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DETECTION OF LEADING VEHICLE AND DISTANCE MEASUREMENT USING DIGITAL IMAGE PROCESSING

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Abstract: The morphological transformation technique on the input image and edge enhancement edges of objects are identifying. Image segmentation is done for the obstacle detection with decision tree for the identification of target vehicle from the input image. The relationship between coordinates value in image space and the data of the real space plane was established by applying the ray angles. To know the actual position of the target vehicle in the plane, image pixel coordinates of the vehicle are used. And actual position of the target is calculated. At last, the leading vehicle distance based on the calculating model of inverse perspective mapping was measured. An experiment program in VC++ software was made. Results from the experiment show that the method of measuring the vehicle distance is simple and effective. It is more available and more advanced method to calculate the leading vehicle distance. It can meet the requirement of intelligent vehicle technologies.

Keywords: Digital Image Processing, Obstacle Detection, Monocular Ranging, Leading Vehicle Distance.

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INTRODUCTION

For the prevention of traffic accident it is necessary to have effective vehicle driving information and measuring the distance of a leading vehicle prevents vehicle from accidents. For which advance vehicle control system is an important component of ITS (intelligent transportation system). This method provides a new technique to measure a distance of a leading vehicle based on domestic and international Vision Ranging technology and digital image processing theory and obtains the leading vehicle distance data through the image pre-processing, obstacle detection and ranging model calculation and other steps. This method is a passive ranging method, and not transmits the signal to the outside environment, furthermore, also has easy to update algorithm, equipment light etc.

IMAGE PRE-PROCESSING

To improve quality of an image and to reduce noise present in an image pre-processing of an image is done for foundation of obstacle detection. This is required to select an appropriate way in digital image processing method to conduct a comprehensive pre-preprocessing to image, this paper selects method of morphological opening and closing and edge enhancement to smooth details and to enhance the edges of objects so as to identify.

Morphological Opening and Closing

This paper focuses on image noise reduction by the operation of the mathematical morphological opening and closing .While after space domain enhancement, some interference factors in the image possibly impact Obstacle Detection. With the features of mathematical morphology operation, processing the image captured by grey scale open and close, the effects of image noise removal is the best [2]. Both of the calculations addressed above are the combination of the open calculation (O) and the close calculation(C), which can be represented as:

OC□□*(A* ○*B)*•□(□□*B)* and

CO □□ [*A* •□□□ (□□*B*)] ○ *B*

Here original image is denoted as A; and structure element is denoted as B. The open and close calculation not only make extracting the separate targets easier, but will eliminate some noises, making the grey scale in the target more even and then smoother. As a result, it can eliminate the artifact when extracting the outline of the target, improving the image quality.

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Dilation and Erosion

The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the *structuring element* used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as dilation or erosion. This table lists the rules for both dilation and erosion of traffic accident it is necessary to have effective vehicle driving information and measuring the distance of a leading vehicle prevents vehicle from accidents.

Combining Dilation and Erosion

Dilation and erosion are often used in combination to implement image processing operations. For example, the definition of a morphological *opening* of an image is erosion followed by dilation, using the same structuring element for both operations. The related operation, morphological *closing* of an image, is the reverse: it consists of dilation followed by erosion with the same structuring element. The following section uses imdilate and imerode to illustrate how to implement a morphological opening. Note, however, that the toolbox already includes the imopen function, which performs this processing. The toolbox includes functions that perform many common morphological operations.

Morphological Opening

You can use morphological opening to remove small objects from an image while preserving the shape and size of larger objects in the image. For example, you can use the imopen function to remove all the circuit lines from the original circuit image, circbw.tif, creating an output image that contains only the rectangular shapes of the microchips. After using algorithm for opening of image,

Fig 1: Morphologically open Rectangular microchips

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Fig 2: Dilation and Erosion of Rectangle

EDGE ENHANCEMENT

Because image edge depicts the contour, enhancing the image edges has important implications for the object recognition. Image enhancement is divided into two main categories: Space domain method and frequency domain method. Study the use of space-domain processing methods, as much as possible to shorten the processing. In the pixel matrix size of M rows, N columns of the image, the template R with m rows, n columns carried space domain linear filtering is given by the following formula:

