A likelihood-ratio framework for craniofacial superimposition

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This study introduces a method for the computation of Likelihood Ratio values associated with identification using Craniofacial Superimposition. The method relies on a collection of head Computed Tomography scans, which are used to simulate facial photographs and also provide skull 3D models for the relevant population. The experimental study shows the feasibility of our approach.

Keywords: Craniofacial Identification, Craniofacial Superimposition, Likelihood Ratio, Disaster Victim Identification, Artificial Intelligence.

Структура співвідношення правдоподібності для черепно-лицьового накладання

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Досліджується метод обчислення значень коефіцієнта ймовірності, пов'язаних з ідентифікацією за допомогою черепно-лицьового накладання. Метод ґрунтується на наборі сканів комп'ютерної томографії голови, які використовуються для моделювання фотографій обличчя, а також забезпечують 3D-моделі черепа для відповідної популяції. Експериментальне дослідження показує здійсненність нашого підходу.

Ключові слова: черепно-лицьова ідентифікація, черепно-лицьове накладення, співвідношення ймовірності, ідентифікація жертв катастрофи, штучний інтелект.

Craniofacial superimposition (CFS) involves superimposing a recovered skull over an ante mortem facial image of the suspected individual. Morphological analysis of the correspondences between skull and face is then used to assess the possibility of a match [1]. While CFS has been used for over a century [2], it is still undergoing development. The recent European project MEPROCS [3] produced the first CFS standard, including best practices, main sources of error/uncertainty and technical requirements for video and computer-aided CFS systems. The reliability of CFS is also being investigated [4], improving the acceptance in the scientific community, which is still affected by the scarcity of studies and their severe limitations [5]. In terms of technological developments, CFS incorporated the use of digital 3D models of the skull, which in turn enabled the creation of computerized, automatic skull-face overlay (SFO) methods based on Artificial Intelligence [6]. This led to significant time savings and increased the applicability of the technique to scenarios involving a much larger number of victims.

CFS is involved, together with most forensic identification techniques, in the current paradigm shift in evaluation and reporting of forensic evidence. Subjective evaluations from an expert are being replaced by quantitative, reproducible and objective measurements. Also, reporting and interpretation of uncertainty is done using likelihood ratio (LR) [7], as opposed to probability or any other measure, following the current guidelines of the European Network of Forensic Science Institutes (ENFSI).

While the LR framework is virtually applicable to any kind of evidence, it requires information that might be impossible or impractical to acquire. This study introduces a practical framework for the computation of LR associated with identification using CFS. The framework relies on an automatic SFO method such as [6] and a collection of corresponding skull and facial 3D models. Cephalometric landmarks must also be marked on the 3D models in the collection.

A key aspect of the method is the use of simulated photographs. These are obtained from the facial 3D models through a simple rendering process, which provides the ability to generate many photographs with the desired pose and other photographic conditions. By projecting the 3D facial landmarks locations onto the photograph, we obtain the location 2D facial landmarks. Indeed, in automatic SFO methods, the overlap process is based on the superimposition of a set of corresponding landmarks in the skull and the face. The projection error is the average distance between facial and cranial landmarks once the SFO has been performed. This measures the quality of the overlay, and its value (score) is used as evidence for the computation of the LR.

Following the person-generic approach, the opposing propositions are:

Hs: the skull belong to the same subject of the facial photograph

Hd: the skull belong to a different subject from that of the facial photograph

As for the relevant population, we considered the sex estimated from the facial photograph, together with the overall pose of the face. Same-source and different-source scores are obtained by performing SFO over data from the same or different subject. To this end, once the compatible subjects have been selected, multiple photographs are simulated from each model, SFOs are carried out and the corresponding scores are computed. Once the two score sets have been calculated, the underlying distribution is estimated using Kernel Density Estimation. Finally, the two likelihood values are computed, followed by a division operation delivering the LR value.

The materials involved in the study are a set of 78 head CT scans of different subjects with at least 6 visible landmarks. There are 50 men and 28 women, aged from 18 to over 80 years. These materials were collected directly from French hospitals and medical center archives in 2008 and 2009.

The experimental study involved the calculation of 100 LR values for positive cases and other 100 LR values for negative cases. These test scenarios were created by simulating photographs as well. The median LR value for positive cases was 190.3, while for negative cases the value was 0.0. Computation time was close to 1 minute per computation.

The introduced LR framework is practical and sound. The main limitation of the approach is due to the use of simulated photographs from 3D models. Computed LR might not be reliable for photographs showing facial expressions beside neutral, occlusions and other unfavorable photographic conditions that cannot be simulated adequately.

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Interference in the construction of gas meters through the action of foreign objects: features

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Methods of unauthorized disclosure and interference in the operation of gas meters are considered, and the most characteristic changes introduced when interfering with the design of the measuring and counting mechanisms of the metering devices are described.