Using Ant's Colony Algorithm for Improved Segmentation for Number Plate Recognition

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***Abstract*— In this paper a number plate recognition system has been designed using the ant colony optimization technique. This system can be implemented in surveillance systems, detection of stolen vehicles and checking of vehicles at toll plazas, posts, barriers sand other entry points.**
In this paper, an ant colony based number plate extraction method is proposed. Ant colony optimization technique serves better results in edge detection while applying image segmentation, so using the concept in number plate recognition promises better accuracy. The Ant colony optimization (ACO) is an optimization algorithm inspired by the natural behavior of ant species that ants deposit pheromone on the ground for foraging. ACO is introduced to give a better image edge detection. The proposed ACO-based edge detection approach is able to establish a pheromone matrix that represents the edge information presented at each pixel position of the image, according to the movements of a number of ants which are dispatched to move on the image. Furthermore, the movements of these ants are driven by the local variation of the image's intensity values. Eventually, this gives the number plate area extracted from the image with improved accuracy. Finally a character recognition model is used to give out the final vehicle license number.

Keywords—Number Plate recognition, number plate localisation,Ant colony system,edge detection,character recognition

I. INTRODUCTION

Vehicle number plate recognition can be used for the task of vehicle identification. It can be used in many applications such as entrance admission, security, airport or harbor cargo control, traffic control and speed control. Our approach can be broadly divided into the following two methods: (i) extraction of the vehicle number plates from captured source images using ant colony optimization (ACO) and (ii) the recognition of character of the vehicular number plate. We have used image processing techniques such as edge detection using ACO, thresholding thinning, dilation and erosion for locating and isolating the number plate and characters. ACO is used in our system to extract the number plate edge information directly in contrast to it serving as a post processing algorithm to enhance the edge information that has already been extracted by conventional edge detection algorithms.

II. ANT COLONY OPTIMIZATION

ACO iteratively finds the optimal solution of the target problem through a guided search (i.e., the movements of a number of ants) over the solution space, by constructing the *pheromone* information. K ants are applied to find the optimal solution in a space χ that consists of M1 × M2 nodes.

• Initialize the positions of K ants, and the Pheromone matrix $\boldsymbol{\tau}^{(0)}$.
• For the construction-step index n = 1 : N,
– For the ant index k = 1 : K,
∗ Consecutively move the k-th ant for L steps, according to a probabilistic transition matrix $\mathbf{p}^{(n)}$ (with a size of M1M2 × M1M2).
– Update the pheromone matrix $\boldsymbol{\tau}^{(n)}$.
• Make the solution decision according to the final pheromone matrix $\boldsymbol{\tau}^{(N)}$.

III. SYSTEM MODEL

We have used a series of image processing techniques which are implemented in MATLAB. Our algorithm is divided into following parts:

- Capture image.
- Pre-processing on the captured image.
- Plate region extraction using ACO.
- Segmentation of character in the extracted number plate
- Character recognition.

A. IMAGE ACQUISITION

The first step is to acquire the image using electronic devices such as an optical camera; webcam etc.as in figure 1. The images are to be captured from a particular distance so as to have a fixed area of the

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Fig. 1. Original Image

number plate. The images will be stored as color JPEG format on the camera . Next, we proceed using the Matlab function to convert the vehicle JPEG image into BMP format .

B. PRE-PROCESSING.

1) Size conversion:

The image can be converted to 128*128 ,256*256, 512*512 pixels for edge detection. High accuracy and quick implementation was achieved for 256*256 pixels. Hence in our simulation the images were converted to 256*256 pixels before segmentation as shown in figure 2.

2) Gray Processing:

It involves conversion of color image into a gray image. The method is based on different color transform. According to the R, G, B value in the image, it calculates the value of gray value, and obtains the gray image at the same time. Gray scale image is shown in figure 3.

3) Median Filtering:

When images are acquired there is lot of noises present in image. These noises affect the recognition rate greatly. The noise cannot be eliminated in gray processing. To remove noise from the image median filters are used so that image becomes free from noise.

Fig. 2. Resized bitmap image

Fig. 3. Grayscale Image

IV. PROPOSED ACO-BASED IMAGE EDGE DETECTION APPROACH FOR PLATE REGION EXTRACTION

The ACO-based image edge detection approach aims to utilize a number of ants to move on the image for constructing a pheromone matrix, each entry of which represents the edge information at each pixel location of the image. Furthermore, the movements of the ants are steered by the local variation of the image's intensity values.[11]

The proposed approach follows the following processes

A. Initialization Process

K ants are randomly assigned on our image **I** with a size of M1 ×M2, each pixel of which can be viewed as a node. The initial value of each component of the pheromone matrix $\boldsymbol{\tau}^{(0)}$ is set to be a constant τ_{init}.

