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Image Recognition in Tools Detection System for CNC Milling Machine

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Abstract— This paper intends to implement the digital image processing analysis for industrial robotic control system. In this paper, tool changing control system is built to check the tool magazine's places to put or take the tool by using digital camera. Before changing the tool in the tool magazine, the system needs to check the desired place is free or not. The program, shown in this paper, can test not only the present or absent of tool in the desired place of tool magazine, but also can estimate the tool diameter if the tool is presented in the desired place. This system works as a hardware sensor for tool safety control system.

Keywords— Object Recognition, Binary Image, Threshold Value, Filter Design, Hardware Sensor.

I. INTRODUCTION

This document intends to improve image processing system in automation and control systems. In this paper tool changing control system is built to check the present or absent of place of tool magazine by using machine vision system (Image Processing).

The system consists of a hardware sensor (digital camera), tool transporter, tool magazine, various types of tools. The main task of the system is that the camera attached on tool transporter takes the image of the desired place of tool magazine. The output of the camera is connected with the tool changing control system. The program of the system is determined the present or absent of the desired place, and the size of the tool can be calculated if the tool is present in that place. If the tool is absent, the program gives an alarm to the operator.

The general concept of the system can be seen in Fig. 1. In this document, only the machine vision system is emphasized.

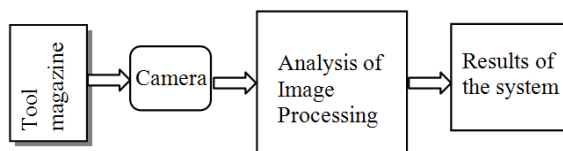


Fig. 1 System Block Diagram

II. A BRIEF REVIEW OF IMAGE PROCESSING

The human perception has the capability to acquire, integrate, and interpret all this abundant visual information

around us. It is challenging to impart such capabilities to a machine in order to interpret the visual information embedded in still images, graphics, and video or moving images in our sensory world. It is thus important to understand the techniques of storage, processing, transmission, recognition, and finally interpretation of such visual scenes [7].

A. Image Representation

Consider the representation of 24bit BMP images. It's a combination of three main colours; Red (R), Green (G) and Blue (B). Let i and j denote two integers where $i=1,2,...,m$ and $j=1,2,...,n$. In addition, let $f(i,j)$ denotes an integer function such that $0 \leq f(x,y) \leq 255$. $f(i,j)$ represents $R(i,j)$, $G(i,j)$ and $B(i,j)$.

$$F = \begin{bmatrix} f(1,1), & f(1,2), & \dots & f(1,n) \\ f(2,1), & f(2,2), & \dots & f(2,n) \\ \vdots & \vdots & \dots & \vdots \\ f(m,1), & f(m,2), & \dots & f(m,n) \end{bmatrix}$$

An address (i,j) defines a position in F , called a pixel, pel or picture element. The element of F denote the intensities within a number of small rectangular regions within a real (i.e. optical) image.

To change the gray-scale of image, the following formula is obtained;

$$I(i,j) = 0.3 \times R(i,j) + 0.59 \times G(i,j) + 0.11 \times B(i,j)$$

Many of the industrial image processing systems in use nowadays manipulate images in which $m=n=512$ and $W=255$. This leads to a storage requirement of 256 Kbytes/image. In this system, the images are used the dimension of $m=640$, $n=426$ and $W=255$, and the storage requirement is 300Kbytes/image [2].

B. Binary image

The pixels in a binary image can assume only two values, 0 or 1. The applicability of binary images is, however, limited because the over-all information content in such images is limited. A gray level image may be converted to a binary image by threshold process. [7]

C. Threshold

The goal of threshold is to segment an image into regions of interest and to remove all other regions deemed inessential.

Usually, a binary image is obtained from a gray-level image by some process of information abstraction.

The advantage of the B-fold reduction in the required image storage space is offset by what can be a significant loss of information in the resulting binary image. However, if the process is accomplished with care, then a simple abstraction of information can be obtained that can enhance subsequent processing, analysis, or interpretation of the image.

The simplest such abstraction is the process of **image thresholding**, which can be thought of as an extreme form of gray-level quantization. Suppose that a gray-level image f can take K possible gray levels $0, 1, 2, \dots, K - 1$. Define an integer threshold, T , that lies in the gray-scale range of $(0, 1, 2, \dots, K - 1)$. The process of thresholding is a process of simple comparison: each pixel value in I is compared to T . Based on this comparison; a binary decision is made that defines the value of the corresponding pixel in an output binary image g :

$$g(i,j) = \begin{cases} 0, & \text{if } I(i,j) \geq T \\ 1, & \text{if } I(i,j) < T \end{cases}$$

Of course, the threshold T that is used is of critical importance, since it controls the particular abstraction of information that is obtained. Indeed, different thresholds can produce different valuable abstractions of the image [7].

