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Implementation of Process System and Intelligent Monitoring Environment using Neural Network

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Abstract

This research attempts to suggest a detecting method for cutting position of an object using the neural network, which is one of intellectual methods, and the digital image processing method. The extraction method of object information using the image data obtained from the CCD camera as a replacement of traditional analog sensor thanks to the development of digital image processing. Accordingly, this research determines the threshold value in binary-coding of an input image with the help of image processing method and the neural network for the real-time gray-leveled input image in substitution for lighting; as a result, a specific position is detected from the processed binary-coded image and an actual system designed is suggested as an example.

Key words : Image Processing, Neural Networks, processing system

1. Introduction

More amount of or more complicated data has been processed thanks to the recent rapid industrial and computer technology development, and especially, the performance and processing technology of cameras, which correspond human's visual organ, has considerably been developed thanks to the sensor technology[1]. Accordingly, various types of image signal processing methods are suggested due to the rapid development of the technology such as computer, multimedia and signal processing[2]. In these days, machine vision system and high-performance microprocessor are introduced in industrial worksites, and image and multimedia are applied to manufacturing automation[3].

This research will discuss about determination of a threshold value among binary-coding methods, which are used as pre-process of various image processes such as separating objects from backgrounds, extracting pixels having more density than a certain value or simplifying general information of an image. The binary coding of images include p-tile (simple threshold) method, mode method, average binary coding method, iterative binary coding method and adaptive binary coding method; however, in this research, a method using a threshold value and mode method for the binary-coding of fish input images following the histogram pattern is suggested. Based on this, positions are extracted though the binary image projection by introducing the vision system to the processing system used in fisheries, where traditional mechanical methods are widely used.

The results are tested in the electrical controller, which are composed of main computer, image grabber board, digital I/O card and microprocessor.

This paper includes five sections. Section 2 describes image analysis and neural network configuration extracting the threshold; Section 3 explains the overall system designed to use in the experiment; Section 4 reports on the threshold extraction method and the experimental result through the system. In the conclusion, the adaptability of the system to actual industrial worksites is proposed.

2. Design of neural network to extract threshold

The image obtained through the grabber board of the CCD camera of the system is 320x240, 256 grayscale level. In order to find the position data in the input image and target area, binary coding and projection of images are used in the study.

Among the pre-processes of the input image, determination of a proper threshold is most important. However, separating the boundary of the desired object from the background – identifying objects and backgrounds using the threshold is difficult. Given that the brightness density of a pixel at the position (x, y) before the process is $f(x, y)$; the density after the process is $g(x, y)$; with t the threshold. The below equation is then derived:

$$g(x, y) = \begin{pmatrix} 1, & f(x, y) \geq t \\ 0, & f(x, y) \langle \ t \end{pmatrix}$$

or (1)

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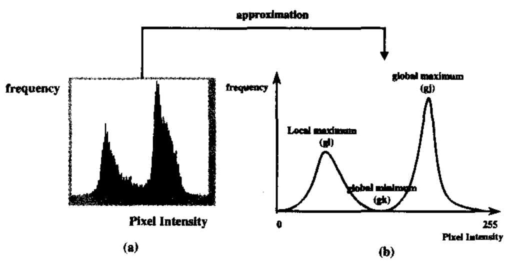
$$g(x,\ y) = \begin{pmatrix} 1, & f(x,\ y) \le t \\ 0, & f(x,\ y) > t \end{pmatrix}$$

In Equation (1), 0 and 1 represent the brightness density 0 and 255 of the binary image of the 256 grayscale image respectively.

Histogram data of images was mainly used to determine the threshold for binary image coding; however, it has a disadvantage in that the proper threshold should be selected after checking the histogram data of the image with the naked eye.

Therefore, in this study, the binary image applying an optimal threshold is acquired for real-time image input, based on the BP algorithm, a commonly used neural network. The position to find the target projection image is then acquired using the obtained binary image.



