IOSR Journal of VLSI and Signal Processing (IOSR-JVSP)
Volume 12, Issue 2 (Mar. - Apr. 2022), pp.44-52
e-ISSN: 2319-4200, p-ISSN: 2319-4197
www.iosrjournals.org

Mutual Authentication Technique with Four Biometric Entities Applying Fuzzy Neural Network in 5G Mobile Communications

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Abstract: *5G mobile communications system is offering very high speed data communications technology having connectivity to all sorts of the networks like 2G, 3G, 4G, WiMAX, MANET, VANET and other adhoc 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 artificial intelligence based mutual authentication system applying fuzzy neural network with four biometric entities is proposed. Voice frequency matching of the salutation or the selective words used by a subscriber like Hello, Good Morning, etc. with his/her stored voice frequency of that particular word is taken as first entity. Second entity is chosen as matching the flipping or clapping sound frequency of the calling subscriber with his/her stored flipping or clapping sound frequency. Then third entity is taken as face image matching of the calling subscriber. Fourth entity is granted as probability of the salutation 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 flipping or clapping sound frequency matching, the face image matching of the subscriber, using particular salutation or greeting word at the time of starting a call are used with the most frequently, more frequently, and less frequently by the calling subscriber like uncertainty in artificial intelligence. Now different relative grades are assigned to the most frequently, more frequently, and less frequently used parameters. Fuzzy operations such as intersection and union 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 the Composite Maxima method and the results are tested according to the invented fuzzy neural rule. If the results are satisfactory, the subscriber or sub-network and the network are mutually authenticated in 5G mobile network.*

Keywords: *Biometric entities; Face image matching; Flipping sound frequency; Fuzzy neural network; Fuzzy operation; Identifier; Mutual authentication; Packet switching; Salutation word; Threat.*

I. Introduction

Fifth generation (5G) mobile communications system [1]-[4], [7]-[10] is offering very high speed data communications technology (2 Gbps to 20 Gbps) having connectivity to all sorts of networks including 2G, 3G, 4G, WiMAX, MANET, VANET and other adhoc mobile networks. Authentication of a mobile subscriber or a sub-network with a main network in 5G mobile communications is an important criterion to check and minimize security threats and attacks [1]-[4]. An advanced artificial intelligence (AI) based mutual authentication system applying fuzzy neural network algorithm with four biometric entities is proposed in this paper. Attackers can target mobile subscribers/sub networks and network with virus, spam, hacking, eavesdropping, malware, phishing, denial of service (DoS), IP-spoofing, and other sort of crimes. Authentication of mobile subscribers and network are an important concern to nullify security threats and to ensure reliable communications. 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 (0.08 ~ 3.5 kHz) which are varying in nature from person to person. Thus voice frequency matching of the salutation or the selective words used by a subscriber like Hello, Good Morning, etc. with his/her stored voice frequency for the particular word is taken as first entity. Second entity is chosen as matching the flipping or clapping sound frequency of the calling subscriber with his/her stored flipping or clapping sound frequency in the database of the network. Then third entity is taken as the face image matching of the calling subscriber with his/her stored face image at the network (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 flipping or clapping sound frequency 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 the most frequently, more frequently, and less frequently by the calling subscriber like uncertainty in artificial intelligence (AI).

Now different relative grades are assigned for the 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 [5]-[10]. Thereafter, the optimum fuzzy operations are computed according to the assumed weightages. Then these optimized fuzzy operations are defuzzified by the 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 5G mobile communications.

In 2G to 4G mobile network, MSC controls all the functions of a mobile network via different registers, especially for voice and low speed data communications. Server controls all the functions via different registers for voice and high speed data communications through packet switching technology. Access Controller or Gateway provides connection to user's network (sub-network) with the server or the switch.

