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Mutual Authentication Technique with Four Entities Using Fuzzy Neural Network in 4-G Mobile Communications

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ABSTRACT : *4-G mobile communications system is offering high speed data communications technology having connectivity to all sorts of the networks including 2-G and 3-G mobile networks. Authentication of a mobile subscriber (MS) or a sub network and a main network are an important issue to check and minimize security threats or attacks. An advanced artificial intelligence based mutual authentication system applying fuzzy neural network with four entities is proposed. Voice frequency of the salutation or the selective words used by a subscriber like Hello, Good Morning etc. is taken as first entity. Second entity is chosen as thumb fingerprint matching of the calling subscriber. Then third entity is taken as face image matching of the calling subscriber. Fourth entity is granted as probability of the salutation or the greeting word from subscriber's talking habit while initializing a call. These four entities such as probability of particular range of frequencies for the salutation word, the thumb fingerprint matching, the face image matching of the subscriber by pixel cluster indexing , using particular salutation or greeting word at the time of starting a call are used with most frequently, more frequently and less frequently by the calling subscriber like uncertainty in Artificial Intelligence (AI). Now different relative grades are assigned for most frequently, more frequently and less frequently used parameters. Fuzzy operations like intersection or minimum and union or maximum are computed taking three membership functions at a time out of four membership functions to adopt fuzzy neural network. Thereafter the optimum or the final fuzzy operations are computed according to the assumed weightages. Lastly the optimized fuzzy operations are defuzzified by Composite Maxima method and the results are tested according to the invented fuzzy neural rule. If the results are satisfactory, the subscriber or the sub network and the network (the switch or the server) are mutually authenticated in 4-G mobile communications.*

Keywords - *Face image matching, Fuzzy neural network, Fuzzy operation, Mutual authentication, Pixel cluster indexing technique, Salutation word, Thumb fingerprint matching.*

I. INTRODUCTION

Fourth generation (4-G) mobile communications system is offering high speed data communications technology (10 Mbps to 2 Gbps) having connectivity to all sorts of networks including 2-G and 3-G mobile networks [1]-[6]. Authentication of a mobile subscriber or a sub network with a main network in 4-G mobile communications is an important criterion to check and minimize security threats and attacks [6]-[10]. An advanced artificial intelligence (AI) based mutual authentication system applying fuzzy neural network algorithm with four entities is proposed in this paper. Generally the scientists may not be able to provide error free data or knowledge using fuzzy logic system. For that a neuro fuzzy system can be used to tune the system and reject unnecessary or redundant fuzzy rules. A neuro fuzzy system has multilayers that embed the fuzzy system.

A person talking salutation or greeting words in different times are always consisting of a very narrow range of frequencies (0.2 ~ 3.5 KHz) which are varying in nature from person to person. Thus voice frequency of the salutation or the selective words used by a subscriber like Hello, Good Morning etc. is taken as first entity. Second entity is chosen as the thumb fingerprint of the calling subscriber matching by pixel cluster indexing technique with his/her stored thumb fingerprint in the database of the network. Then third entity is taken as the face image matching by pixel cluster indexing method of the calling subscriber with his/her stored face image at the network, i.e., the switch or the server. Fourth entity is granted as probability of the salutation or the greeting word from the subscriber's talking habit (set of salutation words) while initializing a call. These four entities such as the probability of particular range of frequencies for the salutation word, the thumb fingerprint matching, the face image matching of the subscriber, the particular salutation or the greeting word at the time of starting a call are used with most frequently, more frequently and less frequently by the calling subscriber like uncertainty in Artificial Intelligence (AI) [11]-[13]. Now different relative grades are assigned for most frequently, more frequently and less frequently used parameters.

Fuzzy membership operations like fuzzy set intersection or minimum and union or maximum are computed taking three membership functions at a time out of four membership functions to adopt fuzzy neural network [11]-[13]. Thereafter the optimum fuzzy operations are computed according to the assumed weightages. Then these optimized fuzzy operations are defuzzified by Composite Maxima method and tested according to the invented fuzzy neural rule. If the results obtained from the fuzzy neural network are satisfactory, the subscriber (MS) or the sub network and the network (the switch or the server) are mutually authenticated in 4-G mobile communications.

4-G network is connected by Internet Protocol IPv4 (Version 4) or IPv6 (Version 6). All sub networks like WLAN, WPAN, WCAN, Wi-Fi, WiMAX, LTE, MANET etc. are connected through the gateways and the access controllers to afford world wide connectivity.

