: One of the most ubiquitous applications, fingerprint recognition is used to lock mobile phones—and since everyone uses their fingerprints to do so, we've used a variety of edge detectors and a graphical user interface to get a reliable reading of fingerprints. The accuracy of the Edge Detection approach has been demonstrated in both picture enhancement and recognition tasks.

(B) Medical Image Diagnosis: Here edge detector is helpful in identifying different organs & important in 3D reconstruction of pre-processing section, not only it can detect all types of scans by using different edge detectors, but it is also very much important in 3D reconstruction of pre-processing section.

(C) Satellite Image: Here, photos captured by satellites in space will be used to locate edges in images of the Earth's surface and other objects via remote sensing. This approach of edge identification is crucial in image analysis and the subsequent boundary extraction of objects inside an image

II. RELATED WORK

Sahil Raheja et al. (2020) [9] When it comes to segmenting images, edge detection is essential. The first and second derivatives of the intensity of the pixels are typically utilized in kernel-based algorithms such as Sobel, Canny, Roberts, etc. The problem is that they don't always find the real edges. In addition, there are many more erroneously identified edges than genuine ones. Because these techniques use a predetermined threshold, this effect occurs. An approach that can dynamically alter its threshold to eliminate mistakenly identified edges is preferred. Methods based on artificial and swarm intelligence can deal with the smallest of nuances. In this study, we provide an edge detection method based on ACO. In this technique, we employ a unique function to capture intensity fluctuation in an image. The threshold must be tweaked for the learning-based approach to work properly. In contrast to the traditional method, which merely takes an average, we have considered a weighted average for the threshold update in our study. Finally, the suggested method's efficacy is demonstrated through an analysis of its performance in terms of PSNR, accuracy, & F-Score.

Z. Dorrani et al. (2020) [10] Collective intelligence search and optimization are well-known as effective approaches to difficult engineering challenges.

Collective intelligence like that displayed by ants as they forage for food is the basis of the ACO. In this work, the ACO algorithm is implemented to detect edges in images. To make the proposed method more dynamic & quick, a fuzzy-based system is suggested. The system regulates both the distance and concentration of the pheromone. As a result, the search space is made more precise and logical by using variable values rather than constant values for the algorithm's parameters. To demonstrate the efficacy of the suggested approach, the fuzzy ant colony optimization technique is used on a number of examples. The collected findings demonstrate that the proposed method is superior to numerous other image edge detection methods in terms of the quality of the extracted edge pixels. Quantitative analysis of the time and entropy of traditional methods and prior works demonstrates the superiority of the suggested method. Additionally, the proposed method's resilience against additive noise is proved.

Cristian A. Martínez et al. (2019) [11] In the metaheuristic known as ACO, a swarm of synthetic ants works together to solve optimization problems. In the realm of image processing, edge detection is crucial. The process involves looking for lines or boundaries in photographs so that information can be gleaned from them. We propose an ACO-based approach for edge identification. A binary image with recognized edges is obtained by the application of heuristic & knowledge information during the building phase, and a repair operator during the enhancement phase. We used both noisy and noise-free photos to evaluate our method. The resulting photos, efficiency, and CPU time are all on par with competing methods.

Gautam Pragya et al. (2018). In [12] The method of identifying an image's true edges is known as picture edge detection. Gradient-based techniques were previously employed to identify discontinuities. First- or second-order pixel differences were used, and if the magnitude value of the gradient exceeded a predetermined threshold, the pixel under observation was classified as an edge pixel. These techniques are rife with mistakes because, in addition to identifying real edges, they also identify fake edges, and false edges are more common than true edges. An edge detection strategy based on ACO and swarm intelligence is described in detail to address this issue, with very few edges being incorrectly detected. ACO performance is measured in terms of efficiency, performance ratio, & peak signal to noise ratio.

Saba. Kheirinejad et al. (2018) [13] A significant task in image processing and machine vision is edge detection. ACO techniques have been widely used recently to solve a variety of optimization problems, including edge detection. In this work, we detect the picture edges using the max-min ant colony optimization (MMACO) approach. Furthermore, in order to identify the nodes that ants visit nearby, we suggest a brand-new heuristic information function (HIF) called the group based heuristic information function (GBHIF). Instead of using two nodes at a time, our suggested HIF takes

advantage of the variation in intensity between two sets of nodes. We demonstrate that the suggested edge detection approach is more robust than the prior algorithms in the section on simulation results.

