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Effecting Pheromone Decay on the Ant Colony Optimization Canny Edge Detector

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Abstract: Edge is A boundary between two disjoint regions formed by a set of connected pixels. The canny edge detector is a computational edge detection operator that detects a wide range of edges in images.The determination of the threshold is the most important step in edge detection based on the Canny edge detection algorithm, on which the success of a generation of true edge maps depends. Ant colony optimization (ACO) is a society metaheuristic that can be used for a variety of optimization problems. It has been used to handle a variety of image processing issues, including image segmentation, classification, analysis, and edge detection.In this paper perform the ACO Canny edge detector, then apply ACOseperatly, For the color file (256*256) that is used in the algorithms. After analyzing the results of the algorithms, it was determined that the ACO is the better than ACO canny edge detecting algorithm. While the second method ACO Canny is better than the ACO when the evaporation rate is equal to 0.001. and The most effective factor in the algorithm's work is pheromone decay, as the best results were obtained when this parameter was reduced to 10^{-10}.

Keywords,Pheromone Decay,ACO, Edge detection, Ant system, Canny.

Introduction

Edge detection is a crucial tool for determining the boundaries of objects in an image during the preprocessing process. For instance, pixels are considered edges whose neighborhood intensity values vary dramatically. Edge detection is a research area in image processing topics that include feature detection, feature extraction, pattern recognition, feature detection, pattern recognition, image analysis, and medicinal applications (N. Riahi et al., 2018). This method recognizes the outlines of objects as well as the boundaries between them and the image's background. To improve the appearance of a blurred image, an edge-detection filter can be applied (B. A. Adu, et al, 2019) (Kumar et al,2020).

The goal of edge detection is to reduce the quantities of information in an image while preserving the structural features for further image processing. The edge in a gray level image is a local feature that separates sections within a neighborhood in which the gray level is more or less uniform with varying values on both sides of the edge (M. Mamta, et al,2019).

Ant System (AS), The definition of a new computational paradigm, that was inspired by the way ant colonies function (D. Marco et al., 1996). they have been not interested in ant colony simulations, but rather in using artificial ant colonies as a tool for optimization. The Ant System paradigm depicts a population of agents who are each governed by an autocatalytic process that is controlled by a greedy force.

Ant colony optimization (ACO) is a bioinspired optimization algorithm that is inspired by ant species' natural foraging behavior. Ants leave pheromone on the ground to indicate a favorable path between a food source and its colony, which other colony members should follow, As a result, the pheromone on that path is reinforced. This activity reinforces itself, resulting in a trail with a high pheromone concentration, while less utilized paths tend to have a falling pheromone level owing to evaporation. Real ants, on the other hand, can choose a road with a lower pheromone concentration to find new sources of food and, or shorter pathways. (R. Nizar, et al,2021).

Canny's edge detector is widely regarded as the best approach for detecting edges. It is based on three basic principles: a small error rate, accurate edge point localization, and a single reaction to a single edge. Canny presented two new techniques in the algorithm to improve the existing edge detection methods. non-maximum reduction as well as double thresholding to choose the edge points, These two thresholds for segmenting the gradient image, on the other hand, were determined through experimenting. (Canny, John.,1986).

Canny Edge Detection

Canny, a common edge detection technique, was initially introduced in 1986. The approach's success is contingent on the development of a comprehensive set of edge point computation objectives. These objectives must be specific enough to define the detector's desired behavior while making a few assumptions about the solution's shape

Use numerical optimization criteria to create detectors for a variety of common image characteristics, such as step edges. They discovered that there is a natural uncertainty principle between detection and localization performance after narrowing the study to step edges. which are also the two major objectives They derive a single operator form that is optimal at any scale using this principle, Edges are identified at max in gradient magnitude of a Convolution image in the optimum detector's simple approximating implementation(Canny, John.,1986).

Canny edge detector uses an enhanced algorithm evolved from Marr and Hildreth's previous work. It's the best edge detection technique since it provides accurate detection, quick responses, and accurate localization. It's widely employed in today's image processing techniques, and it's improving all the time (M.Mamta, et al,2019.

