

## An Application of Fuzzy Controller on JPEG

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**Abstract** - In this paper, An application of fuzzy controller on JPEG for (grayscale) image data compression is presented. The fuzzy controller conducts the search of a better compromise between compression ratio and image quality automatically on the JPEG model. Therefore, the fuzzy controller equipped JPEG is insensitive to the given initial quality on quantization table. Simulations are performed and the results indicate that this fuzzy-control-equipped JPEG is very promising.

**Introduction:** The JPEG algorithm is currently widely in use for image data compression [1]. However, since compression and distortion ratios depend heavily on the source pictures, trial-and-error might need be used to search for the optimal tradeoff between distortion and compression ratios. Fuzzy logic has been successfully used in many applications of process control [2]. In this work, the incorporation of a fuzzy controller in the JPEG algorithm is investigated. The design of JPEG, including coder and decoder, and fuzzy controller on source side is depicted in Fig. 1.

**The mechanism of fuzzy controller:** Since image quality is our primary concern, we use the AGE (average grayscale error) to guide the adjustment instead of BPP (bits-per-pixel).

$$AGE = ((\sum_{i=1}^P M_i - M') / PG) \times 100 \quad (1)$$

where  $M$  and  $M'$  are the corresponding pixels in the original and reconstructed pictures respectively,  $P$  is the total number of pixels in the picture, and  $G$  is the maximum grayscale value. The two inputs,  $\Delta E$  and  $\delta q$ , of the fuzzy controller are defined as follows:

$$\Delta E = TGE - AGE \quad (2)$$

$$\delta q = q_t - q_{t-1} \quad (3)$$

where TGE is the target grayscale error. In this paper, seven fuzzy sets are used--PB (positive big), PM (positive medium), PS (positive small), ZE (zero), NS (negative small), NM (negative medium), and NB (negative big), and their membership functions are characterized by three values--(left boundary, central value, right boundary) and the following equations:

$$\mu_A(X) = \begin{cases} (X - L)/(C - L) & L \leq X \leq C \\ (X - R)/(C - R) & C \leq X \leq R \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$\mu_{NB}(X) = \begin{cases} (X - R)/(C - R) & C \leq X \leq R \\ 1 & X \leq C \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

$$\mu_{PB}(X) = \begin{cases} (X - L)/(C - L) & L \leq X \leq C \\ 1 & X \geq C \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

where  $C$ ,  $L$ , and  $R$  are the central value, left boundary, and right boundary, respectively; and  $A = \{NM, NS, ZE, PS, PM\}$ . For input  $\Delta E$ , the membership functions of fuzzy sets are NB(-100, -6, -3), NM(-5, -3, -1), NS(-2, -1, 0), ZE(-0.5, 0, 0.5), PS(0, 1, 2), PM(1, 3, 5), and PB(3, 6, 100). For input  $\delta q$  and output  $\Delta q$ , the membership functions of fuzzy sets are NB(-1, -0.25, -0.1), NM(-0.15, -0.1, -0.05), NS(-0.1, -0.05, 0), ZE(-0.025, 0, 0.025), PS(0, 0.05, 0.1), PM(0.05, 0.1, 0.15), and PB(0.1, 0.25, 1). Table 1 is the decision table used by this fuzzy controller and the value of its entry  $ij$ ,  $M_{ij}$ , is calculated as follow:

$$M_{ij} = \min(\mu_i(\Delta E), \mu_j(\delta q)) \quad (7)$$

The defuzzification equation for  $\Delta q$ , the feedback from controller to JPEG, is modified from [3].

$$\Delta q = \left( \sum_{i=1}^K \sum_{j=1}^L M_{ij} \times V_{ij} \right) / \sum_{i=1}^K \sum_{j=1}^L M_{ij} \quad (8)$$

where K and L are the number of rows and columns in the decision table respectively. To guarantee that  $\Delta q$  will not be bigger than  $\delta q$  in terms of crisp value,  $V_{ij}$  is decided by the following algorithm.

Step 1. Calculate the corresponding crisp values of fuzzy membership value  $M_{ij}$ .

$$T = u^{-1}_A(M_{ij}) \quad (9)$$

where  $u^{-1}_A$  is the inverse function of  $u_A$  and  $A$  is the corresponding fuzzy set of  $M_{ij}$ . Note that there might be more than one values generated by  $u^{-1}_A$ .

Step 2. Pick the largest  $T$ , say  $T_j$ , whose absolute value-- $|T_j|$ --is no greater than  $|\delta q|$ , that is,  $V_{ij} = |T_j|$ ; otherwise,  $V_{ij} = \delta q$ . In addition,  $\Delta q$  will be smaller than  $\delta q$  in case of overshooting.

