OFFLINE HANDWRITING RECOGNITION USING FUZZY LOGIC

By
MEHUL SENGUPTA
ARIJIT BAGCHI
SUBHADEEP BHOWMICK
PALLAVI CHATTERJEE

UNDER THE GUIDANCE OF

Ms PARAMA BAGCHI

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RCC INSTITUTE OF INFORMATION TECHNOLOGY
[Affiliated to West Bengal University of Technology]
CANAL SOUTH ROAD, BELIAGHATA, KOLKATA-700015

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
RCC INSTITUTE OF INFORMATION TECHNOLOGY

श्रमम् बिना न किमपि साध्यम्

TO WHOM IT MAY CONCERN

I hereby recommend that the Project entitled **Offline Handwriting Recognition using Fuzzy Logic,** prepared under my supervision by

Student's Name	Class Roll	Registration No.
Mehul Sengupta	CSE/2014/084	141170110040
Arijit Bagchi	CSE/2014/091	141170110009
Subhadeep Bhowmick	CSE/2014/094	141170110076
Pallavi Chatterjee	CSE/2015/B01	141170110390

of B.Tech (8th Semester), may be accepted in partial fulfilment for the degree of **Bachelor of Technology in Computer Science & Engineering** under Maulana Abul Kalam Azad University of Technology(MAKAUT) formerly West Bengal University of Technology(WBUT).

........…………………………………………

Project Supervisor
Department of Computer Science and Engineering
RCC Institute of Information Technology

Countersigned:

……………………………………………….
Head
Department of Computer Sc. & Engg,
RCC Institute of Information Technology
Kolkata – 700015.

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

RCC INSTITUTE OF INFORMATION TECHNOLOGY

CERTIFICATE OF APPROVAL

The foregoing Project is hereby accepted as a credible study of an engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the project only for the purpose for which it is submitted.

FINAL EXAMINATION FOR EVALUATION OF PROJECT

1. ______________________________

2. ______________________________

(Signature of Examiners)

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Mehul Sengupta
CSE/2014/084

Arijit Bagchi
CSE/2014/091

Subhadeep Bhowmick
CSE/2014/094

Pallavi Chatterjee
CSE/2015/B01

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1. INTRODUCTION

To recognize handwritten letter is not a difficult task for human, but for a computer, it could be very difficult. The problem is how to program a computer to do that kind of task. With conventional approach, it is very difficult to formulate the solution, but the intelligent approach has been developed for this kind of job. A handwritten letter recognition system was used to visualize artificial neural networks. It is already widely used in the automatic processing of bank cheques, postal addresses, in mobile phones etc. To perform letter recognition, some basic knowledge on neural network and image processing is needed. But, the customer may use it without any prior knowledge in image processing or neural network. Handwriting recognition can be done through artificial neural network or fuzzy logic. The development of Fuzzy Logic system, Artificial Neural Network, Genetic Algorithm, etc. have helped human to program computer to decide something that imitate organism behaviour, although in a very basic level .

2.Review of Literature

2.1 INTRODUCTION

Uncertainty is a challenging part in human's everyday life. Since the future cannot be predict, it is impossible to be certain about what exactly is going to happen day to day. The main cause of uncertainty is the information deficiency. Information may be incomplete, fragmentary, not fully reliable, vague, contradictory or deficient in some other way. Uncertainity occurs due to deficiency in information. However, in practice, most uncertainties are tolerable, manageable or negligible. There is a high level of uncertainty management in intelligent systems. This is because human reasoning and decision making is fuzzy, involving a high degree of vagueness in evidence, concept utilization and mental model formulation (Wang and Elhag 2006). Human thought is fuzzy in nature, complete with uncertainties, ambiguities and contradictions. Two experts might not place the same level of importance on the same piece of information. According to Aristotelian logic, for a given proposition or state, only two logic values are proposed: true-false, black-white, 1-0. Grey images mainly exist in real life. Unlike classical set theory, fuzzy set theory is flexible which focuses on the degree of being a member of a set. This simple notion leads to new concepts and ideas through which more realistic mathematical representation can be achieved in describing events observed with uncertainty. Fuzzy logic is a qualitative computational approach which describes uncertainty or partial truth.