B. Construction Process

At the n-th construction-step, one ant is randomly selected from the K ants, and this ant is made to move consecutively on the image I for L steps. This ant moves from the node (l,m) to its neighboring node (i,j) according to a transition probability that is defined as[11]

$$p_{(l,m),(i,j)}^{(n)} = \frac{\left(\tau_{i,j}^{(n-1)}\right)^{\alpha}\left(\eta_{i,j}\right)^{\beta}}{\sum_{(i,j)\in\Omega_{(l,m)}}\left(\tau_{i,j}^{(n-1)}\right)^{\alpha}\left(\eta_{i,j}\right)^{\beta}} \quad (1)$$

The constants α and β represent the influence of the pheromone matrix and the heuristic matrix, respectively. where $\tau_{i,j}^{(n-1)}$ is the pheromone value of the node (i, j) , Ω(l ,m) is the neighborhood nodes of the node (l,m) , $\eta_{i,j}$ represents the heuristic information at the node (i, j).

The heuristic information $\eta_{i,j}$ in (2) is proposed to be determined by the local statistics at the pixel position (i, j) as[11]

$$\eta_{i,j} = \frac{1}{Z} V_c\left(I_{i,j}\right), \quad (2)$$

where $Z = \sum_{i=1:M1} \sum_{j=1:M2} V_c(I_{i,j})$,which is a normalization factor, $I_{i,j}$ is the intensity value of the pixel at the position (i,j) of the image **I**, the function $V_c(I_{i,j})$ is a function of a local group of pixels c (called the *clique*), whose value depends on the variation of image's intensity values on the clique c (as shown in Fig. 4). [11]

More specifically, for the pixel $I_{i,j}$ under consideration, the function $V_c(I_{i,j})$ is[11]

$$\begin{aligned} V_c(I_{i,j}) = f(&|I_{i-2,j-1} - I_{i+2,j+1}| + |I_{i-2,j+1} - I_{i+2,j-1}| \\ &+ |I_{i-1,j-2} - I_{i+1,j+2}| + |I_{i-1,j-1} - I_{i+1,j+1}| \\ &+ |I_{i-1,j} - I_{i+1,j}| + |I_{i-1,j+1} - I_{i-1,j-1}| \\ &+ |I_{i-1,j+2} - I_{i-1,j-2}| + |I_{i,j-1} - I_{i,j+1}|) \quad (3) \end{aligned}$$

To determine the function f(·) in (3), the following four functions are considered in this paper; they are mathematically expressed as follows [11]

$$f(x) = \lambda x, \qquad for\ x \geq 0, \qquad (4)$$

$$f(x) = \lambda x^2, \qquad for\ x \geq 0, \qquad (5)$$

$$f(x) = \begin{cases} \sin(\frac{\pi x}{2\lambda}) & 0 \leq x \leq \lambda; \\ 0 & else. \end{cases} \qquad (6)$$

$$f(x) = \begin{cases} \frac{\pi x \sin(\frac{\pi x}{\lambda})}{\lambda} & 0 \leq x \leq \lambda; \\ 0 & else. \end{cases} \qquad (7)$$

The parameter λ in each of above functions (4)-(7) is used to adjust the functions' respective shapes.

C. Update Process

The approach performs two updates operations for updating the pheromone matrix. The first update is performed after the movement of each ant within each construction-step. Each component of the pheromone matrix is updated according to[11]

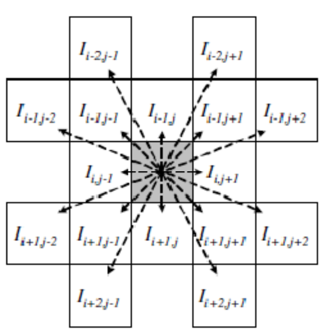

Fig. 4. A local configuration at the pixel position $I_{i,j}$ for computing the variation $V_c(Ii,j)$ defined in (3). The pixel $I_{i,j}$ is marked as gray square

$$\tau_{i,j}^{(n-1)} = \begin{cases} (1-\rho).\ \tau_{i,j}^{(n-1)} + \rho.\ \Delta_{i,j}^{(k)}, & \text{if (i,j) visited by current k-th ant} \\ \tau_{i,j}^{(n-1)}\ , & \text{otherwise} \end{cases} \qquad (8)$$

where ρ is the evaporation rate . $\Delta_{i,j}^{(k)}$ is determined by the heuristic matrix; that is, $\Delta_{i,j}^{(k)} = \eta_{i,j}$.

