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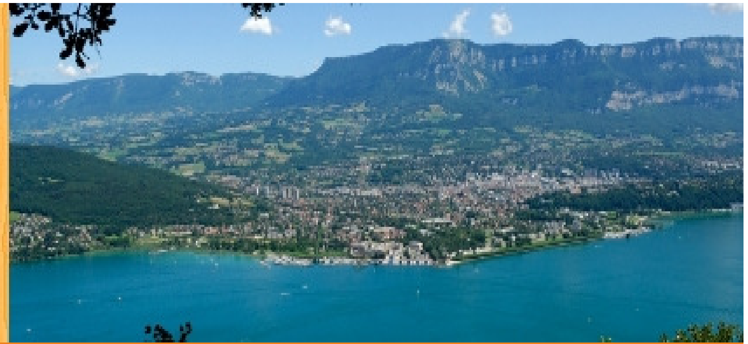

EUROPEAN SOCIETY FOR FUZZY LOGIC AND TECHNOLOGY

European Centre for Soft Computing

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# An automatic method for forensic identification based on soft computing techniques


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# Outline

- Forensic identification by craniofacial superimposition
- Image registration
- Image registration, uncertainty and forensic identification = soft computing
- First stage: 3D skull model reconstruction using evolutionary algorithms
- Second stage: Skull-face overlay using evolutionary algorithms and fuzzy logic
- Concluding Remarks

**OVERVIEW**



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

Skeleton-based human identification (forensic anthropology)

Previous task to the selection of the candidates sample

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

# 1. Forensic identification by craniofacial superimposition

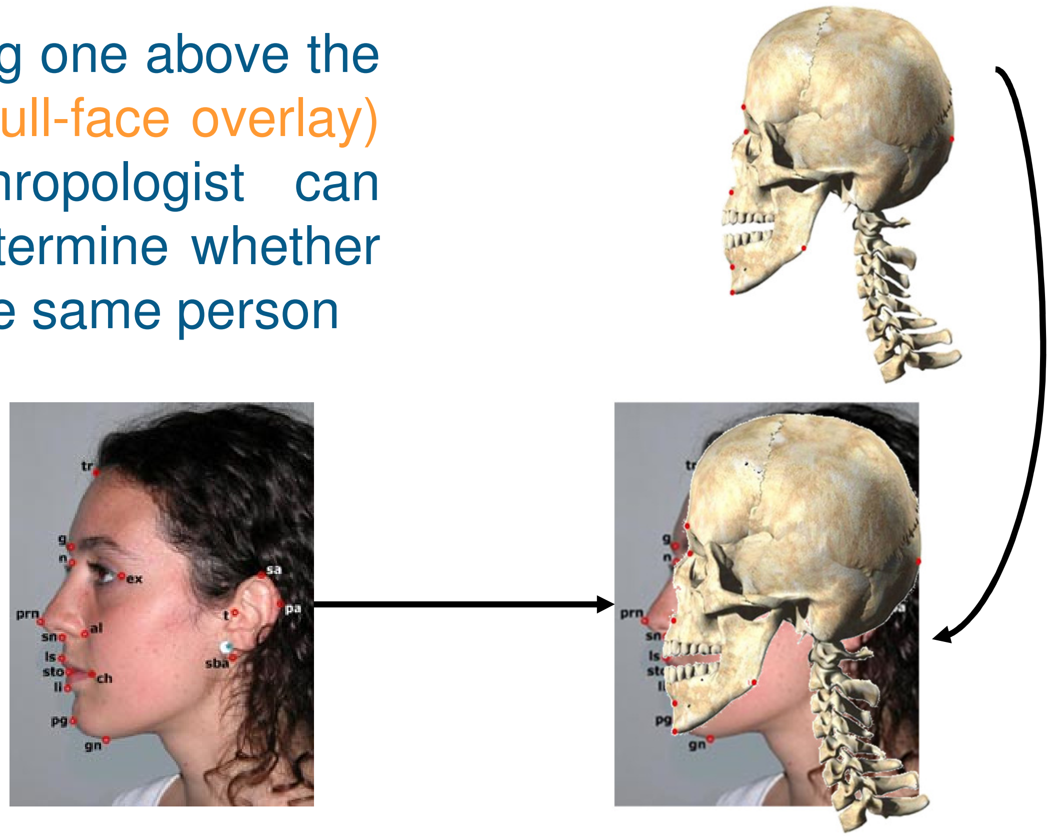
## Forensic identification (II)

CSI:
crime scene investigation


BONES

- 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

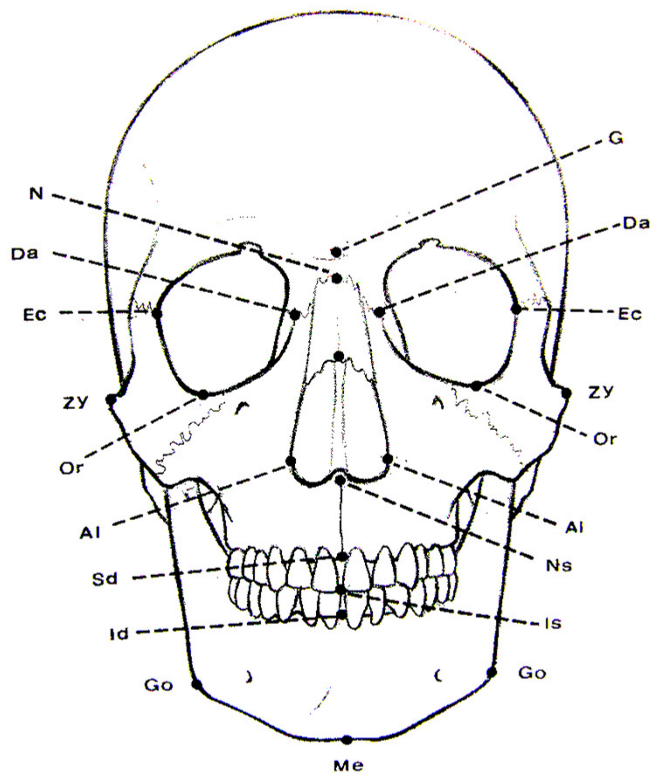
- Projecting one above the other (skull-face overlay) the anthropologist can try to determine whether that is the same person



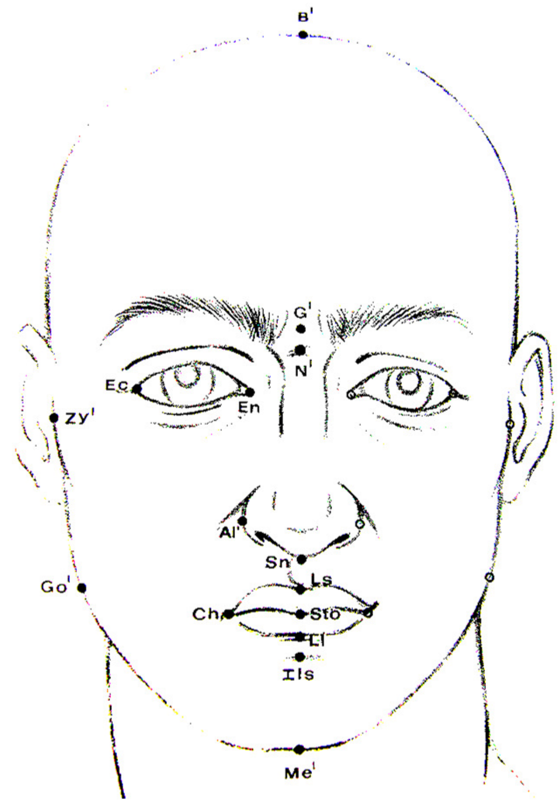
## Cranial and facial landmarks

**OVERVIEW**






Craniometric landmarks

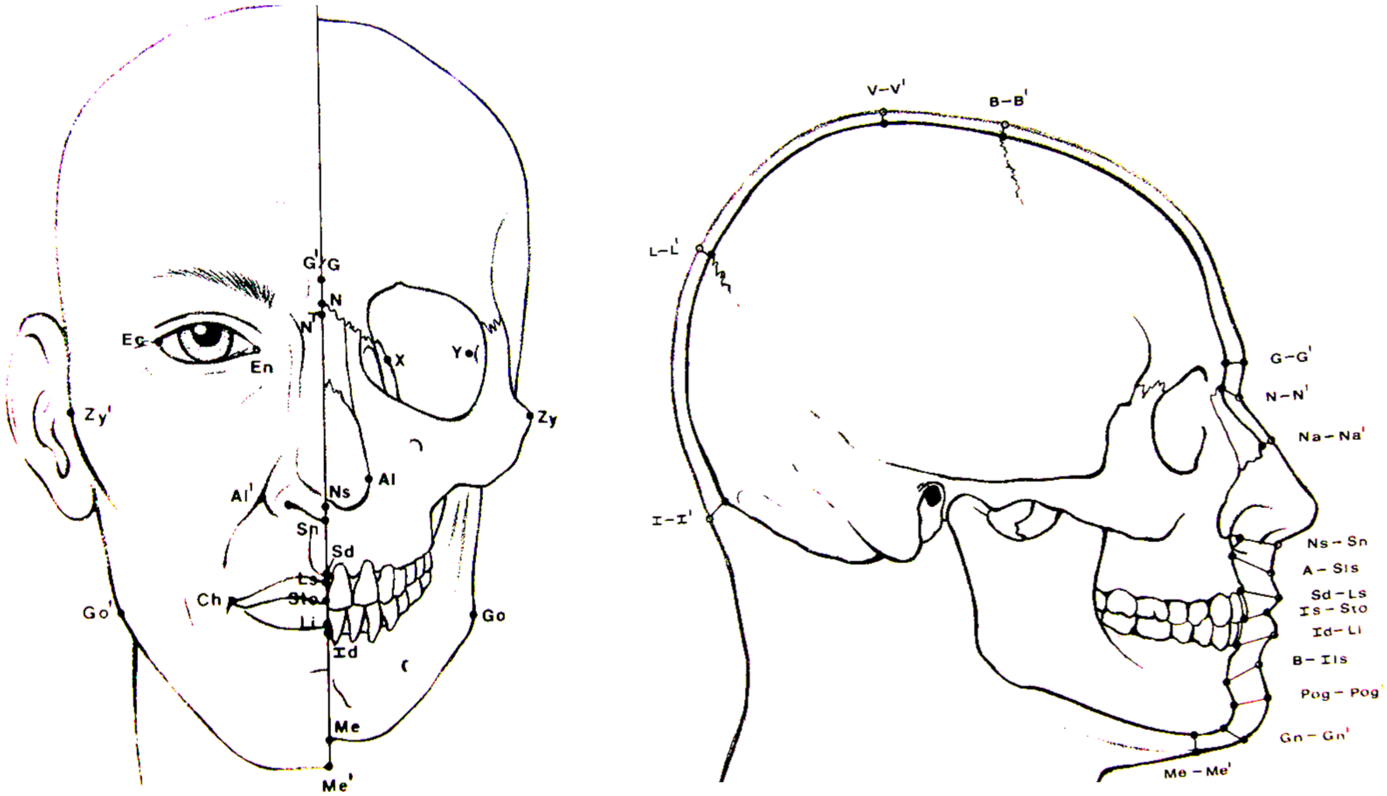



Cephalometric landmarks

# Landmarks matching

**OVERVIEW**






Landmarks correlation

## Real case example

**OVERVIEW**

**1. Forensic identification (FI) by craniofacial superimposition**

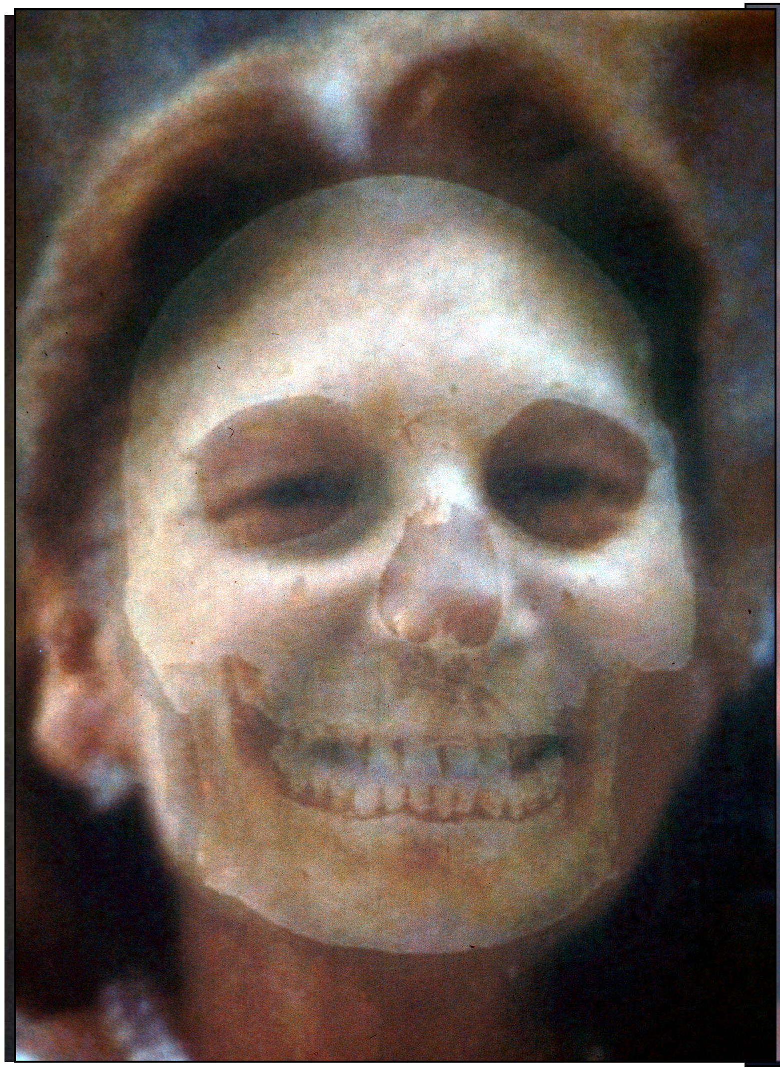
2. Image Registration (IR)

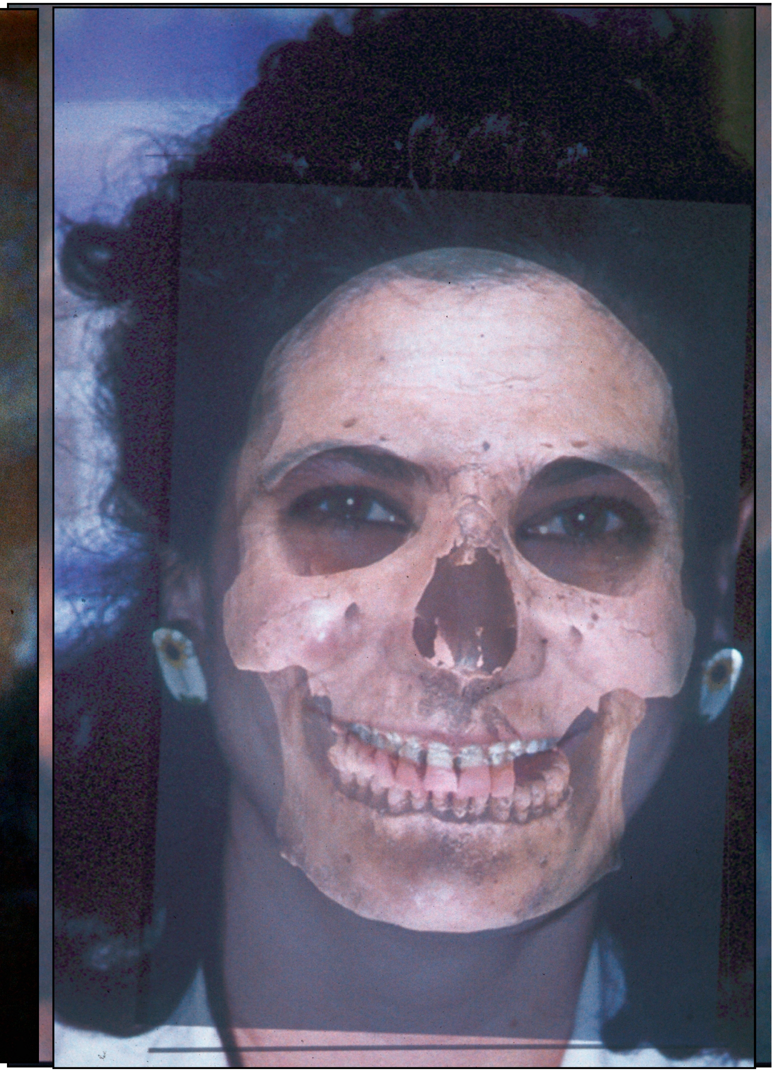
3. IR, Uncertainty and FI = Soft Computing