Jie Jiang et al. (2018) [14] High accuracy and versatility are two benefits of Dr. Carsten Steger's Hessian matrix-based edge detection technique. However, the computation method for this approach is intricate and time-consuming. Applying large-scale Gaussian convolution on a field programmable gate array (FPGA) also requires a huge number of multipliers. An FPGA version of Steger's edge detection technique is suggested as a solution to these issues. For data stream processing, this approach uses parallel and pipeline designs at the task and data levels. In order to minimize the multiplier resources, the original Gaussian convolution kernels are simplified using box-filter, which changes the convolution's multiplication operation into addition, subtraction, or shift operations using the idea of an integral picture. When handling various levels of blur and noise in an image, the suggested FPGA implementation shows good accuracy & anti-noise capabilities. Thus, real-time edge detection needs can be met by the FPGA implementation.

Dr. Ruksar Fatima et al. (2015) [15] Boundaries are characterized by edges, which pose a basic challenge in image processing. By reducing the amount of data & filtering out extraneous information, edge detection of photos maintains crucial structural aspects of the image. Finding an image's object or texture borders is known as edge detection. Because edge detection data is so vast, processing images quickly is a highly challenging task. Depending on the needs of different applications, a variety of techniques are employed for edge detection. An detailed review of numerous studies and approaches used in the subject of edge detection is given in this publication.

Neha Jain et al. (2016) [16] Numerous fields, including computer vision, pattern recognition, & image analysis, have made use of edge detection. Several edge detection methods are applied to images in order to remove irrelevant information while maintaining the fundamental structural characteristics in various areas. This paper looks at several edge detection methods using soft computing techniques and provides a critical evaluation of them.

Yusuf Perwej (2015) [17] One of the most basic tasks in computer vision & image processing is edge detection. Its definition is the technique of identifying the edges of textures or objects that are delineated in a picture. This is due to the fact that edge detection makes image analysis easier by significantly lowering the volume of data that needs to be processed through the removal of unwanted information while maintaining the essential structural details of an image. One popular method for edge detection is Sobel Edge Detection. The Sobel approach finds edges in the edge function by approximating the derivative. However, when there are a lot of white Gaussian disturbances in the

image, it becomes exceedingly difficult to determine the first derivative's peak value since the relevant signals and the noise points are mixed up. Although the Sobel operator is straightforward, noisy environments impair its accuracy. This study presents the Sobel Edge Detection method based on fuzzy filters. In order to improve the membership value of the image in the three fuzzy sets—black, white, and edge—this technique relies on a fuzzy rule-based system that uses a 2X 2 window mask. The filtered image is then sent as input to the Sobel Edge Detection technique. Compared to the conventional Sobel Edge Detection method, which relies on the noise-smoothing impact of unsystematic images, this viewpoint produces better results. To aid in the identification of the legitimate image contents generated by noise, an ideal edge-detection algorithm is required to offer an errorless solution that is adjustable to the various noise levels of these images.

Veerpal kaur Sandhu et al. (2014) [18] One of the core problems of digital images is MRI image segmentation. In this study, we will address, elaborate on, and compare several methods for brain tumor identification. Some mathematical morphological methods will be discussed, and a number of traditional edge detection operators are evaluated. This work offers techniques like mathematical morphology & clever operator, which summarizes quite excellent picture edge detection techniques and serves as a reference for certain detection scenarios where a reduced edge width is needed in a real-world application.

Manisha Kaushal et al. (2013) [19] A variety of techniques, including fuzzy logic, neural networks, genetic algorithms, and other evolutionary computations, are used in soft computing. The discipline of image processing has seen a wide range of applications for these paradigms. One of the most important uses of image segmentation is edge detection, which is the process of identifying and locating abrupt discontinuities in an image. An edge is defined as the boundary between two consistent regions. The hybrid and non-hybrid methods for edge detection are compiled in this work. This work aims to explore the fundamental problems for edge detection methods based on soft computing.

Rebika Rai et al. (2013) [20] In recent years, the social insect metaphor for resolving many issues has gained attention, with a focus on the stochastic construction process that builds the solution probabilistically. ACO is an algorithm that draws inspiration from the way ants forage. Specifically, ants use a volatile chemical called pheromone that they release on the ground to facilitate indirect communication amongst themselves & foraging as a group. The primary objective of edge detection is to find locations in an image where there is a sharp shift in brightness or formal generation of discontinuities using a mathematical set of algorithms. This work investigates the use of ACO, a swarm computing approach, for edge detection in photography.

