ISSN 1392 – 1215 *ELECTRONICS AND ELECTRICAL ENGINEERING* *ELEKTRONIKA IR ELEKTROTECHNIKA* 2010. No. 5(101)

T 170 *ELECTRONICS* *ELEKTRONIKA*

Development of Biometric Systems for Person Recognition: Biometric Feature Systems, Traits and Acquisition

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Introduction

Over the last two decades there has been an increasing research effort devoted for development of automatic biometric recognition systems (BRS). Such systems confirm a person's identity referring on who the person is and not on what the person knows or has. Nevertheless, the majority of automatic user recognition done by ATMs, computers, cellphones, locks and so on still relies on passwords, personal identification number (PIN) generators, ID cards or keys. Modern technology challenges a person to remembering dozens of passwords which should not be all identical for safety and keeping all those keys and cards by ones side. Biometric recognition systems offer a way of identification based on person traits which cannot be forgotten or lost.

Despite its advantages, BRS do not prevail yet because of false acceptance and rejection rates, speed and cost of a system, permanence of a persons' trait used, personal information security [1]. Therefore, a lot of research and improvements must be done in the area of biometric feature systems. An appropriate database is one of the most important factors for the development of a BRS.

In this paper biometric feature systems and multimodal databases for BRS are analyzed. In order to see what areas of research on BRS are the most active today, important biometric features and their mixtures constituting biometric feature systems are critically analyzed. Moreover advances and drawbacks on the use of several traits and their popular databases in multimodal BRS are examined.

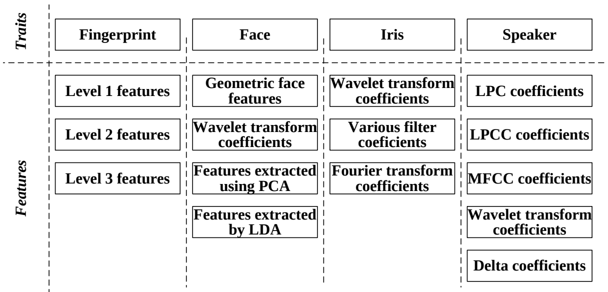

Fig. 1. Possible biometric feature systems of unimodal BRS

Biometric feature systems

For identification any BRS takes a sample from the user of his physiological or behavioral trait. In its raw form the sample contains a lot of redundant information, which takes a lot of space to store and is not convenient to operate with. Because of this, it is needed to reduce dimensionality of sample trying to preserve only the information needed to recognize the user. This is done by extracting the features from a taken sample. A set of features used for the recognition constitutes *biometric feature system*. Unimodal biometric feature systems are formed from the samples of single trait using one or more feature extraction techniques. Fig. 1 summarizes possible biometric feature systems of four unimodal BRS.

The overall performance of a BRS depends on many factors and the selected biometric feature system is no exception. It influences memory requirements, speed, susceptibility to noise, recognition rates, etc. Usually, the selection of a biometric feature system is a search of a trade-off when criteria of the BRS are known. Various biometric features for different human traits have their own advantages and disadvantages, which can be found in scientific articles and surveys. Nevertheless it is quite hard to compare them by results achieved, because various factors stack up influencing the performance of a system, e. g., different databases or decision methods used. At this point one can get interested in *what features and their mixtures are most frequently used to transform samples to feature space of various traits*.

With that respect of almost 2.5 million publications database of IEEE digital library IEEE Xplore [1] was investigated. As there are many traits suitable for person recognition (even such as electroencephalogram [3]) we limited our research to five most frequently explored human traits [4]. The investigation was performed by entering two specific search expressions. Willing to find out the number of publications that mentions a certain feature for a biometric trait of a human being we used

$$\underset{\text{metadata}}{\text{find}}\,(f \cup a)c, \qquad (1)$$

while aiming to find out number of publications mentioning a certain mixture of two features for a certain biometric trait we used

$$\underset{\text{metadata}}{\text{find}}\left(f_1 \cup a_1\right) \cap \left(f_2 \cup a_2\right) \cap c, \qquad (2)$$

here f – feature; a – abbreviation or synonym of the feature; c – a biometric trait.

Top five biometric features and their mixtures for each investigated trait – face [5], fingerprint [6, 7], iris [8], signature [9] and voice (speaker) [10] – were elucidated (Fig. 2).

