A Review on fusion in Multimodal Biometric Spoofing Attack by Different Materials

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Abstract. Biometric gadgets utilize their physiological or behavioural properties for the confirmation and acknowledgment of people. Spoofing attack can be done by using any spoofing materials. Such features can be arranged into unimodal and multimodal frameworks. Some state-of-the-methods have some drawbacks, which reduce the efficiency of the system. Multimodal biometric detecting frameworks utilize at least two behavioural or physiological attributes. The multimodal system has showed to increase the success rate of identification and authentication meaningfully. Data from different modalities are acquired, pre-handled, removed noise, and contrasted and finally converted into features. At last, selection of features acknowledges the identification of a person. In multimodal biometric identification system, biometric features can club at any of the stages, i.e. sensor level, feature level, score level, rank level, and decision level. This paper presents an effective survey on fusion of features at different level in a multimodal biometric system. It also focuses in the field with a better thoughtful of multimodal biometric sensing and handling systems and research inclinations in this field.

Keywords. Sensor Level, Score Level, Decision Level, Feature Level, Fusion, Multimodal Biometric, Spoofing Material

1. Introduction
There is a need to acknowledge validation and approval strategies for asset security in the ongoing progression of data invention. There are numerous methods for exhibiting check and approval. Yet, the biometric validation beats every other system. Biometric detecting and electronic gadgets are basic tools used to confirm and distinguish people. Confirmation requires adjusting individuals to who they give off an impression of being. The biometric ID of an individual dependent on their nature and social qualities. Palm printing, face, fingerprinting and iris are promptly modalities to as the biometric framework. The framework takes a biometric highlight and analyses it against a set up biometric dataset of that individual trying to get a match.

Investigate on multimodal biometric frameworks has been done where voice and face were melded by utilizing the hyperbolic digression [1]. Ross and Jain [2] utilized direct discriminant-based strategies, the entirety run the show and choice tree to combine confront,
unique finger impression and hand geometry biometrics. The analysts detailed that the entirety run the show performed superior than the others. A few combination methodologies were taken into thought, such as the tree classifier, SVM (Support Vector Machine) and multi-layer recognition for voice and confront biometrics [3]. At last, a multimodal biometric framework was projected by combining coordinating of the unique finger impression and Eigen confront from the confront [4]. Table 1 demonstrates state-of-art-methods on multimodal frameworks, showing the sort of biometric modalities and strategies utilized [5]. Figure 1 appears the steps utilized in a multimodal biometric framework.

![Figure 1: Various processes engaged in a multimodal biometric system](image)

| State-of-art                      | Multi biometric          | Algorithm                                      |
|----------------------------------|--------------------------|------------------------------------------------|
| Infrared and visible image fusion [7] | Face & Iris              | Normalization                                  |
| Nature based fusion [8]          | Fingerprint & Signature  | Hidden Markov model                            |
| Biometric authentication [9]     | Fingerprint & Voice      | Threshold settings                             |
| Bimodal biometric verification [10] | Face & Fingerprint      | Normalization techniques                       |
| Feature fusion [11]              | Face & Gait              | Likelihood ratio                               |
| Robust combination method [12]   | Face & Fingerprint      | Neyman-Pearson based methodology               |
| Video surveillance [13]          | Face recognition framework using 3D face modelling technique | Combining the facial mark matching and face recognition |
| Machine learning methods [14]   | Face and iris image      | Detection of an individual’s face, eyes and other parts of the face. |
| Novel digital content protection [15] | Signature and iris  | Feature and decision level fusion.            |
2. Survey: Multimodal Fusion
The multimodal biometric framework depends on information fusion plans and data sorts utilized from different biometric modalities. The primary application using information combination was detailed in 1965 that was further used for design acknowledgment, data retrieval, machine learning, etc. Voluminous writing is available which bargains with distinctive combination plans like sensor level, match score level, feature level, rank level fusion, and decision level including different biometrics. The subsequent sub-sections talk about a few of the investigate utilizing distinctive combination strategies for multimodal biometric frameworks [57]. In this paper further all types of fusion techniques are elaborated.

2.1. Fusion at Sensor Level (SL)
This fusion can take put when the different features are taken of the same biometric characteristic obtained from different sensors or different values of the same biometric prompts procured from a single sensor [Figure 2]. This fusion is assembled into three classes, specifically:

[i] Where different occasions gotten from a single sensor are coordinates to secure the data in a dependable and clear mode.
[ii] Numerous cases gotten from different sensors are put together [16-17] and
[iii] Inter-class numerous sensors have been attempted of this sensor combination mode. [18].