Om Prakash Verma et al. (2011) [21] In this research, we introduce a method for detecting edges in images by combining the ACO algorithm with adaptive thresholding. This yields an edge map of the image that is both dense and interconnected. As a first step, we employ adaptive thresholding to obtain the image's edge map. The computed end points from adaptive thresholding are used to position the ants. The ants' path is determined by the subtle differences in brightness between neighboring pixels. When deciding which neighboring pixel to move an ant to next, only the likelihood of those pixels remaining undetected is considered. To prohibit the ants from passing over a pixel that has already been spotted using adaptive thresholding, two halting rules are put into place. Shannon's entropy function is used for a qualitative analysis of the data.

III. OBJECTIVE

1. To analyse edge detection scheme for image processing by using ant colony optimization.
2. To perform edge detection with ACO implement Sobel and Canny edge detection using hybrid methods

IV. PROPOSED METHODOLOGY

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. In other words, research is an art of systematic investigation. Someone says that necessity is mother of all the inventions and the person engaged in this scientific investigation can be termed as research. The pheromone matrix is created by using picture edge detection methods developed for this study to 2D images. The proposed method for detecting edges in images makes advantage of ACO. The implementation work will utilize a grayscale image. It is a data matrix I whose values reflect intensities within some range, and it is an intensity image. Each pixel in a grayscale image is represented by a single element in a single matrix. ACO techniques will use for the construction of a pheromone matrix that runs for a given number of iterations (Pravin et al., 2019). This is just one of several steps involved in the ACO optimization process. The iterative method will incorporate the construction process and the update process. The deciding step is the last one when the edge matters. The methods of ACO, Canny, and Sobel, as well as the language and tool of MATLAB, will be utilized in this study.

FLOWCHART

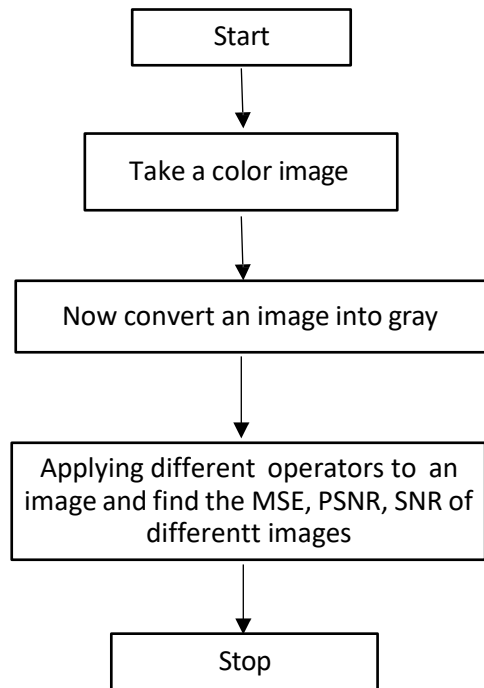


Figure 6: Flow chart of Edge detector

V. DATA ANALYSIS

This work used Ant colony optimization algorithms with a combination of "Sobel" edge detection filter and perform comparative analysis with Prewitt and Sobel filter. In order to create an image edge map that is sufficiently connected, this method of edge detection, which makes use of the Ant Colony Optimization (ACO) algorithm, is utilized. In the beginning, the edge map of the picture is obtained by employing a variety of standard edge detectors from the MATLAB toolbox as well as adaptive thresholding. Calculations are made based on the end points obtained with such detectors. After that, the ants are positioned in these specific locations. The local fluctuation in the intensity values of the pixels acts as a compass to direct the movement of the ants. While advancing an ant to the next probable edge pixel, the probability factor of just undiscovered surrounding pixels is taken into consideration. This ensures that no edges are missed. The two rules for stopping are put into place to stop the ants from moving through the pixel that has previously been identified.

Results of proposed work with comparative analysis of ACO (Sobel, Canny), and Sobel.

