Forensic Science International: Synergy 1 (2019) 271–274

Contents lists available at ScienceDirect

Forensic Science International: Synergy

journal homepage: https://www.journals.elsevier.com/forensic-science-international-synergy/

Craniofacial photographic superimposition: New developments

Douglas H. Ubelaker*, Yaohan Wu, Quinnlan R. Cordero

Department of Anthropology, NMNH, Smithsonian Institution Washington, D.C., 20560, USA

ARTICLE INFO

Article history:
Received 15 August 2019
Received in revised form
2 October 2019
Accepted 3 October 2019
Available online 4 October 2019

Keywords:
Forensic science
Anthropology
Craniofacial superimposition

ABSTRACT

Craniofacial superimposition is a technique used in the field of forensic anthropology to assist in the analysis of an unknown skull. The process involves superimposing an image of the recovered skull over an ante mortem image of the suspected individual. In the past two decades, there has been a decline in the application due to the development of molecular analysis as a more precise and accurate identification technique. Despite its decrease in use, there has been significant development in superimposition techniques in the past five years, specifically to standardize procedures. One project, MEPROCS (The New Methodologies and Protocols of Forensic Identification by Craniofacial Superimposition), has attempted to establish a framework for solving the problems of past superimposition techniques. Future researchers should consider integrating information gleaned from clinical practices with the statistical and technical advances of craniofacial superimposition for better facilitating its use in forensic anthropology.

The method of craniofacial superimposition involves comparison of features of a skull with antemortem photographs of a head and/or face. In the forensic context, photographic superimposition focuses on a recovered skull that likely is of sufficiently recent origin to be of medico-legal interest. Forensic scientists employ the technique when positive identification has not been accomplished but authorities suspect the recovered skull relates to a particular missing person. Analysis goals focus on determining if (1) the skull could not represent the person (exclusion), (2) the skull definitely represents the person (positive identification) or (3) the skull could represent the person. An exclusion indicates that features of the skull are inconsistent with features of the antemortem photographs to the extent that they could not represent the same person. Positive identification suggests that the skull and photograph share so many important features that they represent the same person to the exclusion of all others. The third category indicates that the skull and photograph share sufficient features that an exclusion is not possible but the shared characteristics are not sufficiently unique to allow a positive identification.

It should be noted that craniofacial superimposition should not be confused with techniques of facial approximation. Facial approximation involves estimating the facial appearance from a recovered skull usually to reach out to the public for information possibly leading to identification.

1. Perspective prior to 2015

Methods of craniofacial photographic superimposition have evolved dramatically since crude, early attempts dating back to 1931 (Ubelaker, 2015) [1]. Review articles by Aulsebrook et al. (1995) [2], Damas et al. (2011) [3], Yoshino (2012) [4] and Ubelaker (2015) [1] summarize the history of these developments and the issues encountered. These exhaustive reviews document progress through technological advancement (primarily computerization of the process) and new research documenting the relationship between hard and soft tissues of the head.

The vast literature on research developments and testing dating prior to 2015 is presented in the cited review articles and does not need to be repeated here. Examples of these publications include the Hadi and Wilkinson (2014) [5] study indicating that facial creases display postmortem resilience and can be important features for identification. Campomanes-Álvarez et al. (2014) [6] produced an automated procedure to reduce subjectivity by analysts. Ibáñez et al. (2009) [7] utilized evolutionary algorithms to enhance the process. Ibáñez et al. (2012) [8] introduced a cooperative coevolutionary approach to reduce the time involved and improve applications. Stephan and Davidson (2008) [9] and Stephan et al. (2009) [10] reported new research on anatomical placement of the human eyeball to facilitate comparison. Parzianello et al. (1996) [11] revealed an automatic system for detection of

* Corresponding author.
E-mail addresses: ubelaked@si.edu (D.H. Ubelaker), wuy@si.edu (Y. Wu), quinnlan.c11@gwu.edu (Q.R. Cordero).

https://doi.org/10.1016/j.fsisyn.2019.10.002

craniometric points used in the process.

