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Study of Storage Yard PRIC Key Technologies Based on Modern Measurement and Control

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Abstract: - Pattern recognition and intelligent control (PRIC) based on modern measure and control is developing with the important challenge that machine how to percept external environment information. At the same time, storage yard automation guarantee the efficiency to modern industry and storage yard PRIC technology is the leading edge of storage yard automation. Storage yard PRIC key technologies include fuzzy diagnosis technology in intricate storage yard background based on multidimensional decision-making method using composed fuzzy logic in image matching and hardware system composed of embedded system.

Key-Words: -Storage yard, PRIC technology, Image matching, Fuzzy theory, Embedded system

1 Introduction

Pattern recognition and intelligent control (PRIC) based on modern measure and control is developing with the important challenge that machine how to percept external environment information [1]. The content of PRIC is involved in lots of subjects such as informatics, computer science, control theory, fuzzy theory [2] [3], expert system, applied mathematics, physics, biology, and so on [4]. Along with the development of modern technology, the combination of pattern recognition and intelligent control will certainly change mature with each passing day, and PRIC will be more and more applied in industry operation, aerospace remote sensing, biomedicine, fingerprinting, product detection, etc.

Storage yard automation refer to the automation of deposition and withdrawal of raw material, inventory calculations, yard layout and feed charging schedule, etc. The raw material and products in storage yard are the produce kern of industrial enterprise. It is important of rapid materials circulation and accurate management information to expedite modern manufacture. The actuality of storage yard in China is extensive floor space and dispersed equipment. All these will bring major difficulty in production operation and production control, and increase the cost at the same time. Taking a wide view, even the high automaticity storage yard in China, just realize system device automation, such as: the automation of stocker for material accumulation, the automation of reclaimer machine for collecting material. The stock ground supervision and real time stockpile and so on, are still rely on manhandle in a large degree. Storage yard automation guarantee the efficiency to modern industry and storage yard PRIC technology is the leading edge of storage yard automation. Storage yard PRIC key technologies include fuzzy diagnosis technology in intricate storage yard background based on multidimensional decision-making method using composed fuzzy logic in image matching and hardware system composed of embedded system.

It is difficult to confirm the reference point and detect image for the intricate storage yard background, and fast precise matching image means is one of the key technology in storage yard PRIC. The multidimensional decision-making method using composed fuzzy logic in image matching is adopted according to the practical situation in storage yard. The normally used methods to match images these years are MAD, CF, CCF, etc. However, all these classical characteristic space dimensions have their own limitations to be used under complicated background situations. In order to gain high matching-rate, this paper adopts a multidimensional decision-making with composed fuzzy method to match images. This method can be used to make matching more accurately with little operation cost added, so as to promote the research in this area into practical techniques with a great step.

The dissertation take full advantage of the optimized, minitype and nesting structural embedded control system of single board computer and combine with image processing techniques to obtain industry spot images, which are processed as digital signal to gain image eigenvalue. Then the system complete industry autocontrol course in accordance with homologous steering orders which are determined by the image eigenvalue.

2 Multidimensional Decision-Making Method using Composed Fuzzy Logic in Image Matching

Aim of image matching in storage yard PRIC technology is to find the optimal position of "Reference Point Template" images on "Scene" images and detect images. In the paper we use the "Composed Fuzzy Logic" to decide the correlation between reference point templates and scenes.

2.1 Composition of the fuzzy system

The core of a fuzzy system is an "Inference Engine". First, several input fuzzy sets are composed of fuzzy logic operators. Then the inference engine uses the fuzzy logic operators to infer several output fuzzy sets guided by some IF-THEN expert regulations. Those regulations can be found in an expert knowledge base. The composed output fuzzy sets consist of the result of the fuzzy system. Since in the practical systems inputs and outputs are usually not fuzzy but definite, an applicable fuzzy system should have "Fuzziers" and "Defuzziers" to switch between definite data and fuzzy sets. The usual way is to use "Membership Function" which is a fuzzy mathematical concept. A block diagram of a fuzzy system is shown in Fig. 1 [5].

