Using Fuzzy Logic In Image Matching

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الخلاصة

المنطق المضبب احد الفروع الأساسية في الذكاء الاصطناعي إذ يمثل نظريات وتقنيات تستخدم المجموعات المضببة والتي هي مجموعات بلا حدود قاطعة ويعتبر هذا المنطق طريقة لتوصيف وتمثيل الخبرة البشرية إذ يتم من خلاله وضع حلول عملية للمشاكل.

في هذا البحث تم استخدام المنطق المضبب في مطابقة الصور، إذ تم التعامل مع الصور ذات التدرج الرمادي من خلال إدخال صورتين في كل حالة تنفيذ وإيجاد نسبة التطابق ونسبة الاختلاف بينهما، كذلك حسبت بعض المتغيرات الإحصائية والتي ساعدت في إيجاد خصائص معينة استخدمت لمطابقة الصور.

استخدمت لغة ماثلاب (Matlab version 6.5) لتنفيذ الخوارزمية المقترحة وهي لغة عالية الكفاءة.

Abstract

Fuzzy logic is one of the main branches of artificial intelligence as a representative of the theories and techniques used fuzzy groups and groups that are no definite boundaries, and is considered by this logic to describe and represent the human experience as it is through the development of practical solutions to various problems.

In this research was to use Fuzzy logic in matching images, as it has been working with images, where the gray level images have been lowered,, and inserting two images in each state, the implementation and then find the proportion of matches and the percentage difference between them, as well as the calculated some statistical variables that helped to find certain characteristics to match the images.

Matlab language program (version 6.5) has been made to implement the suggested algorithm, where it considers a high efficiency language.

1. Introduction

Fuzzy logic (FL) is a superset of conventional (Boolean) logic, was initiated in 1965, by Lotfi A. Zadeh, professor for computer science. Basically, FL is a multi valued logic, that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers. Fuzzy systems is an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy. [1] [2]

FL is a simple yet very powerful problem solving technique with extensive applicability. It is currently used in the fields of business, systems control, electronics and traffic engineering.[3] It provide an appropriate technique for describing the behavior of systems which are too imprecisely or ill defined to be amenable to formal mathematical analysis. It allows non liners input/output relationship to be expressed by a set of qualitative if then rules. It is easy to setup and provide accurate responses to ambiguous data. [4]

2. Crisp set and Fuzzy set

Classical sets are also called crisp sets so as to distinguish them from fuzzy sets. In fact, the crisp sets can be taken as special cases of fuzzy sets. Let A be a crisp set defined over the universe X. Then for any element x in X, either x is a member of A or not. In fuzzy set theory, this property is generalized. Therefore, in a fuzzy set, it is not necessary that x is a full member of the set or not a member. It can be a partial member of the sets. [5] The generalization is performed as follows: For any crisp set A, it is possible to define a characteristic function $\mu_x = \{0,1\}$. i.e. the characteristic function takes either of the values 0 or 1 in the classical set. For a fuzzy set, the characteristic function can take any value between zero and one. [6] [7]

3. Fuzzy Set

3.1 Membership function (MF)

MF is the mathematical function which defines the degree of an element's membership in a fuzzy set. MF is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse. [8]

If X is the universe of discourse and its elements are denoted by *x*, then a fuzzy set A in X is defined as a set of ordered pairs as shown in equation (1):

$$A = \{x, \mu_A(x) \mid x \in X\} \qquad \text{---------------} \ (1)$$

$\mu_A(x)$ is called the MF of *x* in A. The MF maps each element of X to a membership value between 0 and 1. [9]

3.2 Type of MFs

The type of MFs is:

1- Numerical definition (discrete MFs) as shown in equation (2):

$$A = \sum_{x_i \in X} \mu_A(x_i)/x_i \qquad \text{--------------- (2)}$$

2- Function definition (continuous MFs) as shown in equation (3) Including of S function, Z Function, Pi function, Triangular shape, Trapezoid shape, Bell shape. [10] [11]

$$A = \int_X \mu_A(x)/x \qquad \text{--------------- (3)}$$

(1) S function: monotonical increasing MF, shown in figure (1)

