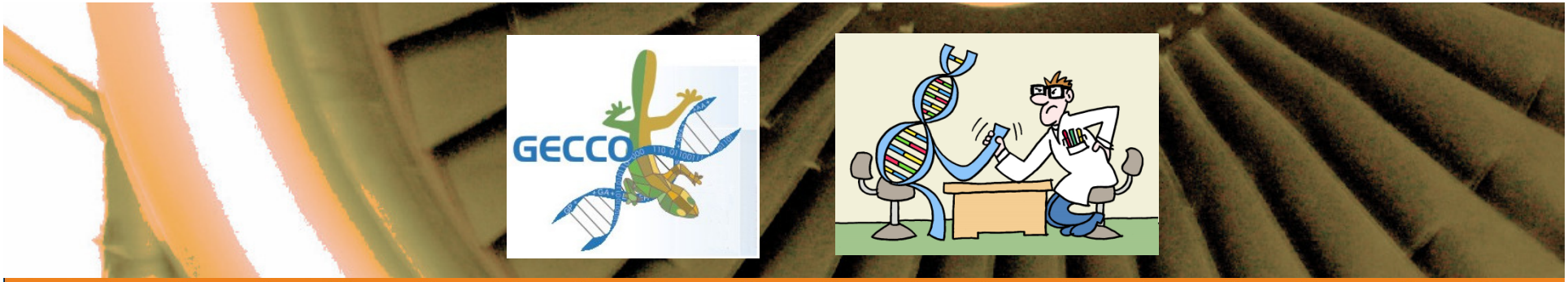


European Centre
for Soft Computing

Forensic Identification by Craniofacial Superimposition using Soft Computing

Oscar Ibáñez, Oscar Cordón, Sergio Damas, Jose Santamaría

THE 7th ANNUAL (2010) "HUMIES" AWARDS
FOR HUMAN-COMPETITIVE RESULTS
GENETIC AND EVOLUTIONARY COMPUTATION CONFERENCE (GECCO 2010)

Overview

1. Craniofacial superimposition in forensic identification
2. Influence of technology on craniofacial superimposition
3. Analysis of human-competitiveness of our result
4. Reasons why our entry is “best” in comparison to other entries

Overview

- Human identification (of alive or dead people) is one of the outstanding research areas in forensic medicine

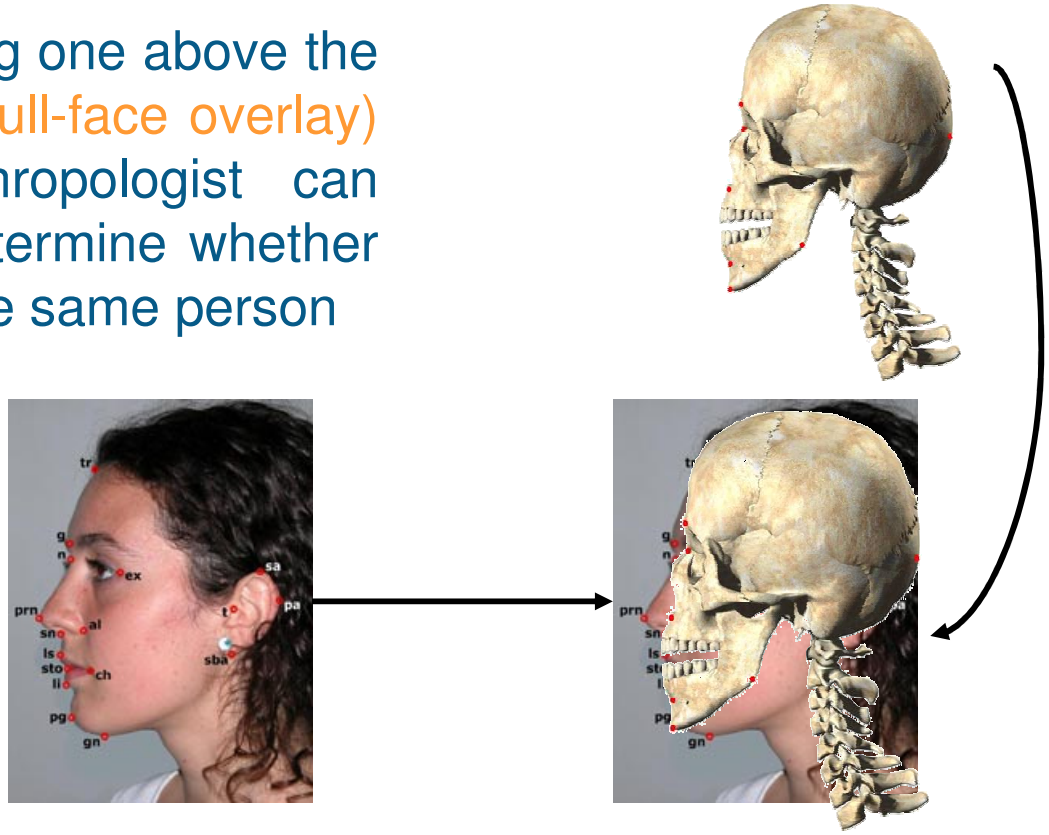
Skeleton-based human identification (Forensic Anthropology)