(a) Histogram of the input image
(b) Approximated histogram
Figure 1. Histogram data of a grayscale image

If the histogram of the input image is expressed as Figure 1 (a), the approximation can be made as seen in Figure 1 (b). If histogram analysis of the 256 grayscale image has two local maximum values, the threshold is generally determined as the brightness at the minimum located between the two maximum values gl and gj. Of course, the search algorithm can be applied to this histogram, but in this study, the neural network performs training with several features obtained from histogram analysis. The histogram data varies depending on external environment changes and differences in the inputted target, in order to extract a proper threshold for the external factors. The neural network diagram used in this study is shown in Figure 2.

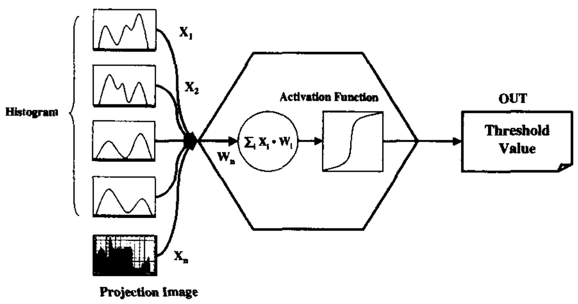
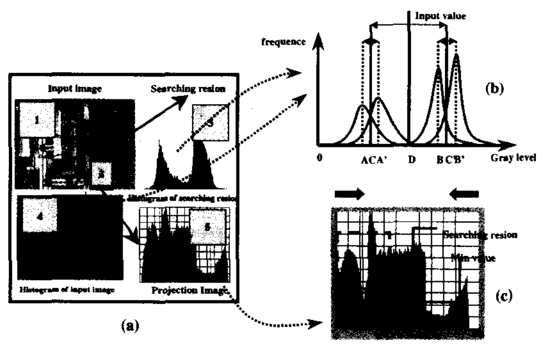


Figure 2. Diagram of neural network following the input pattern

As seen in Figure 2, the histogram analysis of the real-time input image from the CCD camera and image grabber board, and the features extracted through the projection of the binary image were inputted into the input layer of the neural network layer. The output layer produced a threshold corresponding to the trained weight values and the object function (object value) in accordance with features through analysis of the histogram and projection image for the real-time input image. Since the data inputted not using a histogram and projection image data was somewhat distributed considering the process speed, limited features were analyzed and used for this study.

Although several limited features were extracted and one output was obtained, desired values were obtained from non-linear and probable distribution of image histogram and binary projection image using the function approximation capability of the neural network. For the neural network input values, nine features were extracted from the histogram analysis of the input image and two from the projection image. Therefore, a total of 11 features were used as the input for the neural network. The feature extraction method is as follows:



(a) Analysis of image
(b) Histogram approximation of input and target image
(c) Projection image of target area
Figure 3. Histogram data of input image and projection image analysis

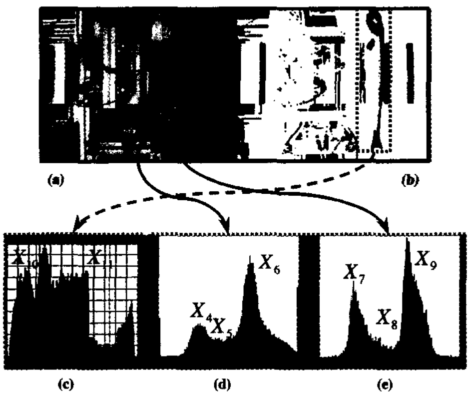
Figure 3 shows the histogram of the binary image and the projection image of the search area. The overall input image is shown in (1); (2) is the target area for finding the positions from the overall input image; (3) and (4) show the corresponding histogram. (5) shows the final projection image. The final data was obtained by analyzing the projection image of the search area through binary coding. As a result, in order to produce a projection image like (5), filtering or other processes were applied to the input images, with selection of threshold holding importance. The processing methods used in this research were the median filter and erosion/expansion process. Here, only determination of threshold is discussed.

As seen in Figure 3, three values were extracted as the neural network input using (3) the histogram of overall binary image and (4) the histogram of the target area.

