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BIO-INSPIRED MULTILAYERED AND MULTILANGUAGE ARABIC SCRIPT CHARACTER RECOGNITION SYSTEM

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Abstract. *Handwritten character recognition is one of the most fascinating, complex and challenging task of pattern recognition research and it has been an ongoing research since the early days of computer. The aim of character recognition is to imitate the human reading capabilities to machine so that it can act like human. Although it is a very difficult task, it has several practical application. Naturally translation, rotation and position are independent of human visual perception which cannot be easily attained by computer system, but these have also some effect on human reading speed and accuracy. Bio-inspired pattern recognition has proved itself a powerful method to deal with complex patterns whereas fuzzy logic is powerful classifier to recognize irregular and implement human reasoning concept. We combine the human visual concept with fuzzy logics to involve the human reasoning for multilanguage Arabic script based language character recognition. The proposed approach is tested on Multilanguage only written in Nasta'liq style and it provides 86.2% accuracy.*

Keywords: Biologically, Nature inspired, Expert system, Multilanguage, Arabic, Urdu, Fuzzy logics, Naskh, Nasta'liq

1. **Introduction.** Handwritten character recognition is one of the most attractive and challenging task of pattern recognition and it has been an ongoing research since the early days of computer whereas online character recognition is started in the late 1950s. The aim of character recognition is to imitate the human reading power to computer so that it can act like human in reading. Although copping the human capabilities to machine is very difficult and complex task, it has many practical applications. With respect to the mode of input, character recognition is classified into three categories: printed offline, handwritten offline and handwritten online. In offline, only the spatial information in the form of image is available whereas in online, additional timing information with strokes elements is available, which makes online character recognition a little easier than offline. Online character recognition is gaining more interest due to increasing popularity of hand-held devices and natural way of input to the machine.

Complex nature objects recognition cannot be statically performed [18]. There are several uncertainties in cognitive system due to various reasons, i.e., static, random, physical,

chaotic and fuzzy. These uncertainties have effect on the accuracy depending on the type of problem, whereas it is very difficult to classify the problem into different uncertainty level [1]. Inconsistencies and variation make handwritten Arabic script based languages character recognition more complex as compared to any other script. Thus, in case of Arabic script recognition especially handwritten, a careful observation is required to divide the complex handwritten recognition into different uncertainty levels. We used the human ventral stream and reasoning concept to divide the handwritten problem into different uncertainty levels.

1.1. **Arabic script properties.** There are at least 26% Muslim in the world having directly or indirectly interaction with Arabic script due to the born of Islam Arabs and it has influenced many languages, i.e., Hindi and Urdu: approximately the same language but different writing style. Actually, Arabic script is used by many languages like Arabic, Persian, Urdu, Punjabi, Sindhi, Pashto, Blochi, etc. in many countries such as Arabian Peninsula, Iraq, Iran, Pakistan, Afghanistan, India, Uzbekistan, Tajikistan and Kazakhstan. Arabic script based languages especially Urdu and Arabic are used in every part of the world.

Arabic script is written in cursive style from right to left and top to bottom in both printed and handwritten. Arabic script based languages are the context sensitive languages and written in the form of ligatures which comprise a single or up to many different characters to form words. Most of the characters have different shapes (4 for Arabic and up to 32 for Urdu) depending on their position in the ligature, e.g., the letter appeared as isolated, middle, center, end shown in Figure 1 and Figure 2. Furthermore, character overlaps each other and also contains diacritical marks (22 diacritical marks in Urdu script) while additional diacritical marks associated with ligature represent short vowels or other sounds. Arabic script has also used the punctuation marks to separate sentences and have white space between ligatures and words for separation.

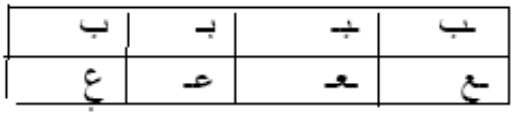

FIGURE 1. Different shapes of (ب and ع) with respect to position from left to right isolated, start, mid and end

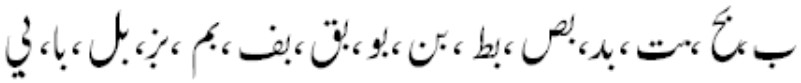

FIGURE 2. Different shape of ب in Nasta'liq style based on association with other characters

Mostly, Arabic script based languages are written in two writing styles: Naskh and Nasta'liq. Naskh is mostly followed by Arabic whereas Nasta'liq is mostly followed by Urdu and Persian. Nasta'liq is the most complex script and character shape may be up to 32 depending upon the association of character on both sides shown in Figure 2. Secondary Urdu is rich in diacritical marks as compared to Arabic and Persian.