Applications depend upon the availability of necessary equipment and/or the costs of technology purchase. Ghosh and Sinha (2001) [12] recognized this problem and presented a practical and economical system.

Some new methods presented prior to 2015 were accompanied by testing. Ibáñez et al. (2011) [13] addressed uncertainty in comparison by testing of weighted and fuzzy-set-theory-based landmarks on previously documented forensic cases. Jayaprakash et al. (2001) [14] tested the reliability of a then new technique of craniofacial morphanalysis. Arat et al. (2003) [15] tested the impact of juvenile growth on displacement of reference landmarks. From perspective in orthognathic surgery, Almukhtar et al. (2014) [16] presented and tested voxel based and surface based registration images.

Reviews in 2015 and earlier indicate that methods of craniofacial photographic superimposition continued to be employed. Questions of admissibility did not prevent use in legal proceedings (Mallet and Evison, 2013) [17]. Lorkiewicz-Muszyńska et al. (2013) [18] provided a case example from Poland of how postmortem computed tomography of the head revealed skeletal features useful for superimposition and identification. Fenton et al. (2008) [19] reported on the use of the technique to address identification issues of remains recovered near the United States/Mexico border. Jayaprakash et al. (2010) [20] advocated for superimposition techniques to be used to address the large number of unidentified dead in Malaysia.

The 2015 review by Ubelaker (2015) [1] featured an analysis of forensic cases he reported on between 1978 and 2009 that involved photographic superimposition. These cases mostly were submitted by the Federal Bureau of Investigation following a long tradition of collaboration with the Smithsonian Institution (Grisbaum and Ubelaker, 2001 [21]; Ubelaker, 2000 [22]). Of 848 total cases submitted during that period, only 14 cases (1.7%) involved photographic superimposition. These cases commenced in the 1990–1994 interval (nine cases) but subsequently diminished in frequency. Although Ubelaker's casefile subsequently has grown to number 987, the number of cases involving photographic superimposition remains 14 (only 1.4%) of all cases.

Ubelaker (2015) [1] credits DNA technology and procedures for the decline in use of photographic superimposition. If photographs of a missing person are available for comparison, likely DNA samples of the person or relatives can be obtained as well. Given FBI capability for DNA analysis and the high level of identification probability possible using molecular approaches, DNA became the method of choice for such cases. Review of those cases that involved photographic superimposition revealed that the technique was most useful for exclusion but did not result, by itself, in positive identification.

As noted above, considerable technological advances had been made by 2015, but uncertainties remained regarding what threshold was required for positive identification. Yoshino (2012) [4] recommended use of multiple antemortem views of a missing person and at least 13 matches of examination criteria for identification. But in general, standards for identification were lacking. In addition, each photograph and skull presented varying degrees of unique features available for comparison.

While research has allowed considerable advancement in the process of comparison, a central issue remains regarding the extent of similarity required for positive identification. Positive identification requires features to match between a skull and photograph. It also requires that the patterns of features that match are sufficiently unique to exclude any other person. Insufficient consideration of uniqueness of the matching features can lead to misidentification.

Chile provides an example of problems that are created when insufficient attention is focused on identification probabilities involved in craniofacial photographic superimposition. On September 11, 1973, a military coup was conducted against the elected President Salvador Allende. Subsequently, the military regime conducted years of institutionalized illegal detention, torture and murder of many supporters of the former Allende administration. When democracy returned to the country in 1988, families of the missing organized and worked with anthropologists to find and identify their loved ones. Many of the dead had been buried in a local cemetery in an area referred to as Patio 29. Volunteers succeeded in locating and exhuming 126 individuals. By 2002, 96 individuals had been identified using traditional techniques, including photographic superimposition. Later genetic analysis determined that many of these 96 individuals represented misidentifications (Bustos Streeter and Intriago Leiva, 2015) [23]. The political backlash and subsequent laboratory reforms have restored confidence in the identification units. However, the history serves as a reminder of the importance of proper attention to criteria for positive identification.