Here, assume that three values are X_1, X_2 and X_3; then, the below equation can be obtained from the approximated histogram in Figure 3.

$$X_1 = C = \frac{A + A'}{2}, \quad X_2 = C' = \frac{B + B'}{2},$$
$$X_3 = D = \frac{C + C'}{2} = \frac{X_1 + X_2}{2} \qquad (2)$$

The results extracted considering the local maximum and minimum values in the histogram pattern, the frequency of histogram, types of input image and brightness depending on external lights were used for the histogram features of the input images. The experiment was performed indoors, and images were received in real-time through the vision system. Also, the threshold was dynamically processed. The variation condition of the external environment was broken down into 12 stages by the features inputted into the neural network to calculate the binary coding results. The histogram of the input image and the target image obtained in each stage and projection image features of the object were then extracted.



(a) Input image and search area
(b) Binary image of input and search area
(c) Projection image of search area
(d) Histogram of input image
(e) Histogram of search area

Figure 4. Extraction histogram features and projection image of the object

As seen in Figure 4, the local maximum and minimum values of histogram and projection images were used to select eight neural network inputs including X4, X5... X11. Here, the features of the projection image, X10 and X11, were the positions searched. The search direction was left; the first maximum was searched, and the minimum was extracted from the next range. The same method to find the maximum/minimum positions was used for the right direction. The positions were expressed in pixel coordinates. If a wrong threshold was selected during binary coding, the desired data was out of range. Therefore, a total of 11 features including three that were extracted using the histogram of the input image and the histogram of the target area were inputted into the neural network

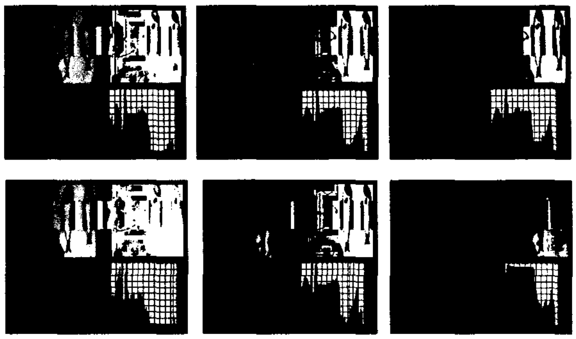


Figure 5. Variation of images depending on external environment (brightness intensity) (Six out of overall stages) Figure 5 shows that the projection result of the binary coded input image varies depending on external environmental changes.

The object selected was that of fish having the same data in order to obtain the data for this research, and external light sources were installed to adjust brightness intensity. The actual object was composed of grayscale pixels, thus very sensitive to brightness intensity. The desired binary result was obtained only when thresholds were differently selected depending on the brightness intensity.

The neural network structure used for this research was a multi-layered static neural network containing the error back-propagation algorithm.

As seen in Figure 6, a multi-layered neural network was designed with one input layer, one output layer and two hidden layers using the error back-propagation algorithm. The input layer, hidden layer and output layer are expressed below:

O_i : The output value of the input layer (11)
O_j : The output value of the first hidden layer (25)
O_k : The output value of the second hidden layer (5)
O_l : The output value of the output layer (1)

$$X = \{X_1, X_2, X_3, X_4, X_5, X_6, X_7\} \in R^k$$
$$O \in R^k$$
$$O \in \psi^3[W_{lk} © \psi^2[W_{kj} © \psi^1[W_{ji} © X]]] \qquad (3)$$

In Equation (1) and (2), the input and output values are defined as real numbers; in Equation (3), $\psi^i[\cdot]$ is the non-linear activation operator and © is a concatenation operator (scalar multiplication or distance measurement). W_{ji} is the weight between the input layer and the first hidden layer; W_{kj} is the weight between the first hidden layer and the second hidden layer; W_{lk} is the weight between the second hidden layer and the output layer. All data was saved in the weight of the forward neural network, and components of the matrix W_{ji}, W_{kj} or W_{lk} were continuously updated during the training process. A supervised training algorithm based on error correction determines proper values for W_{ji}, W_{kj} and W_{lk}.