Figure 2: Fusion at the Sensor Level [6]
2.2. *Fusion at Feature Level (FL)*

This includes joining the different include sets procured from distinctive biometric features into a single vector. At this level of combination, signals from different biometric channels are firstly pre-processed and feature vectors are combined to make a composite include vector, which is at that point encourage utilized for the classification handle in Figure 3. They include level contains data that helps with preparing crude biometric information and subsequently, is accepted to be more viable.

The method included in include level combination happens in two stages, first normalization and media conspiring to revise the area and scale of highlight values. Calculations that bargain with highlight choice incorporate successive forward choice, consecutive in reverse determination and parcel.

This level combination is difficult to achieve as there may be inconsistency of include sets to be combined and the joint highlight set of distinctive biometric sources may not be straight [19]. In the event that the highlight vectors have the same characteristics are accepted, e.g. different unique finger impression impressions of an individual’s finger. When the include vectors have diverse characteristics, e.g. confront and unique finger impression, they can be concatenated to ended up a single include vector [19-21].

![Diagram](image_url)  
**Figure 3:** Detailed description of Feature level fusion [6]

2.3. *Fusion at Decision Level (DL)*

The assembly of distinctive data from numerous biometric traits happens when the individual framework makes an individualistic choice almost the personality of the client of a claimed personality. Here, each biometric feature is pre-classified exclusively and the ultimate
classification is based on the combination of the yields of the different modalities [Figure 4]. Besides, a choice is given for each biometric sort at an afterward organize which decreases the reason for making strides the framework precision through the combination prepare [6]. This combination level makes utilize of the ultimate yield of the person modalities with methods such as ‘AND’ or ‘OR’ making it the only shape of combination [5]. The D-S theory, and Bayesian combination are other approaches employed at this level of combination.

Figure 4: Detailed description of Decision level fusion [6]

2.4. Fusion at Matching Score Level (MSL)

This includes the joining of indistinguishable scores created by a coordinating module for each input highlight and format biometric highlight vector inside the database [see Figure 5]. The highlight levels are handled independently instead of combining them and a person coordinating score is inferred [22-23]. The coordinating score level combination can too be called estimation level combination.

Taking after the classifying approach, an include vector is outlined utilizing the coordinating scores yield by the solitary matcher, which is encourage classified into either accept or reject category [24]. Taking after the combination approach, the scores of person coordinating are connected to end up a particular scalar score that’s utilized to reach the conclusion choice.

The coordinating scores contain sufficient information to create genuine and impostor cases exceptionally clear. Subsequently, the method can be influenced by a few variables which assist diminish the execution of the biometric framework [25-27]. Table 2 elaborated the state-
of-the-art methods for different fusion methods with multimodal modalities such as Face (Fc), Fingerprint(Fp), Hand Geometry(Hg), Speech (Sp), Signature(Sg), Iris(Ir), Voice(Vc) and palm print(Pp).

![Diagram](image.png)

Figure 5: Detailed description of Matching Score level fusion

3. Conclusion and Future work
Biometric detecting advances have without a doubt becomes well known because they utilize exceptional physical properties to check and distinguish. Right now done an itemized investigation of the field of biometrics, beginning from the historical backdrop of the unimodal framework to the current biometric multimodal frameworks. The primary focal point of this work is the combination of highlight level, as this plan gives full dynamic information. It gives better outcomes when contrasted with the match score level and other comparative plans post. There is gigantic extension for advancement in the combination strategy for include level, so creators will attempt to grow new combination calculations, separate highlights and consolidate them on the cell phone stage. This survey will be useful for whom, those want to work in spoof attacking system and in cloud environment.