2. Advances since 2015

In spite of some historical problems with this approach and the increasing availability of DNA analysis, craniofacial superimposition continues to play a significant role in casework. Milligan et al. (2018) [24] provide a California case example. A partial cranium was recovered with evidence of a past craniotomy. Examination revealed the presence of two surgical screws and two plates. The forensic team utilized skull-video superimposition to compare the cranium with an antemortem CT scan. This analysis, along with other evidence, contributed to the identification.

2.1. MEPROCS project

The major advancement in recent years in regard to craniofacial photographic superimposition has centered around activities of the New Methodologies and Protocols of Forensic Identification by Craniofacial Superimposition (MEPROCS) project. This project recognized that procedures for craniofacial superimposition varied greatly among practitioners and lacked protocols and standards. An early phase of this project surveyed procedures employed by 26 participants in 17 different institutions from 13 countries. They judged 60 superimposition problems using their own methodology and technology. The group then met in Israel and later Italy to review results and discuss issues encountered. The summary document (Damas et al., 2015) [25] presented multiple problematic issues, 17 items of best practice and four practices to be avoided. The publication was presented as the first standard of the field and set the stage for new research.

In a follow-up study, the MEPROCS project presented 37 experts with 24 distinct documented skull-face superimpositions (positive and negative cases) involving 18 different problems (Ibáñez et al., 2016) [26]. The participants were requested to judge the comparisons as not evaluable, no match, poor match, doubtful match, good match or perfect match. In regard to final identification decision, they were offered the following options: undetermined; various levels of support (strong, moderate, and limited) of not being the same person or being the same person. Statistical analysis and interpretation of results revealed patterns of criterion usage, expert proficiency, criterion subjectivity and criterion discriminative power.

Using the MEPROCS recommended best practices and assessment criteria, gleaned from previous studies, 12 participants of varying experience addressed additional superimposition scenarios

(Ibáñez et al., 2016) [27]. Statistical analysis of results indicated that following the MEPROCS recommendations improved performance.

2.2. New techniques

In addition to the MEPROCS formal project, numerous other initiatives in recent years have revealed technological advances in craniofacial superimposition procedures (Gordon and Steyn, 2016 [28]; Huete et al., 2015 [29]; Lee et al., 2015 [30]; Park et al., 2015 [31]; Stephan and Claes, 2016 [32]; Stephan et al., 2019 [33]; Yatabe et al., 2019 [34]). Advances have been registered from cranio-facial identification efforts, as well as from the clinical, particularly the orthopedic literature (Weissheimer et al. (2015) [35]. For example, Valsecchi et al. (2018) [36] introduced a new algorithm that offers improved control over subject pose and camera parameters. Additional algorithms have been offered by Liu and Li (2018) [37] and Gupta et al. (2015) [38]. The orthopedic and orthognathic applications provide technological advances potentially useful in craniofacial superimposition.

In 2018, Gómez et al. published a 3D-2D silhouette-based image registration to facilitate comparative radiography-based forensic identification. This method allows simulation of facial photographs with known camera conditions to establish mathematical relationships (Martos et al., 2018) [39].

In 2018, Munn and Stephan noted that individual posture impacts facial soft tissue dimensions. They particularly addressed how values recorded from the supine position differ from those from an upright position. Using stereo-photographs to map shape change due to posture, they provided correction factors for the key landmarks.

Although many studies have documented facial soft tissue thickness, need continues for additional global data to document variation. Recently, Ayoub et al. (2019) [40] provided such data for the adult Lebanese population. As with other such studies, they documented significant sex differences in the values. New soft tissue thickness values also are now available for Australians (Stephan and Preisler, 2018) [41]. While the individual regional values are important, Stephan (2017) [42] provided updated grand mean values assembled from many published sources. These studies document the population variation involved and offer options for practitioners in local applications.

