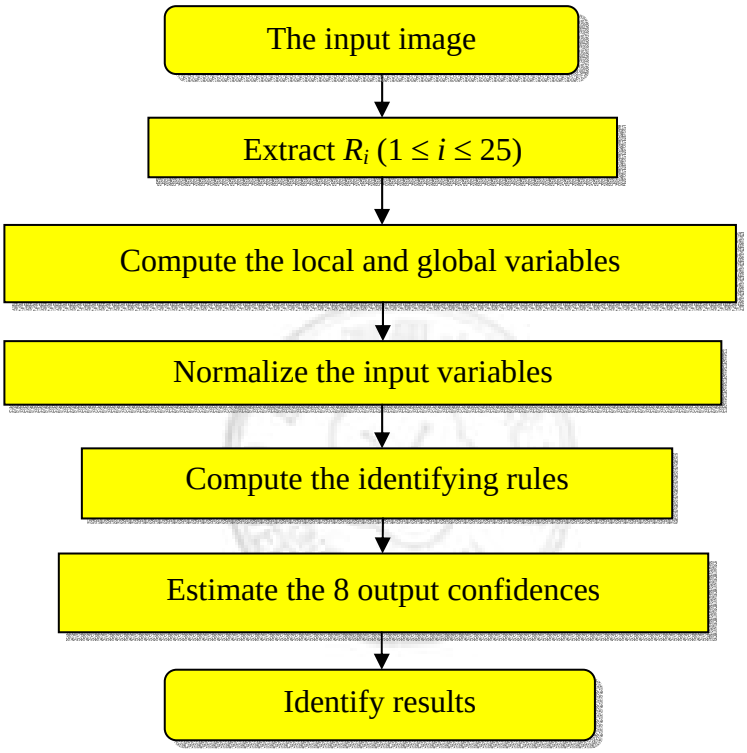
CHAPTER 4

FUZZY LOGIC FUSION

4.1 Basic concepts

The overall algorithm for identifying the photographic composition based on fuzzy logic is described in Fig. 10.



The 25 *ROI*'s is extracted from the processed image firstly. The 7 local features will be calculated for corresponding *ROI's* and 3 global features are computed for the whole image. Then these values of the features will be normalized and is applied as input variables for 18 identifying rules. The 8 output confidences for the corresponding photographic compositions are estimated by 8 rules.

4.2 Input variables

According to the fuzzy model, the range of the features extracted from *ROI*'s need to be normalized into [0, 1]. These 10 features adopted in our method are adjusted by the following Eq. 16 and are represented the confidences for extracted corresponding features.

$$M^* = \begin{cases} 0.5819 \cdot (e^{\frac{M}{C_M}} - 1), & M \le C_M \\ 1, & M > C_M \end{cases} \tag{16}$$

M={*A*, *E*, *HL*, *VL*, *DLL*, *DRL*, S_{ij}, *RV*, *RH*, *RN*},

where C_M is a predefined constant with respect to the range of the feature M.

4.3 Membership functions

The identifying system is Mamdani systems that were designed "by hand" with the associated membership functions and rules guided by analyzes of photographic compositions. Two traditional trapezoidal membership functions are used for 10

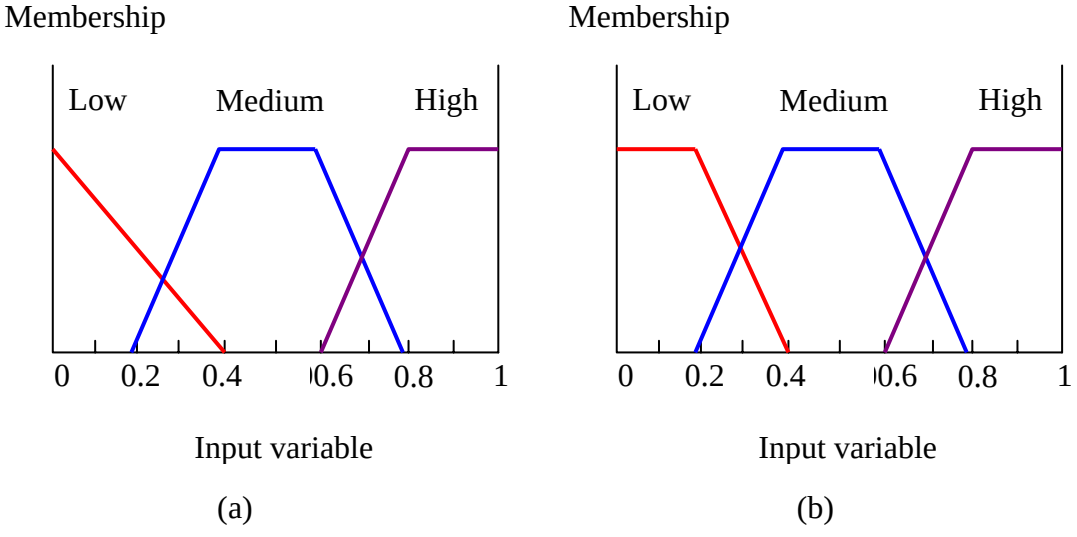


Fig.11. Two membership functions for input variables.