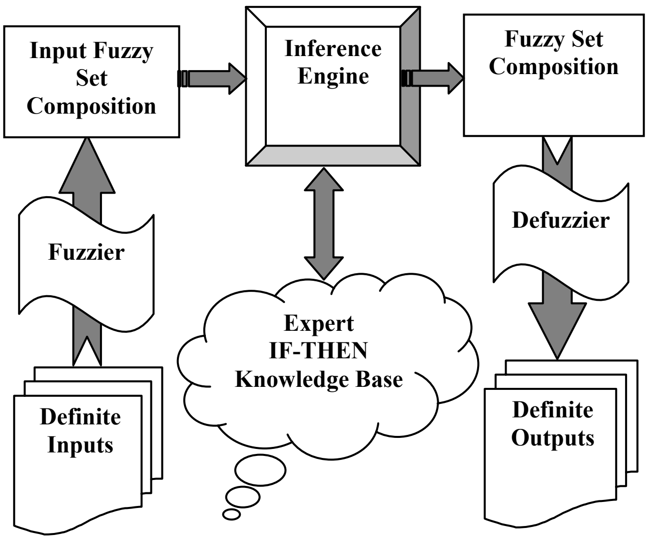

Fig. 1 Block diagram of a fuzzy system

2.2 Cost Function of Fuzzy similarity and Its Simplification

We can use the "maximum S-norm" to define the "Fuzzy Similarity" with:

$$simFS(S,R)=\max\begin{Bmatrix} simMSD(S,R) \\ simCF(S,R) \\ simCCF(S,R) \end{Bmatrix} \qquad (1)$$

Here $S=S(x,y)$ and $R=R(x,y)$ are the image matrices of the "Scene" and the "Reference Point Template".

Where

$$simMSD(S,R)=1-\frac{1}{256}\sqrt{\frac{\sum_x\sum_y(S-R)^2}{A}} \qquad (2)$$

is similarities defined by the hyper-plane dimensions of Mean Square Distance(MSD). Here A is the geometry area of the image. So as,

$$simCF(S,R)=\frac{\sum_x\sum_y S\cdot R}{\sqrt{\sum_x\sum_y S^2}\sqrt{\sum_x\sum_y R^2}} \qquad (3)$$

is similarities defined by the hyper-plane dimensions of Correlation Factor(CF). And,

$$simCCF(S,R)=\frac{\sum_x\sum_y(S-\bar{S})\cdot(R-\bar{R})}{\sqrt{\sum_x\sum_y(S-\bar{S})^2}\sqrt{\sum_x\sum_y(R-\bar{R})^2}} \qquad (4)$$

is similarities defined by the hyper-plane dimensions of Corrected Correlation Factor(CCF).

In formula (4) where $\bar{S}=\frac{1}{A}\sum_x\sum_y S$ and $\bar{R}=\frac{1}{A}\sum_x\sum_y R$ are the average brightness of the scene and the reference point template [6].

Considering formula (1), we define a semantic sentence as the expert regulation: "A template is similar with scene where one of these similarities is very high." For example, we can say the similarity is higher than 90% if MSD is higher than 0.9, no matter how low CF and CCF are. In another word, if MSD is high or CF is high or CCF is high, FS will surely be high. The method can be implemented as the following steps:

Step 1: Calculate the three similarities defined in formula (1) over the whole scene.

Step 2: Choose the one with the maximum value as the fuzzy similarity to represent the similarity of the position.

Step 3: Choose the maximum fuzzy similarity of any position

In the position determined in step 3, we can say the reference point template and the scene matches best.

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In fact, any S-norm such as Dombi S-norm, Dubois-Prade S-norm, direct sum, Einstein sum and algebraic sum [7] can be used in this method. Instead of using "maximum S-norm", we can define the fuzzy similarity in many different ways using different S-norm operations.

To simplify formula (1), we let

$$\begin{cases} sumS = \sum_x \sum_y S(x,y) \\ sumR = \sum_x \sum_y R(x,y) \\ sumSS = \sum_x \sum_y \left[S(x,y)\right]^2 \\ sumRR = \sum_x \sum_y \left[R(x,y)\right]^2 \\ sumSR = \sum_x \sum_y S(x,y)\cdot R(x,y) \end{cases} \quad (5)$$

Then

$$simMSD(S,R) = 1 - \frac{1}{256} P_1 \quad (6)$$

where,

$$P_1 = \sqrt{\frac{1}{A}\left(sumSS + sumTT - 2sumST\right)}$$

In the same way, we can take advantage of the sequence from formula (5) to get $simCF(S,R)$ and $simCCF(S,R)$ as following:

$$simCF(S,R) = \frac{sumSR}{\sqrt{sumSS}\sqrt{sumRR}} \quad (7)$$

$$simCCF(S,R) = \frac{sumSR - \frac{1}{A} sumS \cdot sumR}{\widehat{S}\cdot\widehat{R}} \quad (8)$$