II. PROPOSED ARTIFICIAL INTELLIGENCE BASED AUTHENTICATION TECHNIQUE IN 4-G MOBILE NETWORK

It is having two different phases, namely, Subscriber Enrollment Phase and Subscriber Authentication Phase. The first phase, Subscriber Enrollment Phase is done at the time of enrollment of a subscriber in a network.

2.1 Subscriber Enrollment Phase

The subscriber is enrolled to a particular switch or a server belonging to the network. In case of a sub or small network like WLAN, WPAN, MANET etc. connected with the 4-G mobile network via an access controller or a gateway, the Controller or the Manager of the sub network feeds the required entities or parameters and acts as a subscriber (MS). This phase is executed once.

ASE1: The subscriber sends an application request to the mobile service provider for a new SIM.

ASE2: After receiving the request, the authority asks to submit his/her different parameters of talking and the thumb's fingerprint and the face image (Biometric attributes) for storing in the database of the network against his/her mobile phone number.

ASE3: (i) Which frequency range in voices is appearing most frequently, more frequently and less frequently used by the subscriber in talking the salutation or the greeting words?

(ii) How much the calling subscriber's thumb fingerprint is matched most frequently, more frequently and less frequently with his/her stored thumb fingerprint in the network?

(iii) How much the calling subscriber's face image is most frequently, more frequently and less frequently matched with his/her stored face image in the network?

(iv) Which salutation words are most frequently, more frequently and less frequently used by the calling subscriber at the time of starting a mobile call?

The frequency of the salutation word is measured by a sophisticated electronics instrument in Hz up to one decimal place. The thumb fingerprint and the face image of a calling subscriber are taken by a digital camera with high resolution; generally both the instruments may be inbuilt in a mobile phone (MS). A vertical indicator line is drawn on top of the camera in the MS, the tip of the thumb for fingerprint and the tip of the nose of the calling subscriber for face image are placed just above the indicator line.

ASE4: The authority uses above four databases in the server or the switch for storing the subscriber's parameters based on the talking habit. The first database, D_V stores the subscriber most frequently, more frequently and less frequently used voice frequencies for each salutation word and its corresponding relative grades. The first range of voice frequency for the salutation word most frequently used, D_{VR1} of D_V, is assigned relative grade or weightage by 0.65. The second class D_{VR2} of D_V, stores the more frequently used voice frequency of the salutation word having relative grade 0.55. The third range D_{VR3} of D_V, is the less frequently used frequency of the salutation word with relative grade 0.25.

Likewise a database is prepared for measuring the frequency range of the salutation word most frequently, more frequently and less frequently for predicted all the salutation words used by the subscriber. D_{VR1}, D_{VR2}, D_{VR3} of D_V is calculated as per following formula. Suppose D_V ranges between a Hz (lower frequency) to b Hz (higher frequency), the server or the switch computes this, c = (a+b)/2 and d = (b−a)/6 [since three equal divisions are made]. D_{VR1} ranges between e = (c−d) Hz to f = (c+d) Hz. D_{VR2} ranges between g = (e−d) Hz to h = (e−1) Hz and i = (f+1) Hz to j = (f+d) Hz. D_{VR3} ranges between k = (g−d) Hz = a Hz to l = (g−1) Hz and m = (j+1) Hz to n = (j+d) Hz = b Hz.

The second database, D_F stores the thumb fingerprint images of all subscribers against their mobile numbers in the server or the switch of a network, e.g., each thumb fingerprint image consisting of (128 × 128) pixels, but

any pixel size may be considered. Then the calling subscriber's thumb fingerprint image is compared with his/her stored thumb fingerprint image in the database (noted against his/her mobile number) by matching pixel intensity values which contain specific pixel values like 100~220, named pixel cluster indexing technique, i.e., pixel-wise comparing for even pixel values or odd pixel values or certain range of distinguished pixel values like 100~220 for monochromatic thumb fingerprint. Thus the minimum numbers of the pixels are compared in this pixel cluster indexing image matching process [14]. This pixel cluster indexing technique affords simple, fast and accurate method for comparing between two images. The numbers of pixels are matched either having the same values of the chosen pixels containing in the thumb fingerprint image (completely matched) in the pixel cluster indexing format or thresholding to some limiting values, i.e., the mismatch pixels' values are considered up to certain range or any appropriate value. If the calling subscriber's thumb fingerprint matching by pixel cluster indexing technique to his/her stored thumb fingerprint image falls under category of more than 80% to 100% pixels matching, relative grade is 0.8, stored in D_{FR1}. If 60% to 80% pixels are matched for the calling subscriber's thumb fingerprint image, relative grade is 0.6, stored in D_{FR2}. If less than 60% pixels are matched, relative grade is 0.3, stored in D_{FR3}.