Analysis of investigation results shows that a set of wavelet transform coefficients is the most universal feature used to transform samples of all traits under investigation. Features calculated using Gabor filter are closely related to wavelet transform (they accelerate the transform). Because of this it is one of the most frequently used features as well. Face and voice recognition, though very commonly and successfully performed by a human being, do not achieve high recognition rates as fingerprint or iris recognition does. That is why the research on finding better features is very active. The most popular feature mixture for face recognition is features extracted by principal component analysis (PCA) and by linear discriminant analysis (LDA). These methods are related and it is common to compare recognition performance of BRS based on these features. In voice recognition the most frequently mixture of features mentioned is mel-frequency cepstral coefficients and formants. On the whole, mel-frequency cepstral coefficients are frequently used with other features for feature fusion. A combination of minutiae coordinates also called as level 2 features and level 1 features based on extraction of global features can be considered as a golden standard for fingerprint recognition. Iris recognition probably demonstrates the best recognition rates. Features for iris pattern recognition are usually obtained using transformation of frequency domain. As recognition rates are probably the best of all unimodal systems, the use of feature mixtures are not popular. Because of the interrelationship wavelet transform and Gabor filter is the only mixture of techniques that standout among others. Signature recognition has probably the biggest number of various features. Possibly because of this and the reason that a big number of these features have to be used for a successful recognition, authors tend not to list all features used in the fields of metadata.

Biometric traits in multimodal systems

Multimodal biometric feature systems are formed from the samples of several traits of a person using one or more extraction techniques. Although the majority of today real-world deployed systems are unimodal, a single source of information they rely on might cause several problems: noise in the sensed data (voice sample altered by cold, a cut on a finger, defective sensors, poor illumination, etc.), intra-class variations, inter-class similarities in feature system space, non-universality (it may be impossible to acquire a meaningful biometric data sample from a subset of users) and spoof attacks (more common to behavioral traits, but fingerprints are also susceptible) [11]. A multimodal system relies on two or more fairly undependable sources of information and because of this the influence of problems mentioned above is lesser.

Fusion of data from several sources can produce better results thus it becomes increasingly popular. A research of used features for every trait in multimodal systems would be not fully precise as authors tend not to list all features used. So, by the use of

$$\underset{\text{metadata}}{\text{find}}\left(\texttt{multimodal} \cup \texttt{fusion}\right) \cap c_1 \cap c_2 \qquad (3)$$

we have tried to find most popular mixtures of two person traits used in multimodal systems. Keyword `multimodal` was used to separate articles which analyzed multiple person traits. As some authors use word `fusion` interchangeably, it was added to query, too. The remaining keywords were the same titles of 5 traits.

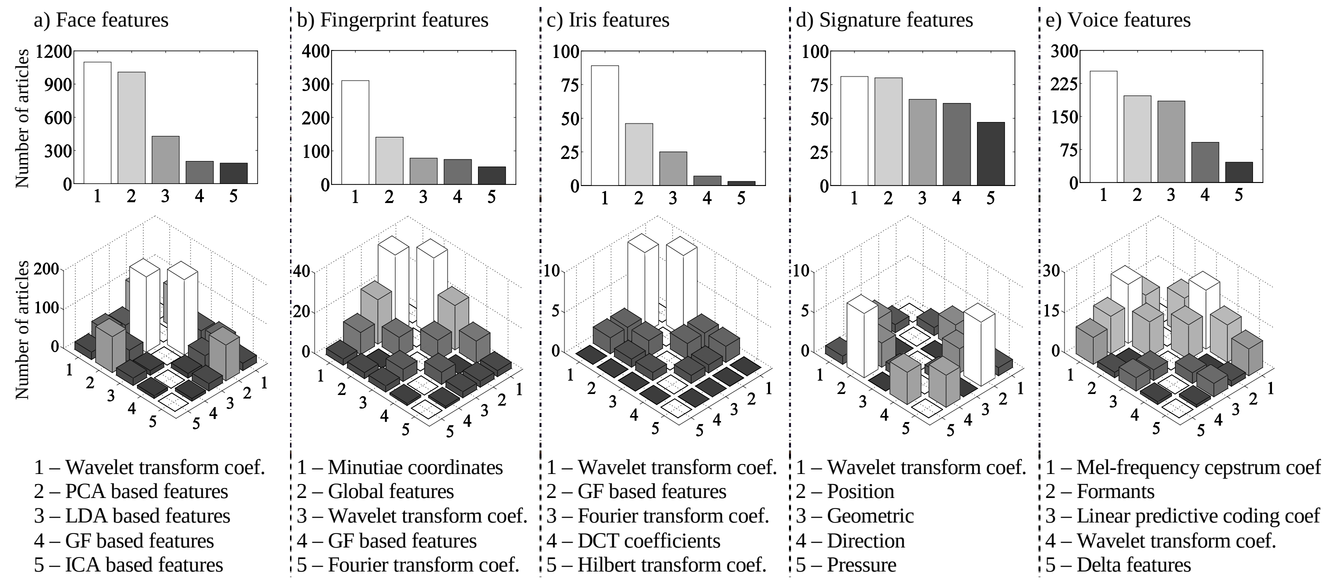

Fig. 2. Number of articles naming five most frequently used biometric features and their mixtures (PCA – principal component analysis, LDA – linear discriminant analysis, GF – Gabor filters, ICA – independent component analysis, DCT – discrete cosine transform)

