UDC681.3:165:669.1

Development and Application of Character Recognition System in Factory Automation Field

Seishirou Takeuchi*1 Osamu Taniguchi*1
Satoru Yamaguchi*1 Minoru Maeda*1

Abstract:

A character recognition system, designated CR30, was developed as an application of character recognition technology in the factory automation (FA) field. The technology and characteristics of the CR30 are described, and application examples of the CR30 at steel plants are introduced.

1. Introduction

The markedly improving performance of microprocessors in recent years has accelerated the attempts to incorporate the latest technology into computers for application in a variety of fields.

One such technology is the image recognition engineering field, which has been a subject of research and development since the advent of computers. As one branch of image recognition engineering, character recognition technology has been studied and applied extensively.

The authors have developed character recognition systems for the factory automation (FA) field, which has lagged behind the office automation (OA) field in terms of commercialization of character recognition technology. Now that character recognition systems have demonstrated their effectiveness mainly in steel production, the outline and typical achievements of the character recognition technology are introduced here.

2. Character Recognition Technology and Its Problems in FA Field

2.1 Application of character recognition technology

Character recognition technology has a long history of research. Various algorithms, from classical template matching and multiple similarity to the latest neural network theory, have been proposed. The basic theory of pattern recognition technology, including character recognition technology, is still in the research and development stages.

*1 Electronics & Information Systems Division

The evolution of the advanced information age has created the job of entering large amounts of character data into computers and the need for automating character data entry using character recognition technology. To meet these needs, technological development has been carried out to apply character recognition in the OA field. These efforts have culminated in optical character readers (OCRs) for ZIP Codes and documents, and character recognition has become a well-known technology in the OA field.

The applications expected for character recognition technology in the FA field are the reading of production numbers and other information written on products, and the automatic input of production and distribution control data into factory computer systems. Expectations are high for adapting character recognition technology to high-temperature materials on which bar codes and other markings cannot be used.

2.2 Problems with applying character recognition technology in FA field

Attempts have been made to apply character recognition technology to a variety of objects in the FA field, but character recognition technology has not succeeded as the OCR has done in the OA field.

The problems with the application of character recognition technology in the FA field are summarized below.

2.2.1 Problems with character recognition processing in FA field

Character recognition in the FA field covers not only characters written on paper as in the OA field, but also characters written directly on products moving on production lines. Images contain not only characters, but also background, and noise resulting

form various contaminants. Character images are greatly changed by disturbances due to unsuitable lighting and other causes, and character images of poor quality must be often handled.

Character recognition in the FA field is often required to perform complex processing peculiar to specific manufacturing processes.

2.2.2 Problems with incorporation of character recognition system into manufacturing processes

Character recognition in the FA field is mainly used to read production numbers written on products and check them with production schedules.

Character recognition systems must be thus designed to connect with computer systems of various users. They must also be reliable enough to be built into the manufacturing process and adapted to all operations from image data input to collation with scheduled data.

2.2.3 Problems with image character recognition engineering

In many cases, humans can simply read characters, but pattern recognition technology, including character recognition technology, has large gaps between its actual capability and expected capability. The application of pattern recognition technology calls for various constraints to be imposed.

For example, let us compare the human eye with a character recognition image input mechanism, including a CCD camera. The visual function of humans can extract a target object by finding the target in a wide field of view and control the focal point of the eye. For the character recognition system to perform the same process, complex camera control and sophisticated image processing or pattern recognition are required.

If the position of objects on the line is controlled to fall within the field of view of the camera, the same function as the visual function of a human can be easily accomplished.

When introducing a character recognition system on a production line, it is important to perform comprehensive image processing and character recognition engineering, including not only the character recognition and image processing functions, but also the method of writing the character, and considering how to introduce the system, and how to operate it .

When character recognition technology is applied in the FA field, expensive, dedicated character recognition systems are often required due to the unique characteristics of specific manufacturing processes or products, technical difficulty of image processing or character recognition, and the high load associated with the incorporation of the character recognition system into the line. The resultant drop in cost performance has often precluded the application of character recognition systems in the FA field.

Considering the above problems, the authors developed the character recognition system CR30 with the goals of providing rich image processing and character recognition functions, assuring easy incorporation, and ensuring a system of high reliability at relatively low cost.

The development work particularly focused on the optimum platform environment where comprehensive image processing engineering can be easily carried out. **Photo 1** shows the general view of the standard CR30 system.