Recent publications also have addressed issues relating to perspective distortion (Stephan, 2015) [43], exclusions (Jayaprakash et al., 2015) [44], use of fuzzy integrals (Campomanes-Alvarez et al., 2016) [45], selfie photographs (Miranda et al., 2016) [46], estimation of skull-to-camera distance (Stephan, 2017) [47] and mandible placement (Bermejo et al., 2017) [48]. These publications attempt to resolve problems encountered during case applications.

2.3. Testing

Thoughtful testing represents a critical component for new methods of craniofacial superimposition (Jayaprakash, 2015) [49]. Some of the novel suggested techniques have been accompanied by such testing. For example, Tan et al. (2016) [50] introduced a computer-aided method using a quasi-Newton iterative closest point approach. Their testing of the method revealed it eliminated false matches of 76% of male and 66% of female superimpositions.

Campomanes-Alvarez et al. (2018) [51,52] tested their automated system using fuzzy aggregation functions for craniofacial superimposition using known materials. The statistical analysis of testing results suggested the system was effective to support decision-making.

3. Conclusions

Strong research interest continues in craniofacial superimposition. While problems with past applications have emerged and been identified, new methodology has greatly improved procedures. Advancement has been marked by new technology and by sophisticated statistical analysis and testing on known materials. Use of these techniques has been marginalized in some regions in favor of molecular analysis aimed at identification. However, interest remains strong in many parts of the world where DNA laboratories are less available or cost prohibitive. Economic issues also are associated with the new technological advances in craniofacial superimposition since some require equipment not universally available.

In our view, a major advance consists of strengthened communication among experts. In the MEPROCS project model, such communication elucidates the problem areas and recognizes areas in need of additional research. Although much of this activity centers in the field of forensic anthropology, technological advances originate in the clinical practice of orthopedic surgery and assessment of malocclusion and craniofacial deformities. Approaches to craniofacial superimposition still vary, but the field now has general agreement on the need for testing and the value of experience and new technology.

Declaration of competing interest

The authors have no known conflicts of interest.

References

[1] D.H. Ubelaker, Craniofacial superimposition: historical review and current issues, J. Forensic Sci. 60 (6) (2015) 1412–1419.

[2] W.A. Aulsebrook, M.Y. İşcan, J.H. Slabbert, P. Becker, Superimposition and reconstruction in forensic facial identification: a survey, Forensic Sci. Int. 75 (1995) 101–120.

[3] S. Damas, O. Cordón, O. Ibáñez, J. Santamaría, I. Alemán, M. Botella, F. Navarro, Forensic identification by computer-aided craniofacial superimposition: a survey, ACM Comput. Surv. 43 (4) (2011) 1–27.

[4] M. Yoshino, Craniofacial superimposition, in: C. Wilkinson, C. Rynn (Eds.), Craniofacial Identification, Cambridge University Press, Cambridge, 2012, pp. 238–253.

[5] H. Hadi, C.M. Wilkinson, The post-mortem resilience of facial creases and the possibility for use in identification of the dead, Forensic Sci. Int. 237 (2014), 149.e1-149.e7.

[6] B.R. Campomanes-Álvarez, O. Ibáñez, F. Navarro, I. Alemán, M. Botella, S. Damas, O. Cordón, Computer vision and soft-computing for automatic skull-face overlay in craniofacial superimposition, Forensic Sci. Int. 245 (2014) 77–86.

[7] O. Ibáñez, L. Ballerini, O. Cordón, S. Damas, J. Santamaria, An experimental study on the applicability of evolutionary algorithms to craniofacial superimposition in forensic identification, Inf. Sci. 179 (2009) 3998–4028.

[8] O. Ibáñez, O. Cordón, S. Damas, A cooperative coevolutionary approach dealing with the skull-face overlay uncertainty in forensic identification by craniofacial superimposition, Soft, Comput. Times 16 (2012) 797–808.