It further tends to the different methods of biometric recognizable proof. This survey paper has thusly clarified why more work and arrangements are expected to the referenced issues found in the distinctive biometric detecting frameworks just as the inadequacies of the diverse combination strategies. The prerequisite for separation casting a ballot and improvement of standardized savings plans, for example, ADHAR card in India can be refreshed and redesigned.
| S. No. | Fusion Level | Fusion Approach | Modalities |
|--------|--------------|----------------|------------|
| 1      | MSL [28]     | Min-Max Rule   | Fc, Fp and Hg |
| 2      | MSL [29]     | Sum , decision rule and LDA | Fc, Fp and Hg |
| 3      | SL [30]      | Weighted score level fusion | Ir and Fc |
| 4      | SL [31]      | Principal component analysis (PCA) | Fc and ear |
| 5      | MSL [32]     | SVM classifiers | Fp and Sg |
| 6      | DL [33]      | AND rule, OR rule, majority voting | Hand biometrics |
| 7      | MSL [34]     | Sum, product, maximum median and minimum rule Fc and voice |
| 8      | SL [35]      | Product of likelihoods | Sp and Sg |
| 9      | FL [36]      | Neyman-Pearson theorem | Fc and Ir |
| 10     | MSL          | Sum rule       | Fc, Vc and lip movement |
| 11     | SL[38]       | Weighted geometric average | Sp and Fc |
| 12     | SL[39]       | Weighted Fusion | Fp and finger vein |
| 13     | MSL [40]     | Likelihood ratio | Fp, Fc and Hg |
| 14     | DL [41]      | Bayesian supervisor | Sp and Fc |
| 15     | DL [42]      | Bayesian supervisor, Averaging | Fc and Sp |
| 16     | FL, SL [43]  | Max-of-scores | Fc, Vc, and Sg |
| 17     | MSL [44]     | Local and global decision parameters | Fp, Hg and Vc |
| 18     | SL [45]      | Z-Score normalization and Sum rule | Sp, Sg and Handwriting Features |
| 19     | RL [46]      | Maximum rank, nonlinear weighted rank | PP |
| 20     | FL [47]      | Sum rule       | Palm veins and Sg |
| 21     | FL [48]      | Delaunay triangulation | Fp and Fc |
| 22     | FL, ML       | Similarity measure | PP and Hg |
| 23     | FL [50]      | PCA and ICA    | Fc and PP |
| 24     | DL [51]      | Maximum Likelihood Parameter | Sp and Sg |
| 25     | DL [52]      | AND, OR OPERATOR | Fc and Vc |
| 26     | MSL [53]     | Product-based composite imposter distribution | Fc and Fp |
| 27     | MSL [54]     | SVM, Bayesian Classifier, Multi-Layer Perceptron | Fc and Sp |
| 28     | MSL [55]     | Sum, Min and Product Rule | Fc and Gait |
| 29     | SL [56]      | Particle swarm optimization | Fc and palm print |
References

