Chapter 5
Facial Reconstruction as a Regression Problem

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ABSTRACT

This chapter presents a computer-assisted method for facial reconstruction. This method provides an estimation of the facial outlook associated with unidentified skeletal remains. Current computer-assisted methods using a statistical framework rely on a common set of points extracted form the bone and soft-tissue surfaces. Facial reconstruction then attempts to predict the position of the soft-tissue surface points knowing the positions of the bone surface points. This chapter proposes to use linear latent variable regression methods for the prediction (such as Principal Component Regression or Latent Root Root Regression) and to compare the results obtained to those given by the use of statistical shape models. In conjunction, the influence of the number of skull landmarks used was evaluated. Anatomical skull landmarks are completed iteratively by points located upon geodesics linking the anatomical landmarks. They enable artificial augmentation of the number of skull points. Facial landmarks are obtained using a mesh-matching algorithm between a common reference mesh and the individual soft-tissue surface meshes. The proposed method is validated in terms of accuracy, based on a leave-one-out cross-validation test applied on a homogeneous database. Accuracy measures are obtained by computing the distance between the reconstruction and the ground truth. Finally, these results are discussed in regard to current computer-assisted facial reconstruction techniques, including deformation based techniques.

DOI: 10.4018/978-1-60960-483-7.ch005

INTRODUCTION

In forensic medicine, craniofacial reconstruction refers to any process that aims to recover the morphology of the face from skull observation (Wilkinson, 2005). Otherwise known as facial approximation, it is usually considered when confronted with an unrecognisable corpse and when no other identification evidence is available. This reconstruction may hopefully provide a route to a positive identification. Forensic facial reconstruction is more of a tool for recognition, than a method of identification [Wilkinson]: it aims to provide a list of names from which the individual may be identified by accepted methods of identification. Since its conception in the 19th century, two schools of thought have developed in the field. To answer the question "will only one face be produced from each skull", facial "approximators" claim that many facial variations from the same skull may be produced, whereas practitioners of the other school of thought attempt to characterised the individual skull morphology to make the individual recognisable. In recent years, computer-assisted techniques have been developed following the evolution of medical imaging and computer science. As presented in the surveys in Buzug (2006), Clemens (2005), DeGreef (2005), and Wilkinson (2005), computerised approaches are now available with reduced performance timeline and operator subjectivity.

The first machine-aided methods were inspired by manual methods. Manual reconstruction follows four basic steps, (according to Helmer, 2003): Examination of the Skull, Development of a Reconstruction Plan, Practical Sculpturing and Mask Design. Translated into a computer-assisted framework, these steps are according to Buzug (2006): Computed Tomography Scan of the skull, Matching of a Soft Tissue Template, Warping of Template onto Skull Find and Texture Mapping/Virtual Make-Up. The first step aims to extract structural characteristics: for example key skull dimension for manual methods or crest-lines (Quatrehomme, 1997) for computer assisted ones. Another example is the location, automatically or by an expert of cephalometric points. Skulls and facial surfaces have been collected using a variety of 2- and 3-D methods such as photography (Stratomeier, 2005), video (Evison 1996), laser scanning (Claes, 2006), magnetic resonance imaging (Paysan, 2009; Mang, 2006; Michael, 1996), holography (Hirsch, 2005; Hering, 2003), mobile digital ultrasound scanner (Claes, 2006), computed tomography scanning (Jones, 2001; Bérar, 2006; Tu, 2007) .The second step consists in compiling all the data obtained during the investigation and listing soft-tissue depths for specified points of the face in accordance with the individual 's gender and type of constitution. This is the equivalent of the "Matching of a Soft Tissue Template" step, which aims at identifying an appropriate soft-tissue template from a database or inject in the model the estimated age, body mass index, gender or ancestry.

The third step is either the modeling of the muscles using wax, followed by the embedding of eye glass, then by the modeling of the nose, mouth and eyelids, ... or the deformation of the face template in order to fit the set of virtual dowels placed on the virtual skull on given landmarks. Interactive correction of individual parts of the face was usually necessary in the computerized reconstruction and, similarly, the wax face is reworked to achieve a natural appearance. The last step consists in achieving of a natural-looking face. In summary, the first machine-aided techniques fitted a skin surface mask to a set of interactively placed virtual dowels on the digitized model of the remains (Evenhouse, 1992; Vanezis, 2000; Shahrom, 1996). These techniques did not try to learn the relationships between bone surfaces and soft-tissue surfaces but to use the relationships described in soft-tissue depth tables (Rhine, 1980, 1984). Moreover, skilled operators were necessary in the choice of facial templates, features or sculptural distortions, thus creating a depen-