[9] C.N. Stephan, P.L. Davidson, The placement of the human eyeball and canthi in craniofacial identification, J. Forensic Sci. 53 (3) (2008) 612–619.

[10] C.N. Stephan, A.J.R. Huang, P.L. Davidson, Further evidence on the anatomical placement of the human eyeball for facial approximation and craniofacial superimposition, J. Forensic Sci. 54 (2) (2009) 267–269.

[11] L.C. Parzianello, M.A.M. da Silveira, S.S. Furuie, F.A.B. Palhares, Automatic detection of the craniometric points for craniofacial identification, Anais do IX SIBGRAPI (1996) 189–196.

[12] A.K. Ghosh, P. Sinha, An economised craniofacial identification system, Forensic Sci. Int. 117 (1–2) (2001) 109–119.

[13] O. Ibáñez, O. Cordón, S. Damas, J. Santamaria, Modeling the skull-face overlay uncertainty using fuzzy sets, IEEE Trans. Fuzzy Syst. 19 (5) (2011) 946–959.

[14] P.T. Jayaprakash, G.J. Srinivasan, M.G. Amravaneswaran, Cranio-facial morphanalysis: a new method for enhancing reliability while identifying skulls by photo superimposition, Forensic Sci. Int. 117 (2001) 121–143.

[15] Z.M. Arat, M. Rübendüz, A.A. Akgül, The displacement of craniofacial reference landmarks during puberty: a comparison of three superimposition methods, Angle Orthod. 73 (4) (2003) 374–380.

[16] A. Almukhtar, X. Ju, B. Khambay, J. McDonald, A. Ayoub, Comparison of the accuracy of voxel based registration and surface based registration for 3D