So formula (1) can be simplified as following formula (10),

$$simFS(S,R) = \max\left\{ \begin{array}{l} 1 - \frac{1}{256}\widehat{P}_1, \\ \frac{sumSR}{\sqrt{sumSS}\sqrt{sumRR}}, \\ \frac{sumSR - \frac{1}{A} sumS\cdot sumR}{\widehat{S}\cdot\widehat{R}} \end{array} \right\} \quad (9)$$

where

$$\widehat{S} = \sqrt{sumSS - \frac{1}{A}\left(sumS\right)^2}$$

$$\widehat{T} = \sqrt{sumTT - \frac{1}{A}\left(sumT\right)^2}$$

3 Intelligent control system based on embedded system

We take full advantage of the optimized, minitype and nesting structural embedded control system of single board computer and combine with image processing techniques to obtain industry spot images. Then the system complete industry autocontrol course in accordance with homologous steering orders which are determined by the image processing outcomes.

3.1 System Hardware Organization

Storage yard PRIC system take the embedded computer as its pith, and network cameras are fastened to stockers which answer for material accumulation and reclaimer machines which answer for collecting material by forming binocular vision system. The captured images are disposed in embedded industrial computer, and the corresponding outcomes are used to control PLC which manages the operation of electric machine for storage yard PRIC system. All these relevant treating process are uploaded to upper computer by wireless networks. The block diagram of hardware system can be seen in Fig. 2.

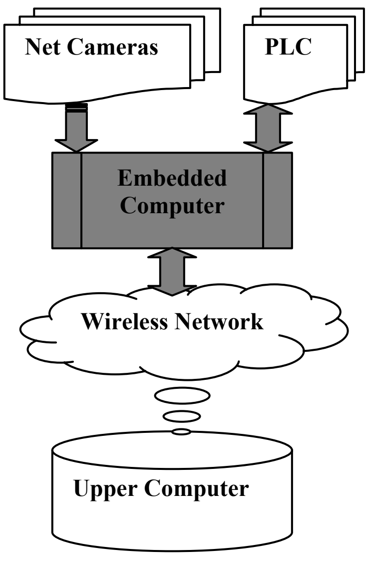

Fig. 2 Block diagram of hardware system

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3.2 System Hardware and Software Description

The hardware and software used in storage yard PRIC system are described as following.

3.2.1 Corresponding Software

The corresponding software include protocol adapter for peripheral equipment, such as net camera and PLC, and image capture and processing segment, target tracing control segment, fast tracing device driver segment, etc.

The operating system adopts Windows® CE for its well-suited characteristic and applicability.

All the software are developed by language C#, for it provide a simple, safe, modern, object-oriented, Internet-centric, and high-performance language for .NET development.

Fig. 3 shows the flow chart by Multidimensional Decision-Making Method using Composed Fuzzy Logic in Image Matching to find reference point template.

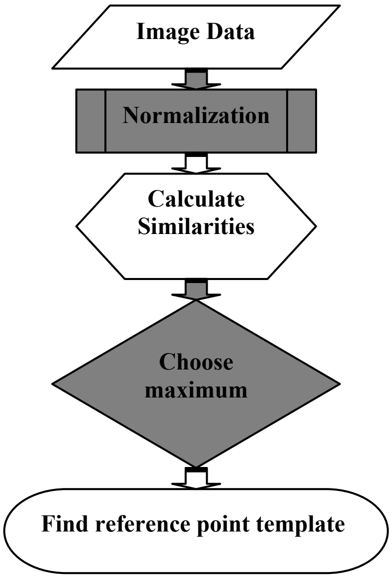

Fig. 3 Flow chart of matching images

The image data are captured by net cameras, and every scene is normalized according to formula (5) in the embedded single board computer. At the same time, calculate the similarities of $simMSD(S,R)$, $simCF(S,R)$ and $simCCF(S,R)$ in term of formula (6), (7), and (8). While choose the maximum fuzzy similarity of every scene just like formula (9), we can find the reference point template and the scene matches best.