Urdu is a superset of all Arabic script based languages because it contains all the shapes of other languages. Local languages of Pakistan like Punjabi, Sindi, Pashto have more different letters than Urdu but with the same basic shapes different diacritical marks shown in Figure 3. All the Arabic script based languages can be written with the 22 ghost character and 22 dots and diacritical marks, but each base ligature has its own phonemes and meanings in every language with the same or different number of diacritical marks. Thus, the basic shapes (glyph) are the same for all Arabic script based languages with only difference in font, i.e, Naskh, Nasta'liq and diacritical marks followed by every language.

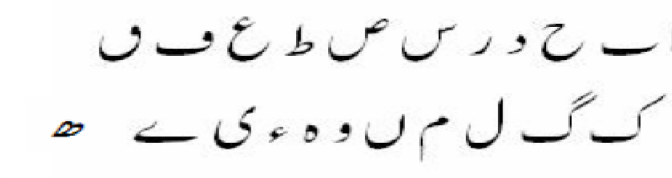

FIGURE 3. Basic ghost character for Arabic script based languages written in Nasta'liq

1.2. **Human visual system.** Several complex pattern recognition applications have been studied under human visual concept for object recognition, especially in motion detection, object recognition. Human brain does not store the picture; it stores only the spatial information of the objects [2]. The visual sense is activated in response to curve and geometrical characteristics [4]. This object spatial information is stored in neurons, i.e., various orientation lines, edges and endpoints, etc. [3] whereas the recognition is based on the matching of the spatial relationships stored in the mind instead of image matching the whole image. The human visual system is more sensitive to curved line and other geometrical points and has huge storage of context knowledge and thus, human recognition system is very powerful for complex shapes, i.e., handwritten character recognition, motion detection, etc. To understand how human brain can achieve these extraordinary abilities, briefly human visual system is described. This is the fact that suggests to model human visual perception in real world image processing algorithms by using some principle of present in our visual system.

The study performed on monkey shows that object recognition is feed forward for fast recognition, whereas the visual perception is done in hierarchical manner and sensitive to edges, lines, etc. Sharp contour are more discriminate features than gradients whereas straight lines are more important than irregular pattern [1]. Early visual parts are responsible for extraction of simple features; i.e., retina, LGN, V1 and V2 take part in extraction of simple features like edges, orientation, color, etc. The neurons structure becomes more complex and its respective field becomes larger in the upper side of ventral stream [4].

The human recognition system consists of seven or eight major layers and four layers are used for computation [1]. Lower layer neurons are more precise for simple features as compared to upper layer features. Basic division of human visual system is shown in Figure 4. The visual seen by information covered by two eyes is transmitted to the literal LGN. The V1 is the primary visual cortex responsible for static and moving objects and it receives the information from LGN. As a model of V1 neurons, Gabor filter has been used for many applications of image processing, i.e., edge detection, writer identification, texture processing, etc. [5]. The V2 is responsible of orientation and spatial properties such as contour and boundary computation. The contour extraction and feature grouping is performed at first level by the combination of V1 and V2 [1,3,6,7]. Therefore, the first stage is responsible for object motion detection, contour extraction, background

and object detection. LGN, V1 and V2 take part in extraction of simple features like edges, orientation, color, etc. and forward these simple features next for extraction of complex features from these simple features. The second stage is responsible for complex features whereas the third stage is responsible in combining these large numbers of features extracted during Stage 1 and Stage 2 to form complex patterns. The fourth stage object generalization is responsible for the recognition of object. The huge context knowledge of human plays an important role in the recognition. Without the enough context knowledge, human visual perception cannot perform well in case of complex patterns.

