Fifth IFSA World Congress (1993), 777-780

General Purpose Optical Fuzzy Computing Modules

Kazuho TAMANO

Hiroshima Institute of Technology
Fac. of Engineering, Dept. of Electronics
1-1, Miyake 2-chome, Saeki-ku, Hiroshima-city 731-51, Japan
Tel. +81-829-21-3121, Fax. +81-829-23-2679
e-mail tamano@ds5.cc.it-hiroshima.ac.jp

Abstract

Three optical fuzzy calculating modules, MAX/MIN, NOT/THROUGH, and SUP/THROUGH operating modules, are proposed. The MAX/MIN operating module calculates MAX and MIN operations on inputted 2 membership functions. The NOT/THROUGH operating module calculates the complement of the membership function. The SUP/THROUGH operating module outputs an image representing the supremum (least upper bound) of the membership function. The THROUGH operation passes the image of the inputted membership function from the entrance to the exit. This paper demonstrates that these modules can output the image into which the modules transform inputted images on the basis of operation on fuzzy logic.

1. Introduction

An author previously proposed the optical fuzzy calculating systems [1,2,3]. These systems instantaneously inferred the fuzzy rules on the basis of Mamdani's method and product-sum-gravity method proposed by Mizumoto, and classified facial expressions.

The proposed three new calculating modules, MAX/MIN, NOT/THROUGH, and SUP/THROUGH operating modules, can be used to calculate the membership functions by operation which can be easily changed to a binary operation by an electric control signal. The MAX/MIN operating module calculates MAX and MIN operations on 2 inputted membership functions. The NOT/THROUGH operating module calculates the complement of the membership function. This module also passes the image of the inputted membership function from the entrance to the exit. The SUP/THROUGH operating module outputs an image representing the supremum (least upper bound) of the membership function, and an image of the inputted membership function. The computing system combined with these modules may instantaneously infer fuzzy propositions according to program.

2. Fundamental diagram of modules

2-1 Optical representation of the membership function

The membership function used during calculation is represented by an image shown in **Fig. 1**.

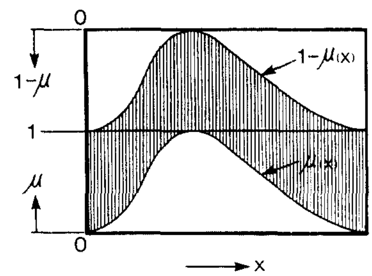


Fig. 1 Image formed by the light representing a membership function.

This image is depicted by light and dark parts. The bottom half of the image shows the a shape of the distribution of the membership function. The upper half of the image is a negative picture of the bottom half. When the module performs the calculations on the fuzzy logic, the image is formed by the parallel light passing through an aperture or by the light from another module. The module outputs both calculated image and its complimentary image of the membership function.

2-2 MAX/MIN operating module

Fig. 2 shows a fundamental optical diagram of the MAX/MIN operating module.

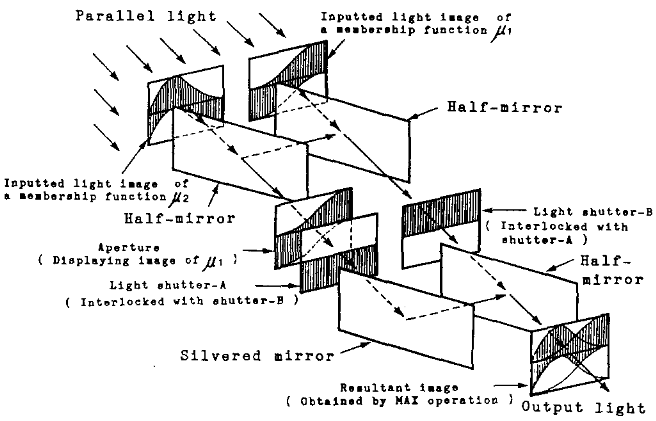


Fig. 2 Fundamental optical diagram on calculation of MAX and MIN operation.

Incident lights representing membership functions, μ_1 and μ_2, travel along two light paths. The half of light representing the image of μ_1 (right side in Fig. 2) passes through the half-mirror. The half of light representing the image of μ_2 (left side in Fig. 2) is reflected by another half-mirror, and the light is synthesized with the light passing through the right half-mirror. If a screen could be set up between the right half-mirror and a light shutter-B, the synthesized light would form an image on the screen so that both or either of the lighted parts of inputted two images will become the lightest part.