3.2.2 Corresponding Hardware

The corresponding hardware include net camera, embedded system Pentium III single board computer, fast tracing device, PLC system , etc. In all these hardware, embedded single board computer is the core instrument which disposes the images and control PLC in one hand, communicate with upper computer through wireless net on the other hand.

Here we choose the Advantech's PCM-9575 [8], which is a new EBX form factor 5.25" single board computer (SBC) with an onboard new VIA Embedded low power Ezra 800MHz processor. This SBC includes a 4X AGP controller, a PCI audio interface, a PCI Ethernet interface, and 2 channel LVDS interface. Its design is based on the EBX form factor that supports the PC/104-Plus interface for ISA/PCI module upgrades. Other on-board features include a PCI slot, an LPT, 2 USBs, IrDA and 4 serial ports: 3 RS-232s, and 1 RS-232/422/485. The SSD solution supports both Disk On Chip® 2000 and CompactFlash™ cards.

The main features of this embedded single board computer using in storage yard PRIC system are as following:

• Embedded low power VIA Ezra 800MHz processor

• Applied EBX form factor standard and supports PC/104+ bus

• Fanless operation at 60ºC

• 133MHz FSB and 4X AGP graphics for high performance applications

4 Experimentation Result

Take a series pictures of the reference point target as the template image under cloudy condition. See fig. 4, where the white column is the reference point with black ring information on it.

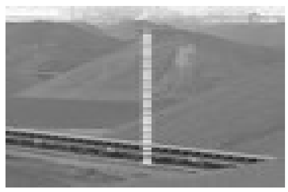

Fig. 4 Template under cloudy weather

Choose three kinds of conditions to do the comparative experiments (see Fig. 5). In Fig.5, a shows the scene under cloudy condition, and b shows the scene with reinforced illumination, while c shows the scene corrupted by Gaussian noise.

From Fig.5, it presents comparative snapshots of the scene under three conditions. The MSD, CF, CCF and multidimensional decision-making method using composed fuzzy logic as shown in formula (9),

a b c

Fig.5 The scenes under three kinds of conditions

whose shortened form is FS algorithm here, are used to find the matching template [9].

The table below shows the accuracy of the recognition experiments with the tracing ranging from 420 to 80 meters (see Table 1, these values are the mean of three kinds of conditions.).

Table 1 shows that, although FS method costs more processing time, it does raise the accuracy rapidly as the effect of introducing fuzzy set composition. Also, the cost is only 4ms longer than CCF method. If the time spent on capture device is considered (this cost can almost be ignored since the concurrency of hardware), FS method can satisfyingly fit the respond speed of 40 fps under our experimental condition. In other words, suppose the capture speed is 40 fps (Note: the capture speed of A601f is 60 fps which is higher than the commonly used 30 fps or 25 fps):

$$T_s = 24ms < T = \frac{1}{40} ms = 25ms \tag{10}$$

Table 1 The accuracy of the recognition experiments

Algorithm	***Accuracy/***%	***Time cost perframe/***ms
MSD	80	12
C F	80	15
CCF	82	20
F S	91	24

Among four algorithms, MSD is the simplest and fastest method and directly reflects the original template, but it is too sensitive to the changes in brightness. So the MSD algorithm more likely to underestimate than to overestimate the similarity. When the brightness of an image changes a lot, the MSD method becomes less effective. The CF method has a clear concept and can be easily represented mathematically, but it is a little difficult to implement. Using the CF method can resist multiplicative brightness change rather than additive change. Based on statistical estimation, the CF method may sometimes overestimate the similarity. The CCF methods can adapt to both additive and multiplicative brightness changes very well, but it has inherited all the other shortages of CF method. It is even more difficult to implement and may easily overestimate the similarities than CF method, especially under conditions with a lot of noise.

5 Conclusion

Storage yard automation [10] is important of rapid materials circulation and accurate management information to expedite modern manufacture. The technology of pattern recognition and intelligent control (PRIC) based on modern measure and control is the leading edge of storage yard automation.

In this dissertation, the key technologies of PRIC system, such as image matching and hardware composed are discussed. Multidimensional decision-making method using composed fuzzy logic in image matching is tested and is validated its applicability in the intricate storage yard background. About hardware, the storage yard PRIC system takes full advantage of the optimized, minitype and nesting structural embedded control system of single board computer. With this board its PC/104-Plus interface, it is convenient for us to expand the peripheral equipments.

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