Chapter 5
Multimodal Genetic Algorithms for Craniofacial Superimposition

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ABSTRACT
Craniofacial superimposition is a forensic process that aims to identify a missing person by overlaying a photograph and a model of the skull. This process is usually carried out manually by forensic anthropologists, thus being very time consuming and presenting several difficulties when trying to find a good fit between the 3D model of the skull and the 2D photo of the face. This contribution aims to provide both a detailed description of the problem and the proposal of two different designs of a multimodal (clearing) genetic algorithm to tackle it. The new proposals will be tested on superimpositions for different real-world identification cases from the Physical Anthropology lab at the University of Granada in Spain, including positive and negative cases, taking the manual and the basic genetic algorithm solutions as baselines for their quality.

INTRODUCTION
Photographic supra-projection (Iscan, 1993) is a forensic process that consists of comparing photographs or video shots of a missing person with the skull that is found. By projecting both photographs on top of each other (or, even better, matching a scanned three-dimensional skull model against the face photo/video shot), the forensic anthropologist can try to establish whether that is the same person.

To do so, an accurate 3D model of the skull is first demanded. Next, the matching of two sets of radiometric points (facial anthropometric (cephalometric) landmarks in the subject photograph, and
cranial anthropometric (craniometric) landmarks in the obtained skull model is considered to guide the superimposition of the skull 3D model and the photograph (Iscan, 1993). Then, a decision making stage starts by analyzing the different kinds of achieved matchings between landmarks. Some of them will perfectly match, some will partially do so, and finally some others will not. After the whole process, the forensic expert must declare whether the analyzed skull corresponds to the missing person or not.

As can be seen, the latter procedure is very time consuming and there is not a systematic methodology but every expert usually apply his/her particular process. Hence, there is a strong interest in designing automatic methods to support the forensic anthropologist to put it into effect.

In this chapter, we will focus our attention on the second stage of the identification task, known as craniofacial superimposition. It is fundamental to adopt a proper and robust technique to align the 3D model and the 2D image in a common coordinate frame by means of image registration (IR) techniques (Zitova & Flusser, 2003). The key idea of the IR process is to achieve the transformation that places different 2D/3D images in a common coordinate system.

Evolutionary Computation (EC) comprises global search algorithms with a general purpose that use principles inspired by natural genetics to solve problems. In the last few years, there is an increasing interest on applying EC fundamentals to IR (Cordón, Damas & Santamaría, 2007; Rouet, Jacq & Roux, 2000; Yamany, Ahmed & Farag, 1999).

As said, the superimposition process is one of the most time consuming tasks for the forensic experts. Therefore, software tools for the automation of their work are a real need. Unfortunately, we can find only few proposals to automate the process and, even worse, the results are not suitable for the forensic experts. We will address the problem by extending our previous approach (Ballerini, Cordón, Damas, Santamaría, Alemán & Botella, 2007; Ballerini, Cordón, Damas & Santamaría, 2009), based on genetic algorithms (GAs) (Goldberg, 1989). These contributions aimed to automatize and drastically reduce the time of the superimposition task by means of a systematic method based on GAs. In spite of the good results achieved, there are some outcomes from our previous proposal that lead us to think we were dealing with a multimodal problem. In particular, the results analysis showed that both the standard deviation and the average fitness values of the best were too high. Hence, in this contribution we propose a multimodal GA aiming to improve the performance of the previous classical GA approach.

The structure of the chapter is as follows. The background section is devoted to introduce EC, the IR problem, the state of the art on craniofacial superimposition, and our previous GA for craniofacial superimposition. Our new proposal is detailed in the next section, where an experimental study is also described. Finally, some future works are outlined and concluding remarks are presented.

BACKGROUND

Evolutionary Computation

EC uses computational models of evolutionary processes as key elements in the design and implementation of computer-based problem solving systems (Bäck, Fogel & Michalewicz, 1997). GAs (Goldberg, 1989), based on the mechanisms of natural genetics and selection, are maybe the most known evolutionary algorithms. A GA works on a population of solutions. A fitness value, derived from the problem’s objective function is assigned to each member of the population. Individuals that represent better solutions are awarded higher fitness values, thus giving them more chances to survive to the next generation. Starting with a random initial population, successive generations are created by the genetic operators: reproduction,
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