The third database, D_I stores the coloured face images of all subscribers against their mobile numbers in the server or the switch of a network, e.g., each face image having (128 × 128) pixels. Then the calling subscriber's face image is compared with his/her stored face image in the database by matching pixel cluster indexing technique [14], i.e., pixel-wise comparing for certain range of pixel values say 120~255 for each R (Red), G (Green), B(Blue) parts separately. Also the coloured face images may be compared by converting to the other attributes like H (Hue), S (Saturation), V (Value) etc. The numbers of pixels are matched either having the same values of the specified pixels containing in the image (completely tallied) as considered in the pixel cluster indexing technique or thresholding to some limiting values, i.e., the mismatch pixels' values are considered up to certain range or any appropriate value. Then average value of matching pixels in R, G, B parts are computed. If the calling subscriber's face image matching by pixel cluster indexing technique to his/her stored face image in the network falls under category of more than 80% to 100% pixels matching, relative grade is 0.9, stored in D_{IR1}. If 60% to 80% pixels are matched for the calling subscriber's face image, relative grade is 0.7, stored in D_{IR2}. If less than 60% pixels are matched, relative grade is 0.3, stored in D_{IR3}.

The fourth database, D_W stores most frequently, more frequently and less frequently used salutation words and their corresponding relative grades. The first row, D_{WR1} of D_W, stores the most frequently used salutation words with relative grade 0.9. The second row, D_{WR2} of D_W, is identified the more frequently used salutation words with relative grade 0.6. The third row, D_{WR3} of D_W, belongs to the less frequently used salutation words with relative grade 0.3. Also flipping frequency may be considered in place of fingerprint.

ASE5: If the authority does not get sufficient information, request for resubmission the correct signature or the database of the subscriber is placed. Then the authority executes the above steps again to create a strong database.

2.2 Subscriber Authentication Phase

When a subscriber initiates a call by speaking a salutation word, then the authentication process starts. Then the server or the switch, i.e., the network executes the following operations:

ASA1: The server or the switch finds the matched frequency of the salutation word within the rows D_{VR1}, D_{VR2}, D_{VR3} of D_V.

ASA1.1: After hearing the first word from a subscriber, either the MS or the network computes the frequency of the salutation word, then match the voice frequency of the salutation word within the stored range D_{VR1}, D_{VR2}, D_{VR3} of D_V and its corresponding relative grade which is taken as v1, If not match, v1 = 0. The membership functions of a fuzzy set F1 is defined as follows, μ_{F1} (a1) = v1, Hence, F1 = {(a1, v1)}.

ASA2: Finds the matched thumb fingerprint within the rows D_{FR1}, D_{FR2}, D_{FR3} of D_F.

ASA2.1: If the thumb fingerprint of the MS is matched, then stores p1= Relative grade of matched location in row, otherwise p1=0. The membership functions of a fuzzy set F2 is μ_{F2} (a2) = p1,

Hence, F2 = {(a2, p1)}.

ASA3: The server or the switch finds the matched subscriber face image within the rows D_{IR1}, D_{IR2}, D_{IR3} of D_I.

ASA3.1: If the face image of the MS (calling subscriber) is compared with his/her stored face image in the server or the switch, then the stores value, q1= Relative grade of matched location in row, otherwise q1=0. The membership functions of a fuzzy set F3 is, μ_{F3} (a3) = q1, Hence, F3 = {(a3, q1)}.

ASA4: Finds the matched salutation or the greeting word within the rows D_{WR1}, D_{WR2}, D_{WR3} of D_W.

ASA4.1: If the salutation word is matched within the stores value of $D_{WR1,}$ D_{WR2}, D_{WR3}, then it stores value, w1= Relative grade of the matched salutation word in row, otherwise w1=0. The membership functions of a fuzzy set F4 can be, μ_{F4} (a4) = w1, Hence, F4 = {(a4, w1)}.