2.2 EVOLUTION OF FUZZY LOGIC

Fuzzy Logic was originally developed in the early 1960's by Professor Lotfi Zadeh, who claimed for the new kind of computational paradigm capable of modeling the uncertainties of human reasoning. In 1965, Zadeh published the first ideas on fuzzy sets, the key concept in Fuzzy Logic. One of its main advantages lies in the fact that it offers methods to control non-linear plants, known difficult to model. At the beginning, fuzzy logic was not accepted by the highly deterministic scientific community. According to the investigation of the Market Intelligence Research Corporation of California in 1991, Japan captured 80% of the world wide market. In 1992, the return in fuzzy products doubled with respect to the previous year whereas companies like OMROM, held about 700 patents at that date. Germany, India, France, Korea, Taiwan and China followed Japan in Fuzzy Logic Research and Development projects.

2.3 IMPLEMENTATION OF FUZZY LOGIC

It is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software or a combination of both. Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy or missing input information. Using Fuzzy Logic a person can make his decision faster. Fuzzy logic is a form of many-valued logic derived from fuzzy set theory to deal with reasoning that is fluid or approximate rather than fixed and exact. In simple words, fuzzy logic is a super set of conventional logic that has been extended to handle the concept of partial truth--the truth values between completely true and completely false. Both fuzzy implementations have a diverse range of applications including medicine, avionics, security and machine learning. Rule based systems explicitly collect the expert's knowledge. These rules and thinking patterns are then programmed into the system. Rule based systems do not require a large training set like that of neural network solution .Unlike rule-based fuzzy logic, neural network do not require thinking patterns to be explicitly specified. Typically two datasets are created to program a neural network. The first dataset is the trainer. This set of input is passed into the neural network and processed. The processing phase consists of storing the input values among an array of memory structures called nodes. Each node remains some information and sorts the remaining information between the neighbouring nodes.[1] Once all the information has been processed it is evaluated and stored as the template for which all other datasets will be compared. The advantage of the rule based fuzzy logic system is that it is easier for the system to rationalize its behaviour to users. Rule based fuzzy logic system behaviour is determined by rules or parameters and the changes to these parameters represent the incentives to take action.

2.4 RESEARCH AND DEVELOPMENT FIELDS OF FUZZY LOGIC

In the early stages, the applications of Fuzzy Logic were confined to control systems and process control where the mathematical model of the plant is unknown, complex and not well defined. But later, the areas where Fuzzy Control has been applied comprise a wide variety of applications, with different complexity and performances. At present, the application of Fuzzy Logic exceeds the control domain since it is also employed for other knowledge based decision making tasks.[2] It involves medical diagnosis, business forecasting, traffic control, network management, image processing, signal processing, computer vision, geology and many more (Costa A.,et al., 1995).

Table 2.1 covers a range of research areas related to Fuzzy Logic as reported in the IEEE 2001 International Conference on Fuzzy Systems.

Table 2.1

Research and Development area	**Main Topics**
Fuzzy Mathematics	Foundations of Fuzzy Logic, appropriate reasoning, evolutionary computation, identification and learning algorithms, rule base optimization.
Control Systems	Fuzzy control theory and applications, process and environmental control, stability criterions issues, multilevel-supervisory control.
Pattern Recognition and Image Processing	Supervised and Unsupervised learning, classifiers design and integration, signal/image processing and analysis, computer vision, multimedia applications.
Soft Computing and Hybrid Systems	Intelligent information systems, database systems, data mining intelligent systems,reliability engineering, Neuro-Fuzzy systems, Internet computing, networks traffic modellingand control.
Electronic Systems	Fuzzy hardware implementation andembedded applications.
Robotics and Automation	Fuzzy Logic in robotics, industrial automation and other industrial applications.

Table 2.2 shows some successful fuzzy systems presently at work.

Table 2.2

SOME SUCCESSFUL FUZZY SYSTEMS PRESENTLY AT WORK

Industrial	Cement kiln Control (Denmark) Automatic train operation (Japan) Water treatment system (Fuji electric, Japan) Water treatment system (Fuji electric, Japan) Smart sensors (Fisher Rosemount, USA) Blast furnace control (NKK Fukoyama, Japan) Nuclear reactor control (Art Fugen, Japan) Fire detector (Cerberus, Switzerland) Camera tracking (NASA, USA) Target tracker in Patriot missile (MMES, USA)
Commercial	Washing machine (Matsushita, Japan) Home heating system and air conditions Photocopy machine (Sanyo, Japan) Fuzzy auto focus still camera (Japan) Vacuum cleaner (Sony, Hitachi, Sanyo,

	Toshiba, Sony) Refrigerator (Sharp) Rice Cooker (Matsushita, Sanyo, Sharp, Hitachi) Home air conditioner (Mitsubishi Heavy Industries, Japan)
Research	Speech recognizer (NTT communication, Japan) Fuzzy medical expert system Helicopter control (LIFE, Japan) Fingerprint classification (NIST, USA) Autonomous robot control (SRI International, USA) Autonomous navigation of robots (ORNL, USA) Used car selection (A used car center in Kansai, Japan)