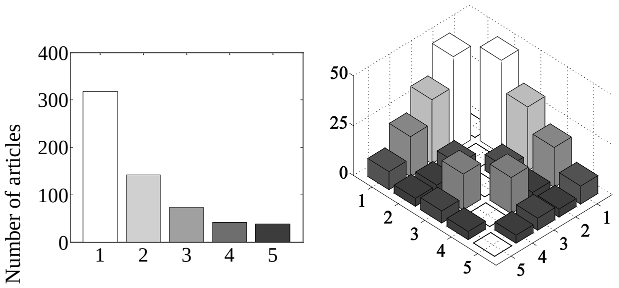

Fig. 3. Number of articles on multimodal systems that include five most popular traits: 1 – face; 2 – voice; 3 – fingerprint; 4 – iris; 5 – signature

The results (Fig. 3) also included articles which did not deal with features for person verification or identification. However, these articles reported on new multimodal databases, reviews, sample preprocessing and so on. Thus, the results still show the interest trends of scientists in usage of several person traits for recognition. Face trait is the most frequently used in multimodal systems. Most commonly it is combined with voice recognition, which is not frequently used with any other trait in a scope of this study. Both of these traits do not demonstrate very good recognition rates, but the sensors for sample capture are widely spread and cheap, acceptable for a user and implementable on third generation GSM networks. Fusion of these traits can greatly increase recognition rates. Face and fingerprint fusion is in the second place according the results. This multimodal system should archive better recognition rates, but requires additional sensor, which, though not so common, starts to emerge in general purpose laptops. The third place goes to fingerprint and iris fusion. Recognition systems based on either of these traits achieve very good result. BRS, fusing iris and fingerprint traits, would demonstrate especially good results and would be suitable for high security applications. Nevertheless, special expensive sensors are required and that lowers an appeal of the system.

Acquisition of the datasets

As multimodal recognition systems offer such advantages as better accuracy, lower vulnerability to attacks, better failure-to-enroll rates and a possibility to successfully claim user identity in situation, when giving a sample of one your traits is impossible, it has its own disadvantages such as lower speed, higher price, lower convenience and problematic collection of a database. However, the advantages seem to be very tempting and the research effort of multimodal systems increases.

A deployed BRS stores only features of enrolled users, still their development requires a wide, well documented database with samples in their raw form, descriptions and comments. Only such databases allow comparing the performance of different BRS on the same scenarios.

Extension or creation of new biometric databases is done mainly because of: the need of more samples from different sessions, the use of different sensors in different acquisition conditions, and addition of new traits. More samples are usually needed because BRS training may lead to overtraining, which can be only seen while testing the system on larger dataset. Special methods are proposed for a proper split of a database to datasets for training and testing [12]. The need of samples taken by different sensors comes in two cases: either a new, advanced sensor is available or checking how much recognition accuracy is affected by different sensor. Different acquisition conditions are needed to see how a recognition algorithm performs in various real life situations.

Table 1. Popularity of multimodal databases

Database	Year	Number of				
		persons	sessions	traits	publications since	
					1913	2008
BioSecure	2008	971	2	2	19	10
		667	2	6		
		713	2	4		
BiosecurID	2007	400	4	8	2	2
Biosec	2007	250	4	4	2	0
IV²	2007	300	1–2	3	0	0
MBioID	2007	120	2	6	0	0
FRGC	2006	741	variable	2	121	54
M3	2006	32	3	3	0	0
MyIDEA	2005	104	3	6	3	2
BANCA	2003	208	12	2	38	5
BIOMET	2003	91	3	6	5	3
MCYT	2003	330	1	2	25	11
Smartkom	2002	96	variable	4	1	0
BT-DAVID	1999	124	5	2	0	0
XM2VTS	1999	295	4	2	102	26
M2VTS	1998	37	5	2	28	3

The development of a good multimodal database requires much more painstaking work and persistence, because it must also include some forgeries for security testing, as many different sensors, sessions and conditions as possible. Because of this some researchers tried to construct multimodal databases using different unimodal datasets or even to generate synthetic databases. Nevertheless, it is advised to perform the evaluation of the system on real multimodal biometric data [13].

All 14 reviewed multimodal databases [14] plus one additional IV^2 database are listed in Table 1. Databases consist of 260.7 persons, 3.6 sessions and 3.7 traits on average. Recent trends in database development are to include more users and traits, however number of sessions is not increased. Some of the databases are used more widely than others thus an investigation on database usage in IEEE Xplore digital library was carried out.