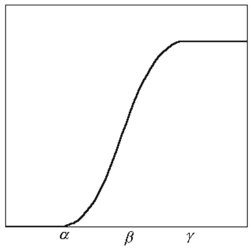

Figure (1): S function

(2) Z function: monotonical decreasing MF, shown in figure (2)

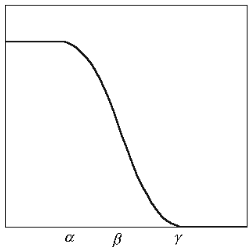

Figure (2): Z function

(3) Pi function: combine S function and Z function, monotonical increasing and decreasing MF, shown in figure (3)

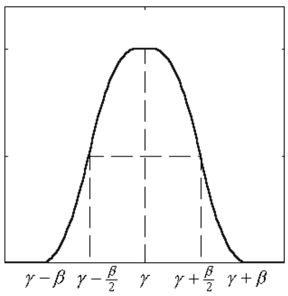

Figure (3): Pi function

(4)Trapezoidal MF, shown in figure (4)

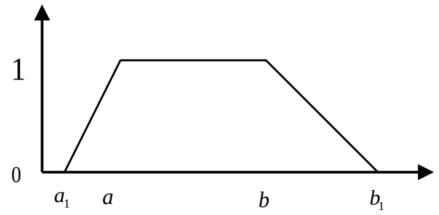

Figure (4): Trapezoidal function

(5) Triangular MF, shown in figure (5)

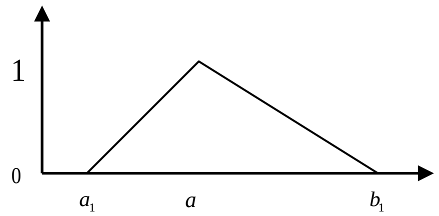

Figure (5): Triangular function

(6) Bell-shaped MF, shown in figure (6)

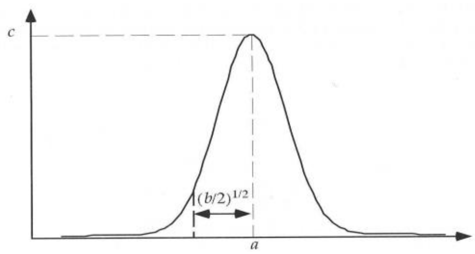

Figure (6) Bell-shaped function

3.3 Fuzzy set Operators

Some of the most important FL operators are given below. [1] [4] [12]

1- Union

The union is the maximum degree of membership of sets A and B. as shown in equation (4):

$$\mu_{A\cup B}(x) = \mu_A(x) \vee \mu_B(x)$$
$$= \max(\mu_A(x), \mu_B(x)) \quad \text{---------------} \ (4)$$

2- Intersection

The intersection is the minimum degree of membership of sets A and B. as shown in equation (5):

$$\mu_{A\cap B}(x) = \mu_A(x) \wedge \mu_B(x)$$
$$= \min(\mu_A(x), \mu_B(x)) \quad \text{---------------} \ (5)$$

3- Complement

The complement of the membership of set A shown in equation (6):

$\overline{\mu_A}(x) = 1 - \mu_A(x)$ --------------- (6)

4- Product of two fuzzy sets

The product of two fuzzy sets in the same universe of discourse is the new fuzzy set A·B with a MF that equals product of the MF of A and the MF of B. as shown in equation (7):

$\mu_{A\cdot B}(x) = \mu_A(x)\cdot\mu_B(x)$ --------------- (7)

5-Multiplying a fuzzy set by a crisp number

When a fuzzy set is multiplied by a crisp number, then its MF is shown in equation (8):

$\mu_{a\cdot A}(x) = a\ \mu_A(x)$ -------------- (8)

6-Equality of fuzzy sets

The fuzzy sets A and B are equal if the fuzzy set of A is equal to the fuzzy set B. as shown in equation (9):

$\mu_A(x) = \mu_B(x)$ ---------------- (9)

7-Normal fuzzy set

The fuzzy set is called normal if there is at least one element x_0 in the universe of discourse X where the MF equals 1.shown in equation 10

$\mu_A(x_0) = 1$ ---------------- (10)

3.4 If-Then rules

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. Usually the knowledge involved in fuzzy reasoning is expressed as rules in the form:

If x is A Then y is B

where x and y are fuzzy variables and A and B are fuzzy values. The if-part of the rule "*x* is *A*" is called the antecedent or premise, while the then-part of the rule "*y* is *B*" is called the consequent or conclusion. [13] Statements in the antecedent (or consequent) parts of the rules may well involve fuzzy logical connectives such as ‘AND’ and ‘OR’. In the if-then rule, the word "is" gets used in two entirely different ways depending on whether it appears in the antecedent or the consequent part. [14] [15]

3.5 Fuzzy Number

If a fuzzy set is convex and normalized, and its MF is defined in *R* and piecewise continuous, it is called as fuzzy number. So fuzzy number (fuzzy set) represents a real number interval whose boundary is fuzzy.

Fuzzy number is expressed as a fuzzy set defining a fuzzy interval in the real number *R*. Since the boundary of this interval is ambiguous, the interval is also a fuzzy set. Generally a fuzzy interval is represented by two end points *a*1 and *a*3 and a peak point *a*2 as (*a*1, *a*2, *a*3) (Figure 7). [16] Fuzzy numbers are used in statistics, computer programming, engineering, and experimental science. The arithmetic operators on fuzzy numbers are basic content in fuzzy mathematics.

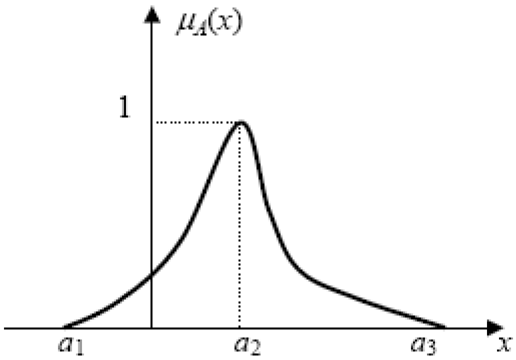

Figure (7): Fuzzy Number A=(*a*1, *a*2, *a*3)

3.6 Fuzzy Inference Systems

Fuzzy inference is the actual process of mapping from a given input to an output using FL. Figure (8), The process involves MFs, FL operators, and if-then rules. there are five parts of the fuzzy inference process: [10] [12] [17]

1- Fuzzification of the input variables

The first step is to take the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. The input is always a crisp numerical value limited to the universe of discourse of the input variable and the output is a fuzzy degree of membership (always in interval between 0 and 1).

2- Application of the fuzzy operator (AND or OR) in the antecedent

If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number will then be applied to the output function. Any number of well-defined methods can fill in for the AND operation or the OR operation.

3- Implication from the antecedent to the consequent

The implication method is defined as the shaping of the consequent (a fuzzy set) based on the antecedent (a single number). The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication occurs for each rule. Two built-in methods are supported, min (minimum) which truncates the output fuzzy set, and prod (product) which scales the output fuzzy set.

4- Aggregation of the consequents across the rules

Unify the outputs of each rule

5- Defuzzification

Input for defuzzification phase is unified fuzzy set formed by aggregation of consequents and output is crisp number. If there are more than one output variables, final output for each variable is a crisp number. The most popular defuzzification method is the centroid calculation, which returns the center of area under the curve

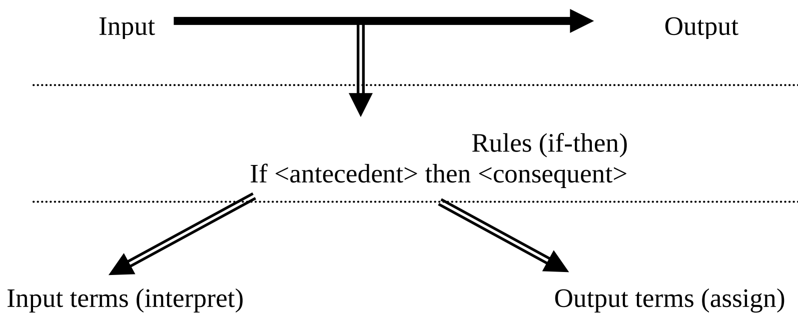

Figure (8): Fuzzy inference system – A general case

4. Image matching

The process of image matching plays an important role in the number of the modern application related to process digital images in the scientific modern fields such as: (multi modularity medical imaging) and (multi spectral image analysis). [18] [19] [20] The process of image matching needs a scanning for the images to make sure of matching and the degree of matching between the two images. [21] [22] As well as can be used in areas of science and technology various related branches of knowledge different physics and engineering s well as images in the geological and biological comparisons of microscopic images to determine the levels of matching and difference between them. [23] [24] [25]