ASA5: The server or the switch computes the fuzzy operations such as fuzzy set intersection (minimum) and union (maximum) taking three fuzzy membership functions at a time out of total four fuzzy membership functions; the four different values of each fuzzy operation such as fuzzy set intersection or union are obtained as mentioned below [11]-[13]:

ASA5.1:

$T_1 = \mu_{F1\cap F2\cap F3}$ (a) = min {μ_{F1} (a1), μ_{F2} (a2), μ_{F3} (a3)}

$T_2 = \mu_{F1\cap F2\cap F4}$ (a) = min {μ_{F1} (a1), μ_{F2} (a2), μ_{F4} (a4)}

$T_3 = \mu_{F2\cap F3\cap F4}$ (a) = min {μ_{F2} (a2), μ_{F3} (a3), μ_{F4} (a4)}

$T_4 = \mu_{F1\cap F3\cap F4}$ (a) = min {μ_{F1} (a1), μ_{F3} (a3), μ_{F4} (a4)}

ASA5.2:

$V_1 = \mu_{F1UF2UF3}$ (a) = max {μ_{F1} (a1), μ_{F2} (a2), μ_{F3} (a3)}

$V_2 = \mu_{F1UF2UF4}$ (a) = max {μ_{F1} (a1), μ_{F2} (a2), μ_{F4} (a4)}

$V_3 = \mu_{F2UF3UF4}$ (a) = max {μ_{F2} (a2), μ_{F3} (a3), μ_{F4} (a4)}

$V_4 = \mu_{F1UF3UF4}$ (a) = max {μ_{F1} (a1), μ_{F3} (a3), μ_{F4} (a4)}

ASA6: For ascertaining authenticity of the mobile subscriber (MS) as well as the network (Server or MSC or PDSN), fuzzy neural network algorithm on the results of the fuzzy operations have applied.

Different weightages to these fuzzy operations (intersection and union) are imposed and these weightages are assigned by altering different values in practical examples according to any one or two entities like face image or thumb fingerprint matching or voice frequency or flipping frequency or probability of salutation words etc. belonging to the least relative grade or the lowest fuzzy membership function value causing authentication failure while examining the fuzzy neural rule.

$WT_1 : WT_2 : WT_3 : WT_4 = 0.5 : 0.4 : 0.35 : 0.3$

$WV_1 : WV_2 : WV_3 : WV_4 = 0.9 : 0.8 : 0.7 : 0.65$

The values of the fuzzy operations are multiplied by the corresponding weightages for computing the optimum or the final values, i.e.,

$FT_1 : FT_2 : FT_3 : FT_4 = T_1 \times WT_1 : T_2 \times WT_2 : T_3 \times WT_3 : T_4 \times WT_4 = 0.5T_1 : 0.4T_2 : 0.35T_3 : 0.3T_4$

$FV_1 : FV_2 : FV_3 : FV_4 = V_1 \times WV_1 : V_2 \times WV_2 : V_3 \times WV_3 : V_4 \times WV_4 = 0.9V_1 : 0.8V_2 : 0.7V_3 : 0.65V_4$

Thereafter all the final values of a particular fuzzy operation are defuzzified by a defuzzifying function by the server or the switch. Defuzzification is done by the Composite Maxima method, here applying max (FT_1, FT_2, FT_3, FT_4) = a, and also max (FV_1, FV_2, FV_3, FV_4) = b. The fuzzy neural rule on the results of the final defuzzified outputs are determined according to examine several values on the practical examples and the best suited values are taken.

Thus as per fuzzy neural rule, if $a \geq 0.24$, and $b \geq 0.63$ both satisfies, then only the network (the switch or the server) ensures that the subscriber or the sub network is authentic, hence their mutual authenticity is verified. Also if the above two fuzzy neural conditions or any one of them are not satisfied, the network, i.e., the switch or the server ensures that the user like the sub network or the mobile subscriber (MS) is unauthentic. In this case the network, i.e., the switch or the server sends an authentication failure message to the subscriber or the sub network. The block diagram of the mutual authentication technique applying fuzzy neural network as shown in Fig. 1 is described the above procedures.