In essence, 4G aims to transfer communications architectures from traditional vertical stovepipe to horizontal integrated systems. Personal Networks like WLAN, WPAN, WCAN, WHAN, ISDN, PSTN, PDN, MANET, VANET, Wi-Fi, WiMAX, LTE, etc. are a dynamic network building on the above mentioned wireless networking technologies, which facilitate personalized communications with any number of subscribers anywhere at any time. Latest mobile technologies in 4G such as WiMAX (Worldwide Interoperability of Microwave Access) is standardized in 2008 A.D., offering data rate up to 40 Mbps, and LTE (Long Term Evolution) is standardized in 2010 A.D., extending data speed up to 100 Mbps using OFDM (Orthogonal Frequency Division Multiplexing) or OFDMA (Orthogonal Frequency Division Multiple Access) technique with MIMO (Multiple-Input-Multiple-Output) antennas. Then the personal networks can be expanded or shrunken depending on the availability of users, their demands, and environment. 4G mobile network works seamlessly on the basis of IPv4 (Internet protocol version 4) or IPv6 with packet switching technology. All sub-networks are connected through the gateways and the access controllers to afford world wide connectivity.

Many of the technologies to be used for 5G mobile system will start to appear in the systems used for 4G mobile, but the new 5G mobile system has to formulate in a more concrete manner. The major issue in 5G mobile system is that there is such an enormously wide variation in the requirements, superfast downloads data to small data requirements for IoT (*Internet of Things*). Accordingly a layer approach is likely to be adopted. Thus 5G mobile technology is ubiquitous access to high and low data rate services. 5G mobile technology must have wide levels of connectivity using World Wide Wireless Web (wwww) with better quality of service (QoS).

II. Mutual Authentication Technique with the Help of Four Biometric Entities Applying Fuzzy Neural Network in 5G Mobile Communications

The proposed technique has two phases, namely, Subscriber Enrolment Phase and Subscriber Authentication Phase. Subscriber Enrolment Phase is done at the time of enrolment of a subscriber in a network and any modification of information or data, when it is requested by the MS (Mobile Subscriber).

A. Subscriber Enrolment 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 5G 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 flipping or clapping sound 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 the most frequently, more frequently, and less frequently used by the subscriber in talking the salutation or the greeting words?

(ii) Which frequency range of the flipping or clapping sound is applied most frequently, more frequently, and less frequently by the subscriber?

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

(iv) Which salutation words are the 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 and the flipping or clapping sound are measured by a sophisticated electronics instrument or Matlab programming software in Hz. The face image of a calling subscriber is 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 nose of the calling subscriber for face image are to be 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 the 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 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 or $i = (f + 1)$ Hz to $j = (f + d)$ Hz. D_{VR3} ranges between $k = (g - d)$ Hz $= a$ Hz to $l = (g - 1)$ Hz or $m = (j + 1)$ Hz to $n = (j + d)$ Hz $= b$ Hz.

The second database, D_F stores the range of flipping or clapping sound frequency used by each subscriber, but making flipping sound is more feasible than clapping sound for mobile call. Therefore, the flipping sound is considered. From that most probable, more probable, and less probable flipping frequency of the subscriber are computed, and its relative grades or membership functions are allocated as per above method for voice frequency of salutation word. D_{FR1} of D_F, offers the most frequently (dominant) used frequency of the flipping sound which assigns relative grade 0.9. The second class, D_{FR2} of D_F, gives the more frequently used frequency of the flipping sound that allots relative grade 0.6. The third range, D_{FR3} of D_F, calculates the less frequently used flipping sound frequency, and it is having relative grade 0.3.

The third database, D_I stores the face images of all subscribers against their mobile numbers in the server or the switch of a network. Each face image contains square size (128 × 128) pixels, but any face image size may be considered. Then the calling subscriber's face image is compared with his/her stored face image in the database by matching each location pixel, i.e., pixel-wise comparing. The numbers of pixels are matched either having the same values of the pixels containing in the image, i.e., completely matched or thresholding to some limiting values, i.e., the mismatched pixels' values are considered up to certain range or any appropriate value. If the calling subscriber's face image matching to his/her stored face image (in the network) falls under category of 81% to 100% pixels matching, relative grade is 0.9, stored in D_{IR1}. If 61% to 80% pixels are matched for the calling subscriber's face image, relative grade is 0.7, stored in D_{IR2}. If 41% to 60% pixels are matched, relative grade is 0.3, stored in D_{IR3}.