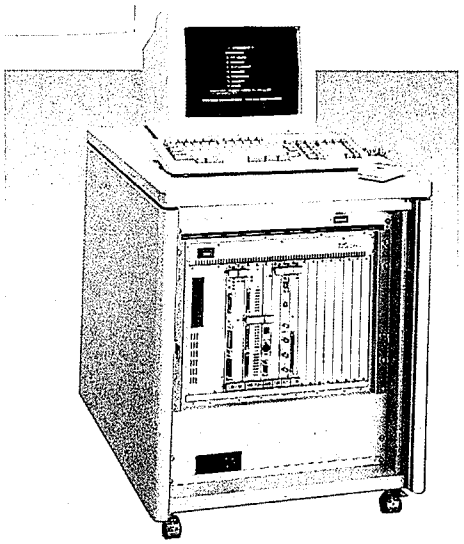


Photo 1 General view of FA character reader CR30

3. Characteristics and Technology of CR30

3.1 High recognition of various character types

3.1.1 Character recognition engine[1)]

One difficulty of character recognition in the FA field is that it must adapt to characters of various shapes. Various types of characters, such as ink jet printed characters stenciled characters, and printed or marked characters are used on specific objects. Printed characters in the same font greatly change in shape under the influence of noise.

A character feature extraction algorithm based on the weighted direction index histogram method capable of recognizing handwritten Chinese kanji characters at a high rate, and the modified Bayes discriminant function are adopted as the core of the character recognition algorithm of the CR30 to handle a wide variety of character fonts and changes in the shape of character images. Character recognition, including that of handwritten characters, in the FA field has been achieved by adopting this method to substantially improve the recognition performance and handling of various kinds of characters.

3.1.2 Dictionary for recognition

The dictionary to be used in the discriminant function of the character recognition algorithm is created by the principal component analysis method, which can reflect the deformation of images due to noise and small printed character defects.

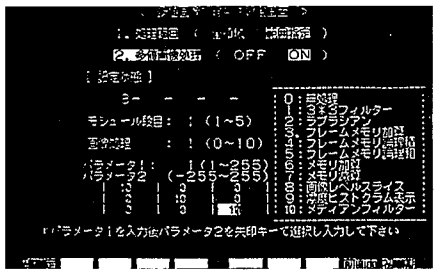
A dedicated dictionary that includes the effect of noise can be simply made by sampling characters on the production line in the dictionary registration and creation stages.

3.1.3 Image processing

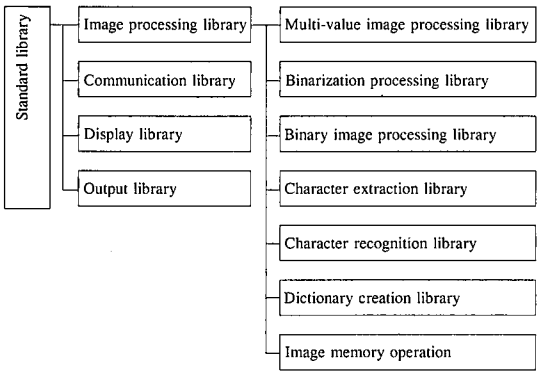
Character recognition is difficult to achieve in the FA field, mostly because character contamination and image noise vary depeding on manufacturing process and objects read, and because noise cannot be eliminated by simple processing. That is, noise elimination calls for a complex image processing optimization characteristic for each specific object.

An image processing library effective for eliminating various types of noise was developed and installed in the CR30. For the ease of optimizing, image processing functions can be interchanged and set on a menu.

Fig. 1 shows the way a given filter can be simply designed on a menu and the configuration of processing libraries.



(a) Multi-value image processing function setup screen



(b) Standard library configuration

Fig. 1 CR30 image processing functions

The CR30 also has an environment in which the image processing algorithm can be additionally developed on the image processing board as software with the digital signal processor (DSP).

3.2 System for easy production line customization

The CR30 can be easily built as a system adapted for the operation of a particular line, connected with surrounding equipment, including the process computer system, and expanded. In other words, an easy-to-use and low-cost dedicated character recognition system with a custom-made machine interface that can be furnished to suit the operations of a particular production line and the wishes of the operator. **Fig. 2** shows the basic hardware configuration of the CR30.

3.2.1 Operating system

The fundamental operating system (OS) of the CR30 is OS/9*(1) /68K, a compact multitask and real-time OS. All applications can be easily developed on the main CPU board by using the dedicated CR30 libraries. The dedicated applications can be customized from recognition system modules to user-machine interfaces and communication control with other computer systems. As described above, an optimum dedicated application system can be supplied at low cost to meet the operation and peripheral equipment of a particular production line.