R = $w_1 z_1 + w_2 z_2 + - - - - + w_{mn} z_{mn} = \sum_{i=1}^{mn} w_i \; z_i$

w_{mn} is the template coefficient and z_{mn} is the image pixels under template. Using Laplace second-order differential image edge enhancement, the corresponding algorithm is as follows:

$g(x, y) = f(x, y) - \nabla f^2$ (2)

Where *f* (x, *y)* is the image before handling;

g(*x* , *y*) is the image after Laplace enhancement; and

Define Laplace transform operator ∇f^2 as:

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

Find that :

∇f^2 • •*f* (*x* •1,*y*) • •(*x* •1,*y*) • •*f*(*x*,*y* •1) • •*f* (*x*,*y*1) • •4*f*(*x*,*y)*

Using Laplace transformation the image is much clearer than before, with edge part enhancement and background keynote maintenance.

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OBSTACLE DETECTION ON ROAD

Identification and calibration of the target present in the image is the process of detection on road obstacle [3] [4]. First, decrease the calculated amount by threshold segmentation and thinning method to the pre-processing image. Then, identify the target vehicle.

Image segmentation is a process that partitions an image into its constituent regions or objects. To show the different parts in the image separate it into several regions. For the fast speed and stable performance in threshold segmentation calculation, it involve following steps: (1) identification of segmentation threshold; (2) comparison and classification of segmentation threshold and pixel value. By extracting target from the image below, obtaining gray histogram statistic. Then obtain gray information from the histogram, and determines the basic location of the road. The basic process of obtaining the threshold value and detecting the road region including:

►select the areas below the road, determine whether it involve both of the two categories gray scale value, namely pavements and markings. If not direct to step ;

►select an initial threshold T_o, obtain the segmentation threshold of the two categories gray scale values by iteration method, and eliminate the impact of markings through the threshold value, then obtain an independent road gray scale;

►calculate the range of gray scale μ_u and μ_d by parameter method;

►Divide road region by μ_u *and* μ_d.

Image Thinning

Image thinning is done for the reduction of calculated amount of obstacle detected in the image after dividing the image in terms of the threshold value, then created the basic lane area. It reduces a large amount of memory usage for structural information storage. Define the mathematical morphology method as:

$S \oplus B \cdot S \backslash (S \times B)$

Where the definition of set difference $S \backslash (S \times B)^C$

is $S \cap (S \times B)^C$, $(S \times B)^C$ refers complementary set of initial image $S \times B$.

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IDENTIFICATION OF ANOTHER ROAD OBSTACLE

Decision tree identification method is used for the detection of road obstacles other than target such as pedestrians, non-motor vehicles, etc. these elements are eliminated by some certain criterion condition for the vehicle target in the image. Vehicles, etc. Establish the decision tree in terms of relevant factors in the identification processing: (1) within the road; (2) the difference between the targets connected domain gray and road area; (3) the grown form and range of the connected domain. After obtain the location of the vehicle ahead, calculate the practical location through the image, then find out the distance value of the vehicle ahead.

DEVELOPMENT OF A MODEL

After obtaining the location of obstacle in the image, input the data to the ranging model, and the distance of the vehicle ahead can be achieved. Therefore, it is important to develop the accuracy ranging model. The process of acquisition image by camera is the transform from 3-d Euler space to 2-d Euler space. To measure and calculate the practical data through the image data, it is the inverse process of the above one to some extent, and the model development is based on image transform.

Image Transform Theory

The geometric transform is a process of developing a Mapping function between the points in the initial image and the image after deformation. It is showed as follows: $[x,y]$ $[X(u,v),Y(u,v)]$ or $[u,v]$ $[U(x,y),V(x,y)]$, Where $[u, v]$ refers to the co-ordinate of the output image pixel; $[x, y]$ refers to the co-ordinate of the input image pixel. X、Y、U、V is the only mapping function that ascertains the spatial alternation, X、Y defines as forward mapping, which is mapping the input to output; and U、V define as Reverse Mapping, which is mapping the output to the input. Generally show the space transformation with a 3×3 transformation matrix: $[x'',y,w]$ $[u,v,w]T$.