2.6 UTILIZATION OF FUZZY LOGIC–BASED TECHNOLOGIES IN MEDICINE AND HEALTHCARE INTERNAL MEDICINE

Internal medicine is a classic field of research in computer-aided diagnosis which began in the 1960s with high hopes that difficult clinical problems might yield to mathematical formalism. The main areas in internal medicine can be classified into rheumatology, gastroenterology, hematology , and pulmonology. Designing and tuning fuzzy rule–based systems for medical diagnosis was discussed by Rotshtein . A fuzzy inference system was developed to aid in the diagnosis of pulmonary embolism using ventilationperfusion scans and correlated chest X-rays. The Mamdani fuzzy model was successfully employed to implement the inference system .

Cardiology and Vascular Surgery

In the mid-1990s several workers pointed to the concept of fuzzy sets in cardiovascular medicine. Implementation of fuzzy control of a total artificial heart was one application. The main task of the artificial heart control system is to maintain sufficient organ perfusion by controlling the pumping rate. Another application that incorporates fuzzy logic is a system called TOTOMES which was designed to assess cardiovascular dynamics during ventricular assistance. This involves multi-interpretation tasks and dynamic system identification as well as fuzzy reasoning for realizing state estimation and detection and diagnosis of malfunctioning. Other applicationsinclude coronary artery disease fuzzy classifier, ECG classification and diagnosis, and treatment and diagnosis of heart disease.

Intensive Care

Intensive care applications are close to anesthesia in their medical function nevertheless, applications can be divided into blood pressure and respiration regulation, EEG monitoring and pain relief. Keeping the oxygenation status of newborn infants within physiologic limits is a crucial task in intensive care. Many automated systems based on fuzzy logic have been developedwhich are capable of distinguishing between critical situations and artifacts. For online monitoring of patients in ICU, a system for breath detection was developed based on fuzzy sets and noninvasive sensor fusion.

Endocrinology

An expert system (PROTIS) used for deduction of fuzzy rules was developed for treatment of diabetes. Another decision support system for treatment of diabetic outpatients using fuzzy classification was described by Stadelmann. Fuzzy inference was utilized for a diagnostic system of diabetic patients by quantitative analysis of the dynamical responses of glucose tolerance tests. A knowledge-based system was also developed for monitoring diabetics which consisted of fuzzy rules and hierarchical neural networks.

Oncology

The use of fuzzy logic for oncology has been concerned with classification (for discriminating cancer from normal tissue) and therapy advice. Therapy was mainly based on advanced image processing magnetic resonance image analysis for tumor treatment planning and ovarian cancer has been attempted.

Gerontology

This is a good example of how fuzzy logic could be applied in a flexible way. A fuzzy relational system was used to implement the databases for building a veterinary expert system. Later on, a few broader applications started to emerge such as the work by Lim who analyzed the difficulties of designing an inference system for the diagnosis of arthritic diseases including variations of disease manifestations under various situations and conditions.

Anesthesia

The first real-time expert system for advice and control (RESAC) in anesthesia was developed to advice on the concentration of inhaled volatile anesthetics. Anesthetists were confident enough to follow the dosage advice given by RESAC in most of the patients. On the other hand, direct application of fuzzy logic rule-based controllers has been implemented for controlling drug infusion to maintain an adequate level of anesthesia by monitoring blood pressure and muscle relaxation. Evoked potentials were also used as a measure of depth of anesthesia for controlling drug infusion using fuzzy logic controllers and EEG monitoring, supervisory control or a safety shell has been used to oversee the performance of a controller and to direct the controller to take corrective actions in the case of special situation such as disturbances. Based on this indication, fuzzy logic is used to decide the amount of drug infused to maintain a constant depth of anesthesia .

Gynecology

The time intervals between two subsequent tests have been modeled as fuzzy sets, since they allow the formal description of the temporal uncertainties.

2.7 FUZZY SETS

Prof. LotfiZadeh discovered fuzzy logic in 1965 from his idea about fuzzy sets. As defined by Zadeh, a fuzzy set is a class of objects with a continuous of grades of membership. A fuzzy set is characterized by a membership function. The representation depends not only on the concept, but also on the context in which it is used. The word fuzzy has become common knowledge and a household term. The terms associated with fuzzy – imprecision, uncertainty, approximate, inexact, incomplete or not totally reliable, unclear or ambiguous.[3] The concept of high temperature in the context of weather and in the concept of furnace would necessarily be represented by very difficult fuzzy sets.