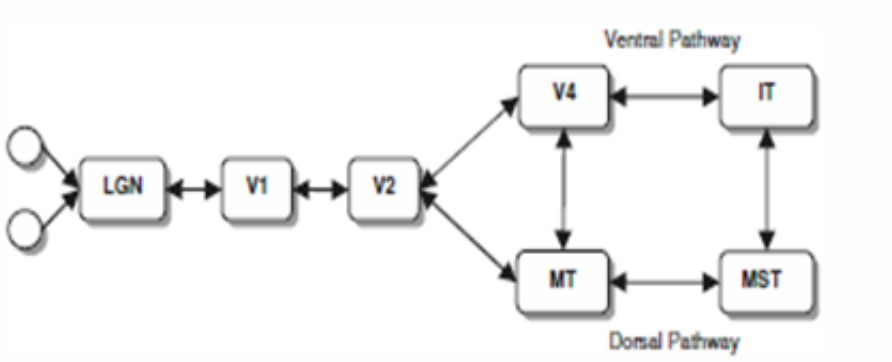

FIGURE 4. Human visual system [3]

In the case of human imitating, it is very difficult to build such a big memory as of human that can be used as a clue for recognizing the complex objects, but we can divide the complex task into layers inspired by using human biological system concept and each layer can be focused by different uncertainty level using fuzzy logics.

The computer can perform complex problems more precisely, efficiently and much faster than human; however, there are still many problems such as pattern recognition, image processing where a few months old child can perform much better than the latest algorithms available today. Bio-inspired pattern recognition has been under consideration by the computer scientist and neuroscientist since mid eighties to model human vision system into applications of pattern recognitions [8]. Biological inspired image recognition in human indicates that processing is intergraded at different levels, i.e., small pattern to complex patterns. The implementation of human integration principle helps to achieve robust system in term of speed, accuracy and efficient. The understanding of visual information processing and perception principle is one of the most challenging task of contemporary science. The deeper understanding of human biological vision helps to advance the pattern recognition research. The selectivity, transformation invariant, speed and context knowledge are the most important features of human visual perception. Moreover, human is able to detect the familiar and unfamiliar objects even in variable environment, i.e., face recognition in different pose, illumination, expression and environment. The real time data may be ambiguous, incomplete produced due to several reasons, i.e., blurred edges, irregular and missing patterns. Biological concept can be modeled using fuzzy logics, evolutionary computation and neurcomputing. Different methods based on statistical methods, Neural networks, etc. for handwritten character recognition have been presented in literature [1,9-11]. The rest of the paper is organized as follows: Section 2 discusses Multilanguage recognition system inspired by biological; finally, results are discussed in Section 3.

2. **Multilayer Arabic Word Recognition.** In case of object recognition, few months old child can perform better than the latest algorithms available today. Extra ordinary view device, efficient processing power and huge context knowledge make human power as compared to machine. Human store the few pattern in his mind instead of copy of whole object and recognition is also based on these pattern matching by layer by layer computation of features. The processing of human brain can be modeled in real world application by integrating at different levels, i.e., small pattern to complex patterns extraction. The implementation of human integration principle in Arabic character recognition system helps to achieve robust system in term of speed, accuracy and efficient. The human context knowledge has the biggest role in character recognition. As it is very difficult to build database of high context knowledge, thus to implement the context knowledge in character recognition application, we use the language rules and database for word level modeling. As every language has its own properties, i.e., writing rules, features, and unique complexity thus, the classification process is highly dependent on the language rules. We applied the biological system concept with the help of language rules to recognize the Arabic script based languages in multilayered inspired by human biological system. The linguistics rules of Arabic script based languages are added at every layer using fuzzy logics to handle uncertainties involved in handwritten character recognition. The script rules play an important role in solving the uncertainties using fuzzy logic, i.e., diacritical marks handling, character combination to form bigger patterns.

We divide the system into six layers based on different uncertainties level and we used the fuzzy triangular member function with additional language rule as clue to insert context knowledge into the system at each level L1, L2, ..., L6. Lower levels, L1 and L2 are responsible for preprocessing and simple level features extraction and level 3 and level 4 are responsible for complex structural and geometrical features. L5 is responsible for fusion of structural and geometrical features to form more complex features. L5 is also responsible for character level recognition and L6 is responsible for word level recognition using finite state machine. The spatial information is used at each layer to extract the pattern by combining the smaller pattern using their spatial information. Moreover, some additional features of previous subpart are also used to compute the current subpart feature.