5. Suggested Algorithm

The suggested algorithm is:

1- Start
2- Read image1, image2
3- The size of each image is (75 row and 75 column) (75*75=5625)
4- Show image1, image2

5- Find the membership function of each image (image normalization) by divide each pixel in the two images to 255. (Fuzzification of the input variables)
6- Calculate the parameters (sum, mean, median, max, min, range (range = max-min)) of image1 and image2
7- Check the matching case:
   (Application of the fuzzy operator (AND or OR) in the antecedent), (Implication from the antecedent to the consequent) and (Aggregation of the consequents across the rules)
   a- if each pixel in image1 is equal the pixel in image2 in the same location then the result is the array that name resfm (75 row and 75 column) take the value 1 else the array that name resfm take the value zero. go to 8
   b- if the parameters (sum, mean, median, max, min, range) of image1 is equal the parameters (sum, mean, median, max, min, range) of image2 and each pixel in image1 is equal the pixel in image2 (image1 is equal image2 after rotate 90 degree) then the result is the array that name resfm take the value 1. go to 8
   c- if the parameters (sum, mean, median, max, min, range) of image1 is equal the parameters (sum, mean, median, max, min, range) of image2 and each pixel in image1 is equal the pixel in image2 (image1 is equal image2 after rotate 180 degree) then the result is the array that name resfm that take the value 1. go to 8
   d- if the parameters (sum, mean, median, max, min, range) of image1 is equal the parameters (sum, mean, median, max, min, range) of image2 and each pixel in image1 is equal the pixel in image2 (image1 is equal image2 after rotate 270 degree) then the result is the array that name resfm take the value 1.
8- Find the number of ones in resfm and put in the variable z.
9- Find the number of zeros in resfm and put in the variable x (x=5625-z).
10- Find the Matching Rate MR(MR=(z/5625)*100)
11- Find the Difference Rate DR(DR=100-MR)
12- If MR=100 then print very high matching else if MR between 55 to 99.9 then print high matching else if MR between 50 to 74.9 then print medium matching else if MR between 25 to 49.9 then print low matching else if MR between 0.1 to 24.9 then print very low matching else if MR=0 then print no matching
13- end

6. Execution of Suggestion Algorithm

In this research, the suggested algorithm has been applied in thirty cases, in each case, two gray level images have been inserted to find the matching rate and difference rate between them as it shown in Figure (9), Table (1) and Table (2). Sixty gray level images is used, that performed in simple of execution and calculation.

Table (1) represents the results obtained after implementation of the program and shows the values of matching and the values of the difference between the two images and find a matching type depending on the suggested algorithm.

Table(1): The Result Of Suggestion Algorithm after execution to Selection Images

Case	Number of pixels that can be equal in image1 and image2 (z)	Number of pixels that can not be equal in image1 and image2 (x)	Matching Rate(MR=(z/5625)*100)	Difference Rate(DR=100-MR)	Types Matching
A	2806	2819	49.8844	50.1156	Low matching
B	1881	3744	33.4400	66.5600	Low matching
C	2016	3609	35.8400	64.1600	Low matching
D	96	5529	1.7067	98.2933	Very low Matching
E	5625	0	100	0	Very high matching
F	5625	0	100	0	Very high matching after image2 rotation by 90º
G	5625	0	100	0	Very high matching after image2 rotation by 180º
H	5625	0	100	0	Very high matching after image2 rotation by 270º
I	1422	4203	25.2800	74.7200	Low matching
J	5625	0	100	0	Very high matching after image2 rotation by 90º
K	0	5625	0	100	no matching
L	3589	2036	63.8044	36.1956	Medium matching
M	4007	1618	71.2356	28.7644	Medium matching
N	211	5414	3.7511	96.2489	Very low Matching
O	5625	0	100	0	Very high matching after image2 rotation by 270º
P	157	5468	2.7911	97.2089	Very low Matching
Q	5625	0	100	0	Very high matching after image2 rotation by 180º