*Simulation results:* Experiments are performed on Lena, an image with 512x512 pixels in 256 grayscales, using the JPEG software package developed by Independent JPEG Group with the fuzzy controller implemented by the authors. Ten random initial qualities generated by C's rand() are used to test insensitivity of this fuzzy-control-equipped JPEG. As shown in Table 2, this version of JPEG is insensitive to the given initial qualities, and the final AGEs are very close to the goal, TGE. The measure criterion SNR is defined as follows:

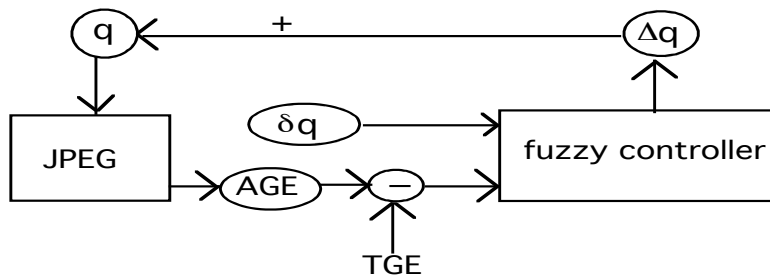
$$SNR = 10 \times \log(G^2 / MSE) \quad (10)$$

where  $G$  is the maximum grayscale value of picture.

*Conclusions and discussions:* The ordinary fuzzy controller could fail to converge for some pictures since it is almost impossible to know the relation between AGE and the JPEG parameter 'quality' in advance. Additionally, in order to guarantee both convergence and good performance for the monotone function as in this case, the present adjustment must be smaller than the previous adjustment in the case of overshooting, that is,  $\Delta q < \delta q$ . The effects of different types of membership functions and their numbers on performance are topics for future research.

#### References

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AGE: average grayscale error  
TGE: target grayscale error

**Fig1.** The schematic diagram of JPEG with fuzzy controller

Table 1. The decision table of fuzzy controlle

		$\delta q$						
		NB	NM	NS	ZE	PS	PM	PB
$\Delta E$	NB	PM	PS	ZE	ZE	PS	PM	PB
	NM	PS	PS	ZE	ZE	PS	PM	PM
	NS	PS	PS	ZE	ZE	PS	PS	PS
	ZE	ZE	ZE	ZE	ZE	ZE	ZE	ZE
	PS	NS	NS	NS	ZE	ZE	NS	NS
	PM	NM	NM	NS	ZE	ZE	NS	NS
	PB	NB	NM	NS	ZE	ZE	NS	NM

Table 2. Simulation results of JPEG with fuz: controller on Lena (TGE=2.0)

Initial q	38	58	13	15	51	27	10	19	12	86
final q	11	11	10	11	11	11	11	11	11	11

quality	AGE	BPP	MSE	SNR
11	1.911	0.237	47.443	31.369
10	2.006	0.226	51.786	30.989

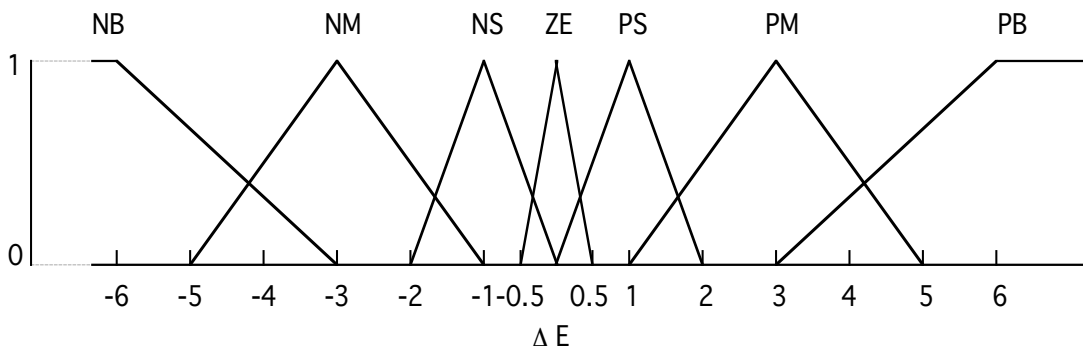


Fig. 2 Membership function for  $\Delta E$

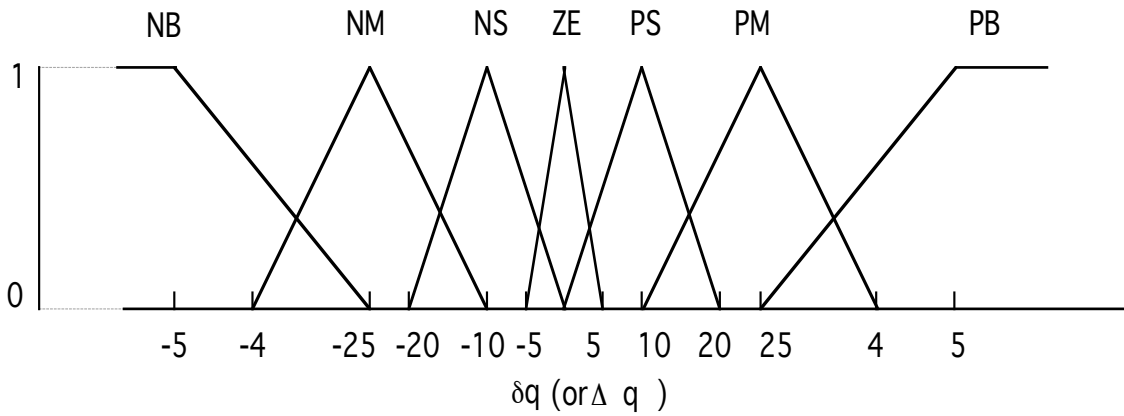


Fig. 3 Membership function for  $\delta q$  and  $\Delta q$