Arabic script based languages are rich in diacritical marks especially Urdu and local language of Pakistan. The same ghost stroke may have different meaning based on the number and position of diacritical marks, i.e., Arabic script based languages contains zero or more secondary strokes associated with primary stroke. We observe the human recognition process on Arabic script based language; A study on 50, native reader of Arabic, Urdu, Punjabi, Sindhi and Pashto on two mostly followed writing styles Naskh and Nasta'liq. Based on our study, we concluded that the first step in recognition of Arabic script based languages is to recognize the base shape first and then diacritical marks recognition is performed [11]. Based on this study, we separated the diacritical marks as a first step at level 1 before performing the preprocessing operation. The diacritical marks separation at lower stage helped to achieve robustness in the system because baseline, skewness etc. can be performed better on base ligature without diacritical marks.

Level-1: If Premise1i then Conclusion1i and If LinguisticPremise1a then LinguisticConclusion1a

Where Premise1i ε Level 0 and LigusticPremise1a ε Language

Level-2: If Premise2j then Conclusion2j If LingusticPremise2b then Linguistic

Conclusion2b

Where Premise1k ε Conclusion1k and LigusticPremise2b ε Language && LinguisticConclusion1a

: :

: :

Level-5: If Premise5z then Conclusion6z If LingusticPremise2g then Linguistic Conclusion2g

Where Premise6z ε Conclusion5y and LigusticPremise6g ε Language && LinguisticConclusion5f

where Premise1i is the set of rules for diacritical marks separation and Conclusion1i the separated diacritical marks with associated positions and LingusticPremise, Linguistic-Conclusion are the primacies and conclusion based on linguistics rules. The above rules are the basis of multilayered biological inspired character recognition system.