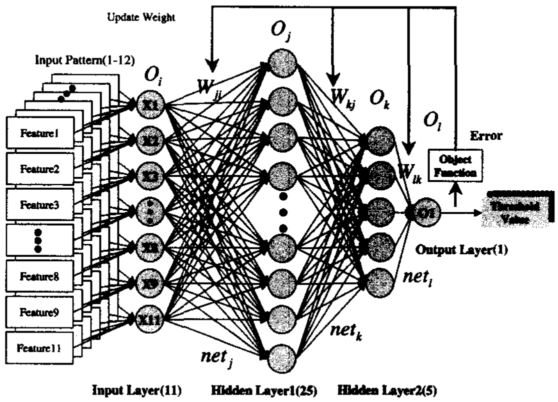


Figure 6. Overall structure of neural network to determine threshold

The non-linear activation function of the neural network in this study used the unipolar Sigmoid function as expressed in Equation (4).

$$\psi[x] = \frac{1}{1-\exp(-x)} \quad \text{Equation (4)}$$

Table 1 shows the training factors of the neural network based on the error back-propagation training algorithm.

Table 1. Training factors of the BP algorithm

Learning Factors of BP Algorithm		
Initial Weights	-1 ~ 1	Random Value
Steepness of the Activation Function	0.5	
Learning Constant	0.8	

Figure 7 is a diagram of the overall back-propagation. algorithm to decide NN weight through off-line training.

3. Experimental system configuration

In this section, the system configuration based on the image process algorithm is described before it was applied to the real system. Figure 8 shows the overall system configuration and the interface relationship between modules. The control module consists of three parts: image acquisition & processing, main controls, and driver. The image process part using the vision system extracts the position data by processing the input image, and delivers the data to the micro-controller through digital I/O, also controlling the motors and other driver devices for driving the actual processing system.

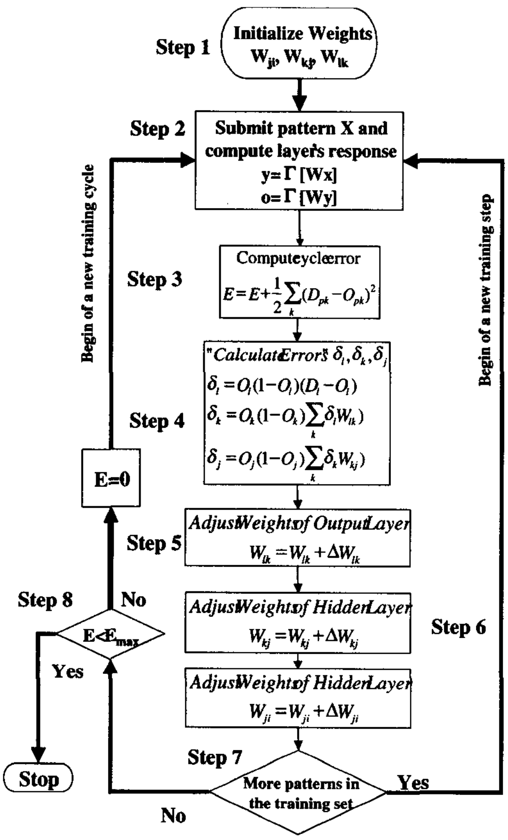


Figure 7. Error back-propagation training algorithm for threshold value.

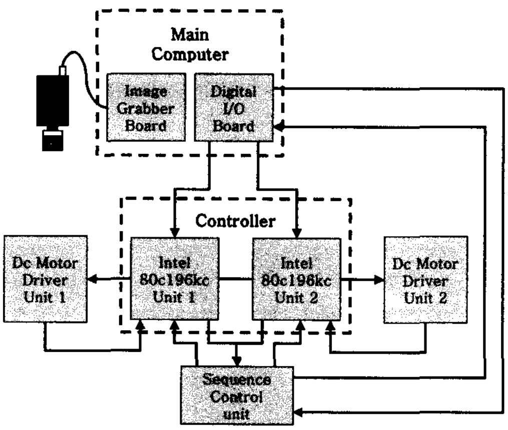


Figure 8. Configuration of the overall system.

As seen in Figure 8, the object data is digitized through the CCD camera and saved into memory on a PC. Desired values are then extracted using the process algorithm and the data is delivered to the control part. When the processor in the control part demands the following data through the digital I/O card while executing programs on the host computer, the previous image data frame is updated and new data is extracted by re-performing the process and delivering it to the control part. This series of processes are repeatedly performed to operate the system.

Figure 9 shows the connection relationship between the micro-controller Intel 80C196KC of the control part and the DC motor of the driver part, the moving environment and the control signal system.