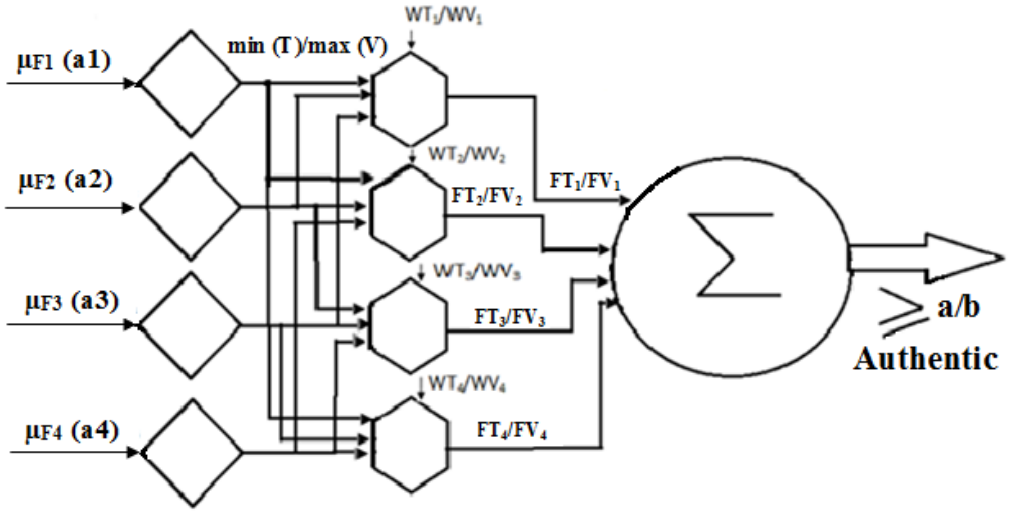

Fig. 1 Block diagram of the fuzzy neural network for the subscriber and the network mutual authentication technique in 4-G Mobile Communications

III. ADVANTAGES OF THE AUTHENTICATION TECHNIQUE

This authentication technique is the most efficient due to applying artificial intelligence [AI] in advanced stage, i.e., fuzzy neural network used. Also it does not require any further information to supply by the subscriber (MS) while making a call. So it is a unique one. Authenticity is determined by the subscriber's talking characteristics (habit), the biometric parameters like the thumb fingerprint and the face image matching by pixel cluster indexing. No cryptography algorithm or any complex functions are applied. This authentication technique ensures correct result within real time basis. Therefore this authentication technique is the best one.

IV. RESULTS AND DISCUSSION

Example 1: A subscriber starts talking with "Hi Guru" in 2536 Hz, the thumb fingerprint is matched 65% to his stored thumb fingerprint, and the face image of the subscriber is matching with his stored face image by 59% pixels, examine mutual authenticity of the subscriber with the network.

After testing voice frequency of the subscriber's salutation word "Hi Guru" stored in the server, the range of voice frequency of the subscriber's particular salutation word "Hi Guru" is found from 2125 Hz to 2893 Hz.

If the voice frequency of the subscriber's salutation word "Hi Guru" is within 2381 Hz to 2637 Hz, then the value D_{VR1} of D_V is 0.65.

If the voice frequency of the subscriber's salutation word "Hi Guru" is within 2253 Hz to 2380 Hz or 2638 Hz to 2765 Hz, then the value D_{VR2} of D_V is 0.55.

If the voice frequency of the subscriber's salutation word "Hi Guru" is within 2125 Hz to 2252 Hz or 2766 Hz to 2893 Hz, then the value D_{VR3} of D_V is 0.25.

If the thumb fingerprint of the calling subscriber is matched with his stored thumb fingerprint image in database within more than 80% to 100%, then the value of D_{FR1} of D_F is 0.8.

If the thumb fingerprint image is matched within 60% to 80%, then the value of D_{FR2} of D_F is 0.6.

If the thumb fingerprint image is matched less than 60%, then the value of D_{FR3} of D_F is 0.3.

If the face image of the calling subscriber is matched with his stored image in database within more than 80% to 100%, then the value of D_{IR1} of D_I is 0.9.

If the face image is matched within 60% to 80%, then the value of D_{IR2} of D_I is 0.7.

If the face image is matched less than 60%, then the value of D_{IR3} of D_I is 0.3.

The salutation or greeting words are stored in the server or the switch for the subscriber in D_{WR1} of D_W like Hello, Oh God, Hi Guru, Jai Ram, Adab, Namaste.

The salutation words are stored in the server or the switch for the subscriber in D_{WR2} of D_W like Good Morning, Good Afternoon, Radhe Radhe, Achhaya, Kaisa Hai.