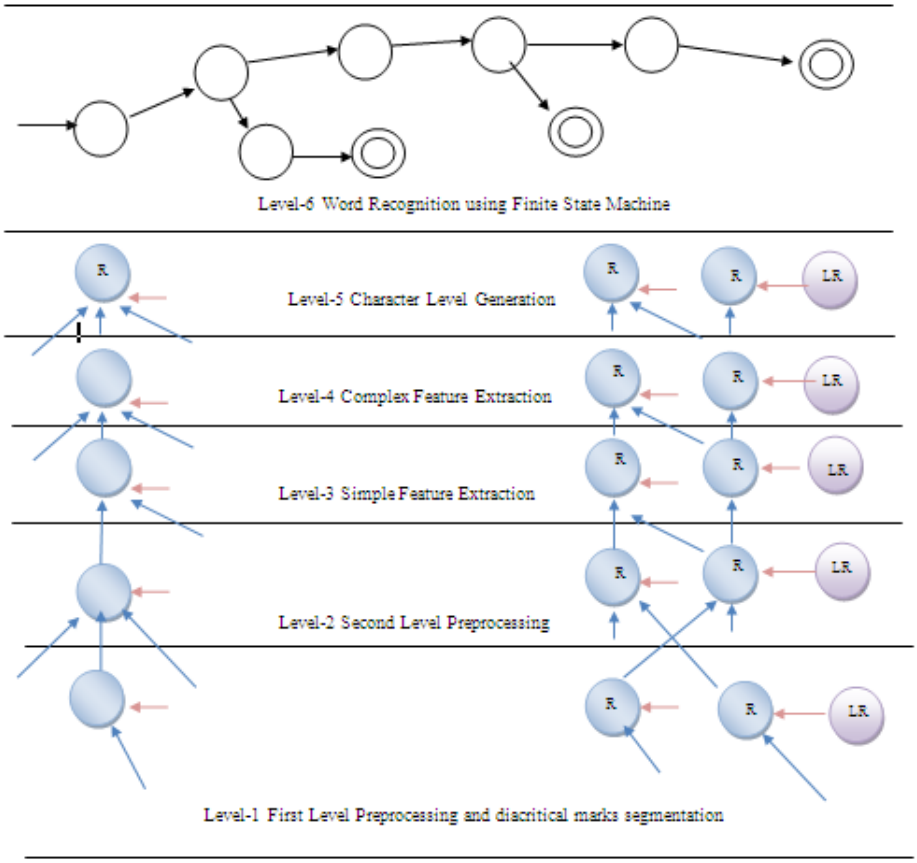

FIGURE 5. Multilevel rule model

The Stage 2 is responsible of geometrics computation and basically extraction of geometrical computation is performed at visual cortex. It is very difficult to read the irregular, non-skewed, non-baseline character. Even the human has brilliant image capturing device and context knowledge, the reading speed and accuracy of non-normalized text is very less as compared to normalized and written on base line text. Although the human visual perception is based on translation and rotation invariant features, but it has some influence on its perception power. In the Stage 2 we performed some preprocessing steps

like baseline estimation, stroke mapping, slant correction etc. [11]. These operations are based on the fuzzy and context knowledge. Although the context knowledge used here is very limited as compared to human, but it can resolve most of the uncertainties involved in it i.e., the baseline is computed by the locally computed angle with additional knowledge of previous word angle. The knowledge of previous word may or may not take part in the correction of baseline. The decision is based on the fuzzy rules, i.e., if the baseline angle computed for current word is closer to the angle of previous and word length is large then the previous has influence on current angle estimation. The following fuzzy rules are used for baseline estimation.

Algorithm:

Step-1: RUN Level-1 Segmentation of diacritical mark from the words and noise reduction
INPUT: Raw input Strokes, Low Level Linguistics Rules
OUTPUT: Primary Strokes, Associated Diacritical Marks, Position Coordinates of each Diacritical Marks.

Step-2: RUN Level-2 Geometrical Computation for Baseline estimation, Slant correction and Mapping
INPUT: Primary Strokes, Associated Diacritical Marks, Position, Low Level Linguistics Rules
OUTPUT: Normalized Word.

Step-3: RUN Level-3 Simple Feature Computation
INPUT: Normalized Words, Low Level Linguistics Rules
OUTPUT: Simple Features.

Step-4: RUN Level-4 Complex Feature Extraction, Formation of Valid Sub Part
INPUT: Simple Features, High level Linguistic Rule
OUTPUT: Complex features, Recognized sub parts.

Step-5: RUN Level-5: Formation of Valid Word [Character Level Recognition]
INPUT: Recognized Sub Parts, Diacritical Marks, Position Information
OUTPUT: Recognized Word.

Step-6: RUN Level-6: Context Level Correction [Word Level Recognition]
INPUT: Recognized Ligature, Linguistic Rules, Finite State Machine
OUTPUT: Recognized Word.

IF word length is Large
And IF the difference current word angle and previous angle is Very Less
Estimate the New angle based on Current and Previous
IF word length is Medium
And IF the difference current word angle and previous angle is Less
Estimate the New angle based on Current and Previous
IF word length is Small
And IF the difference current word angle and previous angle is Less or Very Less
Estimate the New angle based on Current and Previous
$\vdots$
IF word length is Small
And IF the difference current word angle and previous angle is Less
Use the Local Angle

$$NewAngle = F_{Triangular}(\vartheta_c \vartheta_o)$$

Level 3 is responsible for dividing the strokes into sub patterns and extraction of sub patterns. Several patterns vertical lines, end point, junction points are extracted from the

TABLE 1. Fuzzy rules for height of stroke with width

Distance/Position	Up	Down	Inside	Left	Right
Small	MS-1	MS-1	MS-1	MS-1	MS-1
Medium	MS-1	MS-1	MS-1	MS-2	MS-2
Large	MS-2	MS-2	MS-2	NS	MS-3
Very Large	MS-3	NS	NS	NS	NS

TABLE 2. Table 1 result vs height

Size/Score Result	MS-1	MS-2	MS-3
Small	SS	SS	NS
Medium	SS	SS	NS
Large	SS	NS	NS
Very Large	SS	NS	NS