Previous task to select our candidates

- If anthropologists get enough information other techniques might be applied: fingerprint, autopsy, DNA.
- Otherwise

Overview

- Craniofacial superimposition is a forensic process where photographs or video shots of a missing person are compared with "a model" of a skull that is found
- Projecting one above the other (skull-face overlay) the anthropologist can try to determine whether that is the same person



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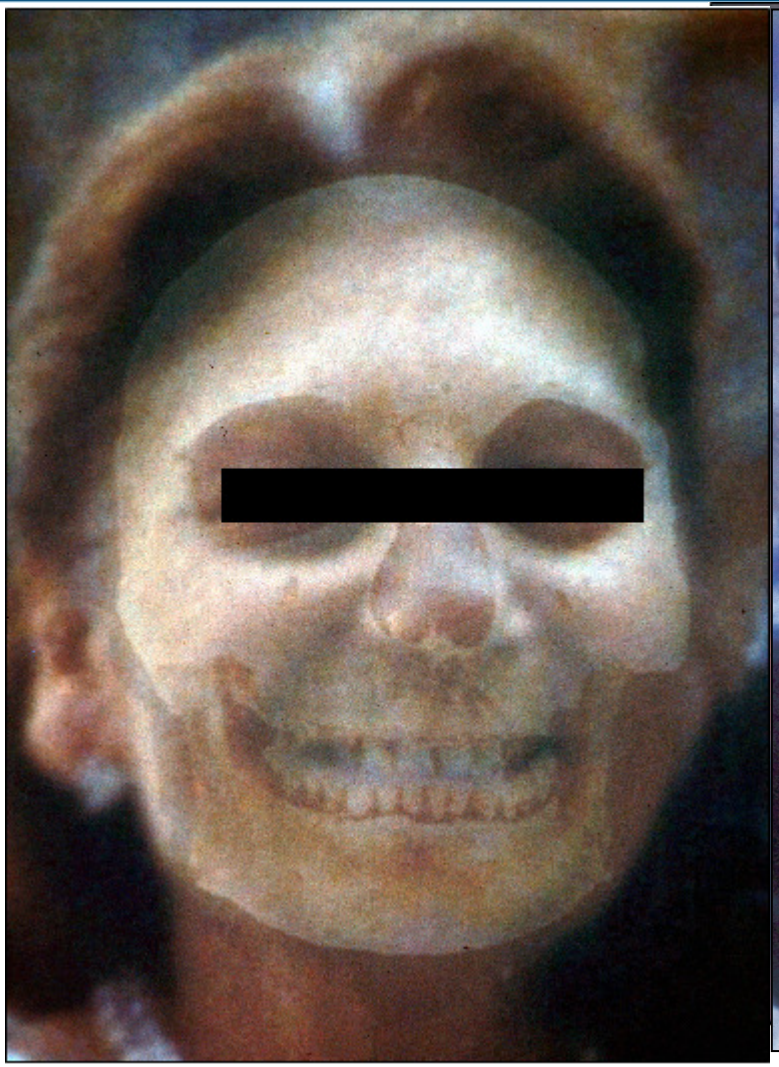

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Photographic superimposition