- A Fuzzy set is defined by naming all its members -
  - I. Possible only for finite sets.
  - II. Example – Set of one digit even numbers i.e. A= {2, 4, 6, 8}.
- A Fuzzy set is defined a property satisfied by its members –
  - I. A={x | P(x)}, where P(x) designates a proposition or property of x.
  - II. Example – A={x | 0<x<10} and x is even} for x ∈ X, where X is the universal set.
- A Fuzzy set is also defined by a characteristics function (F_A) –
  - I. It declares which elements of the universal set (X) are members of the set and which are not.
  - II. Example – Set A is defined by its characteristics function F_A as follows

$$F_A(x) = 1 \text{ for } x \in A$$
$$= 0 \text{ for } x \notin A$$

2.8 CRISP SETS:

The sets which we used in our daily life are crisp sets. Crisp Set's member may or may not be a member of the set. Universal set is always a Crisp set. For example, a jelly bean belongs in the class of food known as candy. Mashed potatoes do not.

2.9 MEMBERSHIP FUNCTIONS:

Characteristics function of a crisp set assigns a value either 0 or 1 to each individual in the universal set. This function can be generalised such that the values assigned to the elements of the universal set fall within a specified range and indicate the membership grade of these elements in the set in question. Larger values denote higher degrees of set membership. Such a function is called Membership Function. Membership Functions may be different shapes. Membership Functions may be separate or they may overlap.
Notations to denote membership function –
μ_A: x → [0, 1] where $\mu_A$is the membership function of a fuzzy set A.
A: x → [0, 1]
An example of membership functions are shown in Figure 1. u is the degree of membership in the set.

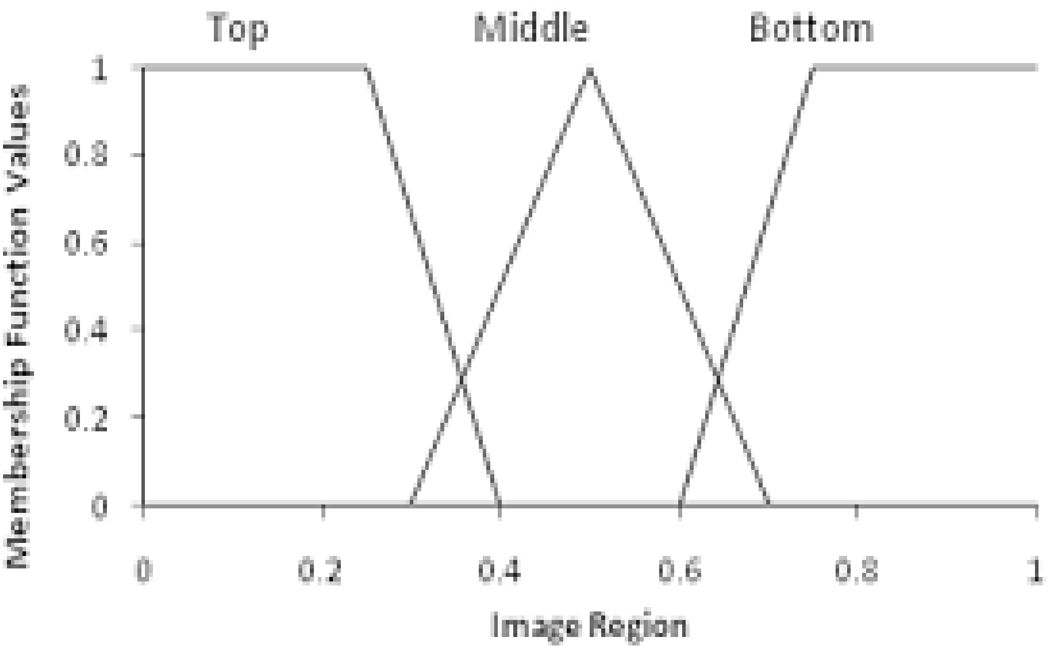


Fig 1:*Membership Functions for the Set of All Numbers*

2.10 FUZZY VARIABLE

Fuzzy sets represent linguistic concepts such as “low”, “medium”, “high” etc. These are often employed to define states of a variable. States of fuzzy variable are fuzzy sets representing linguistic concept, such as “very low”, “low”, “medium”, “high”, “very high” etc. These functions are commonly represented by graphs of trapezoidal or triangular shape. States of the corresponding traditional variable are crisp sets, defined by the right open interval of real numbers. Fuzzy variable facilitate gradual transition between the states and consequently possess a natural capability to express and deal with observation and measurement uncertainties. Crisp variables do not have this capability. Although the definition of states by crisp sets mathematically correct, it is unrealistic due to the unavoidable measurement errors.