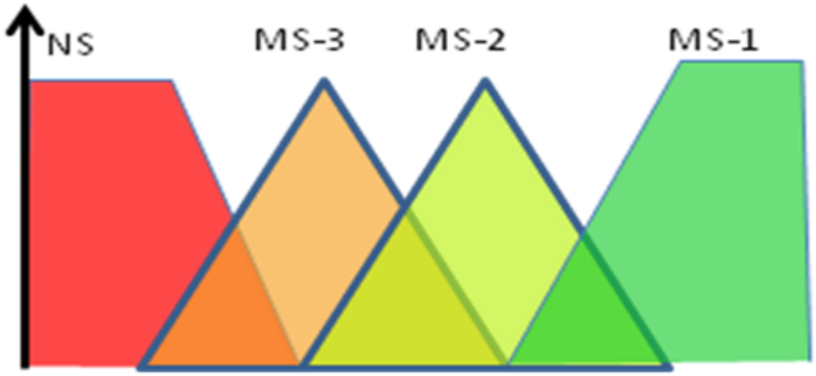

FIGURE 6. Membership function for table

normalized word. The complex pattern extraction from simple pattern and combination of complex pattern to form identified sub unit is performed at Level 4. The simple pattern obtained at Level 3 are combined to form complex patterns, i.e., long vertical up, long vertical down, small vertical up, cusp, loop, hedge, etc., and moreover some complex pattern are extracted, i.e., hedge cusp directions, direction, loop direction and loop shapes. For each sub pattern new pattern are computed with the combination of different associated sub components. L4 gives the recognized subpart, i.e., characters in the strokes. These recognized characters are combined using the linguistics rules and rule based approach at Level 5. The diacritical marks mapping is done using the fuzzy triangular member function. The linguistics rules, associated dot, recognized sub unit with associated units and diacritical positional information based on projection is used for mapping the secondary strokes.

We used the finite state word recognizer for word recognition shown in Figure 7. The finite state machine always in a state to expect a new ligature. When it receives a white space character, then it results accepting state and leaving a white space the system gets ready to read new ligature, shown in Figure 7.

3. **Results and Discussion.** Fuzzy logic has proved itself a powerful tool for classification of irregular and complex patterns. Naturally human recognition system is translation, rotation and position invariant. Thus, it is very difficult to imitate the human perception

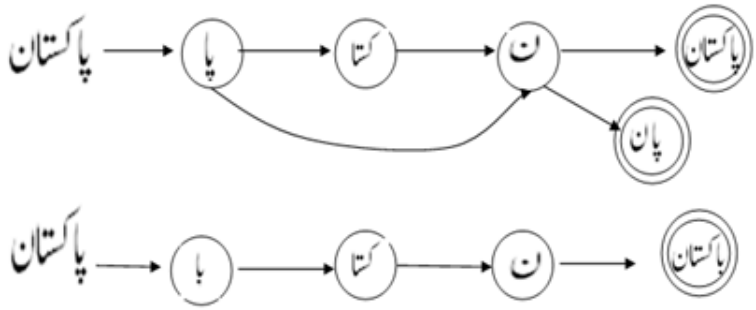

FIGURE 7. Finite state word recognizer machine for Urdu and Arabic

capabilities to machine. Translation, rotation and position has some effect on the recognition system term of reading speed. With the help of fuzzy modeling, linguistic rules and biological division of handwritten ligatures, complex handwritten recognition such as Arabic can be performed. We divide the recognition system into multilayered architecture inspired by human visual perception system. One example is discussed using the layered architecture and layer by layer process is shown in Figure 8.