[1] R. Brunelli and D. Falavigna, “Person identification using multiple cues,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 17, no. 10, pp. 955–966, Oct. 1995.
[2] A. Ross and A. Jain, “Information fusion in biometrics,” Pattern Recognit. Lett., vol. 24, no. 13, pp. 2115–2125, 2003.
[3] S. Ben-Yacoub, Y. Abdeljaoued, and E. Mayoraz, “Fusion of face and speech data for person identity verification,” IEEE Trans. Neural Netw., vol. 10, no. 5, pp. 1065–1074, Sep. 1999.
[4] D. Shubhangi and M. Bali, “Multi-biometric approaches to face and fingerprint biometrics,” Int. J. Eng. Res. Technol., vol. 1, no. 5, pp. 1–7, 2012.
[5] S. Sheena and S. Mathew, “A study of multimodal biometric system,”IJRET, vol. 3, no. 15, pp. 93–98, Dec. 2014.
[6] A. Ross and A. K. Jain, “Multimodal biometrics: An overview,” in Proc.12th Eur. Signal Process. Conf., Sep. 2004, pp. 1221–1224.
[7] S. Singh, A. Gyaourova, G. Bebis, and I. Pavlidis, “Infrared and visible image fusion for face recognition,” in Proc. Defense Secur., vol. 5404. 2004, pp. 585–596.
[8] H. C. Ching and C. Esowaran, “A nature based fusion scheme for multimodal biometric person identity verification at a distance,” in Proc. ICSAP, Apr. 2009, pp. 94–97.
[9] M. A. Kowkko, “Biometric authentication for older adults,” in Proc.IEEE Long Island Syst., Appl. Technol. Conf. (LISAT), May 2014, pp. 1–4.
[10] B. E. Manjunathswamy, J. Thirveni, and K. R. Venugopal, “Bimodal biometric verification mechanism using fingerprint and face images(BBVMFF),” in Proc. IEEE 10th Int. Conf. Ind. Inf. Syst. (ICIIS), Dec. 2015, pp. 372–377.
[11] X. Zhou and B. Bhanu, “Feature fusion of face and gait for human recognition at a distance in video,” in Proc. 18th Int. Conf. Pattern Recognit., (ICPR), Aug. 2006, pp. 529–532.
[12] M. D. J. Ghate and S. B. Patil, “Robust combination method for privacy protection using fingerprint and face biometrics,” in Proc. 4th Int. Conf. Rel., Infocom Technol. Optim. (CRITO)(Trends Future Directions), Sep. 2015, pp. 1–6.
[13] X. Hu, Q. Liao, and S. Peng, “Video surveillance face recognition by more virtual training samples based on 3D modeling,” in Proc. 11th Int. Conf. Natural Comput. (ICNC), Aug. 2015, pp. 113–117.
[14] M. Oravec, “Feature extraction and classification by machine learning methods for biometric recognition of face and iris,” in Proc. 56th Int. Symp. ELMAR, Sep. 2014, pp. 1–4.
[15] M. Wang, K. Fan, X. Li, and Q. Zeng, “A novel digital content protection scheme combining iris identity based digital signature and semi-fragile watermark,” in Proc. Int. Conf. Commun. Technol. (ICCT), Nov. 2006, pp. 1–4.
[16] F. Yang, M. Paindavoine, H. Abdi, and A. Monopoli, “Development of a fast panoramic face mosaicking and recognition system,” Opt. Eng., vol. 44, no. 8, pp. 087005–1–087005-10, 2005.
[17] S. S. Iyengar, L. Prasad, and H. Min, Advances in Distributed Sensor Integration: Application and Theory. Englewood Cliffs, NJ, USA: PrenticeHall, 1995.
[18] M. Faundez-Zanuy, “Data fusion in biometrics,” IEEE Aerosp. Electron. Syst. Mag., vol. 20, no. 1, pp. 34–38, Jan. 2005.
[19] S. R. M. Prasanna, S. K. Sahoo, and T. Choubisa, “Multimodal biometric person authentication: A review,” IETE Tech. Rev., vol. 29, no. 1, pp. 54–75, 2012.
[20] Y. Han, T. Tan, Z. Sun, and Y. Hao, “Embedded palmpit recognition system on mobile devices,” in Proc. Adv. Biometrics, 2007, pp. 1184–1193.
[21] A. A. Ross and R. Govindarajan, “Feature level fusion of hand and face biometrics,” in Proc. Defense Secur., vol. 5779, 2005, pp. 196–204.
[22] K. Woods, W. P. Kegelmeyer, Jr., and K. Bowyer, “Combination of multiple classifiers using local accuracy estimates,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 19, no. 4, pp. 405–410, Apr. 1997.
[23] A. K. Jain and A. Kumar, “Biometrics of next generation: An overview,” in Proc. 2nd Generat. Biometrics, vol. 12, 2010, pp. 23.
[24] M. El-Abed, R. Giot, B. Hemery, and C. Rosenberger, “A study of users’ acceptance satisfaction biometric systems,” in Proc. IEEE Int. Carnahan Conf. Secur. Technol.(ICCST), Oct. 2010, pp. 170178.
[25] M. Hanmandlu, J. Grover, V. K. Madaus, and S. Vasirkala, “Score level fusion of hand based biometrics using t-norms,” in Proc. IEEE Int. Conf. Technol. Homeland Security (HST), Nov. 2010, pp. 7076.
[26] W. Almayan, “Performance analysis of multimodal biometric fusion,” to be published, 2012.
[27] T. Murakami and K. Takahashi, “Information-theoretic performance evaluation of likelihood-ratio based biometric score fusion under modality selection attacks,” in Proc. IEEE 7th Int. Conf. Biometrics Theory, Appl. Syst. (BTAS), Sep. 2015, pp. 18.
[28] Jain A, Nandakumar K, Ross A. Score normalization in multimodal biometric systems. Pattern recognition. 2005 Dec 31; 38(12): 2270–85. CROSSEF
[29] Ross A, Jain A. Information fusion in biometrics. Pattern recognition letters. 2003 Sep 30; 24(13):2115–25.
[30] Sim HM, Axsun H, Hassan R, Othman RM. Multimodal biometrics: Weighted score level fusion based on non-ideal iris and face images. Expert Systems with Applications.2014 Sep 1; 41(11):5390–404