3.2.2 Expandability of hardware functions

The VME system is adopted as the fundamental architecture of the hardware of the CR30. The open system allows additional

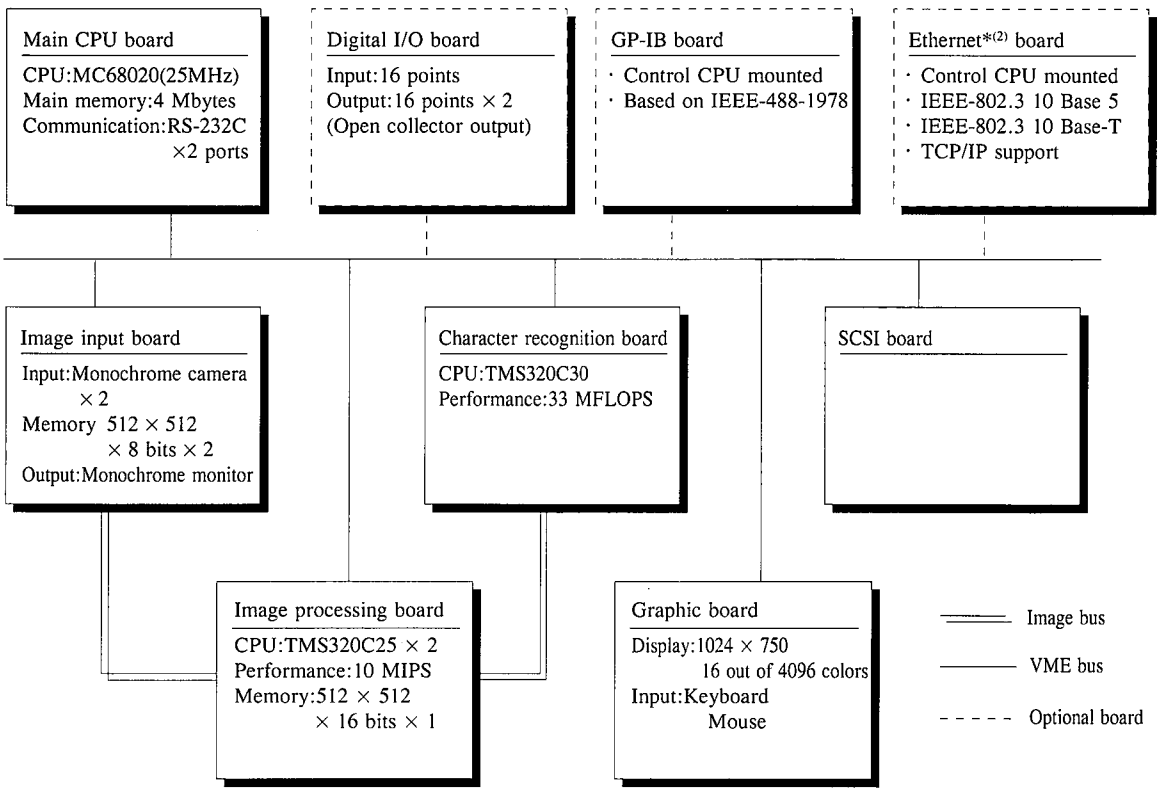


Fig. 2 Hardware configuration of CR30

*(1) OS/9 is the registered trademark of Microware System Corp.of the United States.

*(2) Ethernet is the registered trademark of Fuji Xerox Co.,Ltd.

hardware functions to be added by installing various commercially available general-purpose VME specific boards into the system.

The CR30 system is basically composed of image processing and character recognition boards. Other boards can be changed or added to meet specific applications. For example, PI/O, RS232C and TCP/IP boards can be added as required to augment the communication function, and the basic processing functions can be expanded by adding image memory, camera input, and other boards.

4. Application Examples of CR30 System

4.1 Application to reading characters marked on hot products (example of bloom number recognition system)

In the steel industry, semifinished products like slabs and blooms are manufactured at the steelmaking plant and according to production instructions are supplied to hot strip, plate, wire rod, pipe, or other mills.

At each receiving mill, the product numbers marked on the surfaces of the red-hot slabs and blooms at the steelmaking plant are read to verify production schedule information with the actual products.