Where T refers to transformation matrix; x'、y' are a kind of manifestation mode of x y; x、 y and u v are the coordinates before and after transformation respectively; and w' and w are the homogeneous coordinate introduced for the treatment with three-dimensional matrix. The process of capturing Image by camera involves the image coordinate system and camera coordinate system and the world coordinate system. Figure I. shows the image coordinate system XC, YC. Each pixel coordinate is the numbers of rows and columns in the array. The axis Z of the camera coordinate system is vertical to the image plane, while the XY plane is parallel to the image plane. A datum coordinate system which expresses the location of camera and any

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other objects is known as the world coordinate system, expressed by x、y、z. The image plane is reflected by the focus, to prevent the use of mirror image with negative coordinate.

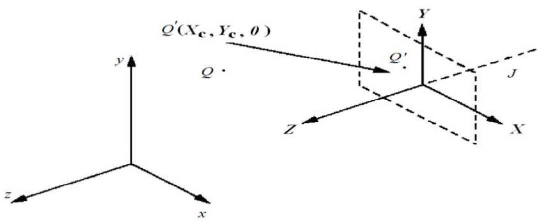

Figure 3: Image, Camera and World Coordinate System

Establish the ranging monocular camera model

If I refers to the three dimensional reality space, while W refers to the image space, the process of capturing image is transformation from I to W. After obtaining coordinate of the bottom of target vehicle in the image space, still need to gain conditions of the images collected and the assumptions for the image scene description. As shown in Figure 2, Camera location (denoted by VC) in the world coordinate system is showed by the positions of l, d, h; view direction is represented by the central axis of the camera with the standard shaft angle $\bar{\gamma}$ and $\bar{\theta}$; inclination of the camera aperture is 2 α ; Camera Definition is $n \times n$. The above parameters can be obtained by measuring or indirectly calculating. $n \times n$ rays is from the camera to the outside space. The reality space angle of the ray which obtains point (XC, YC) in image space is determined by θ and γ.

$$\theta=(\bar{\theta} - \alpha) + Y_c \cdot \frac{2\alpha}{n-1}$$

Where Y_c is the coordinates of the image space,

$Y_c \in$ 0,1, 2,………………., n—1.

In addition, the ground point P, the ground distance dp from the plane S to the camera can be calculated by the following formula

$$d_p = \frac{h}{\tan\theta}$$

Taking these factors, get the formula for calculating the distance the vehicle ahead:

$$d_p=\frac{h}{\tan[(\bar{\theta}-\alpha)+Y_c\frac{2\alpha}{n-1}]}$$

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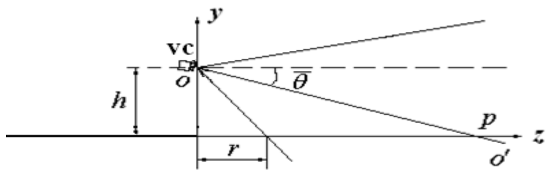
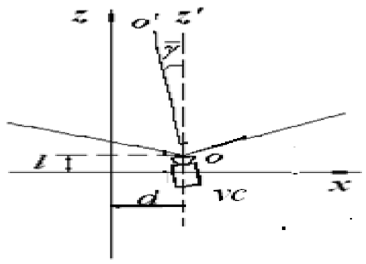
The model has established the relationship between coordinates value YC in image space and the data of the real space plane S by the relationship among the ray angles. Thus, access to image pixel coordinates of the vehicle can calculate the vehicle's actual position in the plane S. As shown in Figure 2, if the central axis of the camera parallels with the world coordinate system z-axis, $\overline{\gamma}$and$\overline{\theta}$are zero, and the calculation process will be simplified:

$$d_p = \frac{h}{\tan[\frac{2\alpha Y_C}{n-1} - \alpha]}$$



(a) Side View



(b) Top View

Fig 4: Schematic diagram of camera parameters

RANGING PROGRAM IMPLEMENTATION

Depending upon ranging model appropriate program is established. Depending on basic functions: achieve the image input, display, storage; and also need to integrate the image preprocessing, obstacle detection and distance algorithm for the vehicle ahead which were described in the paper before. This paper uses Visual C + + to achieve ranging process based on digital image processing.