The fourth database, D_W stores the 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

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 for strong database.

B. Subscriber Authentication Phase

When a subscriber initiates a call by speaking a salutation word, then the authentication process starts. In this time 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, $\mu_{F1}(a1) = v1$. Hence, $F1 = \{(a1, v1)\}$.

ASA2: Finds the matched frequency of the flipping or clapping sound percentage by matching pixels within the rows D_{FR1}, D_{FR2}, D_{FR3} of D_F.

ASA2.1: If the flipping or clapping sound frequency of the MS (Calling Party) is matched, then it stores, $p1$= Relative grade of matched location in the row; otherwise, $p1 = 0$. The membership functions of a fuzzy set $F2$ is $\mu_{F2}(a2) = p1$, hence, $F2 = \{(a2, p1)\}$.

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

ASA3.1: If the face image of the MS (Calling Subscriber) is matched with the stored face image pixelwise, then it stores value, $q1$= Relative grade of matched location in the row; otherwise, $q1$ = 0. The membership functions of a fuzzy set $F3$ is, $\mu_{F3}(a3) = q1$, 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 the row; otherwise, $w1$ = 0. The membership functions of a fuzzy set $F4$ can be, $\mu_{F4}(a4) = w1$, 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:

ASA5.1:

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

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

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

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

ASA5.2:

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

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

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

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

ASA6: For ascertaining authenticity of the mobile subscriber (MS) as well as the network (MSC or Server), 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 and the best values are considered.

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

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

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

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

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

ASA7: 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, i.e.,

$\max(FT_1, FT_2, FT_3, FT_4) = a$, and $\max(FV_1, FV_2, FV_3, FV_4) = b$.

ASA8: The fuzzy-neural rule on the results of the final defuzzified outputs are determined according to examine different values on the practical examples, and then 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 ensures that the user (the sub-network) or the 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 fuzzy neural network in mutual authentication technique is described in Fig. 1.

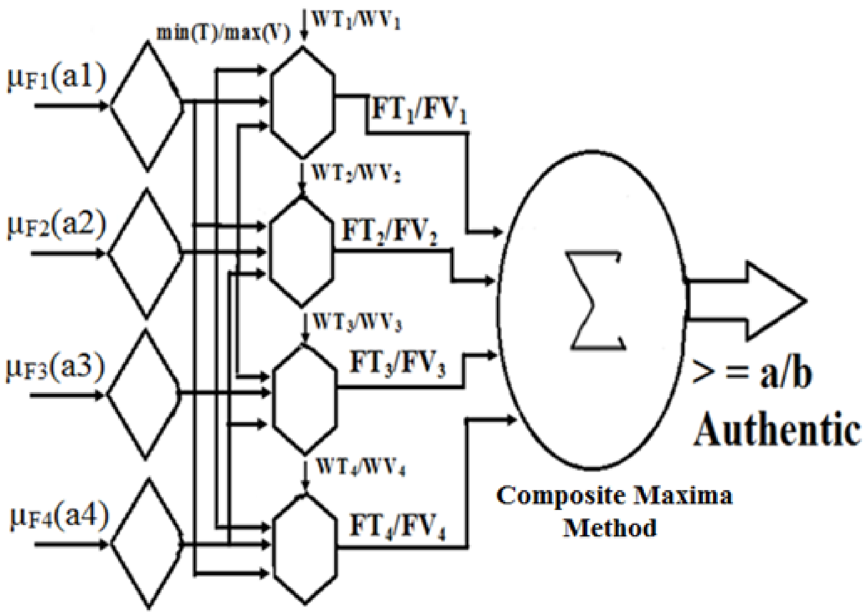


Fig. 1 Block diagram of the fuzzy neural network for the subscriber and the network mutual authentication.