The light passing through the left half-mirror irradiates an aperture. The aperture restricts the light passing through it to form an image representing the membership function μ_1. Changing this shape, a liquid crystal display (LCD) may be useful. If a screen could be set up between this aperture and light shutter-A, the light passed through the aperture would form an image on the screen. The bright areas of the image show the common light areas of the 2 inputted images. The right upper half of the light passed through the right half-mirror is the resulting negative of an image operated on by MIN between μ_1 and μ_2. The right bottom half of the light shows a positive picture of the resulting image of the MAX operation among 2 membership functions. On the contrary, the left upper half of light passed through the aperture represents a negative picture of an image resulting from the MAX operation among 2 membership functions. The left bottom half of light shows a positive picture of an image resulting from the MIN operation among 2 membership functions. If the light shutter-A and the light shutter-B are made by an LCD, their transparencies can be easily regulated by an external control signal. When the upper half of the light shutter-B is blind and the bottom half of the light shutter-B is transparent, the bottom half of light passed through the light shutter-B forms an image resulting from the MAX operation among 2 membership functions. In this case, the bottom half of light passed through the light shutter-A becomes a light forming a negative picture of the resultant image obtained by the MAX operation. A silvered mirror and a half-mirror synthesize this image and reflect the resulting full image out from this module.

When the transparency of these shutters is altered, a synthesized light shows an image formed by the light resulting from the MIN operation among 2 membership functions.

2-3 NOT/THROUGH operating module

Fig. 3 shows a fundamental optical diagram of the NOT/THROUGH operating module.

This module turns the inputted image upside down by rotating the image. The rotated image shows a compliment of inputted image because the inputted image has two pictures that are complementary to each other. An image rotator composed of three mirrors can easily invert the top and bottom of the inputted image. A half mirror is used to split the inputted image into two paths. The light passing through the half mirror is passed to the light shutter-A. Passing the inputted light image to this shutter results in the complement image being outputted. The light shutter-B passes the inputted light image through the module without any transformations.

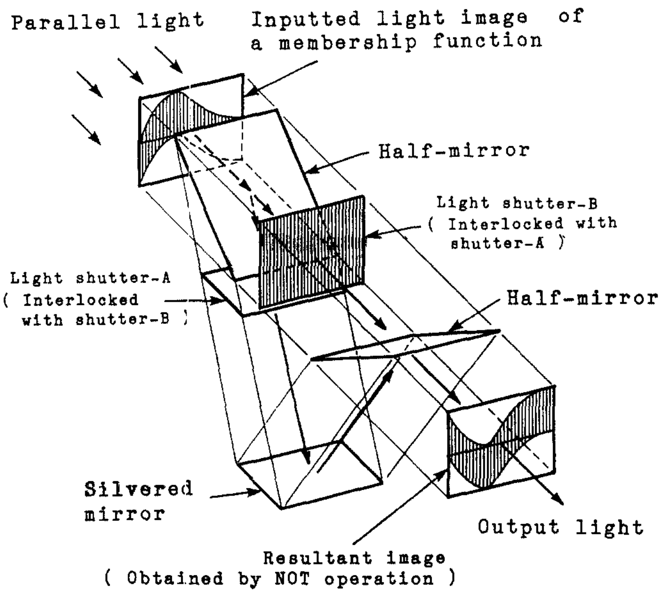


Fig. 3 **Fundamental** optical diagram on calculation of NOT and THROUGH operation.

2-4 SUP/THROUGH operating modules

Fig. 4 shows a fundamental optical diagram of the SUP/TROUGH operating module.

The light passed through the light shutter-A is integrated along the horizontal direction using a cylindrical convex lens. An optical fiber diffraction grating disperses the integrated light horizontally. The diffracted light shows an image of which the vertical width is equivalent to the maximum value of the inputted membership function. The cylindrical convex lens changes the diffracted light into a parallel light and sends it out to the next module. When the light shutter-A is blinded and the light shutter-B allows the light to pass through, this module outputs the inputted image without transformation to the other module.

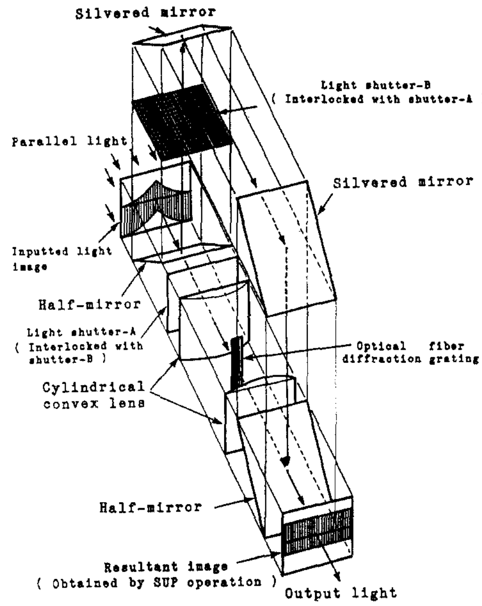


Fig. 4 Fundamental optical diagram on calculation of SUP and THROUGH operation.

3. Image processing by modules

3-1 MAX/MIN operating module

Fig. 5 is a photograph of the optical arrangement for MAX/MIN operating module.

Fig. 6 shows resultant images obtained by MAX and MIN operation between membership function μ_1 and μ_2 which are shown in Fig. 2. In the experiment, the apertures were used instead of the LCD shutters.