There was a strong need for automating this verification of product numbers by character recognition, but conventional character recognition systems could not accurately recognize them. This was because of the great change in character image resulting from poor character image and noise. This restriction created a bottleneck in steelmaking line automation.

Introduced here is a bloom number recognition system using the CR30 that has succeeded in reading hot-marked product numbers with a high recognition rate.

4.1.1 Optimization of recognition process

Photo 2 shows examples of bloom numbers to be read. Image quality greatly changes with such factors as the condition of the marking machine used and the time elapsed after marking. Therefore, faint or blurred characters must often be recognized.

When unclear character that greatly change in shape are to be read with an image processing unit, it is difficult to adapt to the change in character shape by using image processing alone.

Given this technical limitation, a system was built that performs image and character recognition processing with different characteristic functions several times, the determines the highest reliability results from the obtained results according to an evaluation function. Consequently, a character recognition and processing system that performs accurately was obtained for the first time (see **Fig. 3**).

This technology is an example of an optimum recognition and processing system built by freely combining the highly expandable and various image processing functions of the CR30.

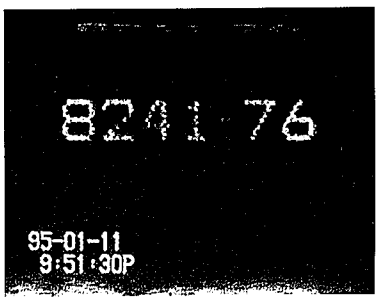
4.1.2 Optimization of system

When operators cannot read illegible bloom numbers, they infer the bloom number from preceding and succeeding characters or from the previous bloom number.

The bloom number recognition system does not use any automatic inference engine entrusts the visual judgment of the operators for but all characters it fails to recognize. When it cannot read a character, the bloom number recognition system informs the operator of the condition with a buzzer and displays the character image on the monitor screen in front of the operator at the same time. Until the operator confirms the character, the line is interlocked to stop the transfer of the bloom. In this way, any unrecognized blooms are prevented from advancing. All of the bloom number images processed are recorded together with their processing day and time in a video tape recorder, and the image processing results are printed out. This bloom acceptance monitoring environment is an improvement on previous monitoring systems.

The bloom number recognition system can now automatically

(a) Thick characters



(b) Thin and blurred characters

Photo 2 Examples of characters marked on hot blooms

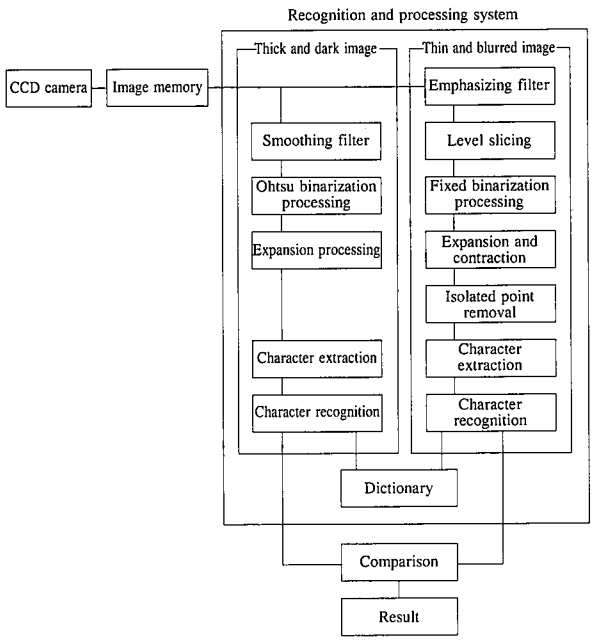


Fig. 3 Recognition and processing system for greatly changing image quality

check more than 95% of incoming blooms on average and free the operators from the visual verification of incoming blooms with schedule information.

4.2 Application to billet number recognition (example of stamped character recognition)

In the steel industry, there is a considerably high need for directly reading the stamped characters on semifinished products.

A system that recognizes numbers stamped on the ends of billets is described below as an application of the CR30 for stamped characters.

4.2.1 Optimization of recognition and processing system

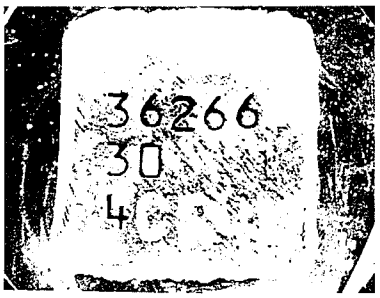
One difficulty with the recognition of stamped characters is that their images greatly change with the depth of the stamp and the condition of the stamped surfaces. The stamped characters are shown on the screen by detecting the shadow they produce. When rust of a darker color than the shadow of the stamped characters is present, or the shadow cast by cut edge irregularities remains on the stamped surface, these phenomena are considered as noise. The recognition performance of the system greatly depends on whether or not these sources of noise can be removed.