The salutation words are stored in the server or the switch for the subscriber in D_{WR3} of D_W like Namaskar, Assalamo Alaokum, Joyguru, Hare Ram, Hare Krishna.

Let the relative grade of D_{WR1} is 0.9, D_{WR2} is 0.6, and D_{WR3} is 0.3.
For salutation word "Hi Guru" is in D_{WR1}, grade w1 is 0.9
Hence, the matched frequency of the salutation word 2536 Hz from the subscriber is in D_{VR1} of D_V whose relative grade is 0.65. Therefore, v1 = 0.65, $\mu_{F1}(a1) = v1 = 0.65$, Hence, F1 = {(a1, 0.65)}.
The matched thumb fingerprint (65%) of the subscriber belongs to D_{FR2} of D_F having relative grade 0.6.
Therefore, p1 = 0.6, $\mu_{F2}(a2) = p1 = 0.6$, Hence, F2 = {(a2, 0.6)}.
The matched face image (59%) of the subscriber belongs to D_{IR3}.
Therefore, q1 = 0.3, $\mu_{F3}(a3) = q1 = 0.3$, Hence, F3 = {(a3, 0.3)}.
The matched the salutation word "Hi Guru" of the subscriber belongs to D_{WR1}.
Therefore, w1= 0.9, $\mu_{F4}(a4) = w1 = 0.9$, Hence, F4 = {(a4, 0.9)}.
Now the fuzzy operations such as fuzzy set intersection (minimum) are computed taking three fuzzy membership functions out of four fuzzy membership functions in total.

$T_1 = \mu_{F1\cap F2\cap F3}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\} = \min\{0.65, 0.6, 0.3\} = 0.3$
$T_2 = \mu_{F1\cap F2\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\} = \min\{0.65, 0.6, 0.9\} = 0.6$
$T_3 = \mu_{F2\cap F3\cap F4}(a) = \min\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\} = \min\{0.6, 0.3, 0.9\} = 0.3$
$T_4 = \mu_{F1\cap F3\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\} = \min\{0.65, 0.3, 0.9\} = 0.3$

Thereafter, we are applying fuzzy neural network algorithm to these fuzzy operations and accordingly the weightages of these fuzzy intersection operations are taken as −

$WT_1 : WT_2 : WT_3 : WT_4 = 0.5 : 0.4 : 0.35 : 0.3$

Now the optimum or the final value is obtained multiplying the fuzzy intersection operation by the corresponding weightage, i.e.,

$FT_1 = T_1 \times WT_1 = 0.5T_1 = 0.5 \times 0.3 = 0.15$,
$FT_2 = T_2 \times WT_2 = 0.4T_2 = 0.4 \times 0.6 = 0.24$,
$FT_3 = T_3 \times WT_3 = 0.35T_3 = 0.35 \times 0.3 = 0.105$,
$FT_4 = T_4 \times WT_4 = 0.3T_4 = 0.3 \times 0.3 = 0.09$.

Then, all the final values regarding fuzzy intersection operations are defuzzified by Composite Maxima method,

$\max(FT_1, FT_2, FT_3, FT_4) = \max(0.15, 0.24, 0.105, 0.09) = 0.24$

Now the fuzzy operations like fuzzy set union (maximum) are calculated taking three fuzzy membership functions at a time out of four fuzzy membership functions.

$V_1 = \mu_{F1\cup F2\cup F3}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\} = \max\{0.65, 0.6, 0.3\} = 0.65$
$V_2 = \mu_{F1\cup F2\cup F4}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\} = \max\{0.65, 0.6, 0.9\} = 0.9$
$V_3 = \mu_{F2\cup F3\cup F4}(a) = \max\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\} = \max\{0.6, 0.3, 0.9\} = 0.9$
$V_4 = \mu_{F1\cup F3\cup F4}(a) = \max\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\} = \max\{0.65, 0.3, 0.9\} = 0.9$

Weightages of this fuzzy union operations are, $WV_1 : WV_2 : WV_3 : WV_4 = 0.9 : 0.8 : 0.7 : 0.65$.

The optimum or the final values regarding fuzzy union operation are as given below:

$FV_1 = V_1 \times WV_1 = 0.9V_1 = 0.9 \times 0.65 = 0.585$, $FV_2 = V_2 \times WV_2 = 0.8V_2 = 0.8 \times 0.9 = 0.72$,
$FV_3 = V_3 \times WV_3 = 0.7V_3 = 0.7 \times 0.9 = 0.63$, $FV_4 = V_4 \times WV_4 = 0.65V_4 = 0.65 \times 0.9 = 0.585$.