4. First stage: 3D skull model reconstruction

5. Second stage: Skull-face overlay

6. Conclusions





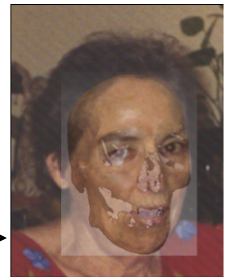
# Methodology

**OVERVIEW**



1. Photo and skull model development

2. Manual skull-face overlay



3. Decision making

Identification {Positive/negative/ likely positive/likely negative/ indeterminate}

OVERVIEW

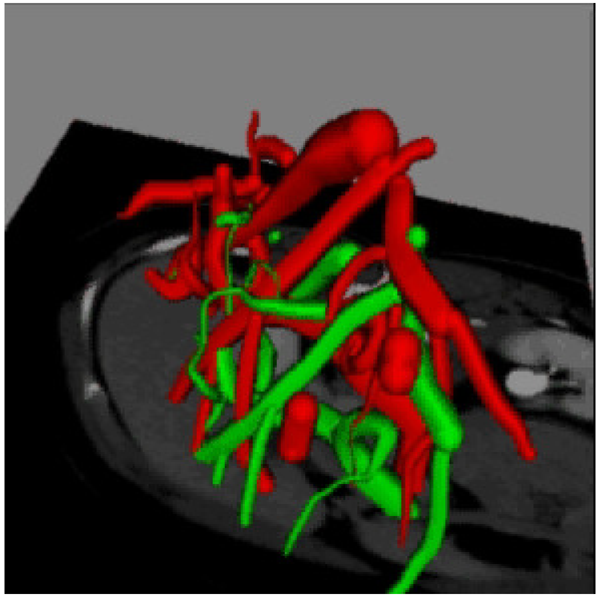


- Methodological basis: Broca's skull-face correspondence (1875), Bertillon's accused physiognomic data collection (1986), and Martin and Saller's anthropological measurements studies (1966) studies
- First documented case in 1880: identification of the skeletal remains of the poet Dante Alighieri
- The first identifications were based on photos: superimposition of the skull and face negatives and developing of the positive of the picture
- The next stage was the use of video superimposition, one of the most extended approaches nowadays
- Digital image processing has boomed the technique
- Recently used to identify the Indian tsunami victims and in terrorism. Other successful case studies: Josef Mengele and "Ivan the Terrible"

**OVERVIEW**



- Image registration (IR) aims to superimpose an image on a similar one considering the same coordinate system



PROBLEM ?

↓

Images acquired in different coordinate systems

↓

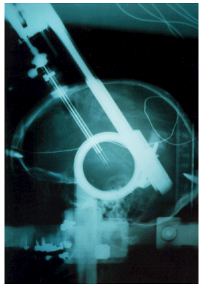
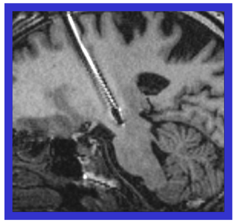
Unknown matching relationship between them

**OVERVIEW**

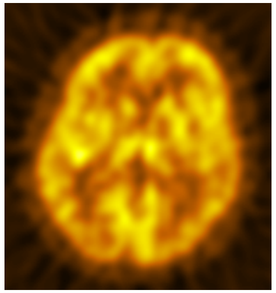
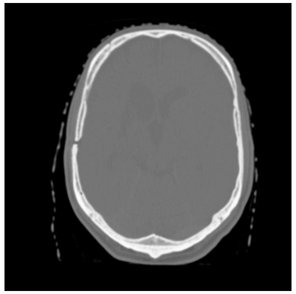
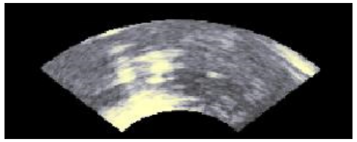


- Surgery planning



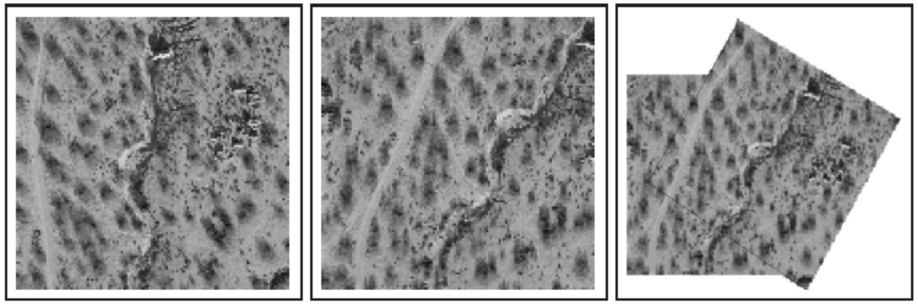
- Image integration: multimodality, 3D/2D, etc.

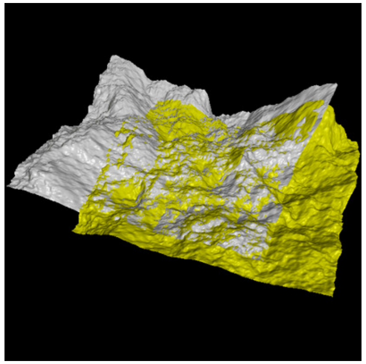





**OVERVIEW**



- Remote sensing





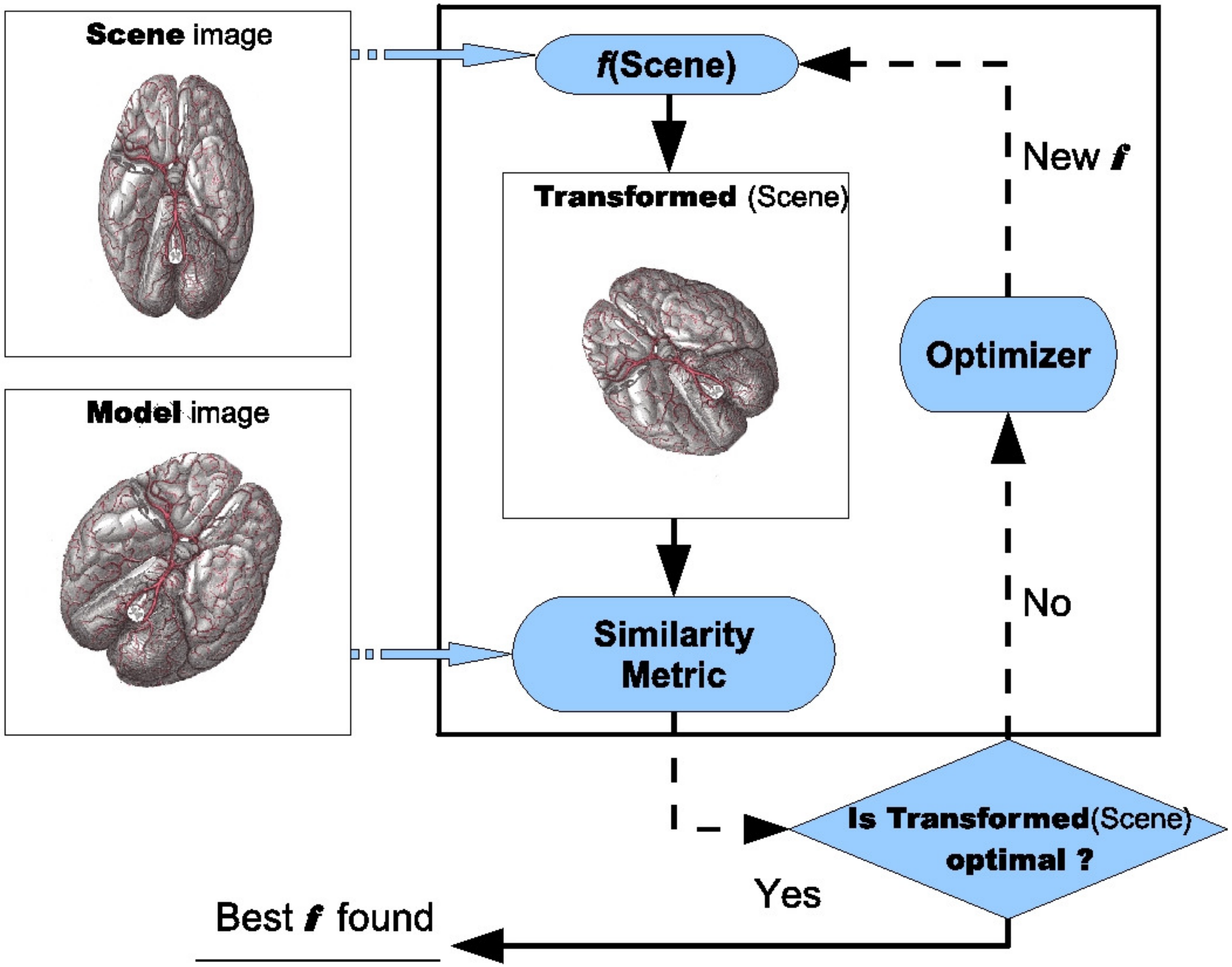
- 3D model reconstruction: CAD, archeology, forensic anthropology, etc.

- IR aims to superimpose an image on a similar one considering the same coordinate system

- IR Components:
  - Scene ($I_s \subset R^2/R^3$) and model ($I_m \subset R^2/R^3$) images
  - Transformation (f: $R^2/R^3 \rightarrow R^2/R^3$)
  - Similarity metric (F)
  - Optimizer (search for the optimal f)

**OVERVIEW**





Scene image
Model image
f(Scene)
Transformed (Scene)
New f
Optimizer
No
Similarity Metric
Is Transformed(Scene) optimal ?
Yes
Best f found

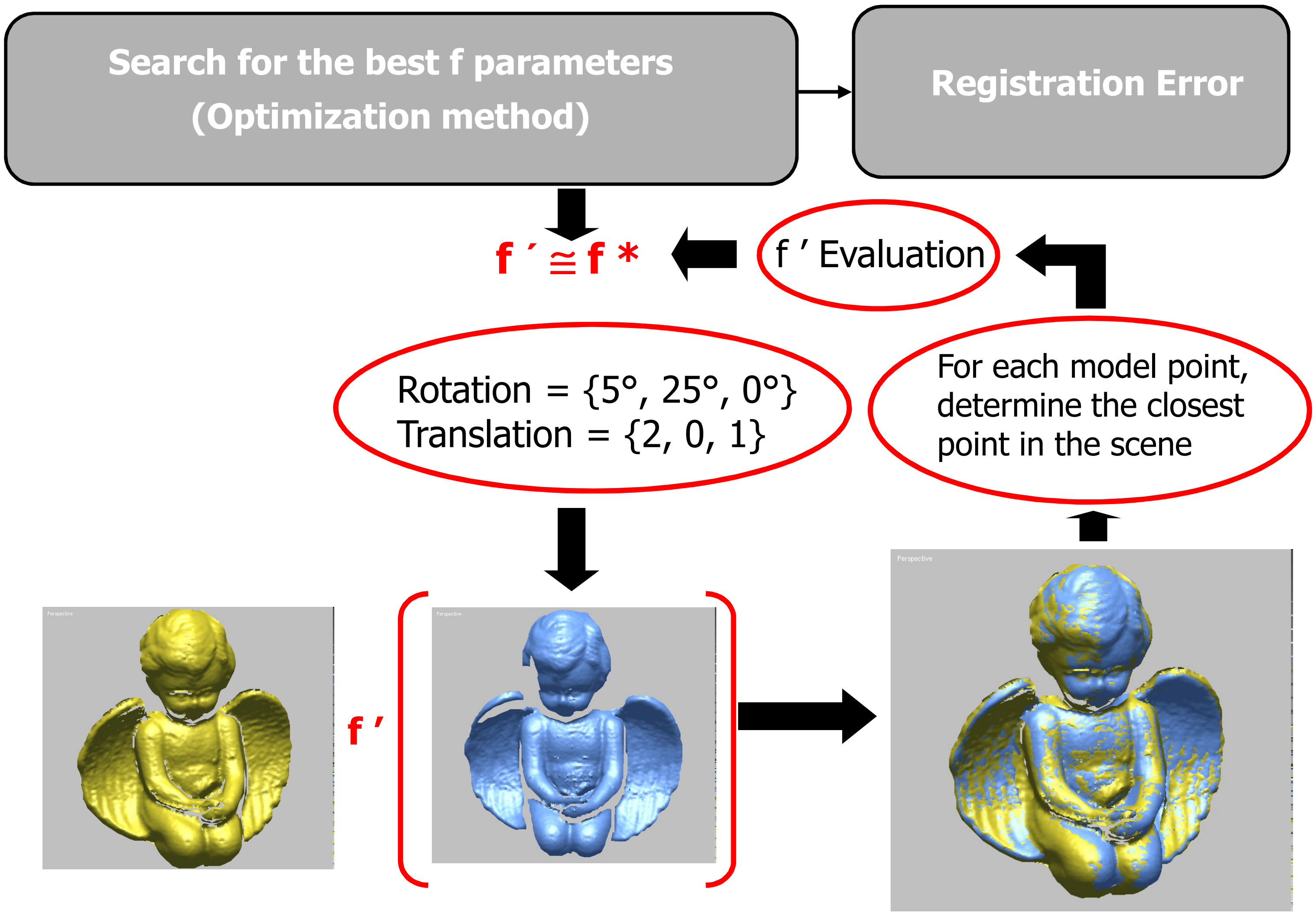
- The problem statement is analogous to some other optimization problems which aim to find the best configuration among a set of choices

$$f^* = \arg\min_f / \max F(I_s, I_m; f) \quad s.t. \quad f^*(I_s) = I_m$$

- Taxonomy of algorithms:
  - Exact: find the optimal solution (NP-hard)
  - Approximate: achieve solutions close to the optimal one in reasonable time
- Classical IR methods ➡ stuck in local optima
- **Evolutionary Algorithms (EAs) have successfully tackled these situations**

**OVERVIEW**





Search for the best f parameters
(Optimization method)
Registration Error
f ′ ≅ f *
f ′ Evaluation
Rotation = {5°, 25°, 0°}
Translation = {2, 0, 1}
For each model point, determine the closest point in the scene
f ′

