OBJECT TRACKING AND CONTROL OF A MODEL TRAIN USING MACHINE VISION TECHNIQUES

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Abstract - Studying a railway signaling system from the actual location may consist of many equipment and enormous costs due to many complexities in the system which require the expert to proceed them. Therefore, the control robotics and vibration (CRV) research group has developed a model train system to benefit the study of the train system. The details of this research began with the study of image processing for detecting and tracking the model train. For machine vision system, there are three main steps of operation which are Real-time image acquisition, Image background subtraction and object tracking. In parts of control system, Fuzzy logic control is used as a method of controlling the model train to stop automatically since the fuzzy logic control is uncomplicated and provides the reasonable logic to make the model train stop at the target accurately.

Index Terms - Machine vision system, Object tracking, Model train, Fuzzy logic control system, Image processing

I. INTRODUCTION

Railway control system consists of many sections such as locomotive,locomotive control system and signaling system. In order to manage all the system smoothly,It is necessary to understand each part of the system clearly.

In this article, we have proposed a model train system for studying a railway system management. Position tracking of the actual train system has various methods such as GPS sensor, calculating from wheel speed and using balise[1] which is installed on a track. But those methods are complicated and required an expert to handle them,so that is why the model train system is supposed to be created. The details of the model train systeminclude two main parts which are Machine vision system and control system.

For the machine vision system, there are three main components involved in the system. The first component is a Real-time image acquisition process which is the process aiming to transform optical image into an array of numerical data, in other wordsthe process transforms an analog image into digital imagewhich is a numeric representation, normally binary, of a two dimensional image.

The Real-time image acquisition process is performed by using LABVIEW which is the softwareproviding functions about image processing and also control system. The second component is an image background subtraction process. In this article, three frames differencing algorithm is used as a background subtraction process[2]-[3] since it is uncomplicatedand provides an effective foreground extraction.

There are four main steps of operation which are frame differencing, Thresholding image, Binary OR operation and Morphological operation on which each operation will be describedfurther. The third component is an object tracking process which is the most significant process of image processing because it is responsiblefor offering the position of the model train to the system and the position is then used to calculate the Euclidean distance that is the input of the control system in this project.

In terms of control system, this project has proposed an application of fuzzy logic control that is used to control the model train to stop at the target accurately.

II. CONCEPT OF USING MACHINE VISION

In this section, the concept of using machine vision will be described. Firstly, the method of foreground detection which is the process extracting the interested object is described.

And then it will be explaining about the use of pattern matching. Finally, the object tracking is described.

1) Foreground Detection

As for the extraction of images of the interested object, the researcher uses the Three frame differencing technique to extract object of interest from the background because this technique is relatively simple and works well with this research.

The method can simply be explained from Fig. 1.

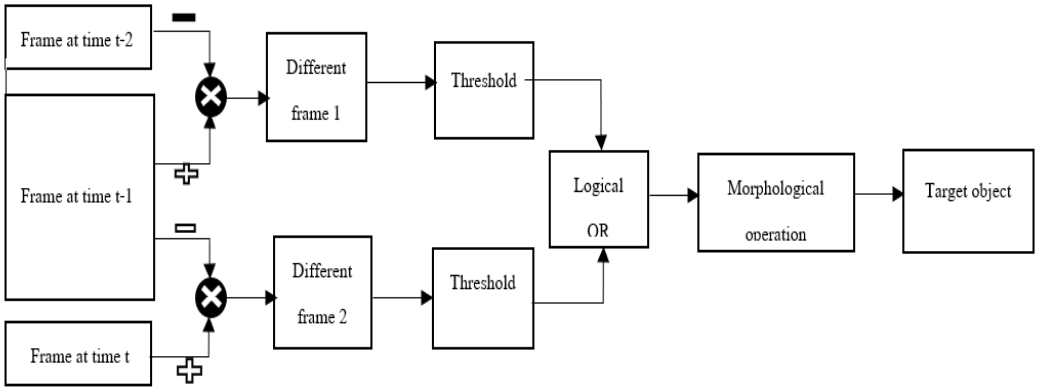


Fig 1: Block diagram of foreground detection

From the figure, the process begins with subtracting two consecutive frames which can be expressed mathematically as equation 1.

$$D_{t+1,t} = |F_{t+1}(x,y) - F_t(x,y)| \quad (1)$$

Where $D_{t+1,t}(x,y)$ is an absolute difference between two consecutive frames of images, $F_{t+1}(x,y)$ is an image frame of image at time t+1 and $F_t(x,y)$ is an image frame of image at time t. By doing so, the process can extract the interested object effectively and the result is shown in Fig. 2.