III. IMAGE RECOGNITION SYSTEM

The general algorithm of the system is shown in Fig. 2. The desired place of tool magazine is captured by camera, and then the captured image is processed in the image analysis system. After that, the result is obtained by the help of the program.

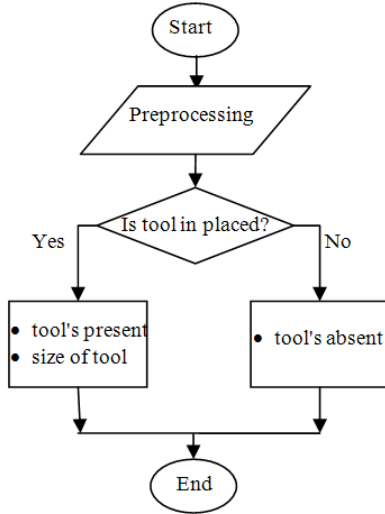


Fig. 2 General algorithm of the image recognition system

A. Preprocessing of the system

The preprocessing step is performed directly on the image obtained from the digital camera. The key function of preprocessing is to improve the image in ways that increase

the chances for success of the other processes. Preprocessing is necessary to perform several analysis operations prior to rebuild the binary image matrix of the captured image.

In the preprocessing step there are five main functions to be taken. They are loading the bmp picture file captured by the digital camera, converting the colour image to gray-scale image, changing to the binary image matrix by using suitable threshold value, removing the noise of the image with median filter, and cropping the binary image to get the specified place.

The consequent results of the preprocessing of the image recognition system can be seen in below.

1) *Converting gray-scale image*: A loaded image is a 24-bits bmp format, and it composes the combination of red, green and blue colours. To convert gray-level, the formula is shown as follow:

$$I(i,j) = 0.3 \times R(i,j) + 0.59 \times G(i,j) + 0.11 \times B(i,j)$$



(a)



(b)

Fig. 3 (a) 24-bit BMP picture, (b) gray-scale image

2) *Changing binary image*: A binary image of the system can be seen in Fig. 4. The initial threshold of the image in this system is 80. It's taken by the experimental test.



Fig. 4 Binary Image of the System

3) *Removing the noise of the image*: Digital images are prone to a variety of types of noise. Noise is the result of errors in the image acquisition process that result in pixel values that do not reflect the true intensities of the real scene. There are

several ways that noise can be introduced into an image, depending on how the image is created [1] [2].

An averaging filter and a median filter are useful for removing grain noise from a photograph. Because each pixel gets set to the average of the pixels in its neighbourhoods, local variations caused by grain are reduced. In the system, both of those filters are used to remove the noise of the image, and the result is shown in Fig. 5.

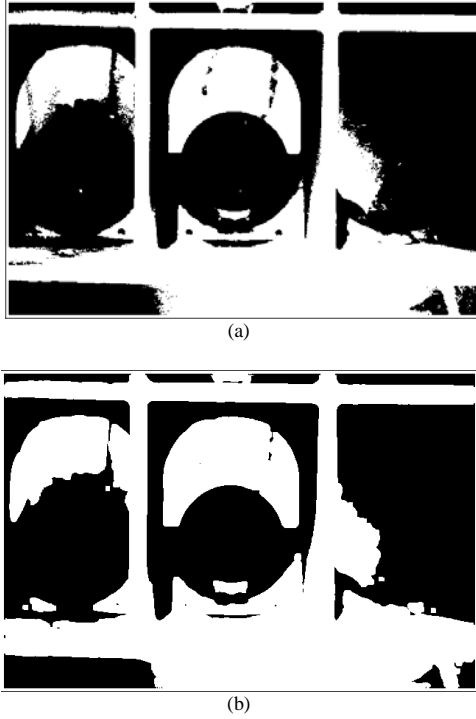


Fig. 5 (a) Original image, (b) Filtered image;

4) *Image Cropping*: Cropping the image removes the undesired region of the image, and then we can emphasise the specified region of the system. In Fig. 6, the result of the cropped image can be evaluated by cropping.



Fig. 6 Cropping the desired region of the image

B. Mathematical calculation

After finishing the preprocessing of the system, the required region of binary image matrix is obtained. The aim of the problem is that the tool is present or absent in the desired

place of the tool magazine. If the tool is present, then the size of the tool can also be calculated. If not, only the alarm message is given to the operator that the place is not blank.

To solve the problem, the boundary of the tool must be found in this region. The boundary itself is usually found by contour following: one point is found on the contour and then it is progressed round the contour either in a clockwise direction, or counter-clockwise, finding the nearest (or next) contour point. To find the starting point, the inner region point that starts to change white (0) to black (1) of the pixels of image matrix is checked [6].

To obtain a representation of a contour, the coordinates of a sequence of pixels in the image can be simply stored. Alternatively, the relative position between consecutive pixels can be just stored. This is the basic idea behind *chain codes*.