## Image registration and craniofacial superimposition (I)

**OVERVIEW**



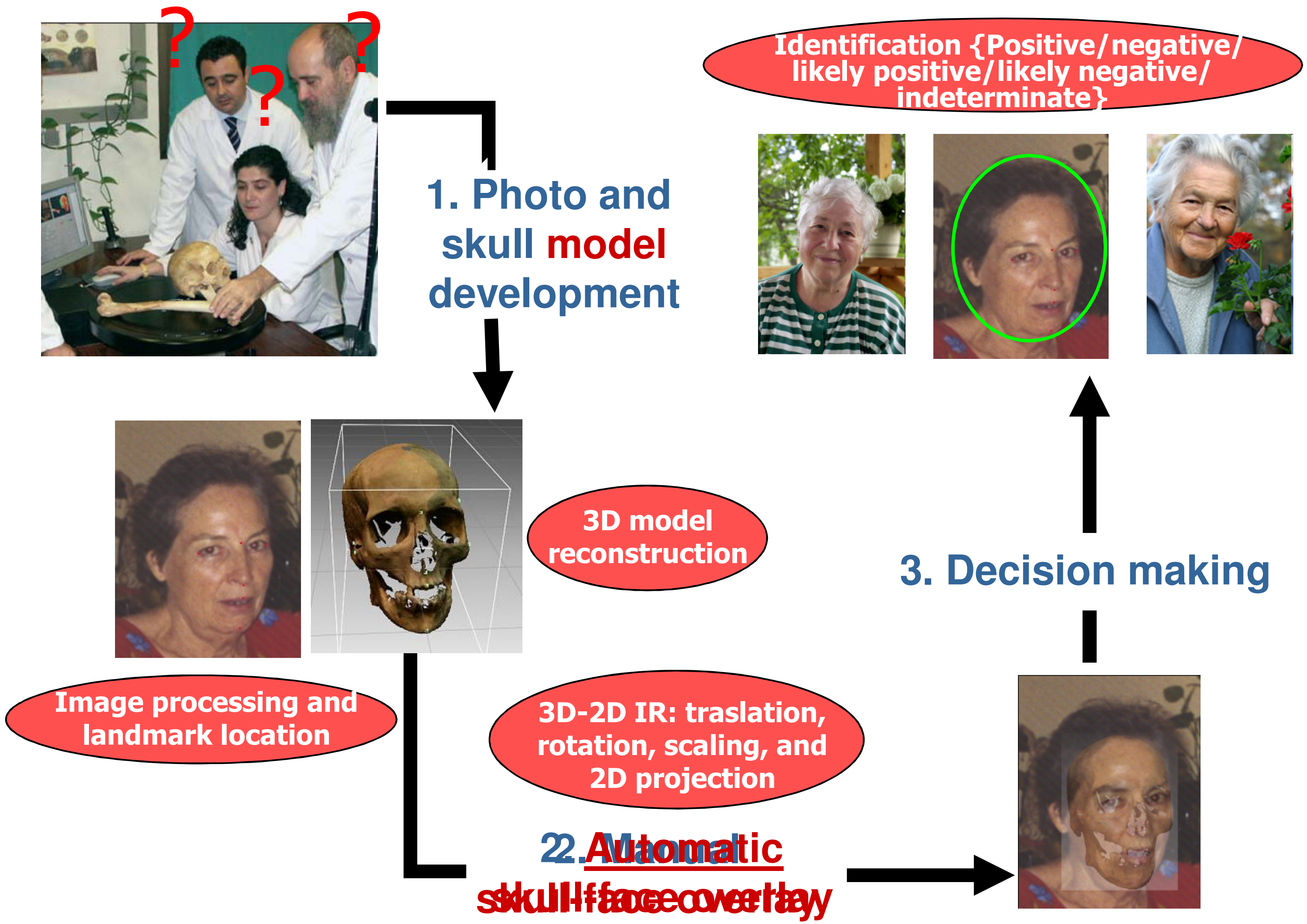
- Many forensic tasks require a 3D model of forensic objects (skulls, bones, corpses, etc.) that could be acquired using a 3D range scanner and a range IR (RIR) method

- The most advanced forensic labs use a 3D skull models to tackle the craniofacial superimposition technique

# Image registration and craniofacial superimposition (II)

**OVERVIEW**



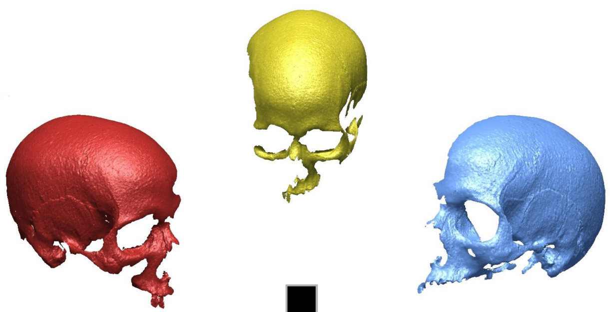


# Computer-based craniofacial superimposition: State of the art (I)

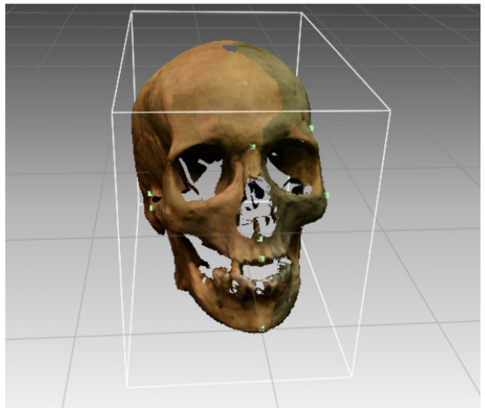
**OVERVIEW**



**3D partial views**





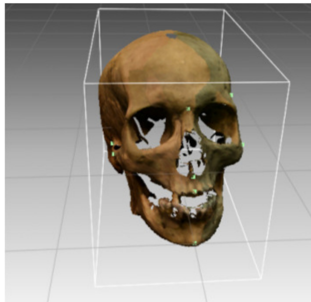


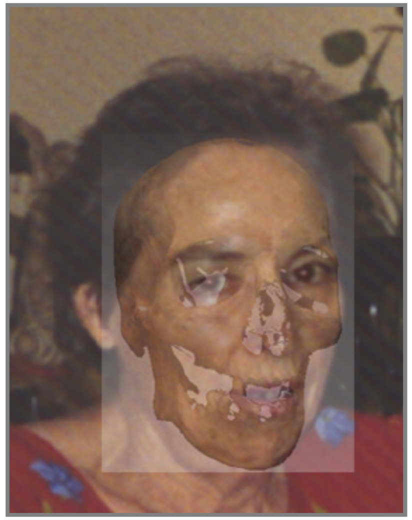
Manual Skull 3D Reconstruction (Pair-wise RIR)
(requires an skilled forensic anthropologist)

## Computer-based craniofacial superimposition: State of the art (II)

**OVERVIEW**



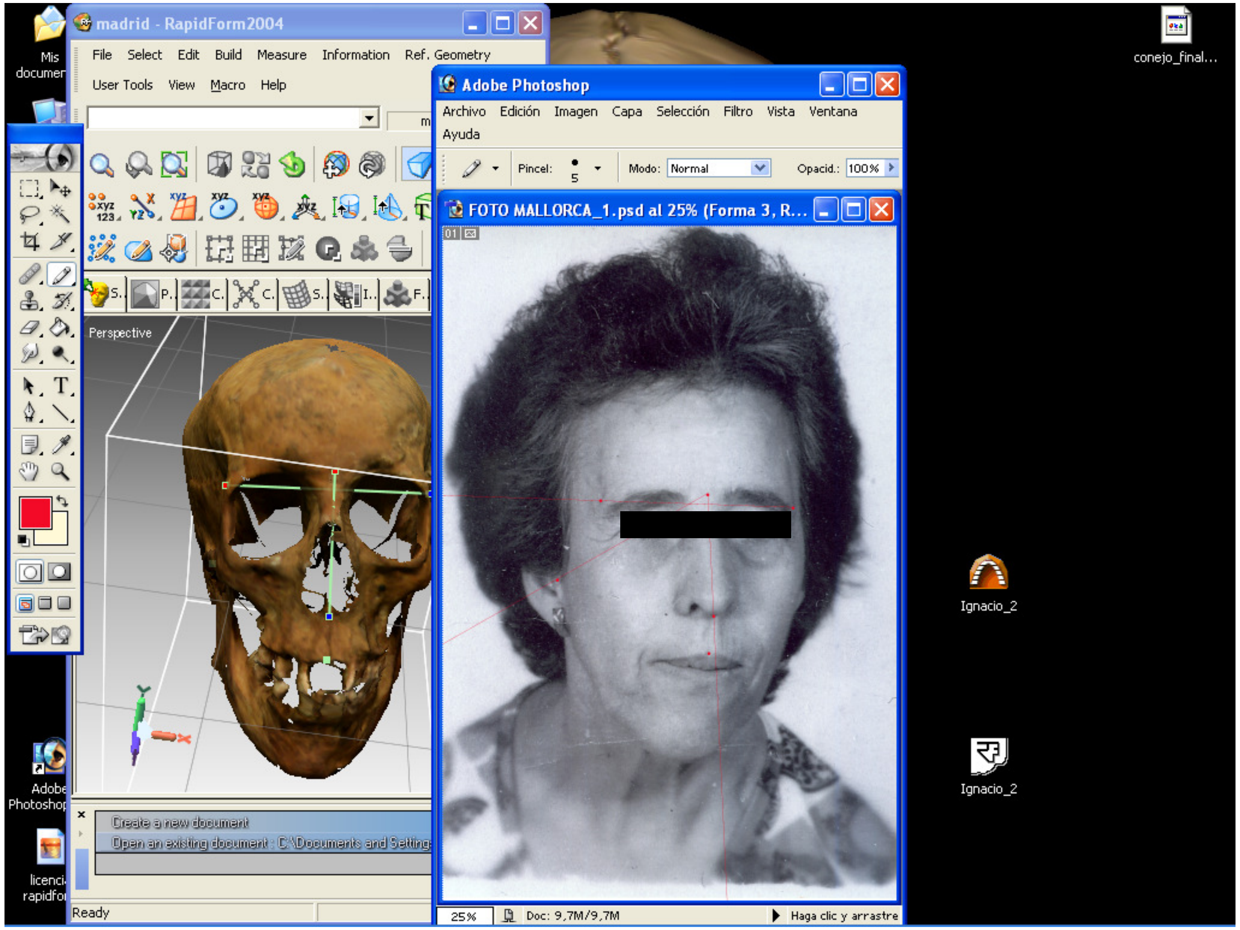



Manual skull-face overlay (very time consuming!)

## Computer-based craniofacial superimposition: State of the art (III)

**OVERVIEW**






Real case of manual craniofacial superimposition

**OVERVIEW**



- There is a need of automatic techniques able to deal properly with incomplete information
- No systematic method exists
- The scanner software only determines the correct alignment if a rotary table is available
- Uncertainty is inherent to landmark location, landmark matching, and to the identification decision
- Even so, the forensic anthropologist is not usually very skillful neither to calibrate the scanner nor to properly match the different views of the skull
- Clear situation of partial matching: landmarks are located in a different location in the skull and the face, some of them do not have a correspondence, etc.
- Manual craniofacial superimposition is very time consuming
- Degrees of confidence in the identification result

**OPPORTUNITY FOR SOFT COMPUTING !**

- Development of an automatic computer-based procedure to assist the forensic anthropologist in the identification task by craniofacial superimposition:

  - Design of automatic RIR methods to achieve accurate 3D models of forensic objects (using EAs)

  - Design of automatic 3D-2D IR methods to perform the skull-face overlay (using EAs and fuzzy sets)

- Initial work supported by two granted projects (national and regional research calls)

# 3. IR, uncertainty and forensic identification = soft computing
## Our computer-based craniofacial superimposition procedure

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition

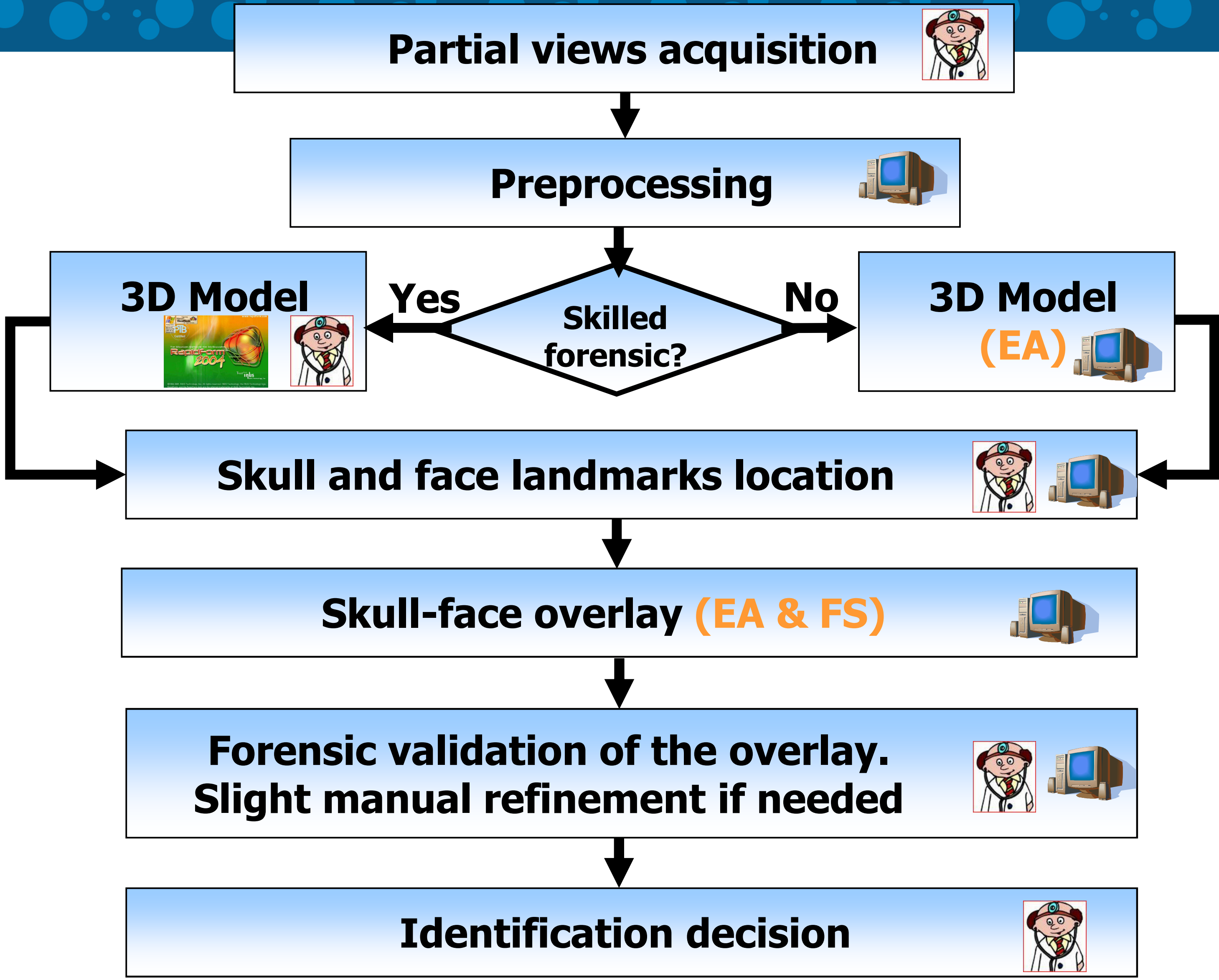
2. Image Registration (IR)

**3. IR, Uncertainty and FI = Soft Computing**

4. First stage: 3D skull model reconstruction

5. Second stage: Skull-face overlay

6. Conclusions



- High complexity of the scenarios:
  - Accuracy-complexity trade-off: views acquired every 45º (8 per skull): small overlapping between adjacent views
  - Symmetries: multimodal search space
  - Huge data set (around 100.000 points in every view)
  - Rather often wrong acquisition of data even with rotary table and mainly without it

- An automatic and robust RIR method is required being able to deal with these scenarios and to achieve 3D models with a precision of millimeters in a reasonable time

- The flexibility of EAs, their good performance in other IR problems, and our previous experience in medical IR led us to consider these soft computing techniques