R	5337	288	94.8800	5.1200	high matching
S	3346	2279	59.4844	40.5156	medium matching
T	129	5496	2.2933	97.7067	Very low Matching
U	0	5625	0	100	no matching
V	26	5599	0.4622	99.5378	Very low Matching
W	5625	0	100	0	Very high matching
X	5625	0	100	0	Very high matching after image2 rotation by 90º
Y	4066	1559	72.2844	27.7156	medium matching
Z	592	5033	10.5244	89.4756	Very low Matching
A1	5625	0	100	0	Very high matching after image2 rotation by 90º
B1	5625	0	100	0	Very high matching
C1	44	5581	0.7822	99.2178	Very low Matching
D1	3316	2309	58.9511	41.00489	Medium matching

Table 2 represents the values of statistical parameters that have been obtained and used to help get the results to match the images.

In Table1 and Table2, the cases of (F,G,H,J,O,Q,X and A1) image1 is the same of image2 after image2 rotation by 90 º or 180 º or 270 º

Table (2): The Result Of Parameters (Sum, Mean, Median, Max, Min, Rang) Of Selection Image

	Parameter Of Image1						Parameter Of Image2					
Case	**Sum**	**Mean**	**Median**	**Max**	**Min**	**Rang**	**Sum**	**Mean**	**Median**	**Max**	**Min**	**Range**
A	5583.4	0.9926	0.1686	1	0.0510	0.9490	5489.4	0.9759	0.1686	0.9845	0.0510	0.9333
B	3461.1	0.6153	0.0118	1	0	1	3512.3	0.6244	0.0941	0.9961	0	0.9961
C	2644.9	0.4702	0.0510	0.8314	0.0275	0.8039	2749	0.4887	0.0471	0.6353	0.0353	0.6000
D	8237.9	1.4645	0.4824	1	0.0039	0.9961	8380	1.4898	0.4706	1	0.0039	0.9961
E	3422.3	0.6084	0.6706	1	0.0824	0.9176	3422.3	0.6084	0.6706	1	0.0824	0.9176
F	3475.5	0.6179	0.6784	0.8431	0.0471	0.7961	3475.5	0.6179	0.6784	0.8431	0.0471	0.7961
G	3475.5	0.6179	0.6784	0.8431	0.0471	0.7961	3475.5	0.6179	0.6784	0.8431	0.0471	0.7961
H	3475.5	0.6179	0.6784	0.8431	0.0471	0.7961	3475.5	0.6179	0.6784	0.8431	0.0471	0.7961
I	4488.1	0.7979	0.7608	1	0.1294	0.8706	4566.7	0.8119	0.8314	1	0.2549	0.7451
J	3422.3	0.6084	0.6706	1	0.0824	0.9176	3422.3	0.6084	0.6706	1	0.0824	0.9176
K	0	0	0	0	0	0	4488.1	0.7979	0.7608	1	0.1294	0.8706
L	14691	2.6117	1	1	0	1	15072	2.6794	1	1	0.3686	0.6314
M	11729	2.0851	0.5729	0.7529	0	0.7529	10906	1.9388	0.7529	1	0	1