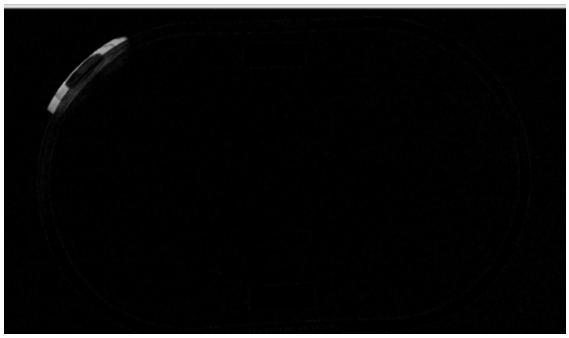


Fig 2: The result of interested object

when obtaining two subtracted images, those images are then partitioned by thresholding in other to separate the interested object more clearly. And the mathematical function of thresholding can be expressed as.

$$D_{t+1,t}(x,y) = \begin{cases} 0, & D_{t+1,t}(x,y) < \text{Threshold} \\ 1, & \text{Otherwise} \end{cases} \quad (2)$$

Where $D_{t+1,t}(x,y)$ is a subtracted frame between two consecutive frames

After that, the result images are combined with binary OR operation since this operation can correct the missing pieces of the object. But in fact, this operation may include noises in the output image,therefore, it needs to be eliminated by using morphological operation. Morphological operation comprises of two sub operations which are firstly erosion and secondly dilation. Erosion is an operation used to eliminate noise and dilation is an operation used to reconstruct the missing pieces of the object caused by erosion. The structuring elements of the two operations are as follow.

Structuring element of erosion operation

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Structuring element of dilation operation

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Finally, the result after being eliminated by erosion and reconstructed by dilation is shown in Fig. 3.



Fig 3: The result of erosion and dilation operations

2) Pattern Matching

When extracting the foreground is done completely, the next step is to search for image that is identical to the template image. Searching image matching to the template image is the process of implementation used to stop the model train at the target accurately.

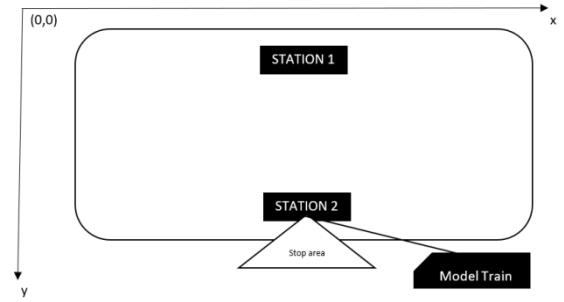


Fig 4: Layout of the model train 1

From the Fig.4, it can be seen that there are two stations in the figure. Our goal is to get the position of the two stations which will then be used to calculate the distance between the model train and the station and then served as the input of the control system further. The algorithm of pattern matching starts with the calculation of image correlation. To do so, the algorithm needs an equation to achieve it.

$$NCC(i,j)=\frac{\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}[w(x,y)-\bar{w}]\left[f(x+i,y+j)-\bar{f}(i,j)\right]}{\left[\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}(w(x,y)-\bar{w})^2\right]^{\frac{1}{2}}\left[\sum_{x=0}^{L-1}\sum_{y=0}^{K-1}(f(x+i,y+j)-\bar{f}(i,j))^2\right]^{\frac{1}{2}}} \quad (3)$$

Equation 3is the normalized cross – correlation equation that is an equation used to calculate the similarity between template image and target image. Where $w(x,y)$ is a pixel intensity of the template image, $\bar{w}(x,y)$ is a average intensity of the template image, $f(x+i,y+j)$ is a pixel intensity of the target image, $\bar{f}(i,j)$ is a average intensity of the target image and L x K is an image size of the template image. The algorithm begins with placing template image on the target image, calculating the NCC value and running over the entire target image. The most matching area on the target image is defined by the area of the target image having the highest NCC value.

3) Object Tracking

Object tracking process is responsible for detecting the region of the interested object extracted by background subtraction.For doing this, LABVIEW provides a function called count object vi which is the function that performs tracking white or black blob on the image as shown in Fig. 5.

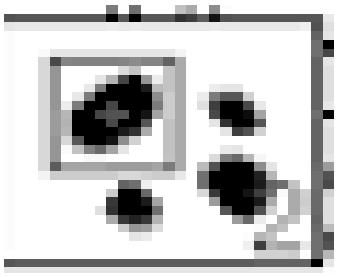


Fig 5: Count object vi

By using count object function, the system can get the position on x and y axis of the model train in real time.

III. CONTROL SYSTEM DESIGN

As mentioned earlier that fuzzy logic control is applied in this project. The design of the fuzzy controller of this research firstlystarts by defining input and output of the controller. Where the input of the controller in this research is the distance between the model train and the terminal.And then determine a set of real numbers from 0 - 2000. These values are derived from calibration offinding the most highestdistance between the model train and the terminal. After that, create a Membership function explained from Fig.6.