Sobel operator

Its kernel is a 3×3 mask operator. The convolution masks for the Sobel based operator is as:

1	2	1	1	0	-1
0	0	0	2	0	-2
-1	-2	-1	1	0	-1

These two masks are applied independently, along with two gradient components, to the image G_x and G_y in the directions, horizontal and vertical, is calculated respectively.

$$G_x = [f(i - 1, j - 1) + 2f(i - 1, j) + f(i - 1, j + 1)] - [f(i + 1, j - 1) + 2f(i + 1, j) + f(i + 1, j + 1)]$$

and

$$G_y = [f(i - 1, j - 1) + 2f(i, j - 1) + f(i + 1, j - 1)] - [f(i - 1, j + 1) + 2f(i, j + 1) + f(i + 1, j + 1)]$$

The gradient magnitude is calculated as:

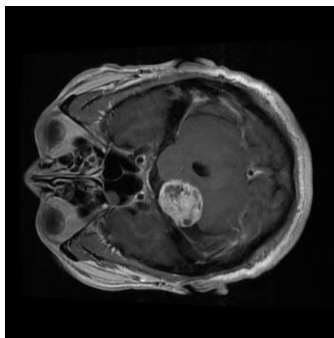
$$G[f(x, y)] = \sqrt{G_x^2 + G_y^2}$$

Canny Edge Detector

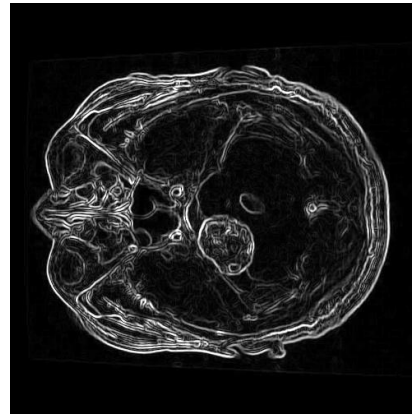
It is one type of edge detector that uses the Gaussian distribution to identify and isolate image borders. It can identify numerous edge types in a picture. After using a Gaussian filter to eliminate noise & smooth the image, it will look for the image's gradient and use non-maximal suppression to highlight it; finally, it will use hysteresis to determine where the image's edges are. Low threshold value, high threshold value, and Gaussian width (which measures picture noise) are all considerations in identifying the hysteresis threshold. In our study, we employ a variety of edge detection techniques, demonstrating their utility through the use of a graphical user interface (GUI) & calculation of several parameters (e.g., mean squared error, PSNR ratio, rms error, SSIM, & signal-to-noise ratio).

Table 1: Results of Brain Tumor Image

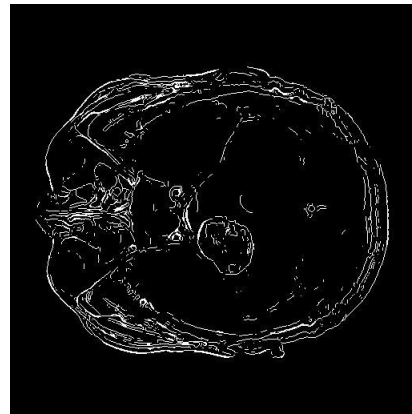
Algorithm	PSNR	SNR	MSE	RMSE	SSIM
Sobel	26.7 49	10.8 99	137.4 59	11.7 24	0.80 1
Proposed ACO+Sobel	22.2 02	1.28 5	391.5 63	19.7 87	0.78 7
Proposed ACO+Canny	23.1 22	6.26 6	316.7 99	17.7 98	0.70 4



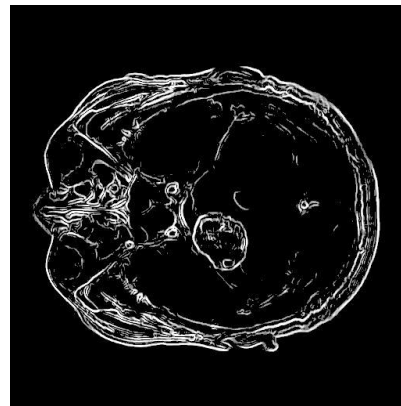
(a) Original Brain



(b) Filter Brain



(c) ACO_Brain



(d) Sobel Brain

Figure 7 Comparison of ant-based edge detection algorithms. (a) Original image of Brain tumor (b) Filter image (c) ACO Brain (d) Sobel brain

VI. CONCLUSION

ACO was used to the issue of edge identification in images & analysis of the edge data contained within each image pixel. Since it's hard to see the big picture, researchers turned to ACO methods to figure out where to go for answers. Since it's hard to see the big picture, researchers turned to ACO methods to figure out where to go for answers. The suggested study has created a Matlab GUI

system for extracting edges from digital images utilizing multiple edge detectors. Using edge detector operators such as Sobel, ACO canny, & ACO sobel, we have analyzed three different digital images, including images of brain tumors, for our proposed study. These digital photos have had many operators applied to them, each of which produces a unique waveform or picture as a result of its processing. The PSNR, RMSE, & SNR of the SSIM are all high, and the MSE is low.

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