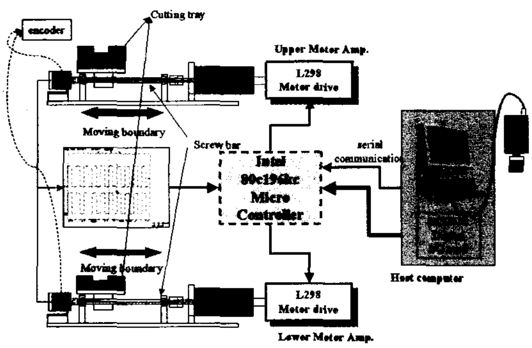


Figure 9. interface relationship of the control part and PC.

Two position values inputted into the processor through the PCI I/O interface card from the PC are converted into proper values for the actual moving distance to drive the motor.

The rotary encoder is built on the revolution axis of the motor, and pulses of forward/backward revolution of the motor are inputted into Intel's 80C196KC HSI to control the closed loop so as to move to the measured position. The data sent from the host computer is an 8-bit position signal, expressed in 256 decimal numbers from 0 to 255. These values refer to the position data and are converted into the moving distance of the DC motor in the driver part in accordance with the control algorithm in the processor, which is then outputted.

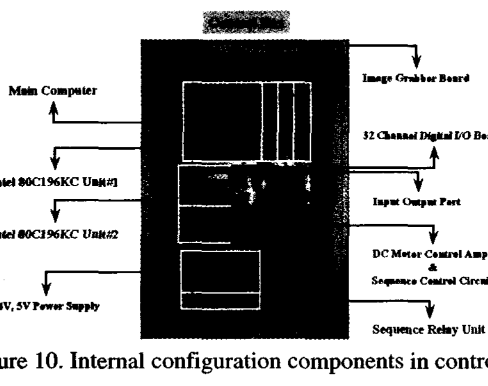


Figure 10. Internal configuration components in control box.

Figure 10 shows the internal components of the control box following the system configuration previously suggested. The encoder is built on the revolution axes of the DC motor, and speed and position data are received. The speed or position control algorithm removes the difference between the directed value and the actual one, to operate the motor. The control component of the system includes various sensors and a pneumatic cylinder. Relays (Static voltage DC24V, Static current 1A) are used for the sequence circuit. The pneumatic cylinder is controlled in this manner.

In the control box, the analog image signal from the CCD camera built into the main computer is quantized. This box includes the image grabber board to save the quantized value into PC memory, the digital I/O board to deliver the position values and measure the system operations, the microcontroller to control the system actuator, and the power source to supply power to the control box and the relays.

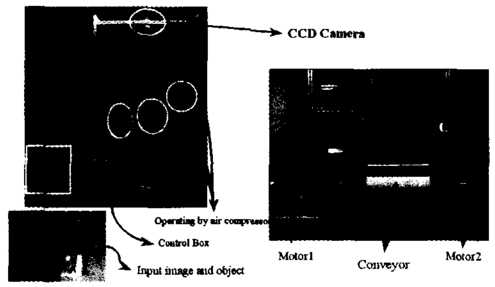


Figure 11. Mechanical configuration of the actual processing system.

Figure 11 shows the mechanical configuration of the actual process system. This system receives the image of the objects moved via conveyor through the upper middle CCD camera and processes the position data of the object.

4. Experiment and Results

In this section, the binary coding using the threshold produced through the neural network training was compared with the traditional binary coding result.

This section provides the experimental results based on image analysis and neural network configuration for extracting the threshold based on Section 2 and the overall system designed in Section 3.

The object used in this research was that of fish, which varies significantly depending on light or object shape. The object image used in this system was 320 x 240 pixels, with each pixel having an 8-bit resolution. 0 to 255 grayscale images were used. In order to estimate the performance of the suggested method, the program which adjusts the input image manually and the program using the suggested algorithm were compared.

External light sources were installed to artificially change the environment for the fish, assumed to show the same data. The actual object was composed of grayscale pixels, so showed a sensitive reaction to external light.

The threshold should therefore be differently applied depending on lighting, to obtain the desired results.