Given that stamped characters are practically unchanged in character line width, noise was removed from stamped character images by using a filter that selectively emphasizes images of the character line width. **Photo 3** shows a raw billet number image and the result of a filtered billet number image for recognition.

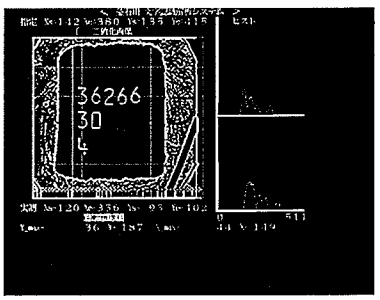
Billets are square in shape and are sometimes turned through 90° during transfer. Characters are stamped on billet surfaces in such a way that the rotational direction of each billet can be determined by image processing.

A special image processing algorithm, including the design of the above-mentioned special filter and the detection of the rotational direction, was achieved with relative ease by the combination of the CR30 libraries.

4.2.2 Optimization of system



(a) Raw camera image



(b) Processed image

Photo 3 Examples of characters stamped on billet

Introduced here is a character recognition system for a billet table at a wire rod mill. The character recognition system reads the billet numbers in a lot on the billet table before the billets are sent to the next step at the wire rod mill.

In terms of hardware, video equipment — such as an image memory device and video switching device — can be added to the CR30 so that the system can process character images typical to the operation of specific lines. The cross-sectional images of up to 13 billets arranged on the billet table are recorded into each image memory by moving and controlling the camera position. When the recording of billet cross-sectional images is completed, the images are sequentially inputted into the CR30 and processed to recognize the characters stored. When the recognition processing of the billets is completed, the results are sent to the process control computer (see **Fig. 4**).

When a character image is rejected by the character recognition and processing system, it is shown on the monitor screen. The operator identifies the character image and enters the correct billet number via the backup terminal.

As described above, the stamped billet character recognition system provides a user-machine interface adapted to the operation of actual manufacturing processes, and its high recognition performance contributes greatly to process automation.

5. Conclusions

Besides the characters marked on hot blooms and the characters stamped on cold billets as described in the application examples discussed above, the CR30 has been applied to the recognition of various other characters, including numbers marked on coils and characters handwritten on labels. It is therefore making great contributions to automation in the processes where it is used.

Because of the excellent performance results of character recognition technology in areas where its practical application was considered difficult, new application potentials for character recognition technology have been realized.

The present CR30 system constantly reflects the experience and expertise accumulated to date in its processing libraries, and has markedly improved in performance compared with the first model.

The CR30 system has succeeded because the authors have not insisted on enhancing the performance of the optical character reader and have fully recognized the incompleteness of character recognition technology. This success owes much to comprehen-

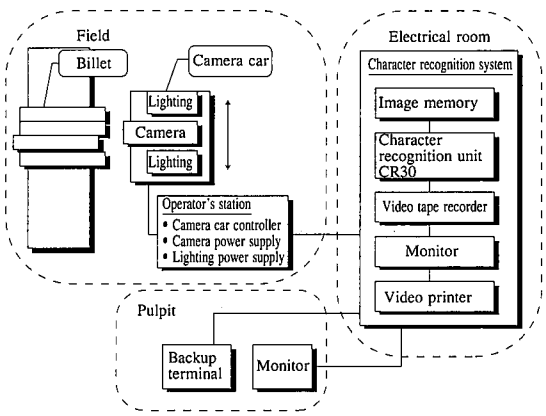


Fig. 4 Stamped billet character recognition system (billet table system)

sive image processing and character recognition engineering, with encompasses the study of character writing, system operation in the implementation phase, camera lighting and other optical system designs, and the suppression of electromagnetic noise at actual mills.

The authors would like to thank users and others concerned with affording opportunities for applying the CR30 system and for providing advice and support from the time when the CR30 system was functionally incomplete.

Reference

1) Miyake, K. et al.: Transactions D of Institute of Electronics, Information and Communication Engineers. 70 (7), 1390 (1987)

*The names of hardware and software described in this report are the trade names or trade marks of specific manufacturers.