confidences or input variables and are shown in Fig. 11. The first membership function

shown in Fig. 11(a) suits the variables of *A*, *HL*, *VL*, *DLL*, *DRL*, *RV*, *RH*, and *RN*; The second membership function shown in Fig. 11(b) is for *E* and S_{ij}. These functions composed of three parts: *High* (H), *Medium* (M), and *Low* (L) [19].

The level of overlap shown in these membership functions is typical of that used for each of the input variables. The identifying system were designed and used for processing information fusion by these 10 variables.

4.4 Fuzzy logic rule-based fusion

Based on the principle of photographic composition, the first level of 18 rules used in the identifying system is to provide the basic information about the structure of the estimated photo. These rules are shown in Equations 17-34. The second level of 8 identifying rules for 8 photographic compositions in our method are implemented by the cross relations between the first level of rules and are described in Equations 35-42. The 8 output variables from these identifying rules are described the possibilities about corresponding 8 photographic compositions.

The aim of the first level of rules is to evaluate the image characteristics with respect to the specific structure. The operators **Max**, **Min**, and **Not** represent fuzzy set operations disjunction, conjunction, and complement, respectively. The operator **Med** is defined as an order operation that determines the median of a set of membership degrees [20]. The operator **Abs** is to obtain the positive distance between two membership degrees. These 18 rules are defined as following equations.

(a) Define the sharpness of central *ROI*'s: the median of sharpness's in fuzzy set *high* from three central *ROI*'s, R_8, R_{13}, and R_{18}.

$$\textit{Rule 1}: T_1 = \mathbf{Med}\{ E_8(\mathrm{H}), E_{13}(\mathrm{H}), E_{18}(\mathrm{H})\} \quad (17)$$

(b) Define the sharpness of bordering *ROI*'s: the median of sharpness's in fuzzy set *low* from six bordering *ROI*'s at two image up-corners $\{R_1, R_2, R_6\}$ and $\{R_4, R_5,$

R_{10}}.

Rule 2: T_2 = **Med**{ E_1(L), E_2(L), E_4(L), E_5(L), E_6(L), E_{10}(L)} (18)

(c) Define the sharpness relationship between *ROI*'s including the two points of left side golden section and central *ROI*'s:

Rule 3: T_3 = **Min**{ **Max**{E_7(H), E_{17}(H)), **Max**{E_9(L), E_{14}(L), E_{19}(L)},

Max{E_8(M), E_{13}(M), E_{18}(M), E_8(L), E_{13}(L), E_{18}(L)}} (19)

(d) Define the sharpness relationship between *ROI*'s including the two points of right side golden section and central *ROI*'s:

Rule 4: T_4 = **Min**{ **Max**{E_9(H), E_{19}(H)}, **Max**{E_7(L), E_{12}(L), E_{17}(L)},

Max{E_8(M), E_{13}(M), E_{18}(M), E_8(L), E_{13}(L), E_{18}(L)}} (20)

(e) Define the diagonal linearity on the diagonal *ROI*'s:

Rule 5: T_5 = **Max**{ **Min**{DLL_1(H), DLL_7(H), DLL_{13}(H), DLL_{19}(H), DLL_{25}(H)},

Min{DRL_5(H), DRL_9(H), DRL_{13}(H), DRL_{17}(H), DRL_{21}(H)}}

(21)

(f) Define the symmetric relationship between two triangle parts divided by the diagonal line:

Rule 6: T_6 = **Max**{ **Min**{$S_{1,25}$(H), $S_{2,20}$(H), $S_{3,15}$(H), $S_{4,10}$(H), $S_{6,24}$(H), $S_{7,19}$(H),

$S_{8,14}$(H), $S_{11,23}$(H), $S_{12,18}$(H), $S_{16,22}$(H)},

Min{$S_{2,6}$(H), $S_{3,11}$(H), $S_{4,16}$(H), $S_{5,21}$(H), $S_{8,12}$(H), $S_{9,17}$(H), $S_{10,22}$(H),

$S_{14,18}$(H), $S_{15,23}$(H), $S_{20,24}$(H)}} (22)

(g) Define the frame relationship between central *ROI*'s and the bordering *ROI*'s:

Rule 7: T_7 = **Min**{ **Max** {E_{12}(H), E_{13}(H), E_{14}(H), E_8(M), E_{12}(M), E_{14}(M)},