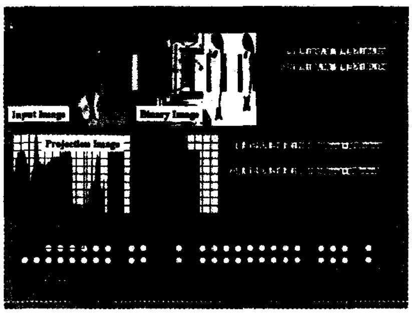


Figure 12. Manual adjustment of threshold.

Figure 12 shows that an operator should check with his/her eyes until a desired result is obtained by moving the slider bar on the lower left of the screen during examination of previously obtained projection images for the input image. Whenever the external factor (here, light) varies, the user needs to adjust it. Figure 13 shows the change of the projection image by adjusting the slider bar to change the input image data

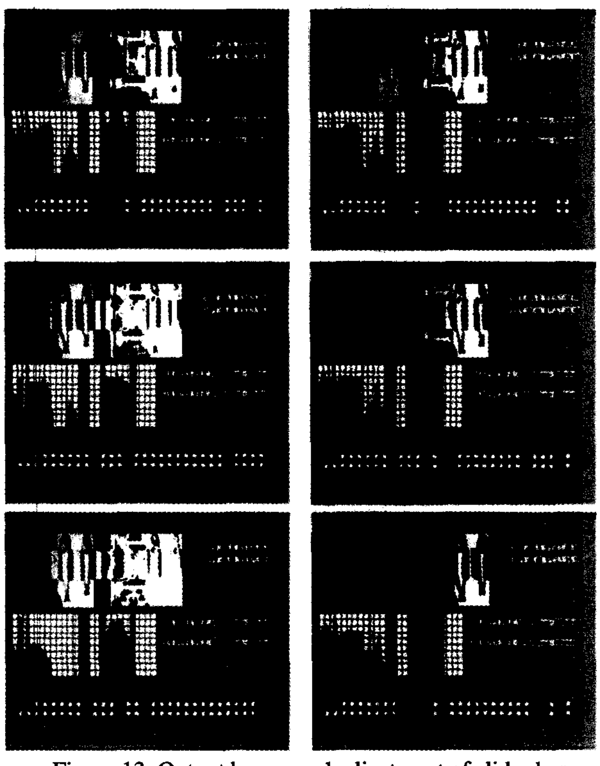


Figure 13. Output by manual adjustment of slider bar.

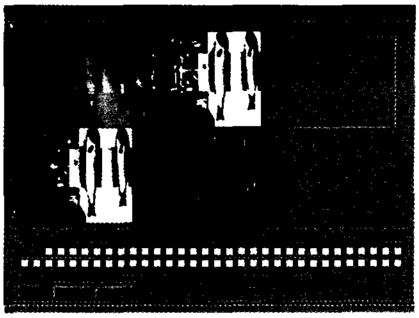


Figure 14. Binary coding result using the neural network.

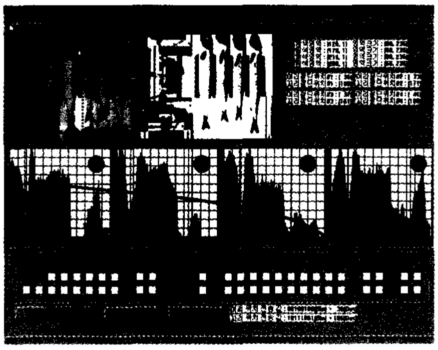


Figure 15. Image processing and monitoring environment for the real system

Figure 14 (1) shows the binary image applying the threshold obtained from the multi-layered neural network based on the error back-propagation algorithm as suggested in this paper to the input image; Figure 14 (2) shows the binary image using a simple threshold.

Figure 15 displays the configuration of the monitoring screen that drives the actual system. It allows four areas to be seen simultaneously.

5. Conclusion

In this research, a histogram was used rather than other image processing methods; projection images and a neural network were used for image erosion and expansion, showing that the experimental result can be adapted to a given environment faster than other algorithms. Also, it can be effectively applied to comparatively different targets. The configured system includes a PC, micro-controller, DC motor and relays, allowing effective processing from upper system to lower system per module. It applies the proposed algorithm which can perform more structural and consistent processing and shows better performance when compared with existing mechanical methods.

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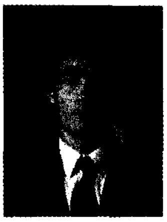

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