The Canny algorithm is a four-step process that begins with applying a Gaussian filter mask to smooth the image to reduce noise effects, then finds the magnitude and the direction of the gradient then applies nonmaximal suppression, which results in lightened edges, and finally applies two thresholds widely recognized as hysteresis thresholding (Deng, Cai-Xia, *et al*,2013).

Create a Gaussian filter and a mask that is appropriate for it. Combine a raw image and a mask. The smooth degree is controlled by the Gauss filtering function's standard deviation σ, where the Gauss filtering function is

$$G(x,y)=\frac{1}{2\pi\sigma^2}\exp\left[-\frac{x^2+y^2}{2\sigma^2}\right] \qquad (1)$$

Then Calculate the image's gradient amplitude and direction.

The gradient amplitude can be calculated as follows:

$$M(i,j)=\sqrt{p_x(i,j)^2+p_y(i,j)^2} \qquad (2)$$

The direction of the gradient is

$$\theta(i,j)=\arctan[p_y(i,j)/p_x(i,j)] \qquad (3)$$

the drawback of this type of classic edge detection approach is poor contrast and noisy images produce unsatisfactory results, a higher amount of noise in images that include its shadow (S. Janvi, et al,2013), It has disjointed edges where the edges should be united, which is an issue. This is a significantly more difficult task than basic edge detection, A low threshold produces false edges, while a high threshold ignores critical edges (Lakshmi, S. & Dr. V. Sankaranarayanan,2010).

Ant Colony Optimization

ACO is a probabilistic guided search technique for discovering optimal pathways in fully linked graphs, by utilizing the pheromone information. Any computing problem that can be reduced to finding good paths on a weighted graph can be solved using this technique. Ants travel around a search space, the graph, which is made up of nodes and edges(Baterina, A. Veronica, & Carlos O.,2010).

Cooperation is an important feature of ACO algorithms: The alternative is to distribute computing resources to a group of very simple creatures (artificial ants) who interact via pheromone. The agent's ability to provide good solutions is an emergent trait (D., Marco, *et al*., 1999).

The main phase in the search for the optimum path is to find the one that is the shortest and carries the most pheromone, which the ants use to communicate with each other. This route indicates that good feedback is activated during the pheromone update stages (Chen, Min,2021).

ACO Canny Algorithm

This paper proposed using ACO with a Canny edge detector to prevent the drawback of the canny detector

Algorithm: ACO Canny Detector

Input: color image(png 256*256).

Output: Edge detector in the image file(binary image).

Step 1:initial the coefficient (Alpha, Beta, evaporation rate, pheromone decay, pheromone matrix).

Step 2:specify the ant number.

Step 3:loop the steps below depending on the number of ants.

Step 4: Move the ants for L steps according to the probabilistic transition matrixdepending on the heuristic information for determining the path between nodes x, y, the pheromone between x, ynodes, the Alpha Influencing pheromone's weight factor,Betaweight factor for heuristic influence,

Step 5: After completingthe route compute local pheromone updates depending on the situation evaporation rate. (Update Process).

The local update is performed after each construction step for each ant input.

Step 6: After all ants have moved into round N, a global pheromone update is performed based on the pheromone decay parameter.

Step 7: Applythe thresholdon the final pheromone matrix (Decision Process)and get a binary image.

Step 8: Apply Canny edge detection on the binary image.

Step 9: Display Result (edge detection).

Step 10: End.