2.11 OPERATIONS WITH FUZZY SETS

Two fuzzy sets A and B are represented by membership function f_A and f_B respectively-

1. Union : $C = A \cup B$, where $f_C(x) = \text{Max}\{ f_A(x) , f_B(x) \}$ for all $x \in X$ (see fig. 2-1)

2. Intersection : $D = A \cap B$, where $f_D(x) = \text{Min}\{ f_A(x) , f_B(x) \}$ for all $x \in X$ (see fig. 2-2)

3. Complement of A is given by A^c, where $f_A{}^c = 1 – f_A$

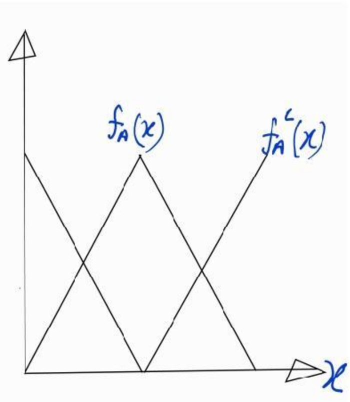


Fig 2.1:*2-3 Complement*

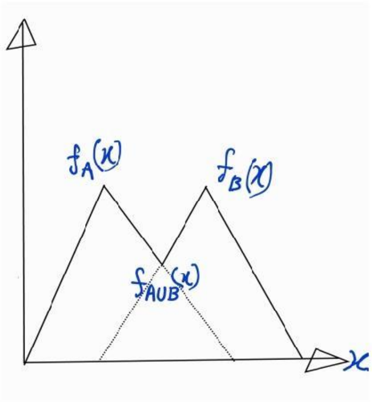


Fig 2.1:*2-1 Complement*

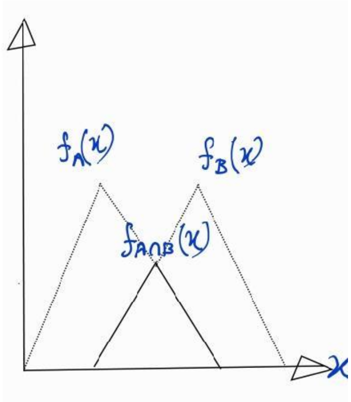


Fig 2.1:*2-2 Complement*

2.12 FEW DEFINITIONS RELATED TO FUZZY SETS

SUPPORT

The support of a fuzzy set A is the set of all points x in X such that $\mu_A(x) > 0$,
i.e. Support (A) = $\{ x \mid \mu_A(x) > 0 \}$, (see figure 3)

CORE

The core of a fuzzy set A is the set of all points x in X such that $\mu_A(x) = 1$,
i.e. Core (A) = $\{ x \mid \mu_A(x) = 1 \}$, (see figure 3)

NORMALITY

The fuzzy set A is said to be normal if its core is non-empty,
i.e. we can always find a point $x \in X$, such that $\mu_A(x) = 1$

CROSSOVER POINTS

A crossover point of a fuzzy set A is a point of $x \in X$ at which $\mu_A(x) = 0.5$
i.e. Crossover (A) = $\{ x \mid \mu_A(x) = 0.5 \}$, (see figure 3)

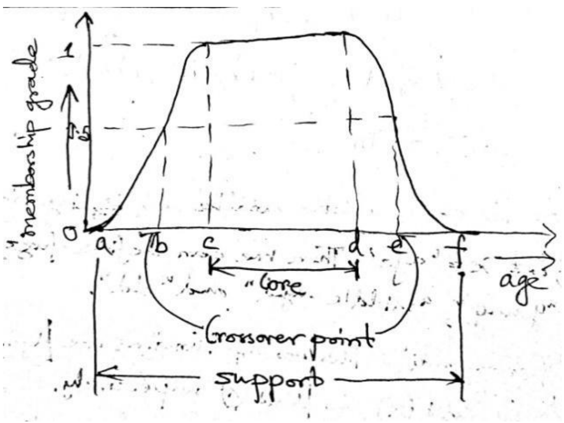


Fig 3:*Crossover Point*

α−CUT OR α−LEVEL SET

Given a fuzzy set A defined on x and any number α∈[0, 1]. The α−cut of A, denoted by α_A or Aα is the crisp set that contains all the elements of the universal set X, whose membership grades in A are greater than or equal to specific value of α.