The dynamic orientation process is a very challenging and time-consuming task for the forensic anthropologist

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Video superimposition

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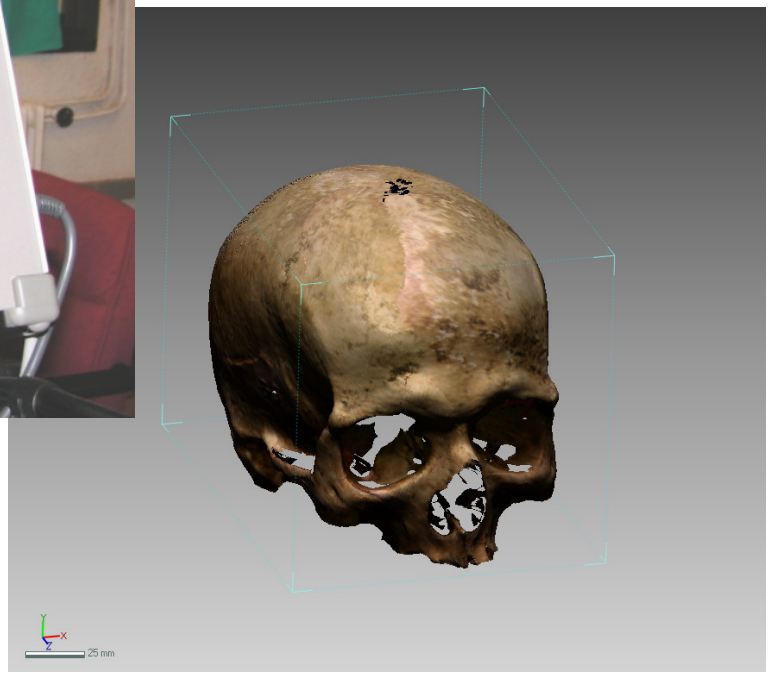
3D superimposition



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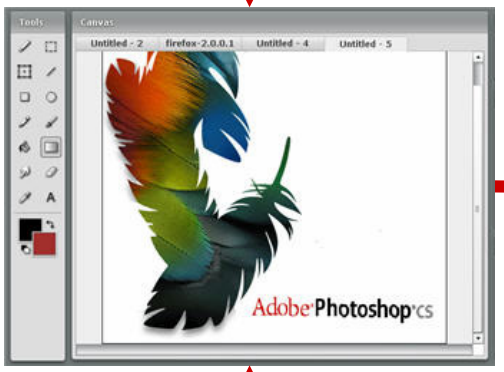
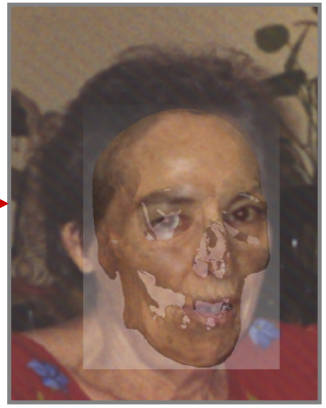
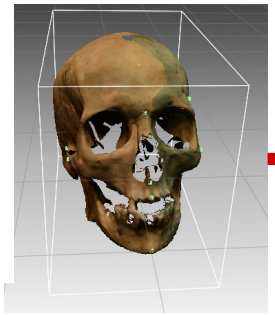
3D Manual Craniofacial Superimposition





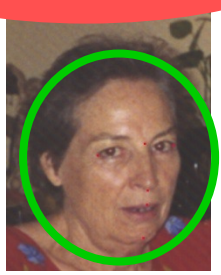


Automatic 3D craniofacial superimposition

{Positive/negative/likely positive/likely negative/undetermined} identification

1. Face enhancement and skull modeling

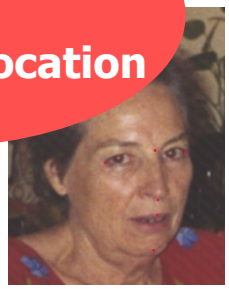




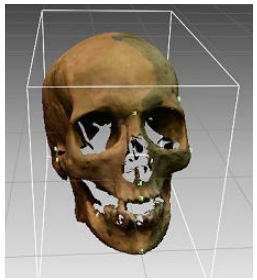

Confidence level = 23% | Confidence level = 13% | Confidence level = 99% | Confidence level = 53%