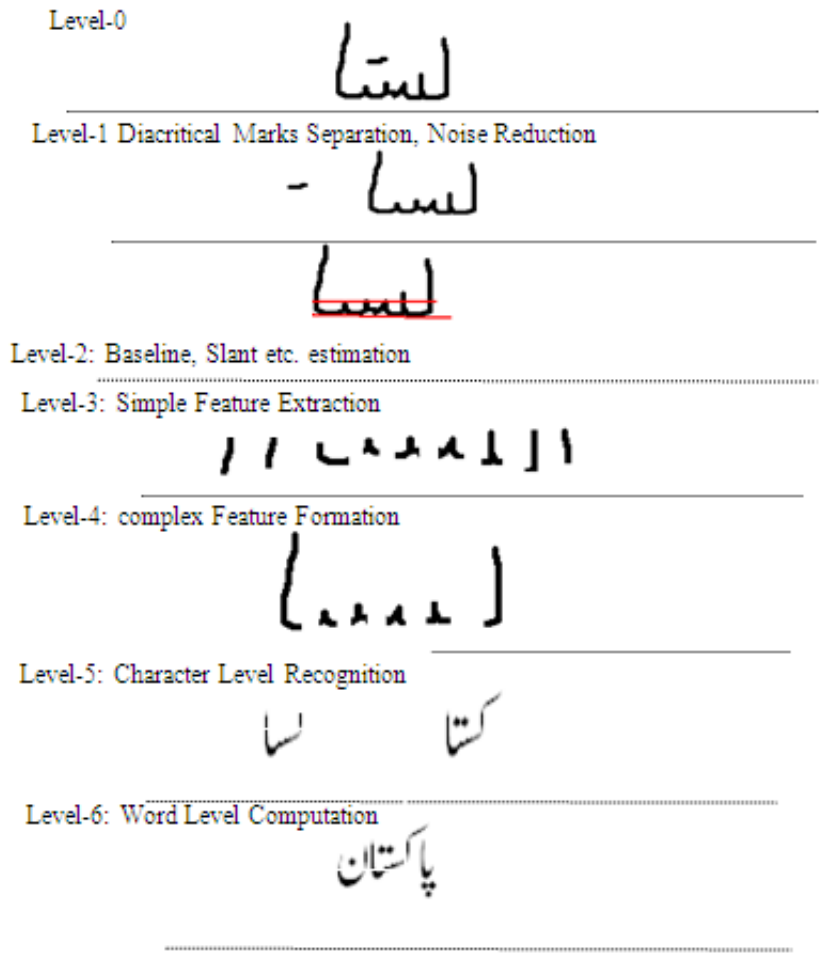

FIGURE 8. Simple example using multilayer fuzzy based approach

Level 0 acquiring the strokes information (x,y) from the input device. Level 1 is responsible of diacritical strokes segmentation and noise reduction. The four diacritical marks are separated from the basic shapes and it positional information is calculated.

Translation, rotation and position also effect at some level on human recognition, while it is very difficult to extract the translation and rotation invariant features, thus, we performed translation and rotation. Level 2 is responsible of baseline, slant, and mapping etc. The simple geometrical features, i.e., loop, vertical up, vertical down, vertical left, down left horizontal attached with horizontal left are extracted from the basic shape. With the help of linguistic rules, these simple features are combined to form the complex features. i.e., loop may be downward, upward, oval etc. Level 5 is responsible forming the character from these local complex features and mapping for diacritical marks.

Every diacritical mark is mapped onto the associated character. This mapping is based on fuzzy triangular member function and linguistics rules are used to help the fuzzy member function in diacritical mapping. Finally the results are compared with [9-12] the work done or Urdu script. Razzak et al. presented rule based system for 40 out of 58 basic character and the system is limited to 5000 ligatures with the accuracy of 78% [11]. The use of layered biologically inspired using fuzzy logics provided significant gain in accuracy and dictionary size (unlimited) as compared to previous approach.

TABLE 3. Recognition rate

System Name	**Classifier**	**Recognition Rate**	**Data Set**
Multilanguage Arabic System (Proposed)	Biological Inspired Multilayered Fuzzy Logic	86.2	Unlimited Full Urdu, Arabic, etc. Only Nasta'liq Style
Rule Based [3]	Fuzzy Rule Based	78	5000 Ligature
Hybrid [10]	HMM + Fuzzy	87.1	1500 Ligature only
OLUCR [Husain et al., 2007]	BPNN	93	240 Ligature only
Online Urdu handwritten Recognition [Malik and Khan, 2005]	Tree Based Dictionary Search	96	49 Ligature only

4. **Conclusion.** This paper presents multilayered fuzzy rules based expert system for handwritten Multilanguage character recognition, i.e., Arabic script based languages inspired by human biological system. The biological visual perception is studied on 50 native readers of Arabic, Urdu, Punjabi, Sindhi and Pashto written in two different script Naskh and Nasta'liq to visualize the level of diacritical marks. The character recognition system is divided into layers according to human visual perception. The linguistics rules are added at each level to add the help of language behavior. The presented biological inspired provide 86.2% accuracy for Arabic, Urdu, Persian and Punjabi written in only Nasta'liq style. The result is increased to 89.4% by using the word level formation using finite state machine at level 6.

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