Not{ **Min**(E_2(H), E_3(H), E_4(H)} },

Min{A_1(L), A_2(L), A_3(L), A_4(L), A_5(L), A_6(L), A_{10}(L), A_{11}(L),

A_{15}(L)}} (23)

(h) Define the symmetric relationship between the bordering *ROI*'s:

Rule 8: $T_8 = \mathbf{Not}\{\ \mathbf{Min}\{S_{1,5}(\mathrm{H}), S_{2,4}(\mathrm{H}), S_{6,10}(\mathrm{H}), S_{11,15}(\mathrm{H})\}\}$ (24)

(i) Define the horizontal symmetry between *ROI*'s:

Rule 9: $T_9 = \mathbf{Med}\{S_{1,21}(\mathrm{M}), S_{2,22}(\mathrm{M}), S_{3,23}(\mathrm{M}), S_{4,24}(\mathrm{M}), S_{5,25}(\mathrm{M}),$

$S_{6,16}(\mathrm{H}), S_{7,17}(\mathrm{H}), S_{8,18}(\mathrm{M}), S_{9,19}(\mathrm{M}), S_{10,20}(\mathrm{M})\}$ (25)

(j) Define the vertical symmetry between *ROI*'s:

Rule 10: $T_{10} = \mathbf{Med}\{S_{1,5}(\mathrm{M}), S_{6,10}(\mathrm{M}), S_{11,15}(\mathrm{M}), S_{16,20}(\mathrm{M}), S_{21,25}(\mathrm{M}),$

$S_{2,4}(\mathrm{H}), S_{7,9}(\mathrm{H}), S_{12,14}(\mathrm{M}), S_{17,19}(\mathrm{M}), S_{22,24}(\mathrm{M})\}$ (26)

(k) Define the brightness difference between the R_{13} and bordering *ROI*'s:

Rule 11: $T_{11} = \mathbf{Max}\{\ \mathbf{Min}\{\ \mathbf{Abs}(A_1(\mathrm{H}) - A_{13}(\mathrm{H})), \mathbf{Abs}(A_5(\mathrm{H}) - A_{13}(\mathrm{H})),$

$\mathbf{Abs}(A_6(\mathrm{H}) - A_{13}(\mathrm{H})), \mathbf{Abs}(A_{10}(\mathrm{H}) - A_{13}(\mathrm{H})\ \},$

$\mathbf{Min}\{\ \mathbf{Abs}(A_1(\mathrm{L}) - A_{13}(\mathrm{L})), \mathbf{Abs}(A_5(\mathrm{L}) - A_{13}(\mathrm{L})), \mathbf{Abs}(A_6(\mathrm{L}) -$

$A_{13}(\mathrm{L})), \mathbf{Abs}(A_{10}(\mathrm{L}) - A_{13}(\mathrm{L}))\}\}$ (27)

(l) Define the diagonal relationship between the central and bordering *ROI*'s:

Rule 12: $T_{12} = \mathbf{Min}\{\ \mathbf{Max}\{DLL_8(\mathrm{H}), DLL_9(\mathrm{H}), DLL_{13}(\mathrm{H}), DLL_{14}(\mathrm{H}), DLL_{19}(\mathrm{H}),$

$DLL_{20}(\mathrm{H})\},$

$\mathbf{Max}\{DRL_7(\mathrm{H}), DRL_8(\mathrm{H}), DRL_{12}(\mathrm{H}), DRL_{13}(\mathrm{H}), DRL_{16}(\mathrm{H}),$

$DRL_{17}(\mathrm{H})\}\}$ (28)

(m) Define the total high brightness difference between the central and bordering *ROI*'s:

Rule 13: $T_{13} = \mathbf{Abs}(\ \mathbf{Med}\{A_1(\mathrm{H}), A_2(\mathrm{H}), A_3(\mathrm{H}), A_4(\mathrm{H}), A_5(\mathrm{H}), A_6(\mathrm{H}), A_{10}(\mathrm{H}),$

$A_{11}(\mathrm{H})), \mathrm{A}_{15}(\mathrm{H})\} - \mathbf{Max}\{A_8(\mathrm{H}), A_{12}(\mathrm{H}), A_{13}(\mathrm{H}), A_{14}(\mathrm{H})\})$

(29)

(n) Define the total low brightness difference between the central and bordering *ROI*'s:

Rule 14: $T_{14} = \mathbf{Abs}(\ \mathbf{Med}\{A_1(\mathrm{L}), A_2(\mathrm{L}), A_3(\mathrm{L}), A_4(\mathrm{L}), A_5(\mathrm{L}), A_6(\mathrm{L}), A_{10}(\mathrm{L}),$