The flowchart for the ACO Canny edge detector is shown below:-

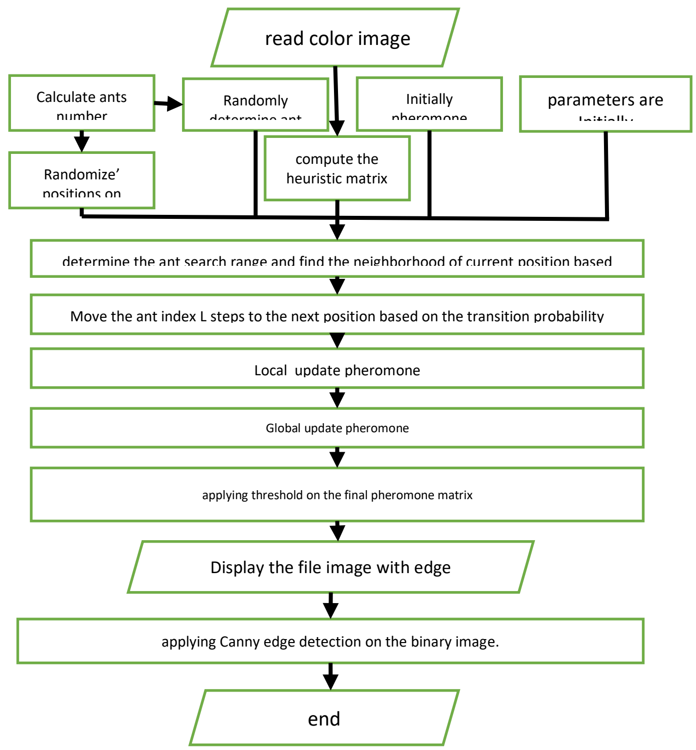

Figure1: ACO Canny edge detector

Experimental Result&Discusion

The algorithm is implemented ACO canny edge detector in Intel(R) Core(TM) i7-7600U CPU and Windows 10. MATLABversion R2020a was used to implement the algorithm. to evaluate the algorithm, many parameters' values take and apply to figures.

Table 1: abbreviation of words

word	abbreviation
Alpha	α
Beta	β
evaporation rate	ER
pheromone decay	PHY

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Table 2: parametersvalues (clique=8, ant Steps=300, pheromone initial=0.0001, β =0.1, ER=0.1, PHY=0.05, Ant number =256) with various values of α

File name	**Alpha**(α)	ACO		ACO+ canny		elapsed time (s)
		PSNR	MSE	PSNR	MSE	
lenargb	0.01	53.70564	0.279201	53.69635	0.279799	24.378
lenargb	0.1	53.70575	0.279193	53.70406	0.279302	24.514
lenargb	1	53.70867	0.279006	53.70427	0.279289	23.241
lenargb	**4**	**53.70985**	**0.27893**	53.69253	0.2800447	27.312
lenargb	8	53.70975	0.2789359	53.68503	0.2805283	24.903
lenargb	10	53.70943	0.278957	53.69128	0.280125	23.869
lenargb	20	53.7091	0.278978	53.70016	0.279553	24.186
lenargb	**60**	53.70754	0.279079	**53.70836**	**0.279026**	24.514
lenargb	100	53.70594	0.279181	53.70305	0.279367	30.065

Figure2: (a) original image (b)ACO when α=4, (c) Canny (d) ACO with Canny (e) ACO when α=60 (f) ACO with Canny

Table 2noticesthe best result for the ACO is best, especially when using α=4 than ACO Canny while when using also when using α=60the best edge detector for ACO Canny influences the image file is better.

Table 3:parameters values (Search clique=8, ant Steps=300, pheromone initial=0.0001, α =10, ER=0.1, PHY=0.05, Ant number =256) with various values of β

File name	**Beta** β	ACO		ACO+ canny		elapsed time (s)
		PSNR	MSE	PSNR	MSE	
lenargb	0.01	53.70941	0.2789581	53.68458	0.2805577	24.212
lenargb	**0.03**	**53.70972**	**0.2789379**	53.68459	0.280557	24.623
lenargb	0.05	53.70951	0.2789516	53.68702	0.2804	24.262
lenargb	0.1	53.70943	0.2789568	53.69128	0.2801254	24.438
lenargb	0.9	53.70867	0.2790056	53.67703	0.2810458	24.703
lenargb	**2**	53.70799	0.2790491	**53.70118**	**0.2794874**	24.140
lenargb	10	53.70653	0.2791433	53.69025	0.2801913	23.945
lenargb	30	53.7055	0.2792092	53.69268	0.2800345	24.820
lenargb	60	53.70493	0.279246	53.70063	0.2795229	30.643

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Figure3: (a) original image (b)ACO when β =0.03, (c) Canny (d) ACO with Canny (e) ACO when β=2 (f) ACO with Canny.

table 3 The best outcome for the ACO is obtained when β =0.03. Also, while employing β =2, the best edge detector for ACO Canny the image file is affected better for this case only.