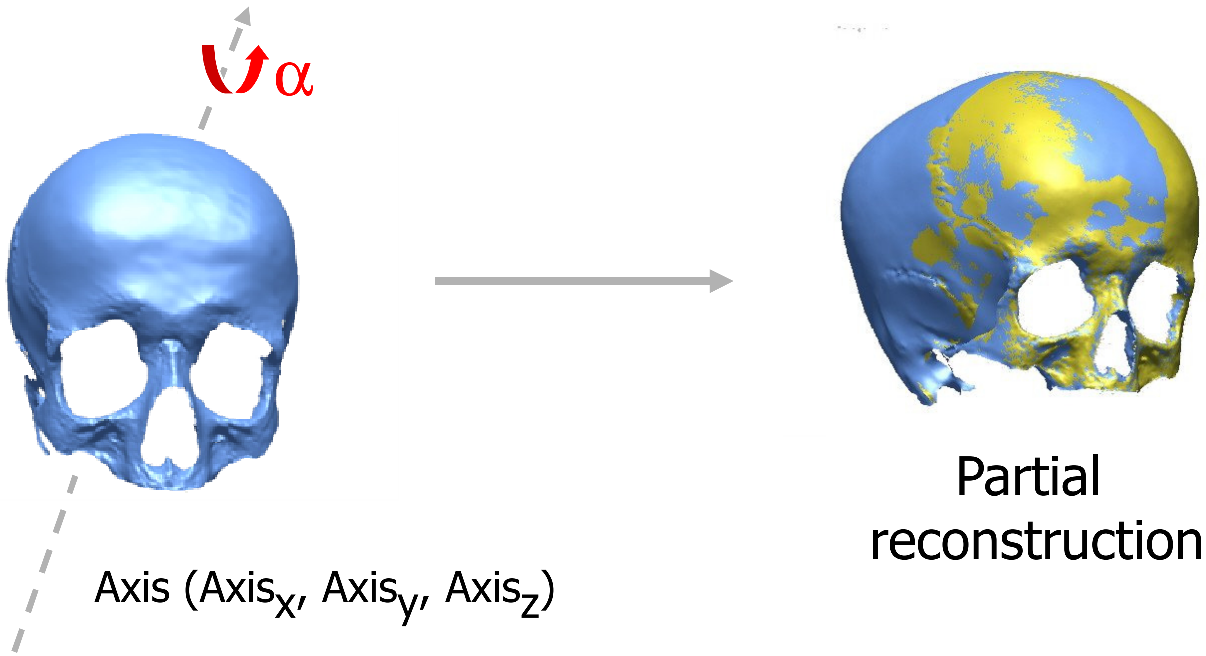
## Evolutionary algorithm-based proposal (I)

**OVERVIEW**



- Coding scheme: real-coded vector representing a rigid transformation with seven parameters

$$\underbrace{\boxed{\alpha}\boxed{Axis_x}\boxed{Axis_y}\boxed{Axis_z}}_{\text{Rotation}}\underbrace{\boxed{t_x}\boxed{t_y}\boxed{t_z}}_{\text{Translation}}$$



## Evolutionary algorithm-based proposal (II)



- Coding scheme: real-coded vector representing a rigid transformation with seven parameters

| | | | | | | |
|---|---|---|---|---|---|---|
| $\alpha$ | $Axis_x$ | $Axis_y$ | $Axis_z$ | $t_x$ | $t_y$ | $t_z$ |

- Fitness function: $F(I_s, \mathrm{I_m}; f) = MIN(M_{edian}SE(\mathrm{I_m}, f(I_s)))$

  MSE is avoided because of the small overlapping between adjacent views

- GCP and KD-Tree data structures are used to speed up the closest point computation

## Evolutionary algorithm-based proposal (III)



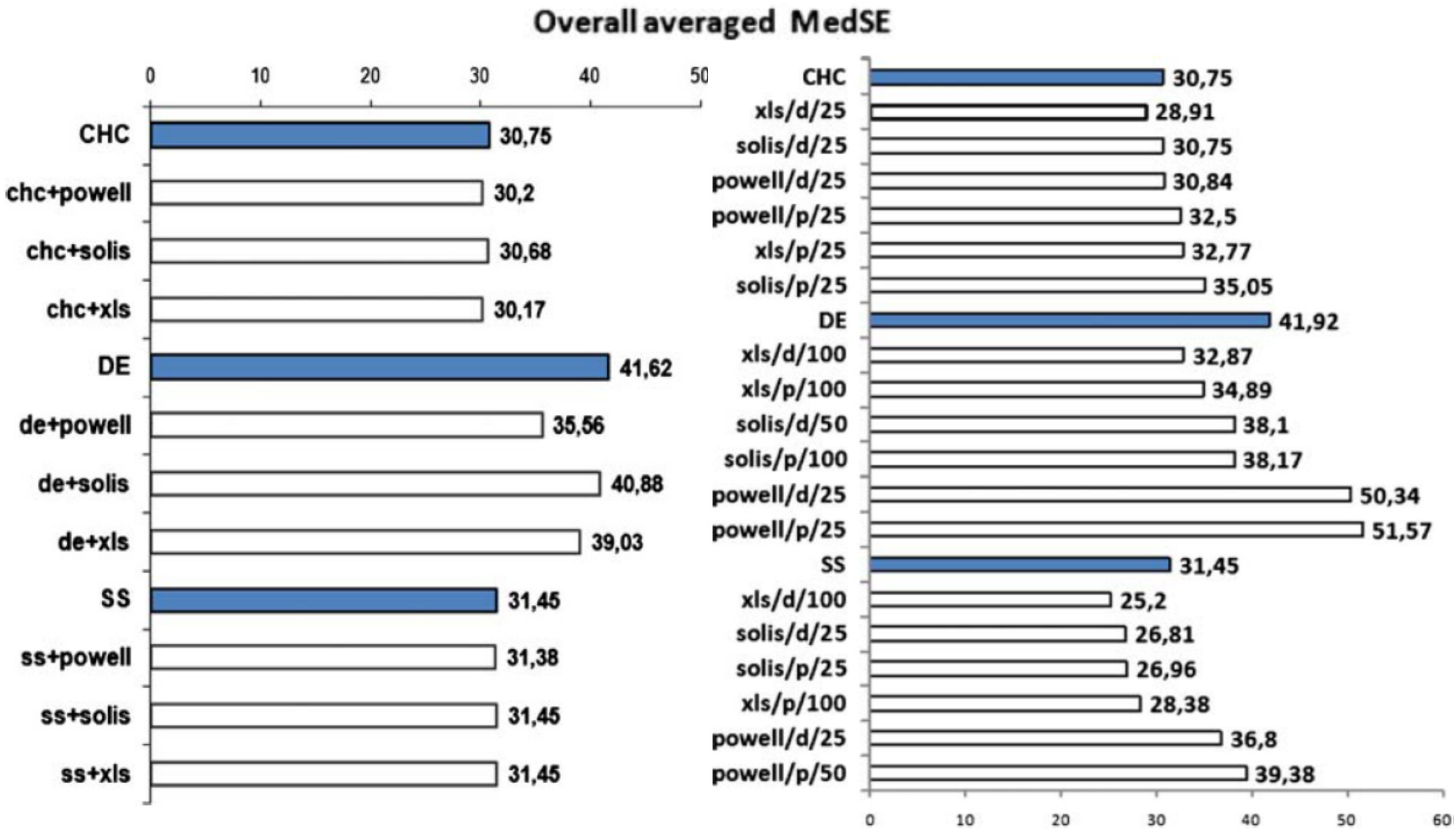
- EA composition: Real-coding memetic algorithms. Combination of:
  - 3 advanced EAs as global search method: CHC, differential evolution, SS
  - 3 different local search (LS) methods: Powell, SolisWets, XLS
- Different LS application mechanisms and intensification-diversification trade-offs have been considered
- Overall, the best evolutionary RIR method for 3D skull reconstruction is based on SS, XLS, a deterministic LS application, and the largest intensification level

## Evolutionary algorithm-based proposal (IV)

**OVERVIEW**



- Good MA designs significantly improve both the basic EAs and the classical RIR methods based on sequential hybridizations:

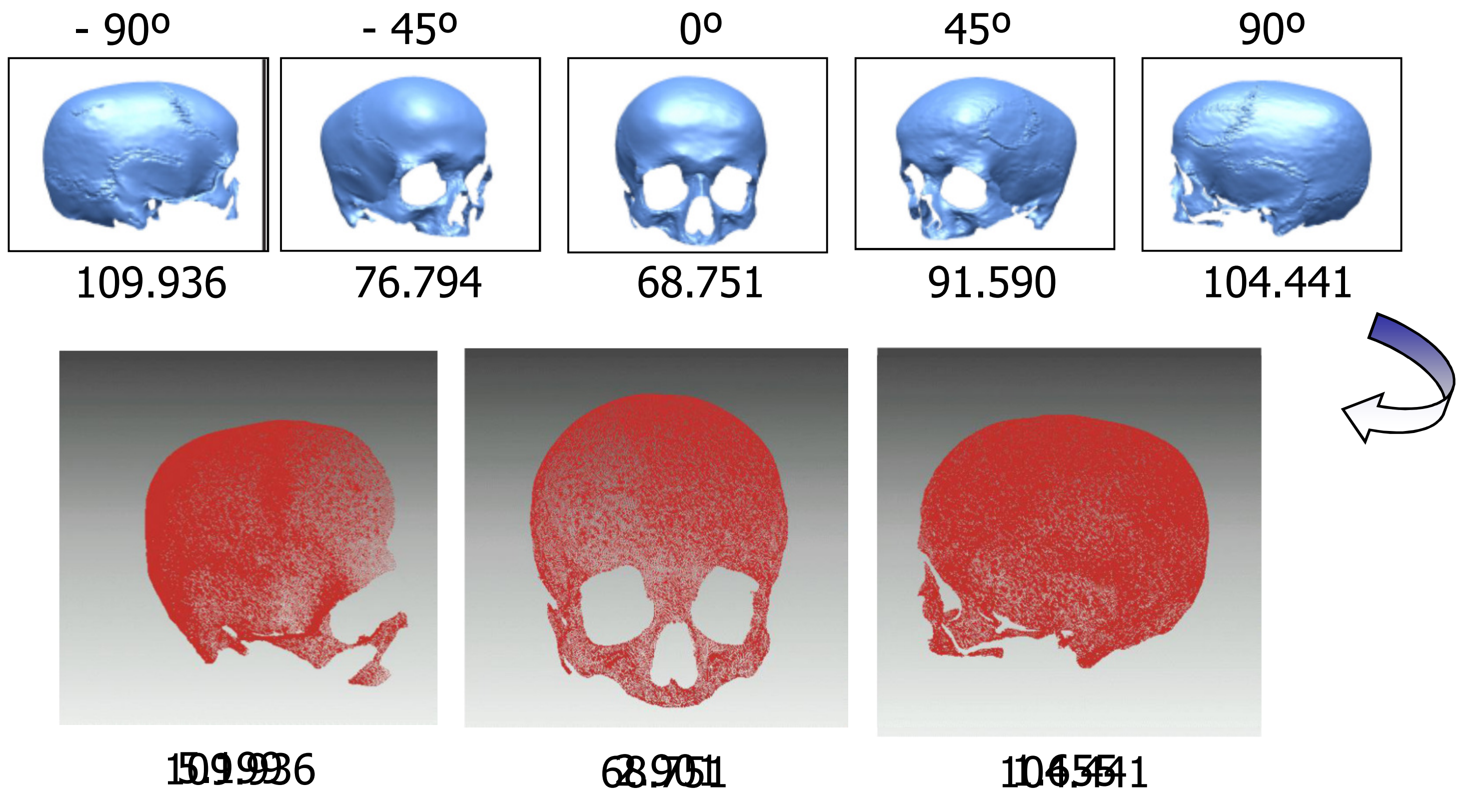



**Sequential hybrids** **Memetic designs**

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
2. Image Registration (IR)
3. IR, Uncertainty and FI = Soft Computing
4. **First stage: 3D skull model reconstruction**
5. Second stage: Skull-face overlay
6. Conclusions

- Range IR of the five frontal views of a skull acquired using the laser range scanner of the Physical Anthropology Lab of the University of Granada (*Konica-Minolta© VI-910* )




- **Automatic extraction of invariant features to reduce dimensionality**

**OVERVIEW**



- Data simplification (point reduction)

| | | Views/Images | | | | |
|---|---|---|---|---|---|---|
| | | $270^\circ$ | $315^\circ$ | $0^\circ$ | $45^\circ$ | $90^\circ$ |
| Original | $Skull_1$ | 109936 | 76794 | 68751 | 91590 | 104441 |
| | $Skull_2$ | 121605 | 116617 | 98139 | 118388 | 128163 |
| | $Skull_3$ | 116937 | 107336 | 88732 | 111834 | 123445 |
| | $Skull_4$ | 129393 | 124317 | 102565 | 125859 | 137181 |
| | $Skull_5$ | 110837 | 102773 | 83124 | 101562 | 110313 |
| Features | $Skull_1$ | 5199 | 915 | 2901 | 2948 | 1655 |
| | $Skull_2$ | 7304 | 10347 | 11106 | 12676 | 11143 |
| | $Skull_3$ | 9023 | 10745 | 8318 | 12265 | 10361 |
| | $Skull_4$ | 8593 | 11020 | 14844 | 12285 | 10025 |
| | $Skull_5$ | 9419 | 9852 | 10764 | 10308 | 9175 |

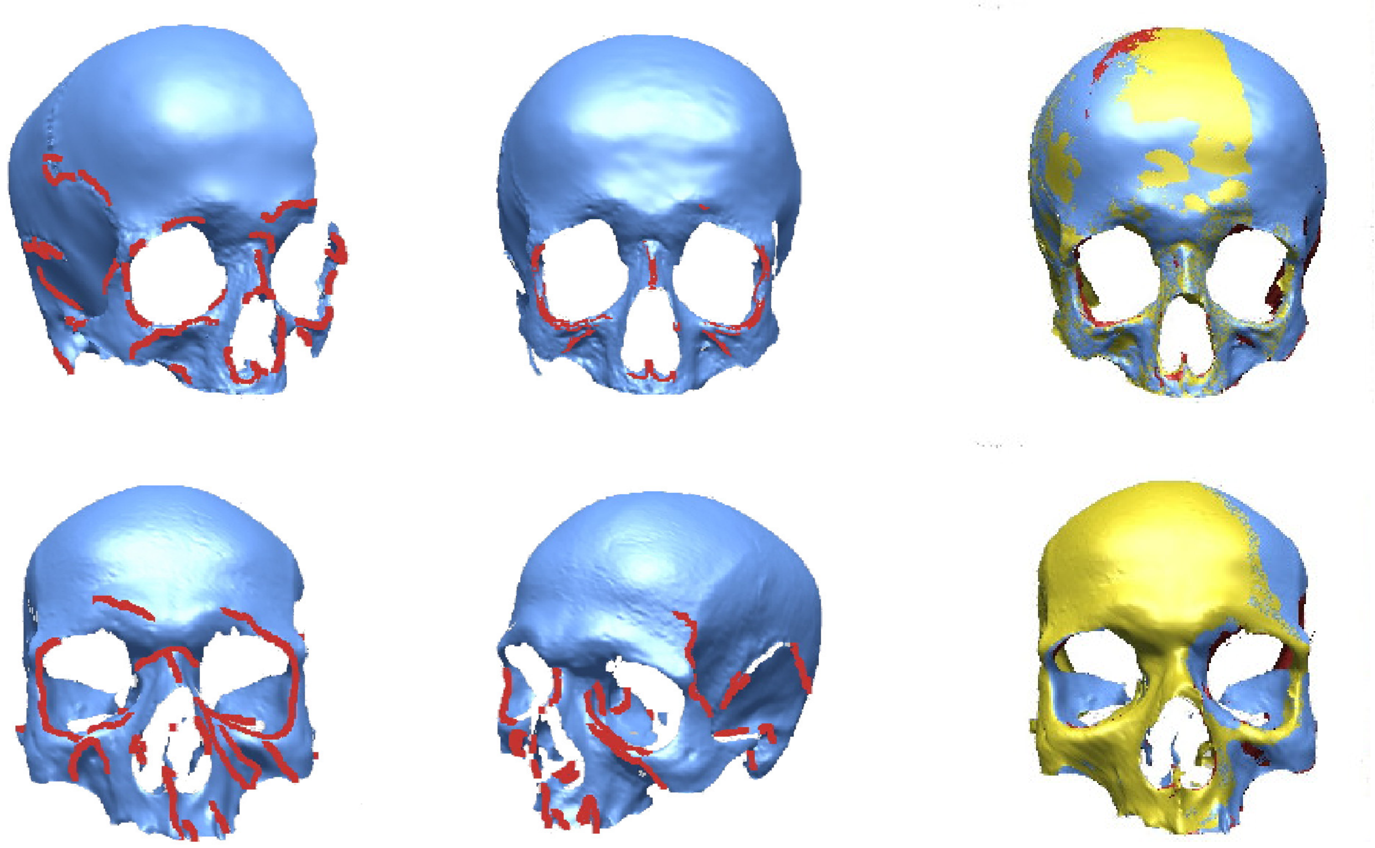
# Results (I)