III. Results and Discussion

First of all, the feasibility study of all subscribers' talking habits from the subscriber's test and documents with the biometric attributes like range of voice frequencies for the salutation words, the flipping sounds frequency ranges, the face images are recorded, and the service provider stores in the network (the server or the switch) those databases having different parameters with values. All the examples are implemented by Matlab program 7.14 Version and the results are very accurate having speedy computation with real time based.

(i) Salutation or Voice Frequency Analysis

A subscriber speaks "Good Morning" as the salutation word; the voice frequency of "Good Morning" is measured by Matlab (7.14 Version). By doing Fast Fourier Transform (FFT), frequency versus amplitude plot is obtained as shown in Fig. 2. Here the threshold for amplitude is taken from a minimum value of 15 to a maximum value of 233.8016, in these threshold amplitude values, the range of frequency is found 132.60 Hz to 2677.4 Hz, and the maximum amplitude value (233.8016) is occurring at the maximum salutation frequency 728.1166 Hz. This maximum salutation (voice) frequency is taken as the instantaneous salutation frequency.

Results:

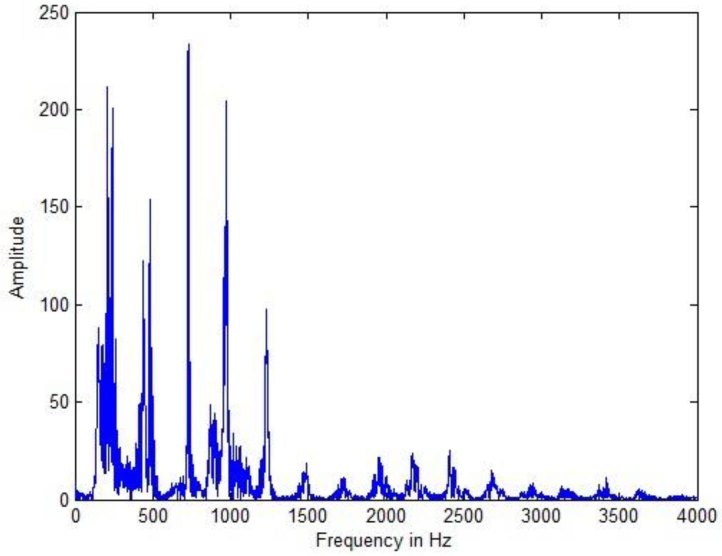


Fig. 2 Salutation word (Good Morning) of a mobile subscriber frequency *vs.* amplitude diagram.

```
>> Salutation_Frequency_ Measurement
FrequencyRange = 1.0e+03 *
   0.1326    2.6774
MaximumFrequency = 728.1166 >>
```

(ii) Flipping or Clapping Sound Frequency Analysis
Flipping sound of a person is stored and analysed by Matlab (7.14 Version) taking FFT, shown in Fig. 3.