Mathematically, α_A or Aα = {x | $\mu_A(x) \geq \alpha$ }, (see figure 4)

STRONG α−CUT OR STRONG α−LEVEL SET

Given a fuzzy set A defined on x and any number α∈[0, 1]. The strong α−cut of A, denoted by $\alpha+_A$or A`α is the crisp set that contains all the elements of the universal set X, whose membershipgrades in A are greater than the specific value of α.

Mathematically, $\alpha+_A$ or A`α = {x | $\mu_A(x) > \alpha$ }

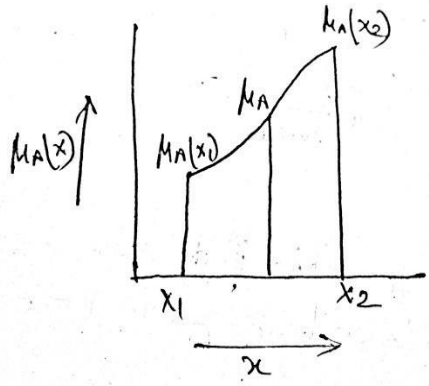


Fig 4: *Strong α-cut*

CONVEXITY

A fuzzy set A is said to be convex, if and only if for any x_1 and x_2 and any λ∈ [0, 1]

$\mu_A(\lambda x_1 + (1 - \lambda) x_2) \geq \min \{ \mu_A(x_1), \mu_A(x_2) \}$

A fuzzy set A is convex, if all its α−level cuts are convex, (see figure 5)

Fig 5:*Convexity*

BANDWIDTH

For a normal and convex fuzzy set, the bandwidth is defined as the distance between two unique crossover points.

Width (A) = $| x_2 – x_1 |$, where $\mu_A(x_1) = \mu_A(x_2) = 0.5$, (see figure 6)

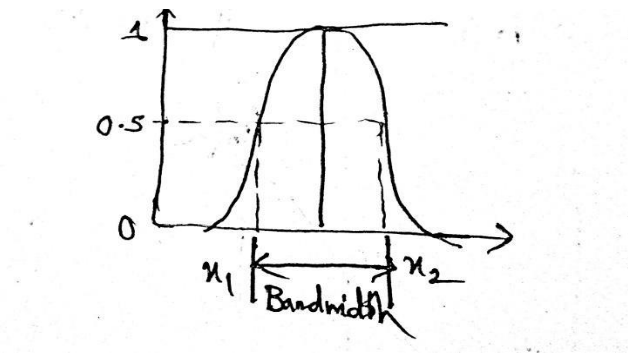


Fig 6: *Bandwidth*

3. Objective of The Project

The objective of our project is to identify a handwriting using fuzzy logic. At first in the pre-processing stage the original image is converted into gray scale image if it is an RGB image. Then binarization is performed and noise is removed using various filters. After obtaining the pre-processed image segmentation is performed. In this stage the individual characters are extracted from the image. Then feature extraction is performed to extract unique features of the characters. Finally the value obtained after extracting the features of the characters is fed into fuzzy toolbox for recognition. We can see the recognized handwriting in a text file.

4. SYSTEM DESIGN:

Our project is basically designing an intelligent system which will recognise handwritten characters singularly. Here we will take a scanned image of handwritten text and perform some operations like pre-processing, binarization, noise removal and then from that we will extract the characters from the text or scanned image which will later go through the feature extraction using type-1 or type-2 Fuzzy Logic. After that with the extracted features we will recognise the letters o characters. The system will be able to work in different web services, police services, banking services and postal services etc. where the handwritten characters need to be recognised and happens to have the most important applications. The design of the system is shown below.

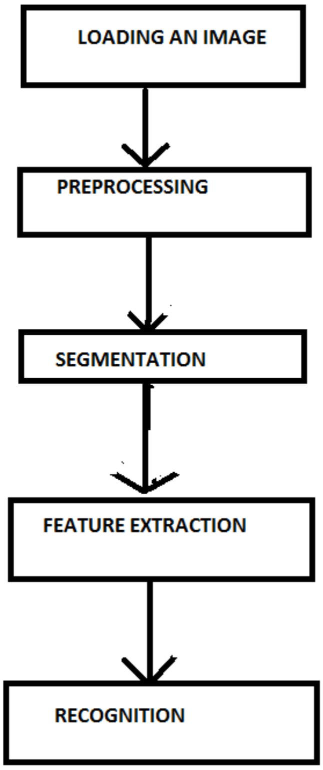


Fig 7:*Flow chart of the working principle of the system*

5. METHODOLOGY FOR IMPLEMENTATION

5.1 IMAGE ACQUIRIZATION

This is the first and foremost task in processing an image. Image can be acquired from taking pictures through camera of from internet so on. But in our case we have written a word, scanned it so that we can get the handwritten text and then work with it.