**OVERVIEW**



**3D views: input**

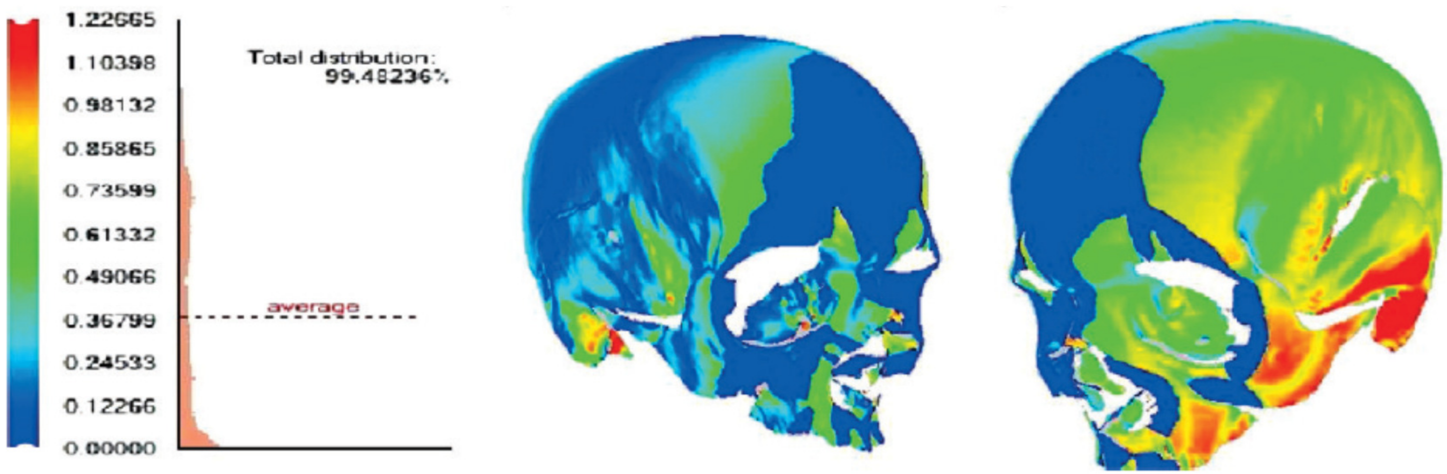
**Reconstruction**



**OVERVIEW**



- Reconstruction error: less than 1 mm
- 3D reconstruction time: 2 minutes
- Method robustness: low standard deviation in 30 different runs



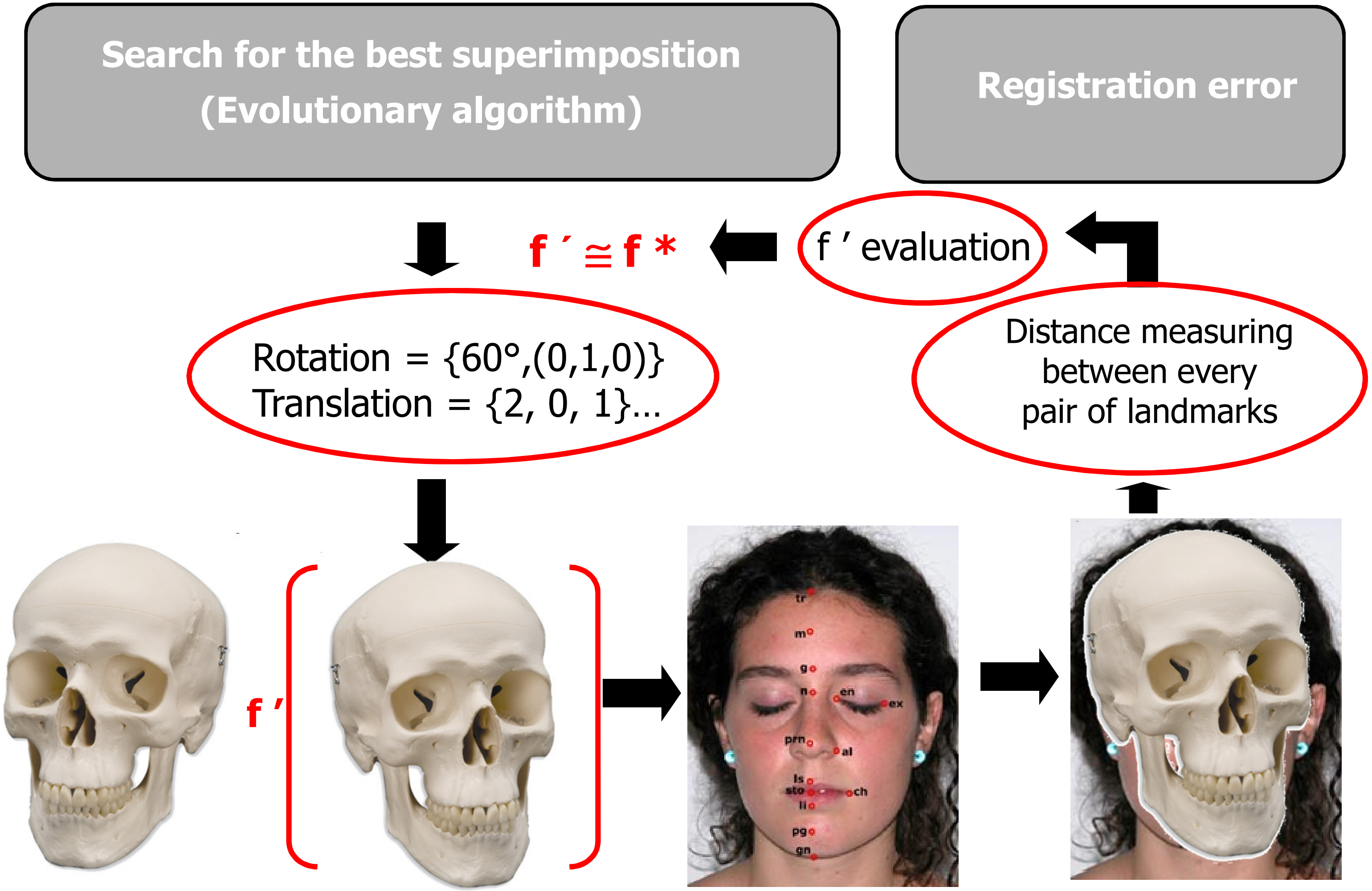
Again, very complex problem:

- The available photographs are provided by the family:
  - Not always good quality, neither good pose
  - Landmarks may be occluded
  - Camera data are unknown
- Uncertainty is inherent both to the landmark location and matching (the latter due to the flesh lack in the skull)
- Skull-face overlay is a very time consuming trial and error manual procedure
- Need of automatic techniques for skull-face overlay (3D-2D IR) being robust, fast, and able to deal with incomplete information
- We will exploit the suitability of EAs and FS to tackle the IR problem and to deal with the sources of uncertainty, respectively

# Considered methodology

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
2. Image Registration (IR)
3. IR, Uncertainty and FI = Soft Computing
4. First stage: 3D skull model reconstruction
5. **Second stage: Skull-face overlay**
6. Conclusions



**OVERVIEW**



- Evolutionary 3D skull-2D face IR problem with a complex registration transformation: translation, rotation, scaling, and projection. Twelve parameters

- Real-coding scheme, better suited for IR

- Advanced EAs: elitist GA, binary tournament, BLX-$\alpha$/SBX crossovers, random mutation. CMA-ES, SS, multimodal GAs, co-evolutionary approaches, …

- Realistic conditions: Variable number of landmarks according to the photograph and the skull conditions. Robustness under multiple runs to allow a single run

- Fitness function: mean of the distances between the facial and the projected cranial landmarks (mean error, ME)

**OVERVIEW**



- The final solution to the skull-face overlay problem should be the transformation making the 3D skull model become accurately located in the same pose of the missing person in the photo

- There are two important moments to be considered:

Photograph acquisition

Skull model acquisition

- Replicating the scenario where the photograph was acquired is rather complex because of the number of unknowns involved in the process (even more than camera calibration in CV)

- The registration transformation to be estimated includes a rotation (R), a scaling (S), a translation (T), and a perspective projection (P)
- Given two sets of 2D facial and 3D cranial landmarks:

$$F = \begin{bmatrix} x_{f_1} & y_{f_1} & 1 & 1 \\ x_{f_2} & y_{f_2} & 1 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{f_N} & y_{f_N} & 1 & 1 \end{bmatrix}, \quad C = \begin{bmatrix} x_{c_1} & y_{c_1} & z_{c_1} & 1 \\ x_{c_2} & y_{c_2} & z_{c_2} & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{c_N} & y_{c_N} & z_{c_N} & 1 \end{bmatrix}$$

the aim is to solve an over-determined system of equations with 12 unknowns $(r_x, r_y, r_z, d_x, d_y, d_z, \theta, s, t_x, t_y, t_z, \phi)$ :

$$F = f(C) = C \cdot R \cdot S \cdot T \cdot P$$

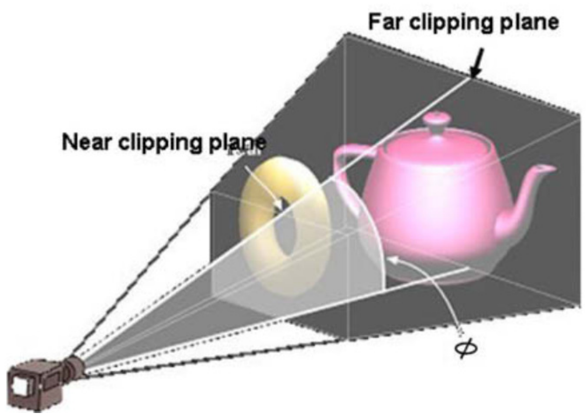
where: $R = (A \cdot D_1 \cdot D_2 \cdot \Theta \cdot D_2^{-1} \cdot D_1^{-1} \cdot A^{-1})$

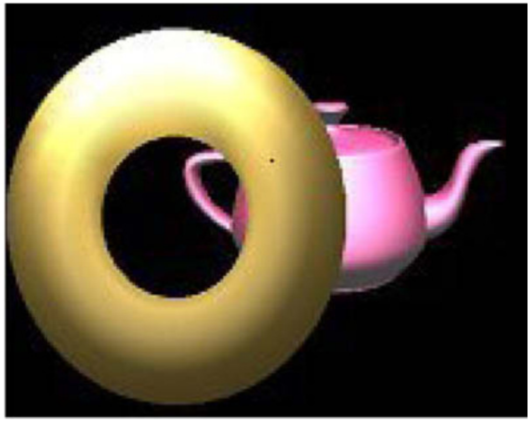
**OVERVIEW**



- Projective transformations are hard to be estimated. Cameras use them to provide a realistic picture of the scene from the observer's viewpoint

- In computer graphics, the pinhole camera is modeled using a frustum given by the near clipping plane (NCP) and the far clipping plane (FCP):



- The frustum determines the visible region

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- Thus, our coding scheme is a vector of 12 real values:

| $r_x$ | $r_y$ | $r_z$ | $d_x$ | $d_y$ | $d_z$ | $\theta$ | $s$ | $t_x$ | $t_y$ | $t_z$ | $\phi$ |
|---|---|---|---|---|---|---|---|---|---|---|---|

Rotation ($r_x, r_y, r_z, d_x, d_y, d_z, \theta$) · Scaling ($s$) · Translation ($t_x, t_y, t_z$) · Projection ($\phi$)

ranging in the following intervals:

$$r_i \in [Centroid - radius, Centroid + radius], \quad i \in \{x, y, z\}$$
$$d_i \in [-1, 1], \quad i \in \{x, y, z\}$$
$$\theta \in [0^\circ, 360^\circ]$$
$$s \in [0.25, 2]$$
$$\phi \in [10^\circ, 150^\circ]$$
$$t_x \in [-length_{FB} - (C_x + radius), length_{FB} - (C_x - radius)]$$
$$t_y \in [-length_{FB} - (C_y + radius), length_{FB} - (C_y - radius)]$$
$$t_z \in [NCP - (C_z + radius), FCP - (C_z - radius)]$$

where:

$$radius = \max(\|Centroid - C_j\|)$$

FB is the frustum Base

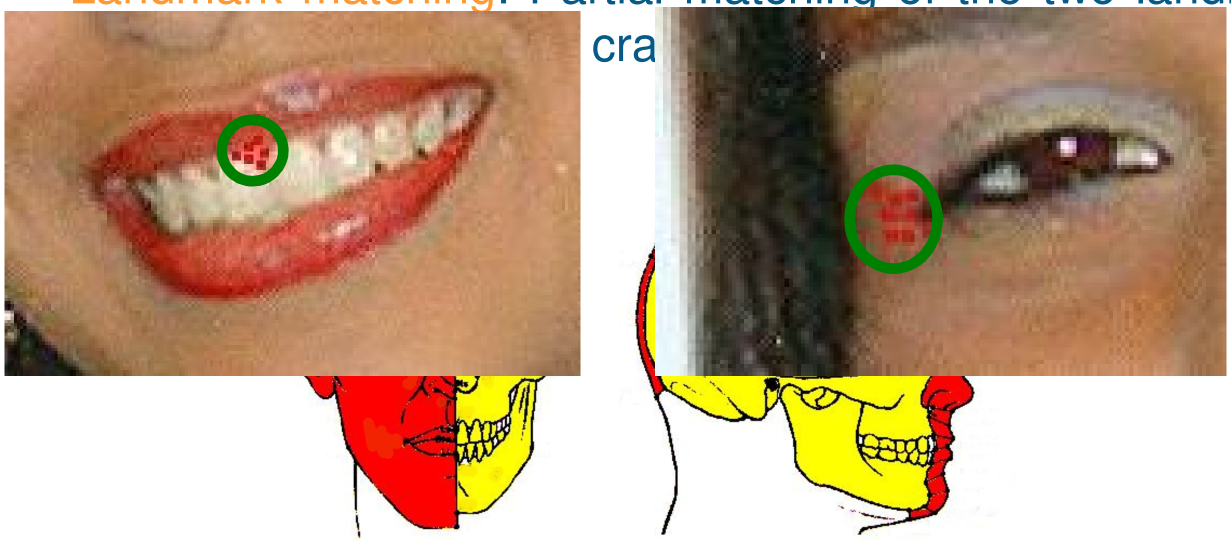
$$length_{FB} = \frac{(\min_{FD} + FCP) * \sin\left(\frac{\phi_{max}}{2}\right)}{\sin\left(90^\circ - \left(\frac{\phi_{max}}{2}\right)\right)}$$

with FD being the Focal Distance and

$$\min_{FD} = \frac{1}{\tan\left(\frac{\phi_{max}}{2}\right)}$$

Two different sources of uncertainty:

1. Inherent uncertainty associated with the two different objects under study (a skull and a face):
   - Landmark location: Every forensic expert is prone to locate the landmarks in a slightly different place
   - Landmark matching: Partial matching of the two landmark
     cra



2. Uncertainty associated with the 3D skull-2D photo overlay process:

- Landmark location: Difficulty to select a good (cephalometric) landmark set due to the photo conditions:
  - face pose, partial occlusions, and poor image quality
  - Forensic anthropologists are prone to locate only those landmarks which can be unquestionably identified!