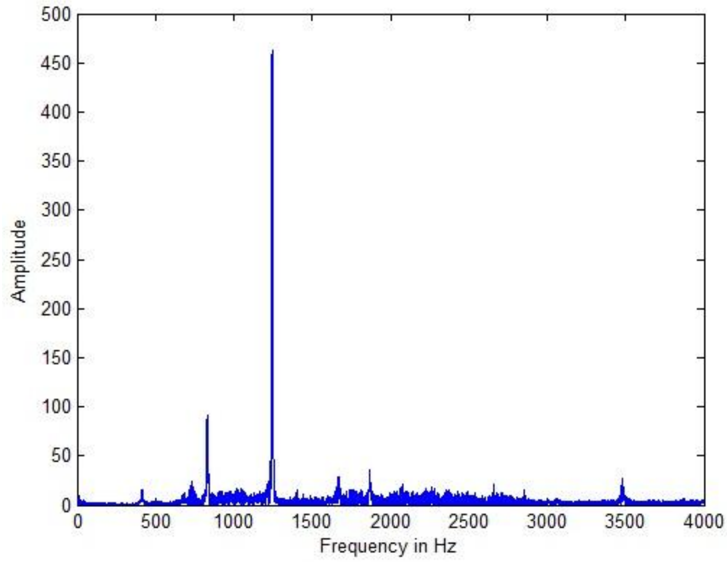


Fig. 3 Flipping sound of a mobile subscriber frequency *vs.* amplitude diagram.

The threshold for amplitude is taken from a minimum value of 15 to a maximum value of 462.4862, in these threshold amplitude values; the range of flipping frequency is computed.

The maximum amplitude value (462.4862) is occurring at the maximum flipping frequency 1244.5 Hz. Similarly, the clapping sound frequency of a person can be measured.

Therefore, the range of flipping sound frequency for the particular subscriber is 413.3 Hz to 3489.8 Hz, and the maximum flipping frequency has occurred at 1244.5 Hz. This maximum flipping or clapping sound frequency is taken as the instantaneous flipping or clapping sound frequency.

```
>> Flipping_Frequency_Measurement
FrequencyRange = 1.0e+03 *
   0.4133    3.4898
MaximumFrequency = 1.2445e+03 >>
```

Example 1: A subscriber starts talking from his mobile with "Good Morning" in 728 Hz, sending the flipping frequency in 1244 Hz, and the colored face image of the subscriber named eit6.jpg is matched with his stored colored face image named eit5.jpg, examine mutual authenticity of the subscriber with the 5G mobile network.

Solution:

After testing voice frequency of the subscriber's salutation word "Good Morning" stored in the network (the server or the switch), the range of voice frequency of the subscriber's particular salutation word "Good Morning" is found from 132 Hz to 2677 Hz.

Table no 1: Voice Frequency *vs.* Relative Grades of D_V

Voice Frequency of the Salutation Word	Grade of D_V
980 Hz to 1828 Hz	$D_{VR1} = 0.65$
556 Hz to 979 Hz; 1829 Hz to 2253 Hz	$D_{VR2} = 0.55$
132 Hz to 555 Hz; 2254 Hz to 2677 Hz, Other frequencies	$D_{VR3} = 0.25$

The stored flipping frequency of the subscriber in the network is found in the range of 413 Hz to 3489 Hz.

Table no 2: Flipping Frequency Matched Percentage *vs.* Relative Grades of D_F

Flipping Frequency of the Subscriber	Grade of D_F
1438 Hz to 2463 Hz	$D_{FR1} = 0.9$
925 Hz to 1437 Hz; 2464 Hz to 2976 Hz	$D_{FR2} = 0.6$

413 Hz to 924 Hz; 2977 Hz to 3489 Hz, Other frequencies	D_{FR3} = 0.3

Table no 3: Face Image Matched Percentage *vs.* Relative Grades of D_I

Face Image Matched Percentage	Grade of D_I
> 80% (greater than 80%) to 100%	D_{IR1} = 0.9
60% to 80%	D_{IR2} = 0.7
< 60% (less than 60%)	D_{IR3} = 0.3

Table no 4: Salutation Word *vs.* Relative Grades of D_W

Salutation or Greeting Words	Grade of D_W
Hello, Oh God, Hi Guru, Good Morning, Good Afternoon, Namaste	D_{WR1} = 0.9
Jai Ram, Adab, Radhe Radhe, Hare Ram, Hare Krishna	D_{WR2} = 0.6
Namaskar, Assalamo Alaokum, Joyguru, Achhaya, Other words	D_{WR3} = 0.3

For salutation word "Good Morning" of the subscriber, it is in D_{WR1} whose relative grade ($w1$) is 0.9.

Hence, the matched frequency of the salutation word 728 Hz from the subscriber is in D_{VR2} of D_V whose relative grade is 0.55.