assessment of surgical change following orthognathic surgery, PLoS One 9 (4) (2014), e93402.
[17] X. Mallet, M.P. Evison, Forensic facial comparison: issues of admissibility in the development of novel analytical technique, J. Forensic Sci. 58 (4) (2013) 859–865.
[18] D. Lorkiewicz-Muszyńska, W. Kociemba, C. Żaba, M. Łabęcka, M. Koralewska-Kordel, M. Abreu-Głowacka, A. Przystańska, The conclusive role of postmortem computed tomography (CT) of the skull and computer-assisted superimposition in identification of an unknown body, Int. J. Leg. Med. 127 (3) (2013) 653–660.
[19] T.W. Fenton, A.N. Heard, N.J. Sauer, Skull-photo superimposition and border deaths: identification through exclusion and the failure to exclude, J. Forensic Sci. 53 (1) (2008) 34–40.
[20] P.T. Jayaprakash, B. Singh, R.A.A.M. Yusop, H.S. Asmuni, Skull-photo superimposition: a remedy to the problem of unidentified dead in Malaysia, Malays. J. Forensic Sci. 1 (1) (2010) 35–42.
[21] G.A. Grisbaum, D.H. Ubelaker, An Analysis of Forensic Anthropology Cases Submitted to the Smithsonian Institution by the Federal Bureau of Investigation from 1962-1994, vol 45, Smithsonian Inst. Press (Smithsonian Contributions to Anthropology, Washington, DC, 2001.
[22] D.H. Ubelaker, A history of Smithsonian-FBI collaboration in forensic anthropology, especially in regard to facial imagery, Forensic Sci. Commun. 2 (4) (2000) 1–9.
[23] P. Bustos Streeter, M. Intriago Leiva, The Chilean forensic medical service, in: D.H. Ubelaker (Ed.), The Global Practice of Forensic Science, Forensic Science in Focus Series, Wiley-Blackwell, Oxford, 2015, pp. 39–47.
[24] C.F. Milligan, J.E. Finlayson, C.M. Cheverko, K.M. Zarenko, Advances in the use of craniofacial superimposition for human identification, in: K. Lathem, E. Bartelink, M. Finnegan (Eds.), New Perspectives in Forensic Human Skeletal Identification, Academic Press, London, 2018, pp. 241–250.
[25] S. Damas, C. Wilkinson, T. Kahana, E. Veselovskaya, A. Abramov, R. Jankauskas, P.T. Jayaprakash, E. Ruiz, F. Navarro, M.I. Huete, E. Cunha, F. Cavalli, J. Clement, P. Lestón, F. Molinero, T. Briers, F. Viegas, K. Imaizumi, D. Humpire, O. Ibáñez, Study on the performance of different craniofacial superimposition approaches (II): best practices proposal, Forensic Sci. Int. 257 (2015) 504–508.
[26] O. Ibáñez, R. Vicente, D. Navega, C. Campomanes-Álvarez, C. Cattaneo, R. Jankauskas, M.I. Huete, F. Navarro, R. Hardiman, E. Ruiz, K. Imaizumi, F. Cavalli, E. Veselovskaya, D. Humpire, J. Cardoso, F. Collini, D. Mazzarelli, D. Gibelli, S. Damas, MEPROCS framework for craniofacial superimposition: validation study, Leg. Med. 23 (2016) 99–108.
[27] O. Ibáñez, A. Valsecchi, F. Cavalli, M. Isabel Huete, B.R. Campomanes-Alvarez, C. Campomanes-Alvarez, R. Vicente, D. Navega, A. Ross, C. Wilkinson, R. Jankauskas, K. Imaizumi, jR. Hardiman, P.T. Jayaprakash, E. Ruiz, F. Molinero, P. Lestón, E. Veselovskaya, A. Abramov, M. Steyn, J. Cardoso, D. Humpire, L. Lusnig, D. Gibelli, D. Mazzarelli, D. Gaudio, F. Collini, S. Damas, Study on the criteria for assessing skull-face correspondence in craniofacial superimposition, Leg. Med. 23 (2016) 59–70.
[28] G.M. Gordon, M. Steyn, A discussion of current issues and concepts in the practice of skull-photo/craniofacial superimposition, Forensic Sci. Int. 262 (2016), 287.e1-287.e4.
[29] M.I. Huete, O. Ibáñez, C. Wilkinson, T. Kahana, Past, present, and future of craniofacial superimposition: literature and international surveys, Leg. Med. 17 (4) (2015) 267–278.
[30] M. Lee, G. Kanavakis, R.M. Miner, Newly defined landmarks for a three-dimentionally based cephalometric analysis: a retrospective cone-beam computed tomography scan review, Angle Orthod. 85 (1) (2015) 3–10.
[31] J.H. Park, K. Tai, P. Owtad, 3-Dimensional cone-beam computed tomography superimposition: a review, Semin. Orthod. 21 (4) (2015) 263–273.