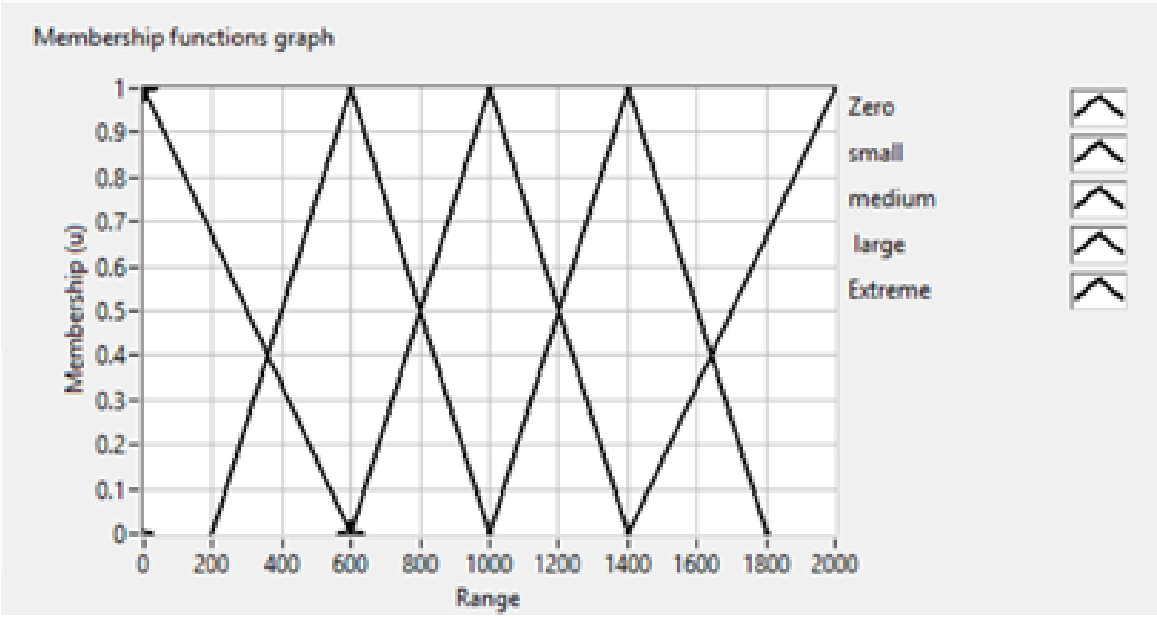


Fig 6: Input membership function

The figure above isthe window to create a Membership function such that the Membership function is a triangle which has the following mathematical functions as (4).
Triangle membership function

$$\mu_A(x) = \begin{cases} \frac{x-a}{b-a} & , a \le x \le b \\ \frac{a-x}{b-a} & , b \le x \le c \\ 0, & x < a \text{ or } x > c \end{cases} \quad (4)$$

Where a, b and care constant and a < b < c

The member function has its own name and these names are Linguistic variable that will be used to convey the meaning of input and output signals. In terms of input, the researcheruses 5 words, including "Zero", "Small", "Medium", "Large" and "Extreme". The meaning of each word is as follows.

"Zero" means Incoming inputs are very small.
"Small" means Incoming inputs are relatively small.
"Medium" means Incoming input is moderate.
"Large" means Incoming input is quite large.
"Extreme" means Incoming input is large.

For output, the sequence of steps is the same as the input. Membership function uses the same function as input which is shown in Fig 7.