Therefore, $v1 = 0.55$, $\mu_{F1}(a1) = v1 = 0.55$.

Hence, $F1 = \{(a1, 0.55)\}$.

The matched flipping frequency 1244 Hz of the subscriber belongs to D_{FR2} of D_F, relative grade 0.6.

Therefore, $p1 = 0.6$, $\mu_{F2}(a2) = p1 = 0.6$.

Hence, $F2 = \{(a2, 0.6)\}$.

The matched colored face image (84.2794%) of the subscriber belongs to D_{IR1}.

Therefore, $q1 = 0.9$, $\mu_{F3}(a3) = q1 = 0.9$.

Hence, $F3 = \{(a3, 0.9)\}$.

The matched the salutation word "Good Morning" 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 are computed taking three fuzzy membership functions out of four fuzzy membership functions in total.

$T_1 = \mu_{F1\cap F2\cap F3}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\} = \min\{0.55, 0.6, 0.9\} = 0.55.$

$T_2 = \mu_{F1\cap F2\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\} = \min\{0.55, 0.6, 0.9\} = 0.55.$

$T_3 = \mu_{F2\cap F3\cap F4}(a) = \min\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\} = \min\{0.6, 0.9, 0.9\} = 0.6.$

$T_4 = \mu_{F1\cap F3\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\} = \min\{0.55, 0.9, 0.9\} = 0.55.$

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.,

$FT_1 = T_1 \times WT_1 = 0.5T_1 = 0.5 \times 0.55 = 0.275.$

$FT_2 = T_2 \times WT_2 = 0.4T_2 = 0.4 \times 0.55 = 0.22.$

$FT_3 = T_3 \times WT_3 = 0.35T_3 = 0.35 \times 0.6 = 0.21.$

$FT_4 = T_4 \times WT_4 = 0.3T_4 = 0.3 \times 0.55 = 0.165.$

Then all the final values regarding fuzzy intersection operations are defuzzified by the Composite Maxima method in fuzzy neural network, i.e.,

$\max(FT_1, FT_2, FT_3, FT_4) = \max(0.275, 0.22, 0.21, 0.165) = 0.275.$

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

$V_1 = \mu_{F1UF2UF3}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\} = \max\{0.55, 0.6, 0.9\} = 0.9.$

$V_2 = \mu_{F1UF2UF4}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\} = \max\{0.55, 0.6, 0.9\} = 0.9.$

$V_3 = \mu_{F2UF3UF4}(a) = \max\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\} = \max\{0.6, 0.9, 0.9\} = 0.9.$

$V_4 = \mu_{F1UF3UF4}(a) = \max\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\} = \max\{0.55, 0.9, 0.9\} = 0.9.$

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 applying fuzzy neural network algorithm are as given below:

$FV_1 = V_1 \times WV_1 = 0.9V_1 = 0.9 \times 0.9 = 0.81.$

$FV_2 = V_2 \times WV_2 = 0.8V_2 = 0.8 \times 0.9 = 0.72.$

$FV_3 = V_3 \times WV_3 = 0.7V_3 = 0.7 \times 0.9 = 0.63.$

$FV_4 = V_4 \times WV_4 = 0.65V_4 = 0.65 \times 0.9 = 0.585.$

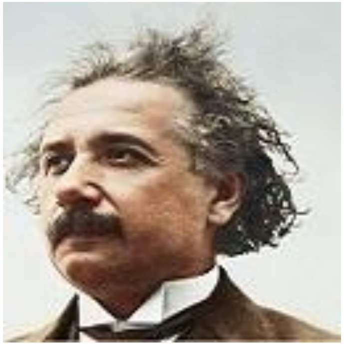
All the final values are defuzzified by the Composite Maxima method that yields:

$\max(FV_1, FV_2, FV_3, FV_4) = \max(0.81, 0.72, 0.63, 0.585) = 0.81.$

Now applying fuzzy neural rule, max(FT_1, FT_2, FT_3, FT_4) = 0.275, i.e., ≥ 0.24, and max(FV_1, FV_2, FV_3, FV_4) = 0.81, i.e., ≥ 0.63; therefore, the network (the server or the switch) ensures that the subscriber or the sub network is authentic; hence, they are mutually authenticated and call is permitted.