Table 4: parameters values (Search clique=8, ant Steps=300, pheromone initial=0.0001, α =10, β=0.1, PHY=0.05, Ant number =256) with various values of ER

Filename	ER	ACO		ACO+ canny		elapsed time (s)
		PSNR	MSE	PSNR	MSE	
lenargb	0.001	53.70497	0.2792432	**53.70776**	**0.279064**	23.776
lenargb	0.01	53.70823	0.2790336	53.6896	0.2802337	23.614
lenargb	0.05	53.70948	0.2789535	53.68148	0.2807575	24.123
lenargb	0.1	53.70943	0.2789568	53.69128	0.2801254	24.438
lenargb	**0.5**	**53.70958**	**0.2789469**	53.68566	0.280488	24.393
lenargb	1	53.70951	0.2789517	53.68975	0.2802239	23.674
lenargb	2	53.70955	0.2789491	53.69973	0.2795808	23.861
lenargb	3	NaN	NaN	53.70355	0.2793349	29.271

Figure4: (a) original image (b)ACO when ER =0.01, (c) Canny (d) ACO with Canny (e) ACO when ER =0.5 (f) ACO with Canny.

Table 4 presents the best result for the ACO is best when using ER =0.5than ACO Canny moreover when using ER =0.001the best edge detector for ACO Canny impacts the image file better.

Table 5: parameters values (Search clique=8, ant Steps=300, pheromone initial=0.0001, α =10, β=0.1, ER=0.1, Ant number =256) with various values of PHD

Filename	PHY pheromone decay	ACO		ACO+ canny		elapsed time (s)
		PSNR	MSE	PSNR	MSE	
LenaRGB	10^{-13}	53.7245	0.2779902	53.65812	0.2822722	25.299
Lena RGB	$\mathbf{10^{-10}}$	**53.72457**	**0.277986**	53.659	0.2822147	25.476
Lena RGB	10^{-3}	53.7218	0.2781633	53.65612	0.2824021	24.920
Lena RGB	10^{-2}	53.71567	0.2785565	53.67775	0.2809993	25.131

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Lena RGB	$3 * 10^{-2}$	53.71142	0.2788288	53.69606	0.2798171	24.751
Lena RGB	$5 * 10^{-2}$	53.70943	0.2789568	53.69128	0.2801254	23.869
Lena RGB	10^{-1}	53.70741	0.2790866	53.68988	0.2802152	25.310
Lena RGB	**1**	53.70355	0.2793349	**53.70355**	**0.2793349**	25.455
Lena RGB	10	NaN	NaN	53.70355	0.2793349	26.821

Figure5: (a) original image (b)ACO when *PHY* =10^{-10} , (c) Canny (d) ACO with Canny (e) ACO when *PHY* = 1 (f) ACO with Canny.

table 5shows the best result for the ACO is best when using *PHY* =10^{-10}but when using *PHY* =1the best edge detector is ACO Canny impacts the image file better.

Conclusion

A novel image processing algorithm based on edge detection uses various kinds of detectors. The current work is discussed from two perspectives: ACO and ACO Canny edge detector. for the color file (256*256). The ACO was decided to be the better edge detecting algorithm after analyzing the outcomes of the algorithms. The Pheromone decay is the most important factor in the algorithm's operation since the best results have been obtained when this value was decreased to10^{-10} for the ACO method.Furthermore, figure 5 deduces that the best Pheromone decay rate is 1for the ACO Canny edge detector only.When the evaporation rate is equal to 0.001, the second approachdepending on table 4, ACO Canny, outperforms the ACO.

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