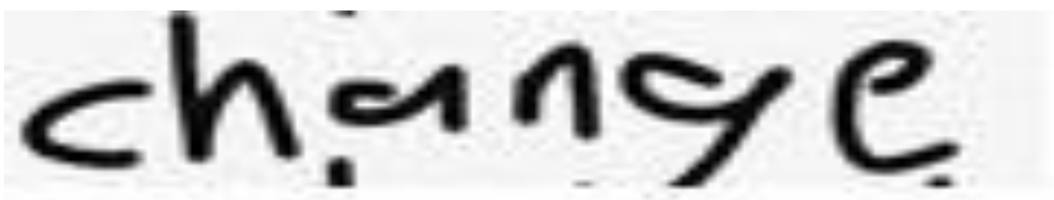


Fig 8: *Original Image Input*

5.2 PREPROCESSING

Pre-processing is the initial task for handling any type of image. It consists of many different methods like *Cropping*, *Resizing*, *Binarizing*, *Noise Removal* or *Filtering* and *Inversion* of an image. Different type of image needs different pre-processing methods. In our case the acquired image has gone through the following steps:

1. At first we converted the original i.e. the scanned image to a binary image.
2. For better results noise should be removed. So we removed the noise from the image using some methods like median, Gaussian and Laplacian filtering etc.
3. After that we inverted the image because to do our job precisely we have to have the handwritten text in white pixel and the background in black pixel.

Fig 9: *Binarized Image*

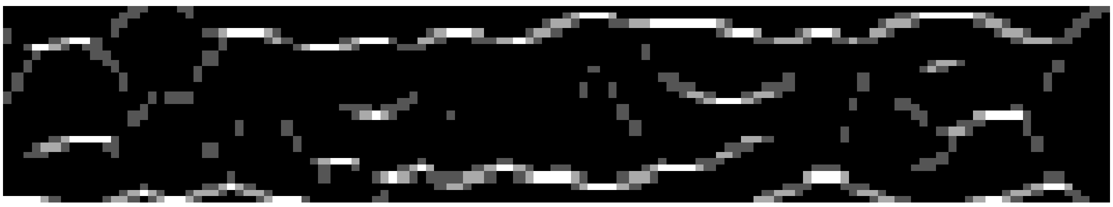


Fig 10: *Noise Filtered Image*

Fig 11. *Skelitonized Image*

5.3 CHARACTER SEGMENTATION

To recognize a character it is very important to segment the text into individual characters. So segmentation is very important. For this using *BoundingBox Feature*, at first each character of the text is embraced with a red colour box each and each box containing a single character is put into an array. The array will contain the characters extracted from the text and from that we can get any character of the text anytime individually. Thus using segmentation character extraction is done and depicted below.

Fig 13: *Extracted Characters*

5.5 FEATURE EXTRACTION USING TYPE-2 FUZZY LOGIC

Initial Feature extraction method:

Our idea of feature extraction of characters is that we consider 4 line segments to extract the features of the characters. The line segments we choose for feature extraction are **horizontal, vertical, 45 degree line and 135 degree line**. We studied that an English characters contains maximum four line segments. So we have implemented these features and finally fed those features into the fuzzy toolbox to recognize the handwriting.[2]

Fuzzy Rule for extraction:-

Table 5.5.1
Table according to the initial feature extraction rule

INPUT IMAGE DATA	HORIZENTAL LINE	VERTICAL LINE	45 DEGREE LINE	135 DEGREE LINE
A	YES	NO	YES	YES
B	YES	YES	NO	NO
C	YES	YES	NO	NO
D	YES	YES	NO	NO
E	YES	YES	NO	NO
F	YES	YES	NO	NO
G	YES	YES	NO	NO
H	YES	YES	NO	NO
I	YES	YES	NO	NO
J	YES	YES	NO	NO
K	YES	NO	YES	YES
L	YES	YES	NO	NO
M	NO	YES	YES	YES
N	NO	YES	YES	NO
O	YES	YES	NO	NO
P	YES	YES	NO	NO
Q	NO	YES	NO	YES
R	YES	YES	YES	NO
S	YES	YES	NO	NO
T	YES	YES	NO	NO
U	YES	YES	NO	NO
V	NO	NO	YES	YES
W	NO	NO	YES	YES
X	NO	NO	YES	YES
Y	NO	YES	YES	YES
Z	YES	NO	YES	NO

Thus each and every character will have one of the following four different features-

- Horizental,vertical,45 degree
- Horizental,vertical,135 degree
- Vertical,45 degree,135 degree
- Horizental,45 degree,135 degree

And we can extract their features according to these groups.