N	1133.4	0.2015	0.0078	1	0	1	1341.2	0.2384	0.1569	0.8275	0	0.8275
O	2604.3	0.4631	0.3059	1	0.0627	0.9373	2604.8	0.4631	0.3059	1	0.0662 7	0.9373
P	2604.8	0.4631	0.3059	1	0.0627	0.9373	9520.6	1.6925	0.6196	1	0	1
Q	3422.3	0.6084	0.6706	1	0.0824	0.9176	3422.3	0.6084	0.6706	1	0.0824	0.9176
R	11729	2.0851	0.7529	0.7529	0	0.7529	11476	2.0402	0.7529	0.7529	0	0.7529
S	10906	1.9388	0.7529	1	0	1	8405	1.4942	0.7529	0.7529	0	0.7529
T	9772.9	1.7374	0.6118	0.9922	0.0706	0.9216	9565.4	1.7005	0.6196	0.9725	0.0784	0.8941
U	0	0	0	0	0	0	323.8706	0.0576	0.0588	0.0588	0.0235	0.0353
V	9802.1	1.7426	0.5882	0.7922	0.1922	0.6000	7262.6	1.2911	0.4039	0.9725	0	0.9725
W	7262.6	1.2911	0.4039	0.9725	0	0.9725	7262.6	1.2911	0.4039	0.9725	0	0.9725
X	2604.8	0.4631	0.3059	1	0.0627	0.9373	2604.8	0.4631	0.3059	1	0.0627	0.9373
Y	1655.1	0.2942	0.0275	1	0.0118	0.9882	1008.8	0.1793	0.0275	1	0.0118	0.9882
Z	14691	2.6117	1	1	0	1	1655.1	0.2942	0.0275	1	0.0118	0.9882
A1	2888.2	0.5135	0.4824	0.9882	0.1176	0.8706	2888.2	0.5135	0.4824	0.9882	0.1176	0.8706
B1	7676.6	1.3647	0.5216	0.9451	0	0.9451	7676.6	1.3647	0.5216	0.9451	0	0.9451
C1	4816.8	0.8563	0.9216	0.9882	0.1922	0.7961	3959.9	0.7040	0.8118	0.9843	0.0471	0.9373
D1	14691	2.6117	1	1	0	1	4219.9	0.7502	1	1	0	1

Statistical Parameters that can be used in algorithm

SUM: sum of elements .For vectors, SUM(X) is the sum of the elements of X

MEAN: Average or mean value. For vectors, MEAN(X) is the mean value of the elements in X
MEDIAN: Median value. For vectors, MEDIAN(X) is the median value of the elements in X
MAX: Largest component. For vectors, MAX(X) is the largest element in X
MIN: Smallest component. For vectors, MIN(X) is the smallest element in X
RANGE: The range is the difference between the maximum and minimum values

A

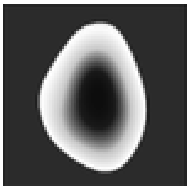

Image1 Image2

Matching rate=100%

B

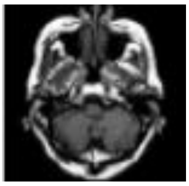

Image1 Image2

Matching rate=33.4400%

C

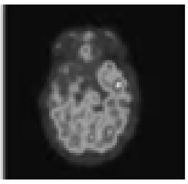

Image1 Image2

Matching rate=35.8400%

D

Image1 Image2

Matching rate=1.7067%

J

Image1 Image2

Matching rate=100%(Rotate90° Image2)

E

Image1 Image2

Matching rate=49.8844%

F

Image1 Image2

Matching rate=100%(Rotate90° Image2)

G

Image1 Image2

Matching rate=100% (Rotate180° Image2)

H

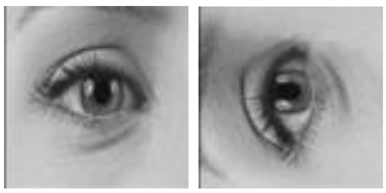

Image1 Image2

Matching rate=100%(Rotate270° Image2)

K

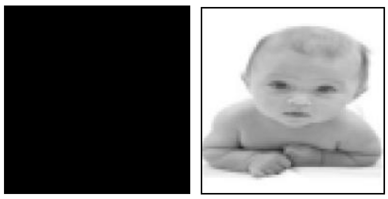

Image1 Image2

Matching rate=0%

Figure (9): The results of matching rate after execution suggestion algorithm to some of execution cases

7. Conclusion

Fuzzy systems, including FL and fuzzy set theory, provide a rich and meaningful addition to standard logic. The mathematics generated by these theories is consistent, and FL may be a generalization of classic logic. The applications which may be generated from or adapted to FL are wide-ranging, and provide the opportunity for modeling of conditions which are inherently imprecisely defined, despite the concerns of classical logicians.

In this research, image matching algorithm has been suggested by using FL. in each case, two images has been input and find matching and difference rate between the two images. some statistical variables (sum, mean, median, max, min, range) have been found to use in image matching.

FL is a very powerful tool that is pervading every field and signing successful implementation. Although the FL is relatively young theory, the areas of applications are very wide: process control, management and decision making, operations research and economies

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