According to the results in Table 1, the most widely used database is FRGC, which was mentioned in 121 articles and 58 of them were released since 2008. However, though it was listed in [14] as multimodal database, its multimodality is questionable as it includes only 2D and 3D facial images, which are samples of the same human trait. The second is a ten year old XM2VTS database still sustaining its popularity (26 publications since 2008) including 4 sessions of 2D face and speech traits from 295 persons. The third place according to popularity in all IEEE Xplore articles is BANCA database consisting of 12 sessions of 2D face and speech traits is mentioned 38 times, however only 5 articles were published since 2008. The third place according to publications since 2008 goes to MCYT database consisting of a single session of fingerprint and signature traits. The newest BioSecure database lags behind by only one article, having 2–6 traits and in different acquisition conditions should increase its popularity quickly.

Conclusions

1. Wavelet transform coefficients are the most universal feature used in biometric systems – it is among five frequently used features used in all five popular traits.

2. Face is the most frequently used trait in multimodal systems. It is used along with 48 % of iris, 44 % of fingerprint, 33 % of voice and 24 % of signature multimodal systems. Usage of fingerprint with iris trait is also distinguishably popular – 43% of systems.

3. Older multimodal databases, e. g., XM2VTS, are still widely used for BRS comparison. However databases such as Biosecure are more versatile and should become more popular soon if an open access would be provided.

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Received 2009 12 27

E. Ivanovas, D. Navakauskas. Development of Biometric Systems for Person Recognition: Biometric Feature Systems, Traits and Acquisition // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 5(101). – P. 87–90.

In this paper biometric feature systems and multimodal databases for biometric recognition systems are analyzed on the basis of scientific publications in IEEE Xplore digital library. It is shown that wavelet transform coefficients are the most universal feature used in biometric person recognition systems – it is among five frequently used features used in all five popular traits. Moreover, face is the most frequently used trait in multimodal person recognition systems – it is used along with 48 % of iris, 44 % of fingerprint, 33 % of voice and 24 % of signature multimodal systems. Analysis of 15 multimodal databases reveals the fact, that older multimodal databases, e. g., XM2VTS, are still widely used for comparison. However databases such as Biosecure are more versatile and should become more popular soon if a free access will be provided. Ill. 3, bibl. 14, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

Э. Ивановас, Д. Навакаускас. Разработка биометрических систем идентификации личности: биометрические системы, признаки и их накопление // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – С. 87–90.

В данной статье, основываясь на научных публикациях, представленных в цифровой библиотеке IEEE Xplore, анализируется использование систем на основе биометрических признаков, а также мултимодальных баз данных для систем биометрического распознавания. Показано, что коэффициенты вейвлет-преобразования являются найболее универсальным признаком в биометрических системах, и часто используются для трансформации всех пяти характерных черт личности. Лицо является самой популярной чертой, используемой в мультимодальных системах заодно с другими чертами: с радужной оболочкой глаз – 48 %, с отпечатками пальцев – 44 %, с голосом – 33 % и с подписью – 24 %. Анализ пятнадцати мултимодальных баз данных показал, что более ранние базы, например, XM2VTS, всё ещё используются. Новые базы данных, например, Biosecure, являются более разносторонними и их популярность должна расти если будет обеспечен свободный доступ к ним. Ил. 3, библ. 14, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

E. Ivanovas, D. Navakauskas. Biometrinių asmens atpažinimo sistemų kūrimas: biometrinės požymių sistemos, bruožai ir duomenų gavyba // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 87–90.

Straipsnyje analizuojamas biometrinių požymių sistemų ir multimodalinių duomenų bazių nagrinėjimas IEEE Xplore skaitmeninėje bibliotekoje pateikiamuose moksliniuose straipsniuose. Parodoma, kad biometrinėse asmens atpažinimo sistemose universaliausias požymis yra vilnelių transformacijos koeficientai, dažnai taikomi penkiems populiariausiems asmens bruožams transformuoti. Multimodalinėse asmens atpažinimo sistemose dažniausiai naudojamas veido atvaizdas jį derinant su kitais bruožais: akies rainele (48 %), piršto antspaudu (44 %), balsu (33 %) ir parašu (24 %). Penkiolikos multimodalinių duomenų bazių taikymo analizė rodo, kad ankstesnės, pvz., XM2VTS, duomenų bazės vis dar dažnai naudojamos. Naujos duomenų bazės, pvz., Biosecure, yra įvairiapusiškesnės ir išpopuliarės, jei bus užtikrinta atvira prieiga prie jų. Il. 3, bibl. 14, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).