Another method called fuzzy rule based feature extraction:

We define a variable g which will return the result from fuzzy toolbox. g is calculated using the formulae g=squareroot(x^2-y^2). We use the value the value of g to decide the range of each character. If it falls within the given range the character is recognized. For example if value of g lies in between 0.5 and 1.5 then the character is A. Thus a little distortion in the characters can easily be handled using this algorithm.[4]

6. IMPLEMENTATION DETAILS (PROPOSED)

Characters that are been extracted at first will then go through some segmentation according to geometry. The primary goal of a rule base generation method is to create a minimum number of rules. This is important under two observed aspects in pattern recognition systems. The discrimination power of the classification process is inversely dependent on the number of classification rules. The number of selected features within a rule has a direct impact on the computational time of the recognition process.[8][9][10]

For the feature extraction we will be following the algorithm mentioned below.

Algorithm: (*Rule based handwriting recognition)*

Step 1: Divide the data space into smaller pattern domains like segments in on-line handwriting (Level **L1**).

Step 2: Compute the geometrical features as fuzzy linguistic variables for each domain (Level **L2**).

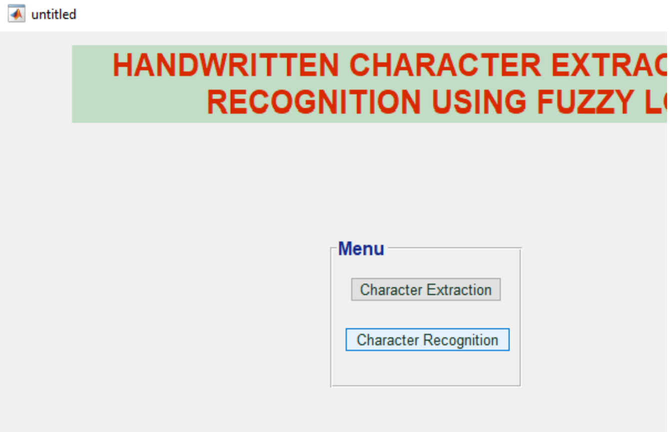
Step 3: Aggregate the features for all domains (from step 2) to form global features (Level **L3**).

Step 4: (a) *Learning Phase:*Form linguistic rules with global linguistic features from Step 3 and integrate them in afuzzy rule base.

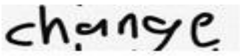
(b)*Classification Phase:*Classify the unknown information by parsing the rule base created in Step 4(a). "CharactersLevel". (Level **L4**)

Step 5: Cross-check the "recognized" character in the given context. In case of error go to Step 4(b) for the next option. In case of failure go to Step 4(a) for adapting. Else list recognized character. (Level **L5**)

7. RESULT/ SAMPLE OUTPUT



HOME PAGE



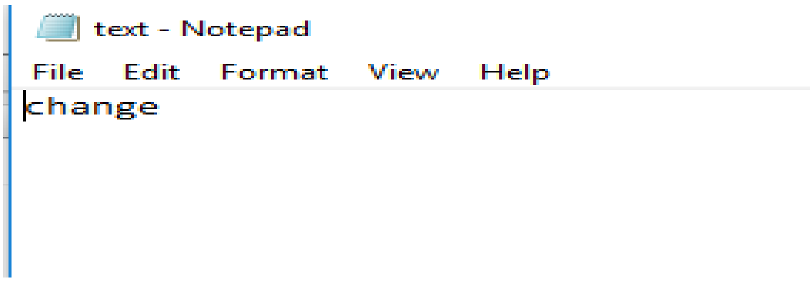
ORIGINAL IMAGE

BINARIZED IMAGE

NOISE FILTERED IMAGE

SKELITONIZED IMAGE

EXTRACTED CHARACTERS



RECOGNIZED IMAGE

8. CONCLUSION

By introducing various new features we have implemented type 2 fuzzy logic. Thus using this software we can identify various handwritings whether good or bad. The future scope of this project is we will try to develope new features so that we can identify the numbers and we will try to identify more distorted handwritings. We will also try to implement more unique features for better accuracy.

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