- Landmark matching: The selected reduced landmark set is usually coplanar or near-coplanar:
  - the equation system becomes undetermined and the 3D-2D IR process gets inaccurate results
  - The preferred photos by the forensic anthropologists are usually those with a frontal pose!

## Fuzzy landmarks to jointly tackle location and coplanarity problems (I)

OVERVIEW



- Each cephalometric landmark is a fuzzy point defined by a bi-dimensional fuzzy set. The higher the uncertainty related to a landmark → the broader the fuzzy region

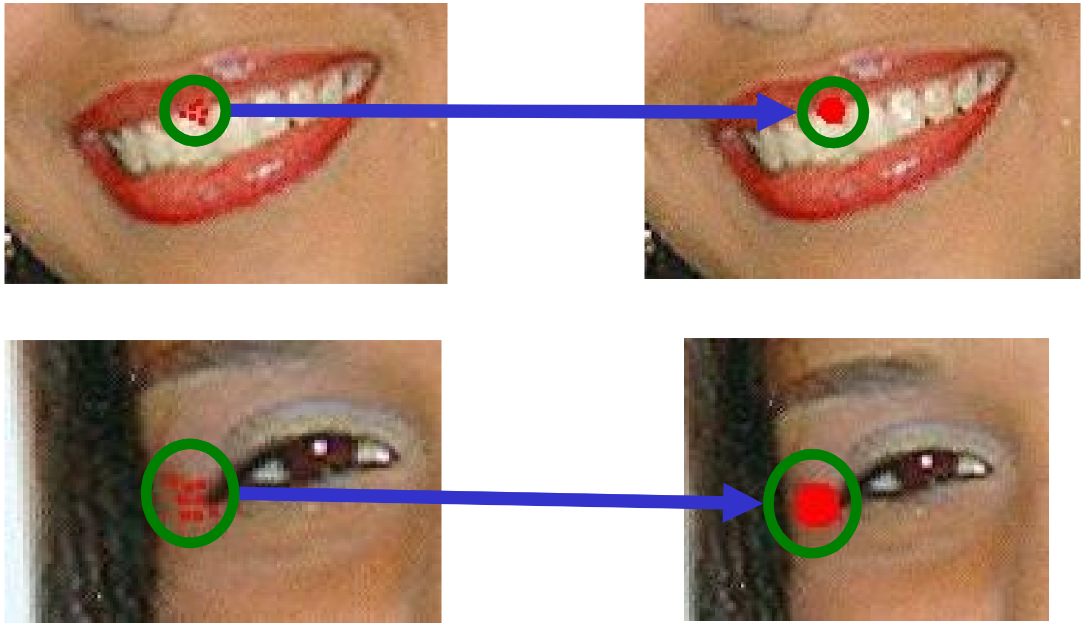
- Solution for the two landmark location problems:
  - The inherent difficulty to locate the landmark in the right place
  - The complexity of locating a significant and unquestionable number of landmarks in a photo

- Thanks to the flexibility given to the forensic expert, (s)he is able to mark a larger number of landmarks located in different planes, thus also solving the coplanarity problem

## Fuzzy landmarks to jointly tackle location and coplanarity problems (II)

OVERVIEW



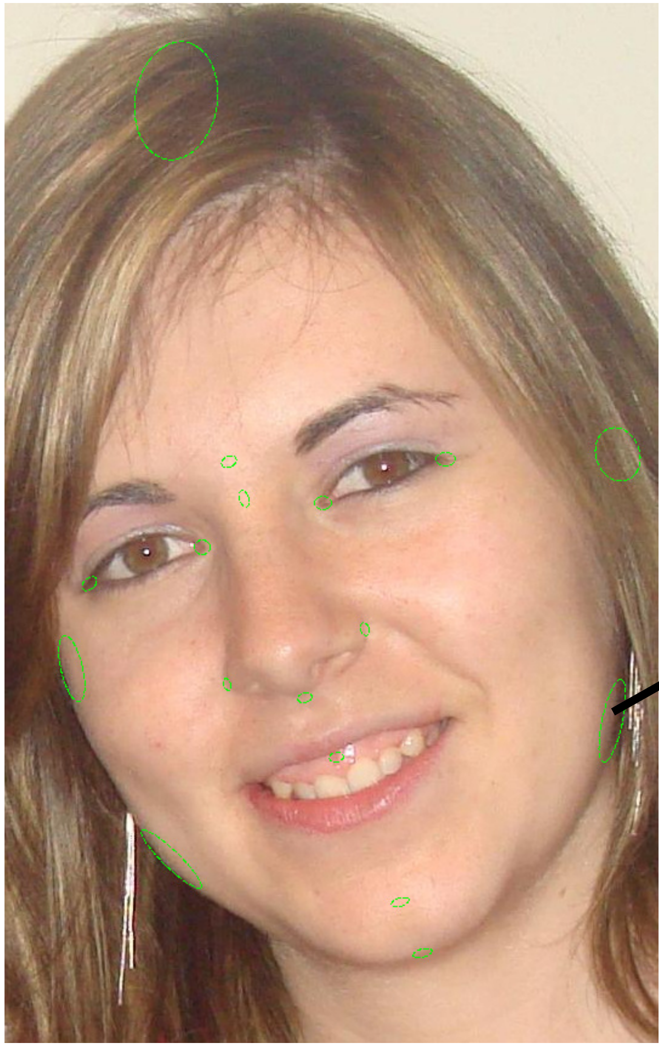


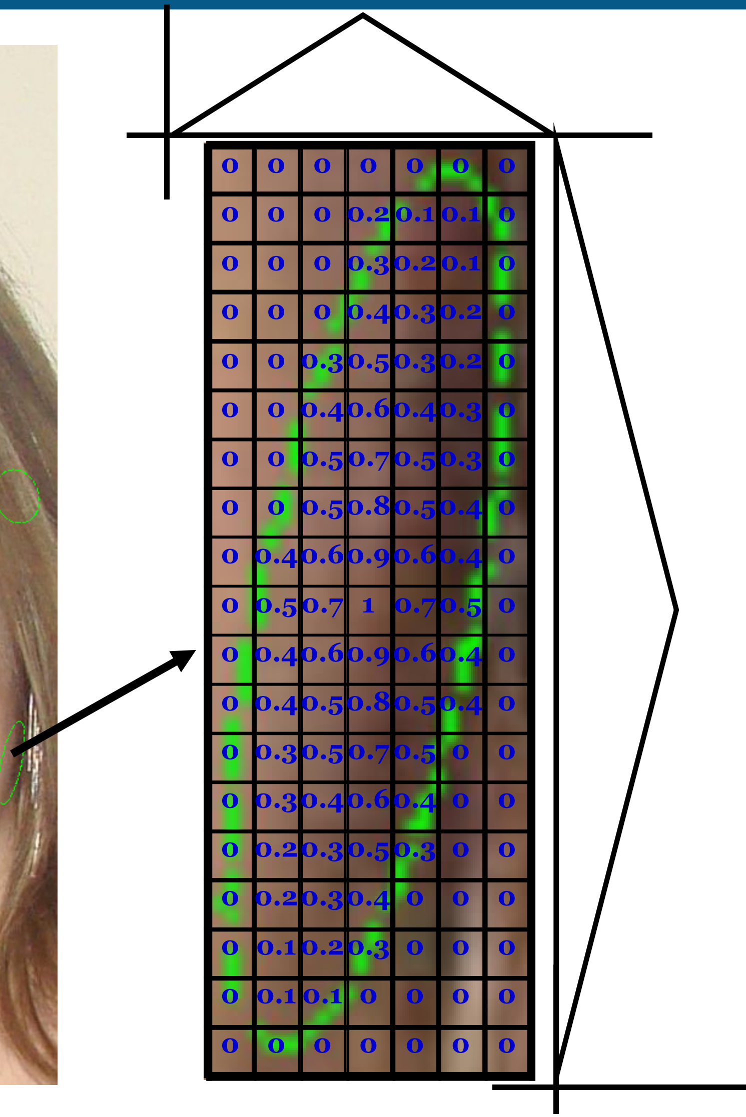
- There is a mask with the membership degree of each pixel to the fuzzy point associated to every landmark
- Need of a new fitness function considering a distance between crisp and fuzzy points

# Fuzzy landmarks to jointly tackle location and coplanarity problems (III)

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
2. Image Registration (IR)
3. IR, Uncertainty and FI = Soft Computing
4. First stage: 3D skull model reconstruction
5. **Second stage: Skull-face overlay**
6. Conclusions

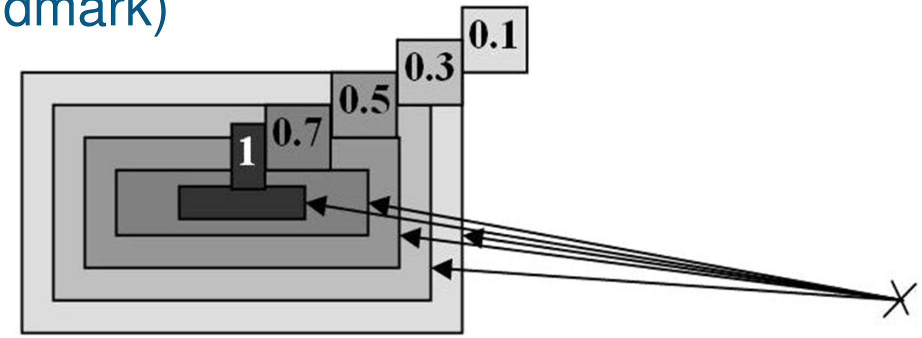




# Fuzzy landmarks to jointly tackle location and coplanarity problems (IV)



- α-cuts to calculate the distance from a crisp point (projected craniometric landmark) to a fuzzy point (cephalometric landmark)




- Crisp-fuzzy distance and new fitness function:

$$d^*(x, \widetilde{F}) = \frac{\sum_{i=1}^{m} d_i \cdot \alpha_i}{\sum_{i=1}^{m} \alpha_i}$$

$$\mathit{fuzzy\ ME} = \frac{\sum_{i=1}^{N} d^*(f(cl^i), \widetilde{F}^i)}{N}$$

**OVERVIEW**



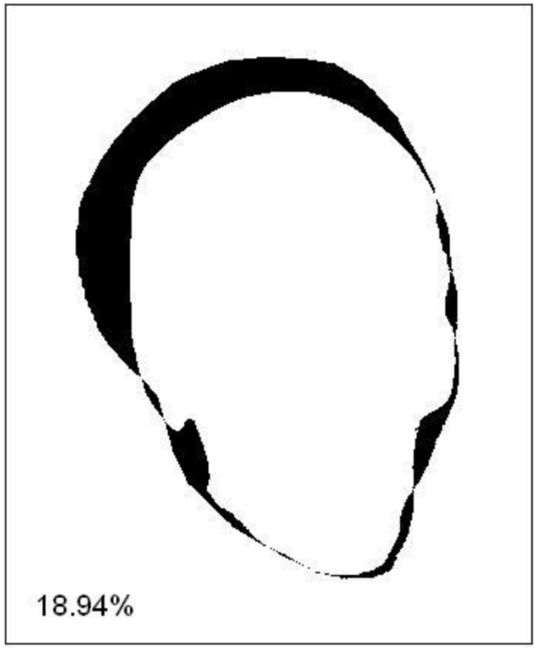
## Experimental design:

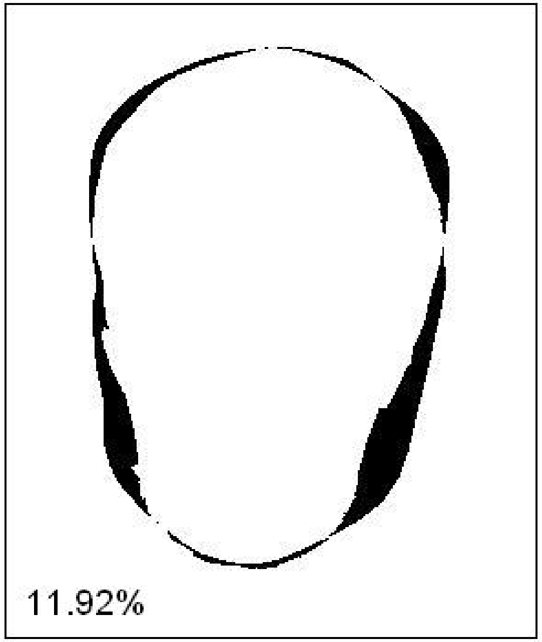
- Target: compare manual vs. automatic SFO results using either near-coplanar crisp or fuzzy cephalometric landmarks
- Robustness analysis: accuracy dispersion in 30 different runs
- Real identification cases previously solved by the Physical Anthropology Lab at the UGR for the Spanish scientific police
- ME is not valid (two different landmark sets)!
- Qualitative analysis → visual comparison of the overlay results by the forensic anthropologists
- Quantitative analysis → percentage of the head boundary not covered by the projected skull boundary (manually defined by the forensic experts)

**OVERVIEW**



## Area Deviation Error:



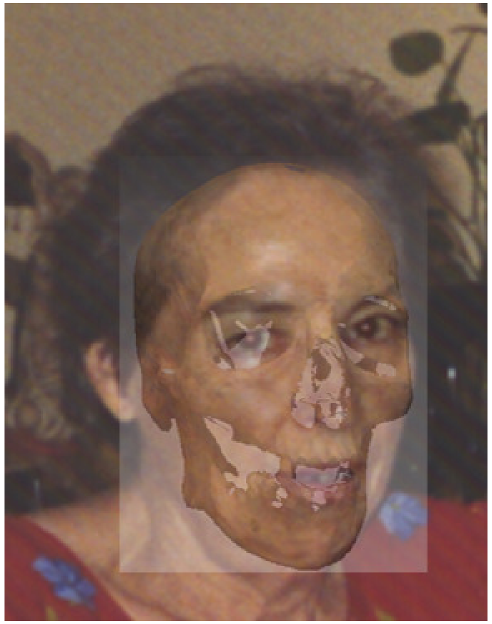

It is not a perfect measure (no information on accuracy of the inner skull parts fitting) but at least it is objective (and complementary)!