3. Decision making

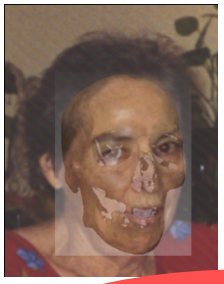
2D Image processing & Landmarks location



3D model reconstruction & Landmarks location



2. Skull-Face overlay



3D model translation, rotation, scaling, and 2D projection

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Overview

- The skull-face overlay is formulated as a 3D/2D image registration problem that aims to determine the best 3D/2D geometric transformation projecting the 3D skull into the 2D photograph

- It is determined by 12 parameters that translate, rotate, scale, and project the 3D skull landmarks to reach the location of the 2D landmarks in the photograph

- Error is measured according to: $$ME = \frac{\sum_{i=1}^{N} \left\| f(C_i) - F_i \right\|}{N}$$

  where C_i and F_i are cranial and facial landmarks, respectively; f is the geometric transformation

Overview

- The skull-face overlay problem was tackled by different evolutionary algorithms:
  - Real-coded GAs (RCGAs)
  - Covariance matrix adaptation-evolution strategy (CMA-ES)
  - Scatter search (SS)
- There are different sources of uncertainty in the skull-face overlay problem:
  - Uncertainty related to the different objects under study
  - Uncertainty related to the 3D/2D overlay process
- Most of the limitations associated to the sources of uncertainty were overcome considering fuzzy set theory

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- Satisfied criteria:
  - (G) The result solves a problem of indisputable difficulty in its field

- Without a doubt, skull-face overlay is a problem of indisputable difficulty in forensic identification. Craniofacial superimposition has been extensively used since the end of the nineteenth century.
- "The dynamic orientation process is a very challenging and time-consuming part of the skull-photo superimposition technique. Correctly adjusting the size and orienting the images can take several hours to complete" [Fenton, 2008]

- [Fenton, 2008] Fenton, T., Heard, A, and Sauer, N. (2008). Skull-photo superimposition and border deaths: identification through exclusion and the failure to exclude. Journal of Forensic Sciences 53(1), 34–40

Overview

- Satisfied criteria:
  - (E) The result is equal to or better than the most recent human-created solution to a long-standing problem for which there has been a succession of increasingly better human-created solutions
  - (F) The result is equal to or better than a result that was considered an achievement in its field at the time it was first discovered
- Our evolutionary-based automatic method achieves significantly accurate overlays as well as it is faster (results in less than 4 minutes) than the rest of skull-face overlay techniques, in several orders of magnitude considering both a visual and a numerical validation of our results
- That is corroborated by world-wide recognized forensic anthropologists

Overview

- Satisfied criteria:
  - (B) The result is equal to or better than a result that was accepted as a new scientific result at the time when it was published in a peer-reviewed scientific journal
- There is just one previous contribution performing an automatic 3D-2D skull-face overlay [Nickerson, 1991]. The performance and the run time required for that computer-based method is far away from ours (Chapter 3 of our entry)
- Our method always gets significantly better results under the same conditions
- [Nickerson, 1991] Nickerson, B., Fitzhorn, P., Koch, S., and Charney, M. (1991). A methodology for near-optimal computational superimposition of two dimensional digital facial photographs and three-dimensional cranial surface meshes. Journal of Forensic Sciences 36(2), 480–500

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- Satisfied criteria:
  - (A) The result was patented as an invention in the past, is an improvement over a patented invention, or would qualify today as a patentable new invention
  - Submitted patent on a novel framework for computer-based craniofacial superimposition [Cordón, 2009] which focuses on the use of evolutionary algorithms to automate this problem
  - [Cordón, 2009] Inventors (in signature order): Cordón, O., Damas, S., Ibáñez, O., Santamaría, J., Alemán, I., Botella, M. Patent title: Method and System for Forensic Identification by Craniofacial Superimposition. Application number: P200901732/3. Application date: 30/07/2009. Priority Country: Spain. Owning Institutions: Foundation for the Advancement of Soft Computing and University of Granada

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- Complex real-world problem with high impact in the society
- Competitive and even better solutions than those of the human expert in a time scale several orders of magnitude lower (several hours vs. a few minutes)
- Our method has already helped the Spanish Scientific Police to solve different real-world identification cases
- Three research projects granted (almost 400,000 € overall)
- High quality publications: ACM Computing Surveys (computer science journal with the highest impact factor), Information Sciences, etc.