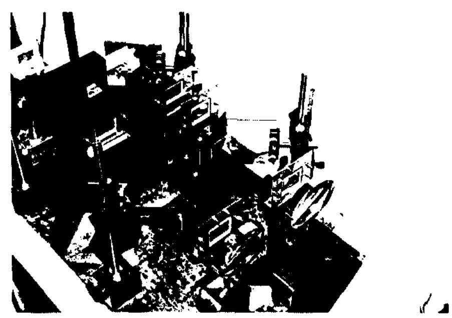
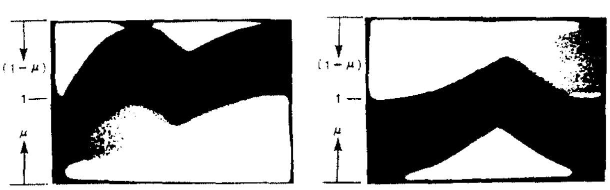


Fig. 5 Optical arrangement of MAX/MIN module.



(by MAX operation) (by MIN operation)

Fig. 6 Resultant images by calculation of the MAX and MIN operations.

3-2 NOT/THROUGH operating module

Fig. 7 shows the photograph of the NOT/THROUGH module.

Fig. 8 shows resultant images formed by the light passing through this module. In this experiment, the apertures were also used instead of the LCD shutters.

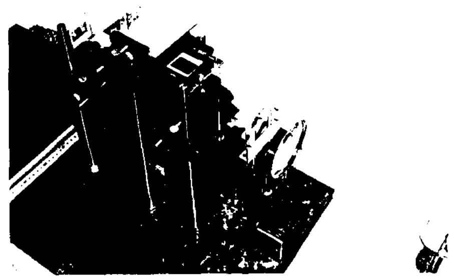
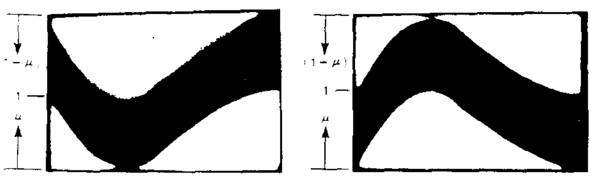


Fig. 7 Optical arrangement of NOT/THROUGH module.



(by NOT operation)(by THROUGH operation)
Fig. 8 Resultant images by calculation of the NOT and THROUGH operations.

3-3 SUP/THROUGH operating module

Fig. 9 is the photograph of the SUP/THROUGH module.

Fig. 10 shows resultant images formed by the light outputted from this module.

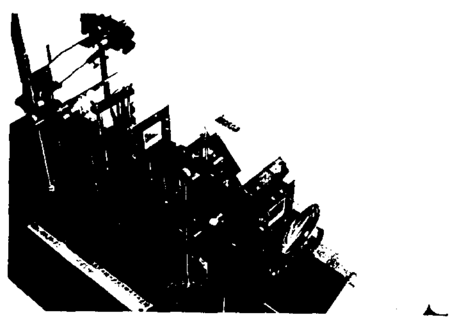
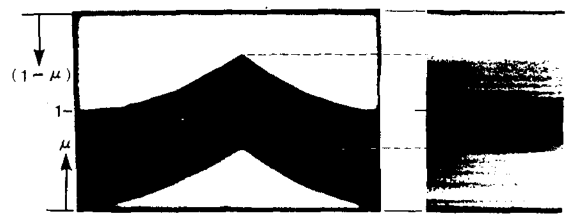


Fig. 9 Optical arrangement of SUP/THROUGH module



(by THROUGH operation) (by SUP operation)
Fig. 10 Resultant images by calculation of the SUP and THROUGH operations.

The photographs of the images shown Fig. 5, 6 and 7 certify that these modules can calculate MAX, MIN, NOT, and SUP operations based on fuzzy logic.

4. Conclusion

This paper showed that three optical modules can output the images transformed by fuzzy operation.

A general purpose optical fuzzy computer is needed to develop other modules, a multiplexer, a demultiplexer and a gate. An image converter using an LCD is useful to make the resultant image clear. The author is developing these modules and the LCD image device.

This research was supported financially by the Lab. for Int. Fuzzy Engin. Res. (LIFE) in 1992.

[Reference]

[1] Kazuho TAMANO : The Development of an Optical Fuzzy Computer (in Japanese), CAD & CIM (Commercial Journal), July, 24/26 (1990)

[2] Kazuho TAMANO : Optical Fuzzy Inference System (in English), J. of Japan Soc. for Fuzzy Theory and Sys., 3(2), 382/386 (1991)

[3] Kazuho TAMANO : Optical Fuzzy Classifying System for Facial Expressions, Proc. of 2nd Int. Conf. on Fuzzy Logic & Neural Networks (IIZUKA'92), D-10-4, 717/720 (1992)