[32] C.N. Stephan, P. Claes, Craniofacial identification: techniques of facial approximation and craniofacial superimposition, in: D.H. Ubelaker, S. Blau (Eds.), Handbook of Forensic Anthropology and Archaeology, Routledge, New York, 2016, pp. 402–415.
[33] C.N. Stephan, J.M. Caple, P. Guyomarc'h, P. Claes, An overview of the latest developments in facial imaging, Forensic Sci. Res. 4 (1) (2019) 10–28.
[34] M. Yatabe, J.C. Prieto, M. Styner, H. Zhu, A.C. Ruellas, B. Paniagua, F. Budin, E. Benavides, B. Shoukri, L. Michoud, N. Ribera, L. Cevidanes, 3D superimposition of craniofacial imaging-the utility of multicentre collaborations, Orthod. Craniofac. Res. 22 (S1) (2019) 213–220.
[35] A. Weissheimer, L.M. Menezes, L. Koerich, J. Pham, L.H.S. Cevidanes, Fast three-dimensional superimposition of cone beam computed tomography for orthopaedics and orthognathic surgery evaluation, Int. J. Oral Maxillofac. Surg. 44 (9) (2015) 1188–1196.
[36] A. Valsecchi, S. Damas, O. Cordón, A robust and efficient method for skull-face overlay in computerized craniofacial superimposition, IEEE Trans. Inf. Forensics Secur. 13 (8) (2018) 1960–1974.
[37] C. Liu, X. Li, Superimposition-guided facial reconstruction from skull, ArXiv 1 (1) (2018) 1–14.
[38] A. Gupta, O.P. Kharbanda, V. Sardana, R. Balachandran, H.K. Sardana, A knowledge-based algorithm for automatic detection of cephalometric landmarks on CBCT images, Int. J. CARS. 10 (11) (2015) 1737–1752.
[39] R. Martos, A. Valsecchi, O. Ibáñez, I. Alemán, Estimation of 2D to 3D dimensions and proportionality indices for facial examination, Forensic Sci. Int. 287 (2018) 142–152.
[40] F. Ayoub, M. Saadeh, G. Rouhana, R. Haddad, Midsagittal facial soft tissue thickness norms in an adult Mediterranean population, Forensic Sci. Int. 294 (2019), 217.e1-217.e7.
[41] C.N. Stephan, R. Preisler, In vivo facial soft tissue thicknesses of adult australians, Forensic Sci. Int. 282 (2018), 220.e1-e12.
[42] C.N. Stephan, Tallied facial soft tissues thicknesses for adults and sub-adults, Forensic Sci. Int. 280 (2018) 113–123, 2017.
[43] C.N. Stephan, Perspective distortion in craniofacial superimposition: logarithmic decay curves mapped mathematically and by practical experiment, Forensic Sci. Int. 257 (2015), 520.e1-520.e8.
[44] P.T. Jayaprakash, N. Hashim, R.A.A.M. Yusop, Relevance of Whitnall's tubercle and auditory meatus in diagnosing exclusions during skull-photo superimposition, Forensic Sci. Int. 253 (2015), 131.e1-131.e10.
[45] C. Campomanes-Alvarez, O. Ibáñez, O. Cordón, Design of criteria to assess craniofacial correspondence in forensic identification based on computer vision and fuzzy integrals, Appl. Soft Comput. 46 (2016) 596–612.
[46] G.E. Miranda, S.G. de Freitas, L.V. de Abreu Maia, R.F.H. Melani, An unusual method of forensic identification: use of selfie photographs, Forensic Sci. Int. 263 (2016) e14–e17.
[47] C.N. Stephan, Estimating the skull-to-camera distance from facial photographs for craniofacial superimposition, J. Forensic Sci. 62 (4) (2017) 850–860.
[48] E. Bermejo, C. Campomanes-Álvarez, A. Valsecchi, O. Ibáñez, S. Damas, O. Cordón, Genetic algorithms for skull-face overlay including mandible articulation, Inf. Sci. 420 (2017) 200–217.
[49] P.T. Jayaprakash, Conceptual transitions in methods of skull-photo superimposition that impact the reliability of identification: a review, Forensic Sci. Int. 246 (2015) 110–121.
[50] J.S. Tan, I. Venkat, P.T. Jayaprakash, Computer-aided craniofacial superimposition using a quasi-Newton iterative closest point approach, Sci. Asia 42 (2016) 136–145.
[51] C. Campomanes-Alvarez, R. Martos-Fernandez, C.M. Wilkinson, O. Ibanez, O. Cordon, Modeling skull-face anatomical/morphological correspondence for craniofacial superimposition-based identification, IEEE Trans. Inf. Forensics Secur. 13 (6) (2018) 1481–1494.
[52] C. Campomanes-Álvarez, O. Ibáñez, O. Cordón, C. Wilkinson, Hierarchical information fusion for decision making in craniofacial superimposition, Inf. Fusion 39 (2018) 25–40.