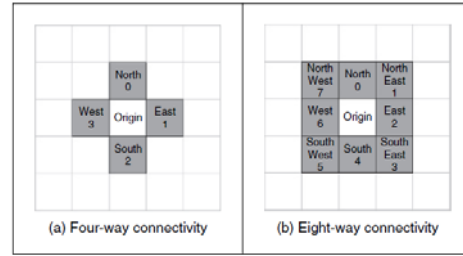


Fig. 7 Connectivity in chain code

The Prewitt edge-detector is used to detect the boundary of the tool in the system. It's similar to the Sobel operator, but is more sensitive to noise as it does not possess the same inherent smoothing. This operator uses the two 3x3 shown below to determine the edge gradient [6].

-1	-1	-1
0	0	0
1	1	1

P_1

-1	0	1
-1	0	1
-1	0	1

P_2

where P_1 and P_2 are the values calculated from each mask respectively. The Prewitt gradient magnitude is defined as:

$$E \leftarrow \sqrt{P_1^2 + P_2^2}.$$

C. Estimation of Size of Tool

By detection of boundary of tool, the contour matrix of the tool is obtained. In order to maximize the accuracy of estimation of size of tool, it is important to find as many points belonging to the tool boundary as possible. The length of the boundary is determined experimentally. Because of the shape of the tool is cylindrical, the size of tool is estimated by using basic equation for a circle;

$$(x - x_c)^2 + (y - y_c)^2 = r^2$$

, where (x_c, y_c) is the centre and r is the radius [5].

In terms of parameters a , b and c , the equation can be written as below;

$$x^2 + y^2 + ax + by + c = 0$$

where, $a = -2x_c$, $b = -2y_c$ and $c = x_c^2 + y_c^2 - r^2$.

By solving the parameters a , b , and c in the least-square method, the location and size of the tool can be calculated [5].

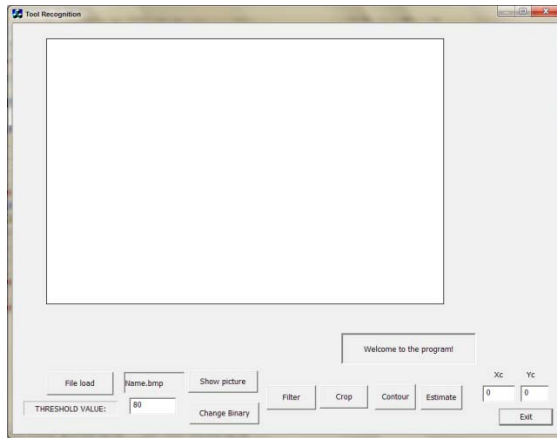


Fig. 8 Initial state of the program shell

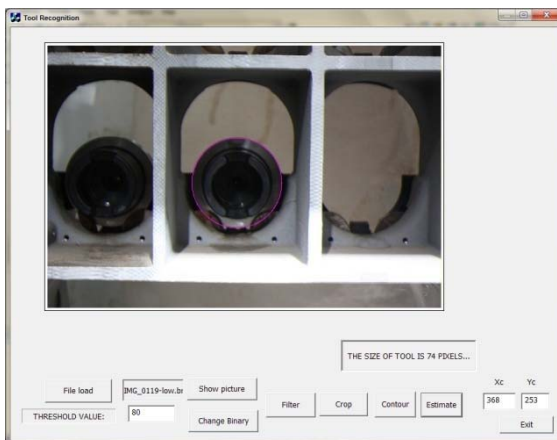


Fig. 9 Program result of present of tool in place

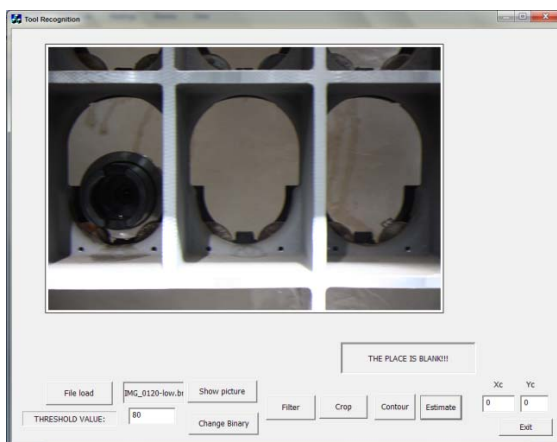


Fig. 10 Program result of absent of tool in place

IV. CONCLUSIONS

To test the program, some pictures of tool magazine are captured by the digital camera. The bmp images are tested with the program, and the execution of the program can examine present or absent of the tool in the desired place of tool magazine. It can also be evaluated the size of tool and the center of the tool if the tool is present in place. The results of the test are shown in Fig. 9 and Fig. 10. The program is written by the help of the Visual C++ in Visual Studio 2008 Software. According to the results of execution of the program, it shows that the algorithm is worth to work with the required control system. For further extension, the program will be extended to execute the real time control system of automation in industrial.

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