$A_{11}(\mathrm{L})), A_{15}(\mathrm{L})\} - \mathbf{Max}\{A_8(\mathrm{L}), A_{12}(\mathrm{L}), A_{13}(\mathrm{L}), A_{14}(\mathrm{L})\})$ (30)

(o) Define the vanishing-point property of the whole image:

Rule 15: T_{15} = **Min**{ **Not**{ **Max**{ *RV*, *RH*}}, *RN*} (31)

(p) Define the horizontal-line property of central *ROI*'s:

Rule 16: T_{16} = **Med**{ **Med**{HL_6(H), HL_{11}(H), HL_{16}(H)},
Med{HL_7(H), HL_{12}(H), HL_{17}(H)},
Med{HL_8(H), HL_{13}(H), HL_{18}(H)},
Med{HL_9(H), HL_{14}(H), HL_{19}(H)},
Med{HL_{10}(H), HL_{15}(H), HL_{20}(H)}} (32)

(q) Define the vertical-line property of central *ROI*'s:

Rule 17: T_{17} = **Med**{ **Med**{CL_2(H), VL_3(H), VL_4(H)},
Med{VL_7(H), VL_8(H), VL_9(H)},
Med{VL_{12}(H), VL_{13}(H), VL_{14}(H)},
Med{VL_{17}(H), VL_{18}(H), VL_{19}(H)},
Med{VL_{22}(H), VL_{23}(H), VL_{24}(H)}} (33)

(r) Define the vertical or horizontal property of the whole image:

Rule 18: T_{18} = **Max**{*RV*, *RH*} (34)

The second level of 8 identifying rules for 8 photographic compositions are described as follows:

(a) Define the property of the sum-like composition:

Rule 19: *Sum* = **Min**{ T_1, T_2} (35)

(b) Define the property of the golden-section-like composition:

Rule 20: *Golden* = **Max**{ T_3, T_4} (36)

(c) Define the property of the diagonal-like composition:

Rule 21: *Diagonal* = **Max**{ T_5, T_6} (37)

(d) Define the property of the frame-like composition:

Rule 22: *Frame* = **Min**{ T_7, T_8} (38)

(e) Define the property of the symmetry-like composition:

Rule 23: *Symmetry* = **Max**{ T_9, T_{10}} (39)

(f) Define the property of the triangle-like composition:

Rule 24: *Triangle* = **Med**{ T_{11}, T_{12}, **Max**{ T_{13}, T_{14}}} (40)

(g) Define the property of the vanishing-point-like composition:

Rule 25: *Vanishing* = T_{15} (41)

(h) Define the property of the horizontal/vertical-line-like composition:

Rule 26: *VH-line* = **Min**{ **Max**{ T_{16}, T_{17}}, T_{18}} (42)

The output membership functions used for 8 output variables generated by rules 19-26 were Gaussians with different widths and centered at different positions [21] (see Fig. 12). By the output membership function, the identifying system gives the confidences for 8 photographic compositions.

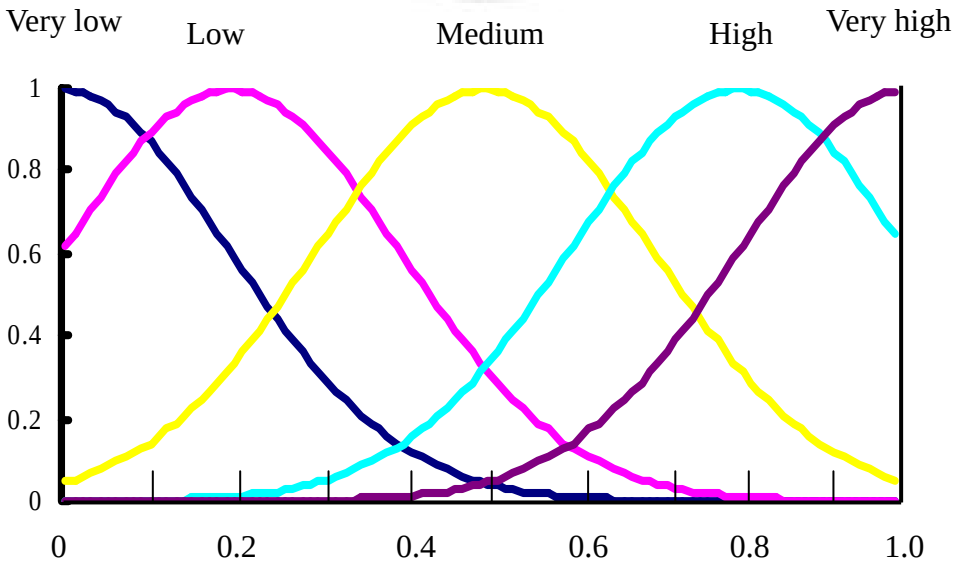


Fig.12.The identifying system output membership functions.