Camera captured image is DIB (device independent bitmap) images, but there is no MFC class for the DIB bitmap. Such as the API function provided by the Win32 SDK is only invoked when using Visual C + + to program, it not only in the processing is limited, but lose the advantages of

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object-oriented languages. Designing a series of function sets of dealing with DIB bitmap, and on this basis, to definite an exclusive class to deal with DIB bitmap can make procedures more efficient and targeted [7]. MFC's C Object class is the root class of most MFC classes. It offers many features and MFC derived classes have both a minimum level of member functions and data. Therefore, using it from API functions related to the Win32 SDK and based on a series of self-built DIB processing functions such as palette function, display function to establish CDib class with C Object class as a parent class.

Establishment of Ranging Program

In the establishment the basis of CDib class, the construction of function based on the CDib class can do edge enhancement, obstacle detection operations. Finally, to set up testing program under the AppWizard framework of VC + + program and integrate these modules, then to establish testing program. In the establishment process of ranging program, it not only need to integrate the aforementioned image processing steps, but also to achieve the processing time calculation and information hinting and other functions.

TEST AND ANALYSIS

Test Purpose and Test Scheme

Based on computer ranging program test of measuring the leading vehicle distance is to capture the image of the vehicle ahead. through the ranging program procedure to gain calculated value of the distance of the vehicle ahead, and to compare the calculated value with the actual distance between vehicles, then to draw program evaluation conclusions on the Ranging scheme. Straight sections of road are chosen as the actual test site. The relevant test parameters are showed in Table I.

Table I. Basic parameters of the range Test

Parameter	Parameter values
$\overline{\gamma}$	0
$\overline{\theta}$	0
Inclination of the camera aperture 2α	0.3236
Camera definition mxn	2048x1536
Distance from the camera to the ground	1.11

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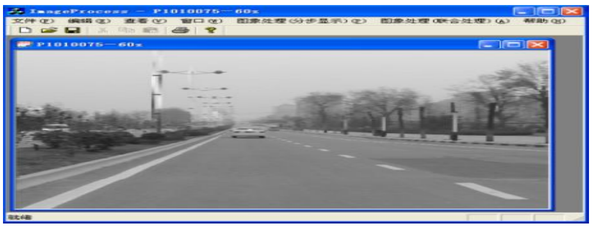
RESULTS AND ANALYSIS

Test results compared with the actual distance of the vehicle and the results are shown in table 2. It can prove that the method can more accurately detect the distance of the vehicle ahead by comparing the test-distance with actual distance. The time-consuming of image processing and calculation less than 1 second indicates that the method is simple, effective and more accurate to obtain the distance between vehicles ahead through a series of operation.

Table II. Test Data of Measuring the Leading Vehicle Distance

No	Actual Distance (m)	Testing Results (m)	Relative Error (%)	Processing Time (100ms)
1	20	20.45	2.25	4
2	40	40.78	1.95	4
3	60	64.95	8.25	3
4	80	86.26	7.81	3
5	100	92.31	7.39	4

(a) Digital image collection



(b) Image Pre-processing

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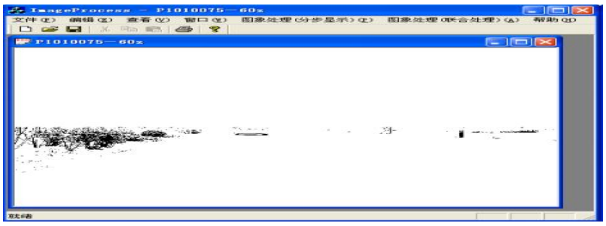

(c) Segmentation and Thinning

(d) Distance Measurement and Calculation

Fig 5 : Leading Vehicle distance image processing

CONCLUSION

Vehicle distance measurement technique uses morphological image preprocessing, threshold-segmentation, decision tree with obstacles detection and the calculating model of inverse perspective mapping to extract necessary information from the image to measure the vehicle distance. This paper introduces new method based on digital image processing. The test results proved that the method of measuring the leading vehicle distance is simple and effective. It can meet the requirement of intelligent vehicle technologies.

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