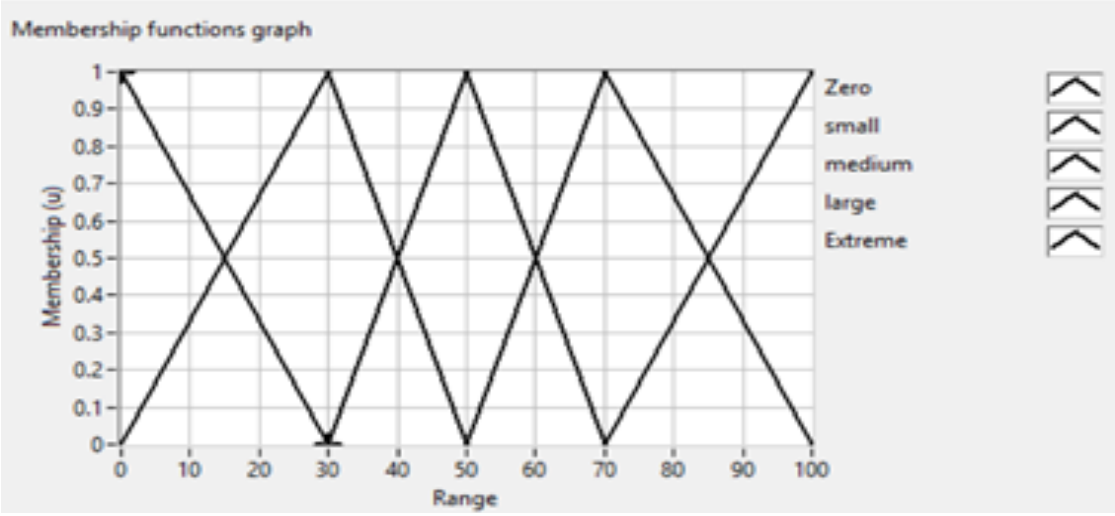


Fig 7: Output membership function

From the figure, it can be seen that the set of output values is a set of positive real numbers that ranges from 0 - 100. These values are the amount of PWM signal output to the motor of the locomotive. Forlinguistic variable, the researcher uses 5 words like inputs such as "Zero", "Small", "Medium", "Large" and "Extreme". The meaning of each word is as follows.

“Zero" means Output is very small.
"Small" means Output is relatively small.
"Medium" means Output is moderate.
"Large" means Output is quite large.
"Extreme" means Output is large.

Then another important part of creating a fuzzy control is to create aRule base.In this part,the researcheruses 10 rulesthat is concluded in the tableI.

Table I. Rule – base table

INPUT	ZERO	SMALL	MEDIUM	LARGE	EXTREME
OUTPUT	ZERO	SMALL	MEDIUM	LARGE	EXTREME

After determining all of the Rule-base, the process of Defuzzification is carried out.From Fig.8, it can be seen that this research uses the center of area as the Defuzzification method, which is to determine the center of the area.

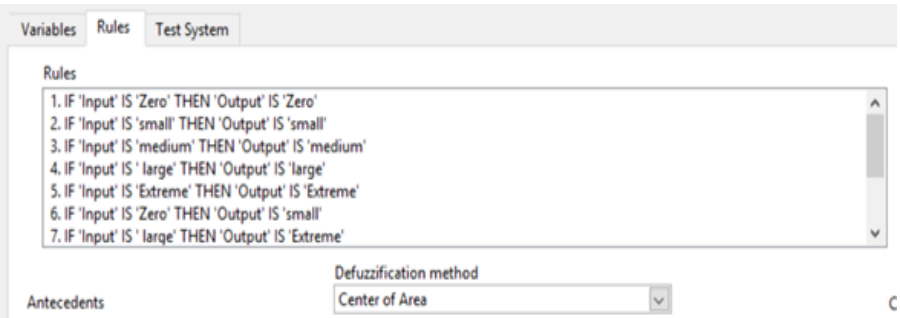


Fig 8: Defuzzification method

IV. METHOD OF IMPLEMENTATION

Parking control concept of the model train uses the principle that When the distance between themodel train and the terminal is greater than zero The model of the train will then move to the terminal as shown in Fig.9.

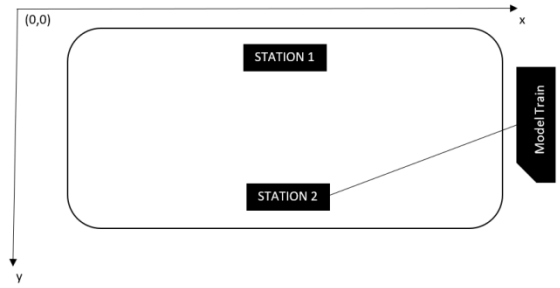


Fig 9: The layout of the model train 2

The speed depends on the distance calculated by equation5.

$$d(x,y) = \sqrt{(x_{Station} - x_{Model\ train})^2 + (y_{Station} - y_{Model\ train})^2} \quad (5)$$

Where d(x,y) is a Euclidean distance between the model train and the terminal, $x_{Station}$ and $x_{Model\ train}$ arethe position of the terminal and the model train on x-Axis, $y_{Station}$ and $y_{Model\ train}$ arethe position of the terminal and the model train on y-Axis.As mentioned earlierthat the fuzzy logic control is used to control the speed of themodel train. With this concept, the model train can precisely park at the terminal.

CONCLUSION

Since the machine vision system part of this research is intended to tracking the model train, which has a certain shape and does not change with time,In addition, the background of the image, which is neglected on the image, does not change with time as well.So the algorithm used in extracting objects of interest and motion detection can be done efficiently and the priceof the devices is not too high.

For the control system, Controller used in this project is able to meet the objectives sincethefuzzy logic control system is a controller that can effectively be used without a mathematical model. That makes the operation easy ,as well as, the controller design in this research can also control the model to park at the terminal quite accurately.

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