OVERVIEW



## Malaga case study: Overlays comparison

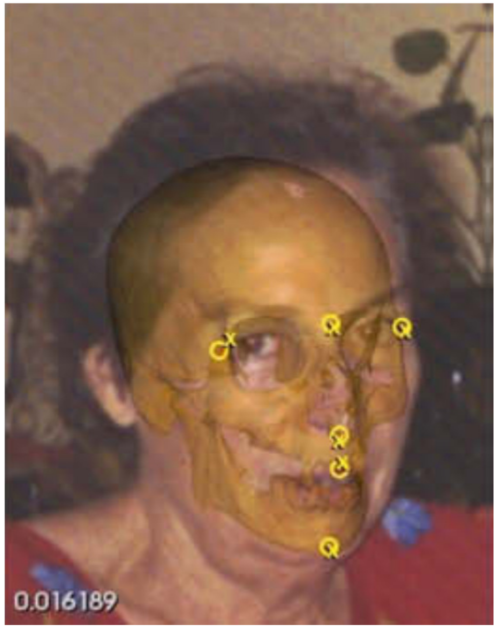
Manual



Area deviation error: 34.70%

**several hours**

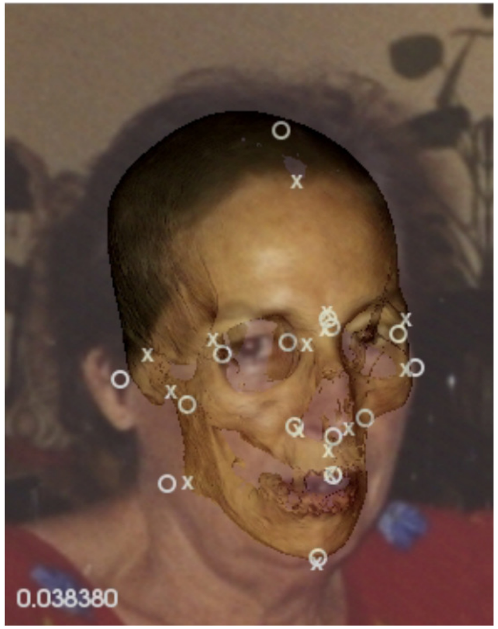
CMA-ES (6 landmarks)




Area deviation error: 28.73%

**15 seconds**

Fuzzy CMA-ES (15 landmarks)




Area deviation error: 13.23%

**2-4 minutes**

# Results: Cádiz case study (I)

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
2. Image Registration (IR)
3. IR, Uncertainty and FI = Soft Computing
4. First stage: 3D skull model reconstruction
5. **Second stage: Skull-face overlay**
6. Conclusions

- Cádiz case study, pose 1: Overlays comparison

Manual

Area deviation error: 32.64%

**several hours**

CMA-ES (8 landmarks)

Area deviation error: 18.22%

**18 seconds**

Fuzzy CMA-ES (10 landmarks)

Area deviation error: 15.84%

**2-4 minutes**

# 5. Skull-face overlay using EAs and fuzzy sets
## Results: Cádiz case study (II)

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
2. Image Registration (IR)
3. IR, Uncertainty and FI = Soft Computing
4. First stage: 3D skull model reconstruction
5. **Second stage: Skull-face overlay**
6. Conclusions

- Cádiz case study, pose 2: Overlays comparison

| Manual | CMA-ES (9 landmarks) | Fuzzy CMA-ES (14 landmarks) |
|---|---|---|
|  |  |  |
| Area deviation error: 31.58% | Area deviation error: 50.28% | Area deviation error: 27.96% |
| **several hours** | **18 seconds** | **2-4 minutes** |

## Results: Cádiz case study (III)

**OVERVIEW**



- Cádiz case study, pose 3: Overlays comparison

| Manual | CMA-ES (11 landmarks) | Fuzzy CMA-ES (16 landmarks) |
|---|---|---|
|  |  |  |
| Area deviation error: 31.84% | Area deviation error: 42.84% | Area deviation error: 21.26% |
| **several hours** | **18 seconds** | **2-4 minutes** |

## Results: Cádiz case study (IV)



- Cádiz case study, pose 4: Overlays comparison

Manual

Area deviation error: 38.22%

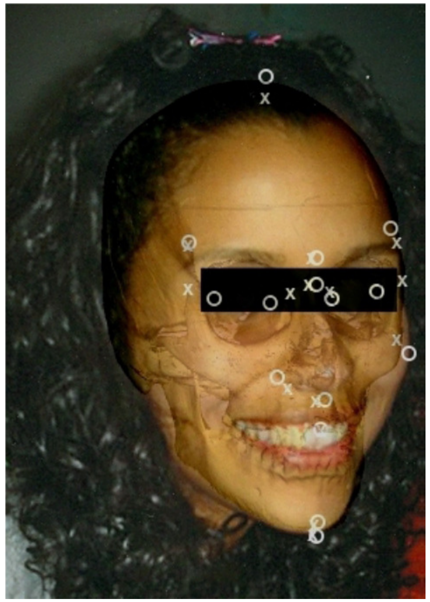
**several hours**

CMA-ES (12 landmarks)

Area deviation error: 53.85%

**18 seconds**

Fuzzy CMA-ES (15 landmarks)



Area deviation error: 18.95%

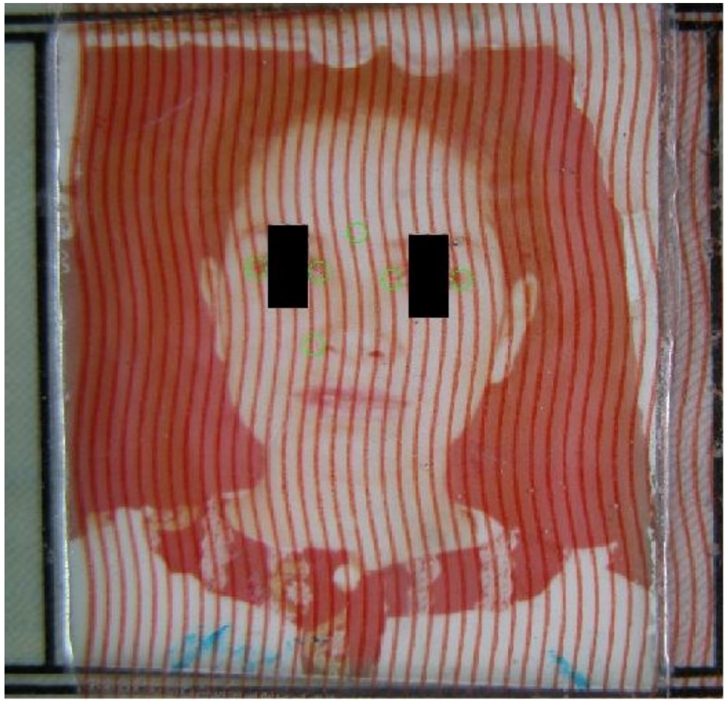
**2-4 minutes**

# 5. Skull-face overlay using EAs and fuzzy sets
## Results: Morocco case study (I)

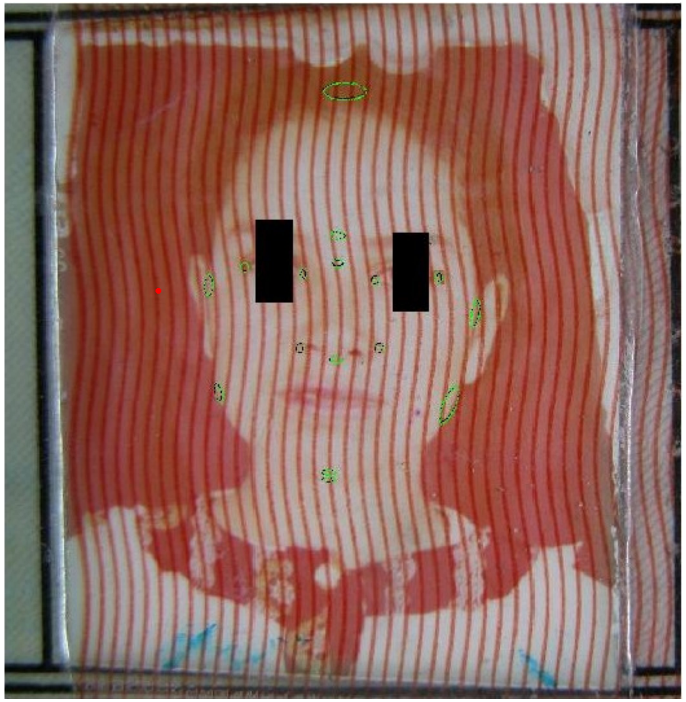
**OVERVIEW**



- Very complex real case. Cádiz (Spain). Single, low quality, passport photo:



6 crisp landmarks



16 fuzzy landmarks

## Results: Morocco case study (II)



- Morocco case study: Overlays comparison

Manual

Area deviation error: 31.73%

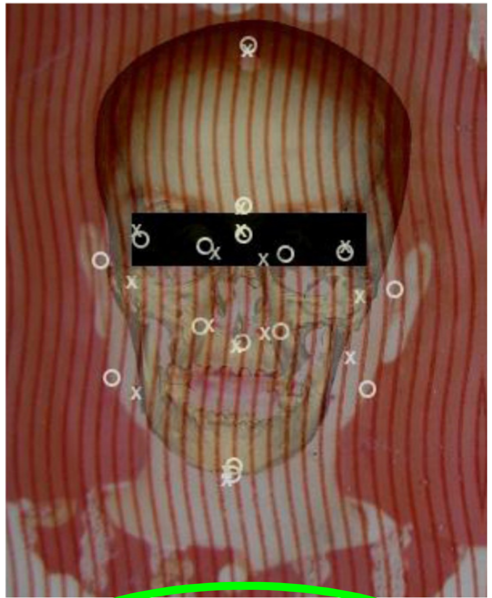
**several hours**

CMA-ES (6 landmarks)

Area deviation error: 32.63%

**15 seconds**

Fuzzy CMA-ES (16 landmarks)

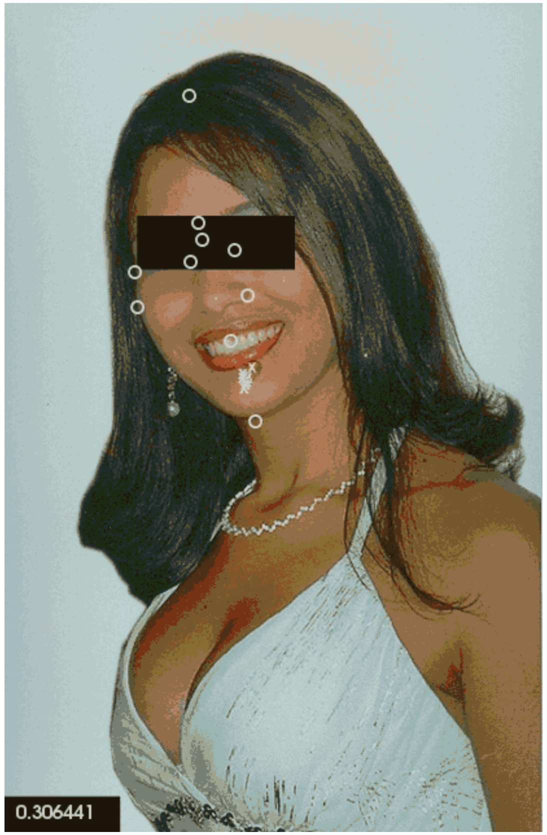


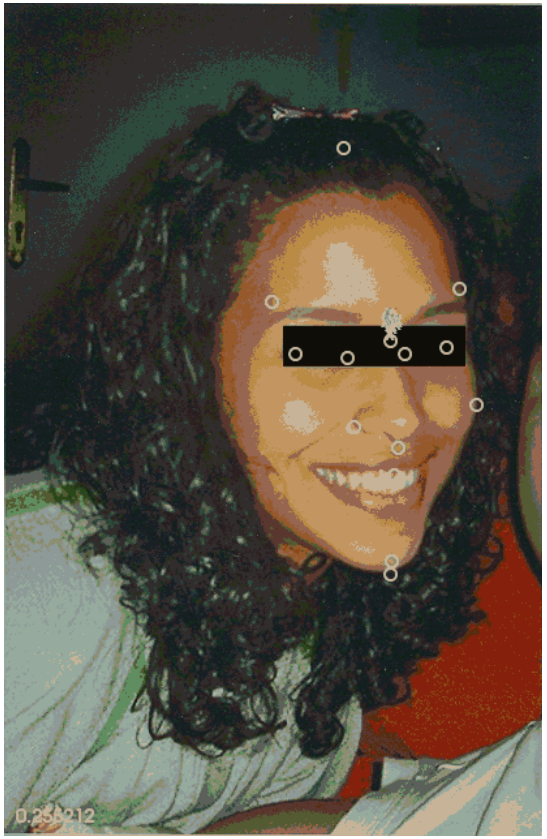
Area deviation error: 11.92%

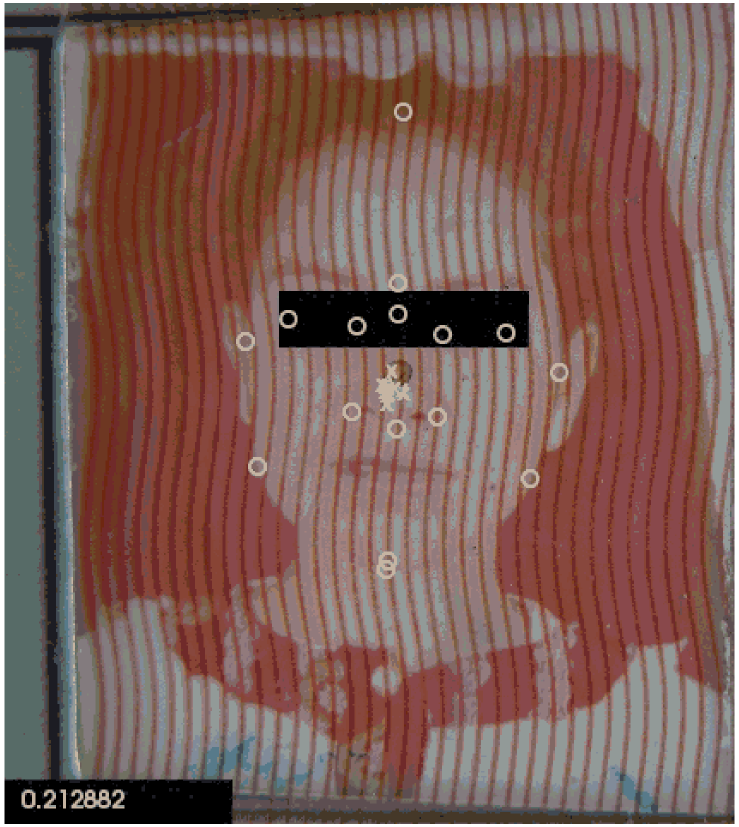
**2-4 minutes**

# 5. Skull-face overlay using EAs and fuzzy sets
## Results: Example runs

### Fuzzy CMA-ES example runs:



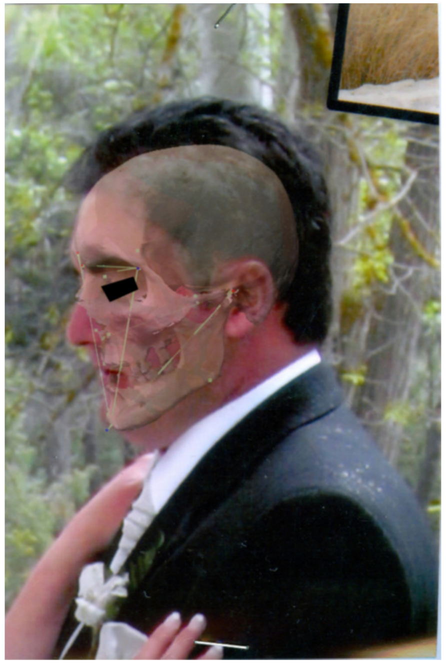


**OVERVIEW**



- Another real case (Granada, Spain):

Manual superimposition



Area deviation error: 13.81%

**several hours**

Fuzzy CMA-ES superimposition


Area deviation error: 4.73%

**2-4 minutes**

- Last real case (Alhambra surroundings, Granada, Spain): First use of our method for a Spanish police identification!