The second update is carried out after the movement of all ants within each construction-step according to

$$\tau^{(n)} = (1 - \psi).\tau^{(n-1)} + \psi.\tau^{(0)}, \qquad (9)$$

where ψ is the pheromone decay coefficient.

D. Decision Process

In this step, a binary decision is made at each pixel location to determine whether it is edge or not, by applying a threshold T on the final pheromone matrix $\boldsymbol{\tau}^{(N)}$. The above-mentioned T is proposed to be adaptively computed based on the method developed in [6]. The initial threshold $T^{(0)}$ is selected as the mean value of the pheromone matrix. Next, the entries of the pheromone matrix is classified into two categories according to the criterion that its value is lower than $T^{(0)}$ or larger than $T^{(0)}$ .The new threshold is then computed as the average of two mean values of each of above two categories. The above process is repeated until the threshold value does not change any more (in terms of a user-defined tolerance).

E. The Summary of The Approach

A summary of the implementation of the proposed approach is presented in Figure 5[11].

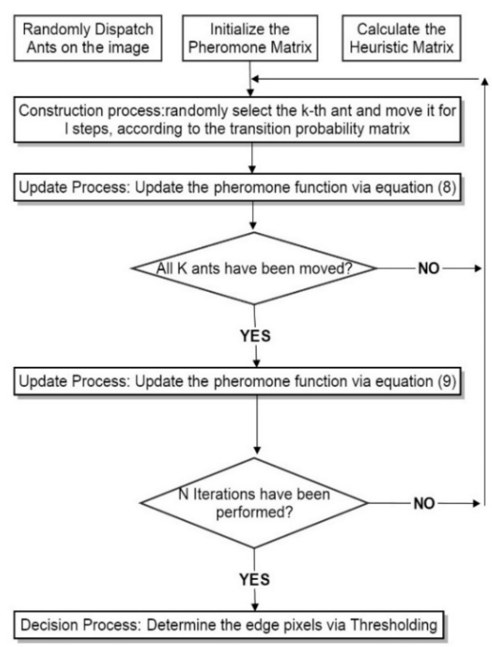

Fig. 5. A summary of the implementation of the ACO-based image edge detection approach.

Fig. 6. Edge detected image using ACO

V. NUMBER PLATE EXTRACTION

Firstly, we remove the undesirable objects in the image using the fore mentioned techniques. The edge detected image(fig. 6) is dilated and then hole filling is applied on this image using the appropriate morphological operations. After this morphological opening and erode operations are performed using the suitable structuring element and therefore we obtain the image shown in fig.7.To extract the detected number plate region connected component analysis is used which gives the row and column indices of the plate area .

VI. CHARACTER SEGMENTATION

We can use a horizontal projection of a number plate for the segmentation, or one of the more sophisticated methods, such as segmentation using the neural networks. In this segmentation we use two types of segmentation horizontal segmentation [7] and vertical segmentation[7].

Fig. 7. Localised Number Plate

Fig. 8.Extracted Number Plate

The Steps involved in character Segmentation are:

A. Preprocessing:

Preprocessing is required for the character segmentation to proceed smoothly The steps involved in preprocessing are: Conversion to Grayscale, Binarization**.** Image binarization is performed using the information of intensity of characters.

B. Object enhancement algorithm:

The median filter is applied to remove the noise from the image. This is followed by Opening morphological operation using the appropriate structure element. Firstly we scaled the gray level of all the pixels into the range of 0 to 1. Secondly, all pixels were sorted by gray level in descending order and the gray level of the top 20% pixels was multiplied by 255. Thus most characters pixels were enhanced while background pixels were weakened.

C. Segmentation

All the possible horizontal lines that could be the edges of the number plate can be eliminated by the Erosion operation(Fig. 9). Then all the regions of the image is filled(Fig. 10).Then the image is Thinned to ensure character isolation as seen in fig. 11.Then the regions having pixel area more than 800) are selected to isolate the non-character regions(Fig.12).

Fig.9. Output of the Erosion Operation.

Fig. 10. Filled Regions.

Fig. 11.Output of the thinning operation

Fig. 12. Isolated Character Region

1) Horizontal segmentation :

For this we calculate the horizontal and vertical projections of intensity. Then we find the local minima for horizontal projection. Based on the threshold calculated from the above local minima's, and using the Bounding Box and Regionprops properties of MATLAB, we find x locations of the segmented regions.

2) Vertical segmentation:

For each of the horizontal segments we follow the same procedure as discussed above to get the vertical bounds.