[31] Chang K, Bowyer KW, Sarkar S, Victor B. Comparison and combination of ear and face images in appearance-based biometrics. IEEE Transactions on pattern analysis and machine intelligence. 2003 Sep; 25(9):1160–5.
[32] Fierrez-Aguilar J, Ortega-Garcia J, Gonzalez-Rodriguez J, Bigun J. Discriminative multimodal biometric authentication based on quality measures. Pattern recognition. 2005 May 31; 38(5):777–9.
[33] Yu P, Xu D, Zhou H, Li H. Decision fusion for hand biometric authentication. IEEE International Conference on Intelligent Computing and Intelligent Systems. 2009 Nov 20; 4:486–90.
[34] Kittler J, Hatef M, Duin RP, Matta J. On combining classifiers. IEEE transactions on pattern analysis and machine intelligence. 1998 Mar, 20(3): 226–39.
[35] Kaur M, Girdhar A, Kaur M. Multimodal biometric system using speech and signature modalities. International Journal of Computer Applications. 2010 Aug; 5(12):13-6.
[36] Nandakumar K. Multibiometric systems: Fusion strategies and template security [Doctoral thesis]. Michigan State University. ProQuest. 2008. p. 1–249.
[37] Frischholz RW, Dieckmann U. BiolID: A multimodal biometric identification system. Computer. 2000 Feb; 33(2): 64-8.
[38] Brunelli R, Falavigna D. Person identification using multiple cues. IEEE transactions on pattern analysis and machine intelligence. 1995 Oct; 17(10): 955–66.
[39] Cui F, Yang G. Score level fusion of fingerprint and finger vein recognition. Journal of Computational information systems. 2011 Dec; 7(16): 5723–31.
[40] Nandakumar K, Chen Y, Dass SC, Jain A. Likelihood ratio based biometric score fusion. IEEE transactions on pattern analysis and machine intelligence. 2008 Feb; 30(2): 342–7.
[41] Bigün ES, Bigün J, Duc B, Fischer S. Expert conciliation for multi modal person authentication systems by Bayesian statistics. International Conference on Audio-and Video-Based Biometric Person Authentication. 1997 Mar 12. p. 291–300.
[42] Bigün J, Duc B, Smeraldi F, Fischer S, Makarov A. Multimodal person authentication. Face Recognition. 1998. p.26–50.
[43] Elmir Y, Elberrichi Z, Adjoudj R. Multimodal Biometric Using a Hierarchical Fusion of a Person’s Face, Voice, and Online Signature. JIPS. 2014 Dec 1; 10(4): 555–67.
[44] Toh KA, Yau WY, Jiang X. A reduced multivariate polynomial model for multimodal biometrics and classifiers fusion. IEEE Transactions on Circuits and Systems for Video Technology. 2004 Feb;14(2): 224–33.
[45] Eshwarappa MN, Latte MV. Multimodal Biometric Person Authentication using Speech, Signature and Handwriting Features. International Journal of Advanced Computer Science and Applications, Special Issue on Artificial Intelligence. 2011. 1–10.
[46] Monwar MM, Gavrilova ML. Multimodal biometric system using rank-level fusion approach. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics). 2009 Aug; 39(4): 867–78.
[47] Rattani A, Kisku DR, Bicego M, Tistarelli M. Feature level fusion of face and fingerprint biometrics. BTAS. 2007 Sep 27, pp. 1-6.
[48] Kumar A, Wong D, Shen H, Jain A. Personal verification using palmprint and hand geometry biometric. Audio-and Video-Based Biometric Person Authorization. 2003, pp. 1060-1060.
[49] Feng G, Dong K, Hu D, Zhang D. When faces are combined with palmprints: A novel biometric fusion strategy. Biometric authentication. Springer, 2004. p. 701–7.
[50] Soltane M, MMEN B. Soft Decision Level Fusion Approach to a Combined Behavioral Speech-Signature Biometrics Verification. International Journal of Signal Processing, Image Processing and Pattern Recognition SIJSIP. 2013 Feb; 6(1): 1–16.
[51] Chatzis V, Bors AG, Pitas I. Multimodal decision-level fusion for person authentication. IEEE transactions on systems, man, and cybernetics-part a: systems and humans. 1999 Nov; 29(6): 674–80.
[52] Hong L, Jain A. Integrating faces and fingerprints for personal identification. IEEE transactions on pattern analysis and machine intelligence. 1998 Dec; 20(12): 305–307.
[53] Ben-Yacoub S, Abduljaoude Y, Mayoraz E. Fusion of face and speech data for person identity verification. IEEE transactions on neural networks. 1999 Sep; 10(5): 1065–74.
[54] Veeramachaneni K, Osadciw LA, Varshney PK. An adaptive multimodal biometric management algorithm. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews). 2005 Aug; 35(3): 344–56.
[55] Tan X, Bhanu B. Fingerprint matching by genetic algorithms. Pattern Recognition. 2006 Mar 31; 39(3): 465–77.
[56] Raghavendra R, Rao A, Hemantha Kumar G. Multisensor biometric evidence fusion of face and palmprint for person authentication using particle swarm optimisation (pso). International Journal of Biometrics. 2009 Dec 16; 2(1): 19–33.
[57] Joseph, Teena, S. A. Kalaiselvan, S. U. Aswathy, R. Radhakrishnan, and A. R. Shamna. "A multimodal biometric authentication scheme based on feature fusion for improving security in cloud environment." Journal of Ambient Intelligence and Humanized Computing (2020): 1-9.