Manual superimposition

Area deviation error: 28.26%

**several hours**

Fuzzy CMA-ES superimposition

Area deviation error: 21.79%

**2-4 minutes**

# 5. Skull-face overlay using EAs and fuzzy sets
## Results: Alhambra case study (II)

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
2. Image Registration (IR)
3. IR, Uncertainty and FI = Soft Computing
4. First stage: 3D skull model reconstruction
5. **Second stage: Skull-face overlay**
6. Conclusions

- Last real case (second photograph):

| Manual superimposition | Fuzzy CMA-ES superimposition |
|---|---|
|  |  |
| Area deviation error: 37.54% | Area deviation error: 21.04% |
| **several hours** | **2-4 minutes** |

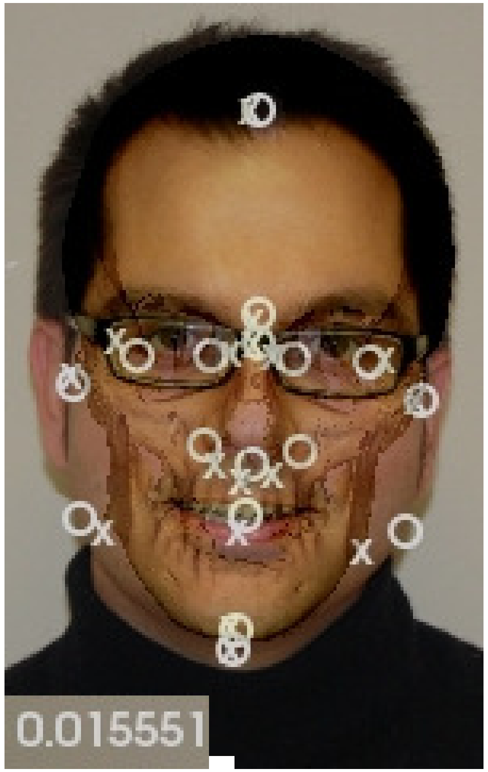
## Results: Negative cases (I)

**OVERVIEW**

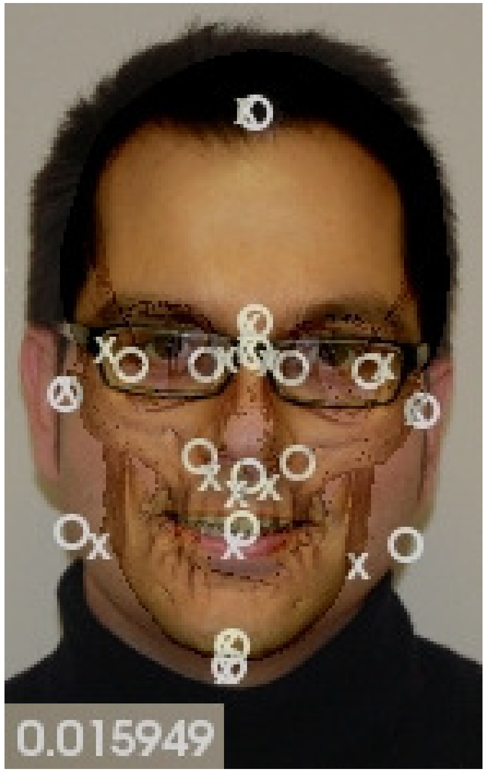


- Skull-face overlay is independent of the decision making stage and our method must get the best possible overlay regardless whether the identification is positive or not:

Best overlay (30 runs)




Worst overlay (30 runs)

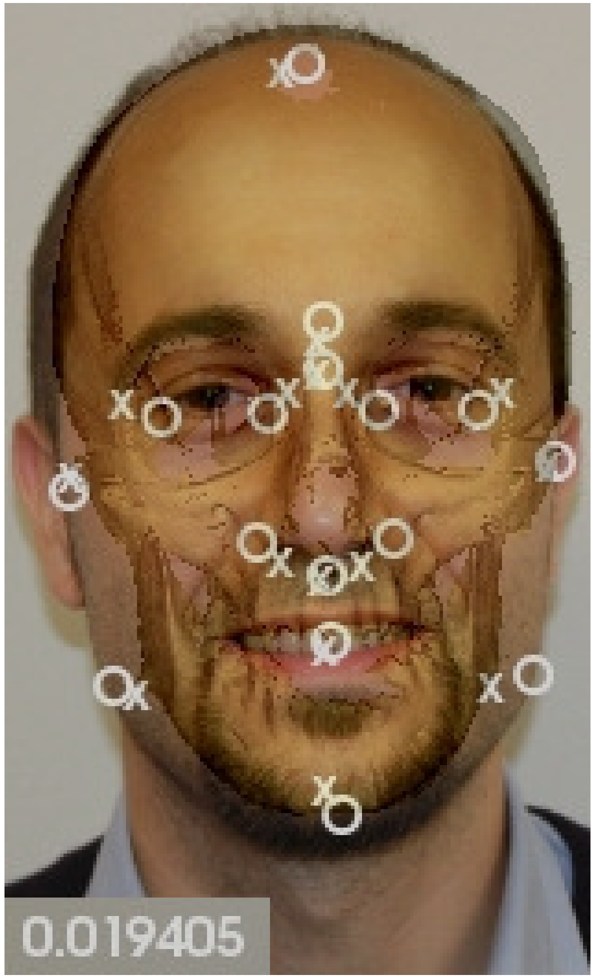


## Results: Negative cases (II)



Best overlay (30 runs)


Worst overlay (30 runs)

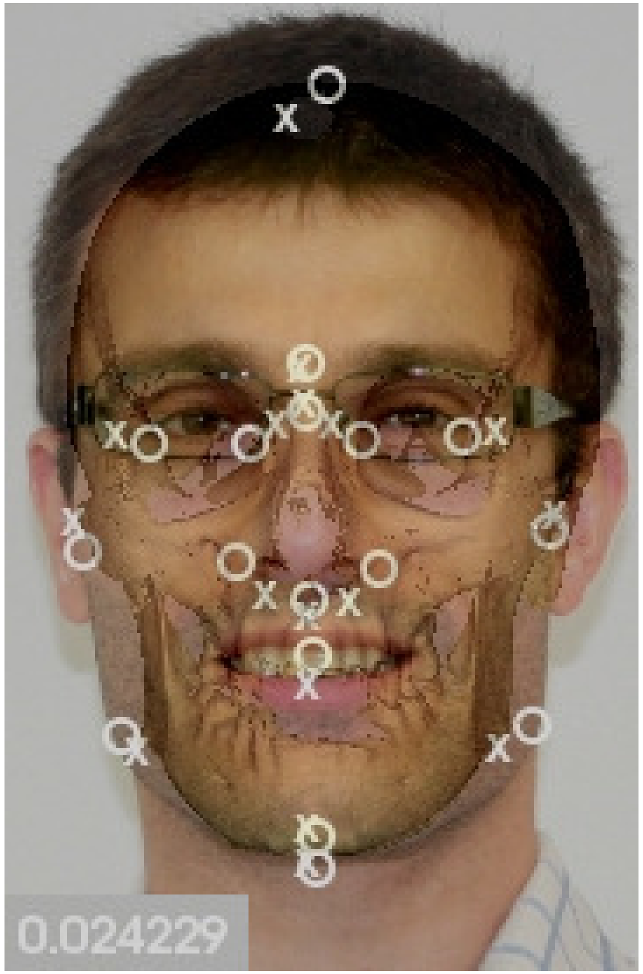


## Results: Negative cases (III)

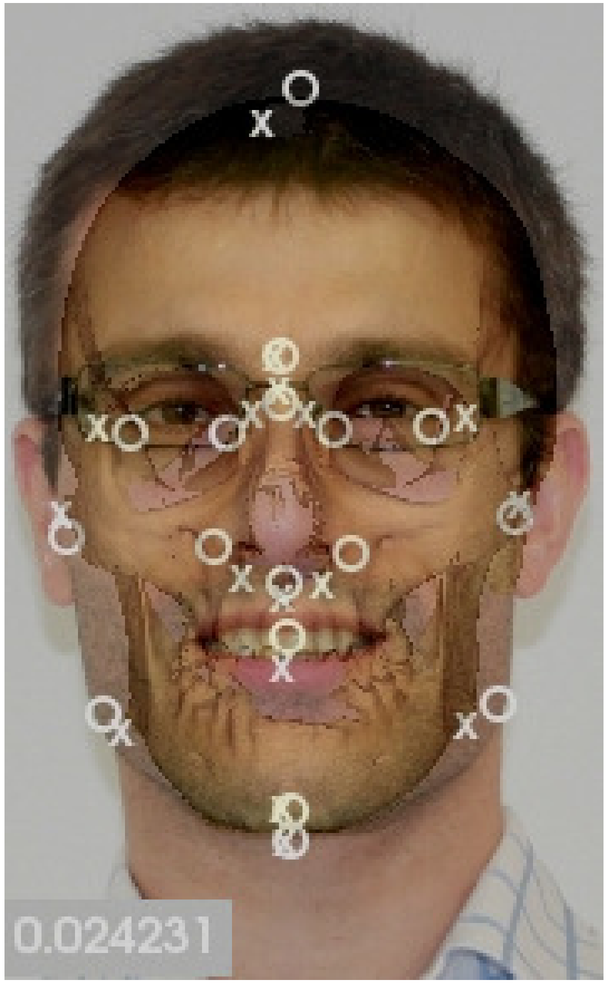
**OVERVIEW**



Best overlay (30 runs)




Worst overlay (30 runs)

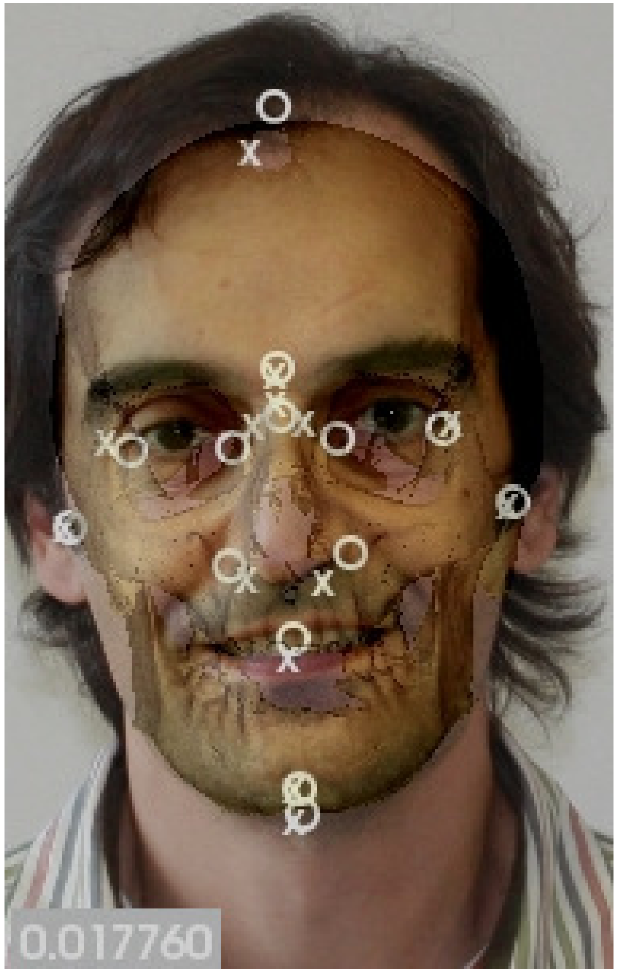


## Results: Negative cases (IV)

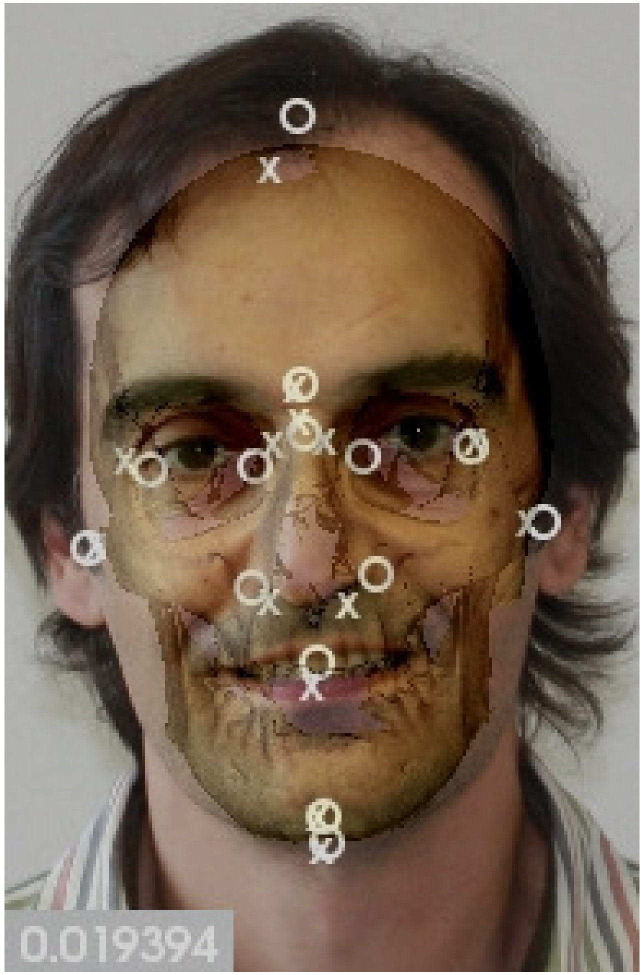
**OVERVIEW**



Best overlay (30 runs)




Worst overlay (30 runs)



- We have successfully tackled the automation of the forensic identification by craniofacial superimposition in order to assist the forensic anthropologist

- Soft Computing is suitable for this task given the intrinsic characteristics of this identification technique

- Our method has been used in the identification of a real-world case for the Spanish Scientific Police (Guardia Civil)

- A web site has been developed for the project:

  www.softcomputing.es/socovifi

## Future works

**OVERVIEW**



Improve the automatic soft computing-based SFO method developed to make it more reliable and customizable to different forensic scenarios:

- A web-based poll is being developed with forensic experts to estimate the landmark location variability
- New fuzzy distances will be considered
- The uncertainty in landmark matching will be shortly tackled
- Objective and semi-automatic SFO validation techniques will be developed (based on anthropometric aspects & computer vision)
- We aim to properly model old-fashioned cameras to tackle identification cases related to the Spain's civil war

# 6. Conclusions
## Obtained results (I)

**OVERVIEW**



### Research Projects:

- Two Spanish Research Plan projects: SOCOVIFI (2006-09) and SIMMRA (2010-12)
- An Andalusian Government Research project (2007-10)
- A recently granted European project: MEPROCS (2012-13). FP7-SEC-2011-1 (Topic SEC-2011.1.4-3 – Advanced forensic framework - Coordination and Support Actions)

### Technology Transfer:

- An international PCT patent was approved by the European Agency in February, 2011
- It will be commercialized in Mexico in 2012

## Obtained results (II): Software package

**OVERVIEW**

1. Forensic identification (FI) by craniofacial superimposition
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4. First stage: 3D skull model reconstruction
5. Second stage: Skull-face overlay
6. **Conclusions**

## Obtained results (III)



### PhD Dissertations:

- Dr. José Santamaría. University of Granada. Spain. Dec. 2006
- Dr. Oscar Ibáñez. University of Santiago. Spain. Sept. 2010

### International Awards:

- IFSA Award for Outstanding Applications of Fuzzy Technology. 2011
- EUSFLAT Best Ph.D. Thesis Award. 2011. Author: Dr. Oscar Ibáñez. Advisors: Drs. Cordón and Damas

## Main publications

**OVERVIEW**



- O. Ibáñez, et al. Modeling the skull-face overlay uncertainty using fuzzy sets. IEEE Transactions on Fuzzy Systems (2011), to appear. IF 2010: 2.683. Cat: Eng., Elec. & Electr. Ord: 15/247. **Q1**.

- S. Damas, et al. Forensic identification by computer-aided craniofacial superimposition: A survey. ACM Computing Surveys (2011), to appear. **IF 2010: 7.806**. Cat: CS, Th& Meth. **Ord: 1/97. Q1.**

- O. Ibáñez, et al. An experimental study on the applicability of evolutionary algorithms to craniofacial superimposition in forensic identification. Information Sciences 179:23 (2009) 3998–4028. IF: 3.291. Cat: CS, Inf. Syst. Ord: 6/116. **Q1**.

- J. Santamaría, et al. Tackling the coplanarity problem in 3D camera calibration by means of fuzzy landmarks: a performance study in forensic craniofacial superimposition. In IEEE Intl. Conf. Comp. Vis., 3DIM, 2009, pp. 1686–1693.

- J. Santamaría, et al. Performance Evaluation of Memetic Approaches in 3D Reconstruction of Forensic Objects. Soft Computing 13:8-9 (2009) 883-904. IF: 1.328. Cat: CS, Inf. Syst. Ord: 41/95. Q2.

- J. Santamaría, et al. A Scatter Search-based Technique for Pair-Wise 3D Image Registration in Forensic Anthropology. Soft Computing 11:9 (2007) 819-828. IF: 0.607. Cat: CS, AI. Ord: 66/93. Q3.

## Research team

**OVERVIEW**



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**18 - 22 July 2011 Aix-Les-Bains FRANCE**

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**Thank you for your attention**

# Questions ?