All the final values are defuzzified by Composite Maxima method which yields −

$\max(FV_1, FV_2, FV_3, FV_4) = \max(0.585, 0.72, 0.63, 0.585) = 0.72$, Now applying fuzzy neural rule, $\max(FT_1, FT_2, FT_3, FT_4) = 0.24$, i.e., ≥ 0.24, and $\max(FV_1, FV_2, FV_3, FV_4) = 0.72$, i.e., ≥ 0.63, therefore the network (the switch or the server) ensures that the subscriber or the sub network is authentic (valid or reliable); hence, they are mutually authenticated.

This problem is solved by Matlab program 7.14 Version. Stored images in database are shown below.

Face image name: skr6.jpg

Thumb Fingerprint: tfp5.bmp

Database file in Microsoft XL:

Sl. No.	Name of Salutation	Grade of Salutation	Voice Freq Low (V1)	Voice Freq High (V2)	Flip Freq Low (F1)	Flip Freq High (F2)	Face Image Name	Thumb Fingerprint Name
1	Hello	0.9	2045	2675	1520	2450	skr6.jpg	tfp5.bmp
2	Hi Guru	0.9	2125	2893	1520	2450	skr6.jpg	tfp5.bmp
..	……	…..	……	……	…...	……	……	…….

The two images, one for thumb fingerprint and another for face image as shown below, are transmitted at the time of calling by the subscriber.

Face image: skr82.jpg

Thumb Fingerprint: tfp82.bmp

(i) First Procedure: In this Matlab program, the results of the thumb fingerprint matching (65%) and the face image matching (59%) as given in the example are fed to the program directly, the results are noted below.

```
>> Example1_Pixel_Index
Enter Salutation Word: 'Hi Guru'
Membership Salutation Word = 0.9000
Low Voice Frequency in Hz = 2125.00
High Voice Frequency in Hz = 2893.00
Give Voice Frequency of Salutation Word in Hz: 2536
Membership Voice Frequency = 0.6500
Give Percentage Matching of Thumb Fingerprint: 65
Membership Thumb Fingerprint Matching = 0.6000
Give Percentage Matching of Face Image: 59
Membership Face Image Matching = 0.3000
The subscriber and the network are mutually authenticated.
Elapsed time is 15.409629 seconds.
>>
```

(ii) Second Procedure: In this Matlab program, the matching of the thumb fingerprint images and the face images program are included in the main program, only the thumb fingerprint and the face image (here the thumb fingerprint file name tfp82.bmp and the face image file name skr82.jpg) at the instant of calling are transmitted. Thumb fingerprint images are matching the gray values considering pixel values 120~255 by pixel cluster indexing technique. The colour face images are matched R, G, B attributes separately pixel-wise taking pixel values 100~255 by pixel cluster indexing technique, and the average pixel value of the R, G, B matching is computed. The following results are obtained.

```
>> Example1_Image_Pixel_Index
Enter Salutation Word: 'Hi Guru'
Membership Salutation Word = 0.9000
Low Voice Frequency in Hz = 2125.00
High Voice Frequency in Hz = 2893.00
Give Voice Frequency of Salutation Word in Hz: 2536
Membership Voice Frequency = 0.6500
```

Give Thumb Fingerprint Image Name: 'tfp82.bmp'
Percentage Thumb Fingerprint Image Matching = 65.2039
Membership Thumb Fingerprint Matching = 0.6000
Give Face Image Name: 'skr82.jpg'
Percentage Face Image Matching = 59.4259
Membership Face Image Matching = 0.3000
The subscriber and the network are mutually authenticated.
Elapsed time is 23.516610 seconds. >>

V. CONCLUSION

In this advanced artificial intelligence (AI) like fuzzy neural network based authentication technique using pixel cluster indexing matching for the face image and the thumb fingerprint, the subscriber or the sub network as well as the main network mutual authentication scheme is developed in 4-G mobile communications. A novel artificial intelligence in the form of fuzzy neural network is introduced to the network (the server or the switch) for higher accuracy and stable mutual authentication system. Thus this technique affords mutual authentication within a real time basis in 4-G mobile communications network and the results are highly suitable to practical environment.

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