This example is implemented by Matlab program 7.14 Version. The database in Microsoft XL stored for the subscriber in the 5G mobile network.

The face image stored in database Transmitted at the time of calling



Face Image Name: eit5.jpg eit6.jpg

(i) Matlab Program Result: The program is running by Matlab 7.14 Version. The matching of the colored face images program is embedded in the main program, only the colored face image (here eit6.jpg) at the time of calling are supplied. The colored face images are matched R, G, B attributes separately pixel-wise making threshold value up to 5 for completely matching, because the difference of pixel values up to 5 is taken as 0 or completely matching which does not constitute any difference in image or color. Then the average pixel value of the R, G, B matching is computed. The following results are obtained.

```
>> Example1
Salutation Word Used = Good Morning
Membership Salutation Word = 0.9000
Low Voice Frequency in Hz = 132.00
High Voice Frequency in Hz = 2677.00
Voice Frequency Used = 728 Hz
Membership Voice Frequency = 0.5500
Low Flipping Frequency in Hz = 413.00
High Flipping Frequency in Hz = 3489.00
Flipping Frequency Used = 1244 Hz
Membership Flipping Frequency = 0.6000
Face Image Used = eit6.jpg
Percentage Face Image Matching = 84.2794
Membership Face Image Matching = 0.9000
The subscriber and the network are mutually authenticated.
Elapsed time is 2.816780 seconds.
>>
```

Example 2: Another subscriber calls from same mobile with "Good Morning" in 832 Hz, sending the flipping frequency in 915 Hz, and the colored face image of the subscriber named sit7.jpg is matched with the stored colored face image named eit5.jpg, examine mutual authenticity of the subscriber with the 5G mobile network.

Solution: The result by Matlab program (7.14 Version) is obtained as mentioned below.

```
>> Example2
Salutation Word Used = Good Morning
Membership Salutation Word = 0.9000
Low Voice Frequency in Hz = 132.00
High Voice Frequency in Hz = 2677.00
Voice Frequency Used = 832 Hz
Membership Voice Frequency = 0.5500
Low Flipping Frequency in Hz = 413.00
High Flipping Frequency in Hz = 3489.00
Flipping Frequency Used = 915 Hz
Membership Flipping Frequency = 0.3000
```

Face Image Used = sit7.jpg
Percentage Face Image Matching = 75.0346
Membership Face Image Matching = 0.7000 Image Name: sit7.jpg
The subscriber and the network are not mutually authenticated.
Elapsed time is 2.859049 seconds.
>>
Therefore, other persons cannot use the mobile of original subscriber.

IV. Conclusion

This authentication technique is the most efficient due to applying artificial intelligence [AI] in advanced stage, i.e., fuzzy neural network applied. Also it does not require any further information to be supplied by the subscriber (MS) while making a call. So, it is a unique one. Authenticity is determined by the subscriber's talking characteristics (habits), i.e., biometric parameters such as the frequency of the salutation word, the frequency of the flipping sound, and the face image analysis. No cryptography algorithm or any complex functions are applied. This authentication technique ensures correct results within real time basis.

In this proposed fuzzy neural network based mutual authentication technique, the subscriber or the sub-network as well as the main network mutual authentication scheme is developed in fifth generation (5G) mobile communications which offers low to very high speed data rate (upto 20 Gbps). A novel artificial intelligence in the form of fuzzy neural network is introduced to the network (the server or the switch) for higher security and stable mutual authentication system. The results obtained by this technique are highly suitable to practical environment. Therefore, this technique affords mutual authentication in 5G mobile communications within a real time basis.

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