VII. CHARACTER RECOGNITION.

The OCR technique used uses correlation method to match each individual character against the complete alphanumeric database. Hence the number is identified.

A. Preprocessing:

The following operations are performed before preparing the template: Binarization, Inversion of intensity of the characters. Hence we find the connected component that represents the character.

B. Creating the template:

The template for each character is formed using the alphanumeric database(Fig 13). Also, since we have filled each character in the grayscale image special care needs to be taken for some particular characters such as 8,B,4 etc.(Fig 14).

Fig. 13. Example of Alphanumeric database

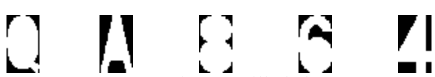
Fig. 14. Filled character

C. Character Recognition:

We compared the pixel values of the matrix of segmented character and the template matrix to calculate the score for each of the characters**.** For every match 1 was added to the matching score and for every mis-match 1 was decremented from the matching score. This was done for all the pixels. We generated a match score for every template and the one which gives the highest score was taken to be the recognized character. Since we are matching scores, there is a high probability that scores of similar looking characters and numerals may overlap giving a wrong result. Integrity checks have been put into place for the same.

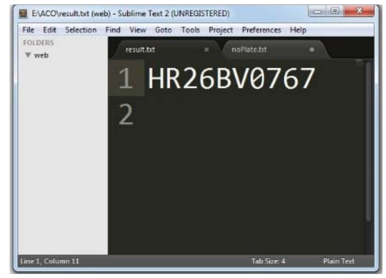

Fig. 15. Output of OCR on Segmented Number Plate

- First two characters are alphabets
- The next two characters are numerals.
- The last four characters are numerals.

For example if B is present in the first two characters, but the score determines it to be 8 rather than B, the output comes out to be B for the same.

The final output is written to a text file as shown in Fig. 15.

VIII. RESULTS AND COMPARISONS

We ran our system on 30 varying test cases. It was observed that 92.6% percent characters were recognized successfully. The recognition failed when the number plate could not be successfully localized. There were also errors due to similar looking characters which can be reduced by defining further rules for the format of the number plate string. There are quite a few approaches possible for edge detection for the plate localization stage. Edge detection can be performed using gradient operator (Robert, Sobel, Prewitt).The conventional approaches are computationally expensive because their computation proceeds pixel by pixel. Hence , the computation time quickly increases with the size of the image. And most of these techniques use a huge search space for the image edge detection [19]. Therefore edge detection task is memory and time consuming without optimization. The ACO approach thus has the potential of overcoming the limitations of conventional methods.

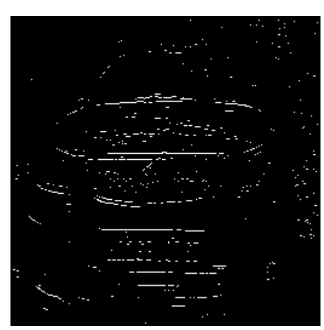
Fig. 16. Edge detection using Robert operator

Fig. 17. Edge detection using Sobel operator

For diverse and robust cases like covering shadow, illumination and varying weather, Sobel and Prewitt do not work. These approaches take in shadow and other external variations as strong intensity variations. ACO ignores this variation as ants don't treat these variations as strong enough and hence, don't keep on depositing pheromones in shadow line providing better results[8][12]. We performed comparison of the ACO technique with Conventional approaches to edge detection like SOBEL operator [13], Prewitt operator [14], Robert's operator [15]. It was observed from the experimental results that ACO performs better. As seen in fig.16 Robert approach shows broken edges, hence it poses in problem in subsequent plate localization steps. It was also observed as seen in fig.17 that the Sobel Approach gives multiple candidate regions hence making it difficult to detect the number plate edge specially in the cases where the size of the number plate is almost equal to the size of the front grills.

IX. CONCLUSION

The Number Plate Recognition system is designed for the detection of the number plates of the vehicles which can be used for further processes like storing, allowing vehicle to pass or to reject vehicle. This paper implements Ant Colony Optimization algorithm to successfully segment number plate area from the source image, and further applies a character recognition to get the vehicle license number. We developed the system using ACO with improved robustness. The system was implemented in MATLAB and tested on real test images. Image segmentation was performed using the ACO technique and number plate region extraction was then performed via thresholding. Further the character isolation was performed using techniques such as thinning, erosion region filling and finally a specific area threshold was used for extracting the characters. Finally the characters obtained were compared with the alphanumeric database and the output was obtained on a text file for a successful detection. The characters were recognized with a high accuracy and when compared to other edge detection techniques such as Robert and Sobel, ACO performed better for number plate localization.

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