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- "As far as I know, your research group has the most advanced technique in craniofacial superimposition. I would like to express my deep appreciation for your achievements" M. Yoshino (Director of First Forensic Science Division of the National Research Institute of Police Science in Japan)

- "They have been able to develop a new software tool to automate the important craniofacial superimposition technique used in forensic identification. That software is now a crucial step forward for this technique because it provides reliable craniofacial superimpositions with the required accuracy in a really short period of time" M. Botella (Director of the Physical Anthropology lab of the University of Granada in Spain, Collaborator of the applicant team)

Forensic Identification by Craniofacial Superimposition using Soft Computing

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Manual craniofacial superimposition

Up to 24 hours

Evolutionary craniofacial superimposition

Up to 4 minutes

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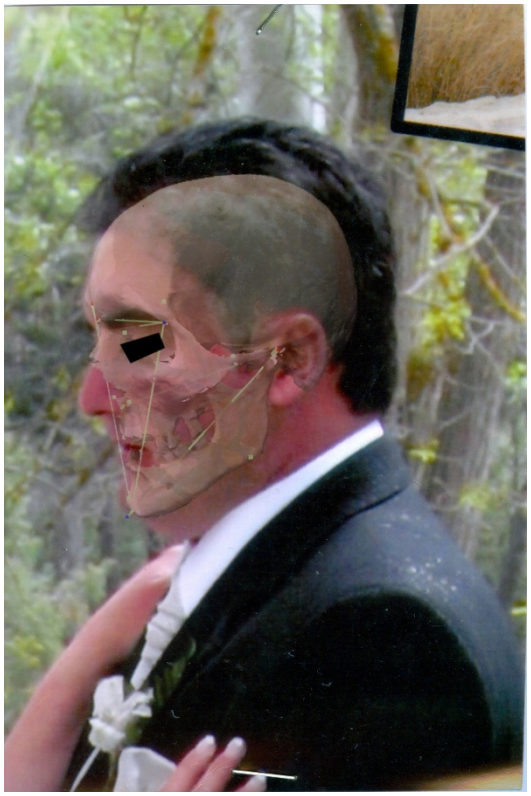

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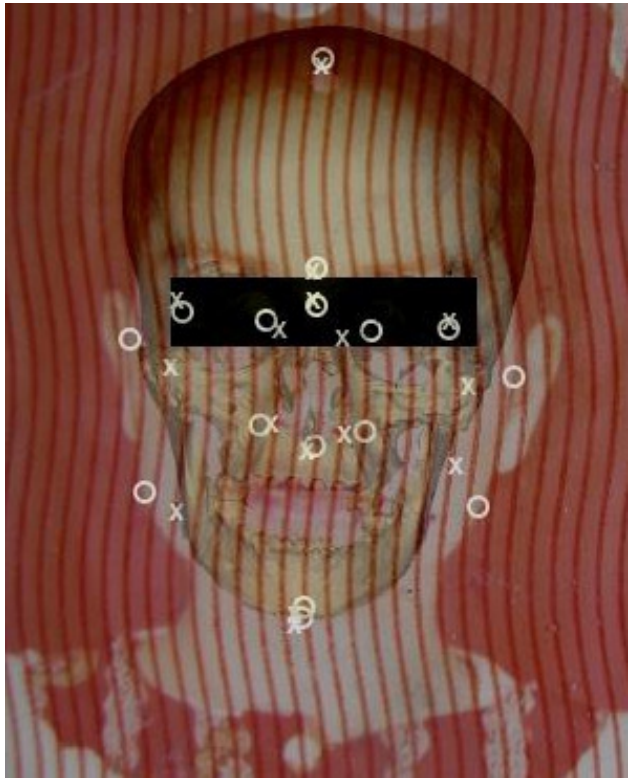

Up to 4 minutes

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Questions ?