Computer Methods and Programs in Biomedicine 143 (2017) 59–65

Contents lists available at ScienceDirect

Computer Methods and Programs in Biomedicine

journal homepage: www.elsevier.com/locate/cmpb

Automatic gender determination from 3D digital maxillary tooth plaster models based on the random forest algorithm and discrete cosine transform

Betül Akkoç[a,*], Ahmet Arslan[b], Hatice Kök[c]

[a] Department of Computer Engineering, Faculty of Engineering, Selçuk University, Aleaddin Keykubad Campus, Konya 42075, Turkey
[b] Department of Computer Engineering, Konya Food & Agriculture University, Konya, Turkey
[c] Department of Orthodontics, Necmettin Erbakan University, Konya, Turkey

ARTICLE INFO

Article history:
Received 17 October 2016
Revised 23 February 2017
Accepted 1 March 2017

Keywords:
Gender determination
Feature extraction
Image processing
Random forest algorithm

ABSTRACT

Background and Objective: One of the first stages in the identification of an individual is gender determination. Through gender determination, the search spectrum can be reduced. In disasters such as accidents or fires, which can render identification somewhat difficult, durable teeth are an important source for identification. This study proposes a smart system that can automatically determine gender using 3D digital maxillary tooth plaster models.

Methods: The study group was composed of 40 Turkish individuals (20 female, 20 male) between the ages of 21 and 24. Using the iterative closest point (ICP) algorithm, tooth models were aligned, and after the segmentation process, models were transformed into depth images. The local discrete cosine transform (DCT) was used in the process of feature extraction, and the random forest (RF) algorithm was used for the process of classification.

Results: Classification was performed using 30 different seeds for random generator values and 10-fold cross-validation. A value of 85.166% was obtained for average classification accuracy (CA) and a value of 91.75% for the area under the ROC curve (AUC).

Conclusions: A multi-disciplinary study is performed here that includes computer sciences, medicine and dentistry. A smart system is proposed for the determination of gender from 3D digital models of maxillary tooth plaster models. This study has the capacity to extend the field of gender determination from teeth.

1. Introduction

Identity is a collection of the individual characteristics of a person, and is different for each person, while identification is the process of recognition of these properties. One of the primary aspects of identification is gender; through gender determination, the search spectrum can be reduced. Moreover, performing identification is often difficult following certain situations such as traffic accidents or fire-related disasters. Durable teeth can be an important source for identification.

Several studies of the identification of an individual from teeth have been conducted in the medicine and dentistry research field. Hasanreisoğlu et al. conducted a study of Turkish people, which reported that men have larger dimensions of maxillary central incisor and canine than women [1]. Zirahei et al. stated that maxillary canines are statistically significant in gender determination [2]. There are studies showing that measurements from mandibular canines are an important tool in gender determination [3,4]. In the studies conducted by Parekh et al., these authors stated that the maxillary arch width and maxillary canine teeth can show gender dimorphism [5]. The fact that men have statistically deeper and wider dental arches than women had already been presented in many studies [6–8].

In the study carried out by Al-Khatib et al. using 3D imaging, they found that gender difference was statistically significant in dental arch size [9]. In the study conducted by Horvart using 3D data, it was shown that maxillary anterior teeth had gender-based differences [10]. Shin, in his study, performed gender analysis from maxillary tooth plasters using principal component analysis and the K-nearest neighbour algorithm [11]. In our study [12], a system is suggested that can automatically determine gender from 2D tooth plaster images taken in a controlled environment.

* Corresponding author.
E-mail addresses: betulakkoc@selcuk.edu.tr (B. Akkoç), ahmet.arslan@gidatarim.edu.tr (A. Arslan), hkok@konya.edu.tr (H. Kök).

http://dx.doi.org/10.1016/j.cmpb.2017.03.001
0169-2607/

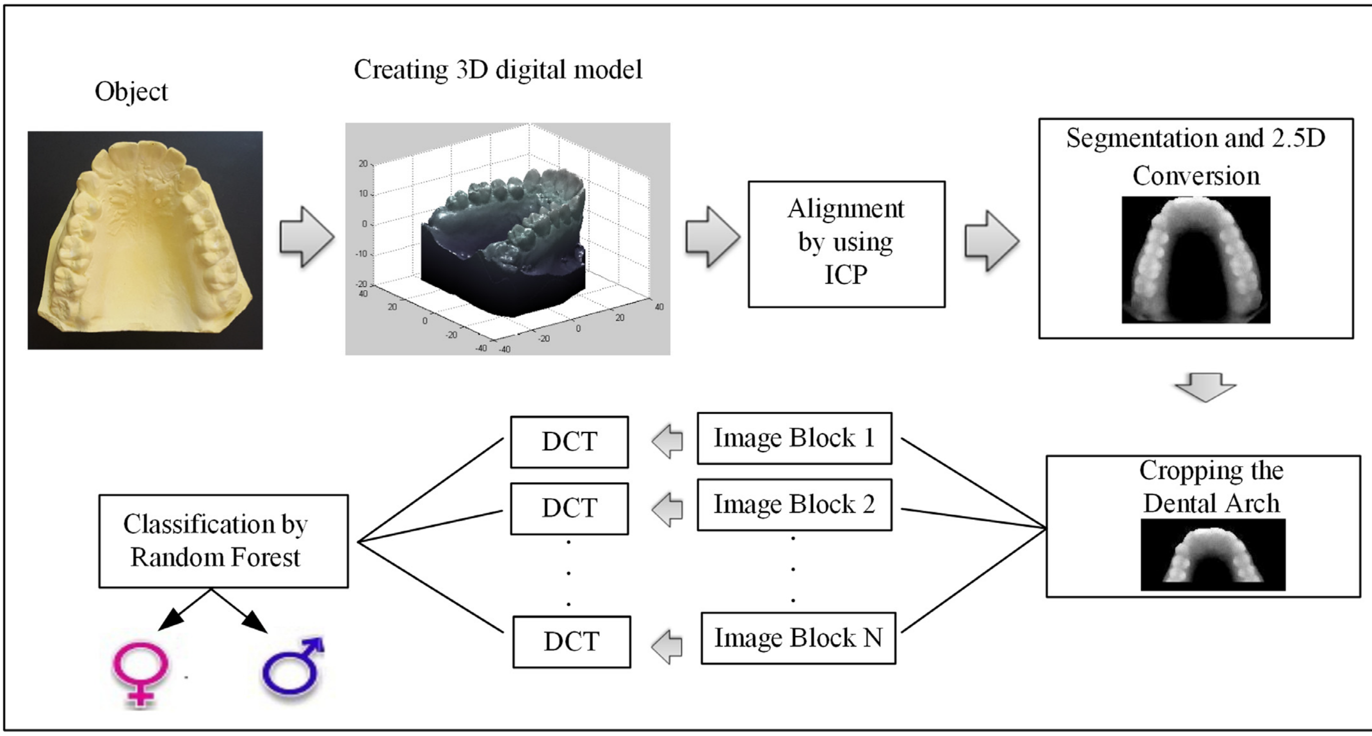

Fig. 1. Steps of the fully-automatic gender determination system.

In this paper, automatic gender determination was carried out using local DCT and the RF algorithm for 3D digital maxillary tooth plaster models. Our study contributes to the literature in the following ways:

- Automatic dental arch segmentation was carried out using 3D digital maxillary tooth plaster models; related features were automatically obtained and gender determination was performed.
- A system was devised that could adapt itself to other populations in a rapid and straightforward manner.
- A multi-disciplinary study was realised that involved computer science, medicine and dentistry.

This paper is organised as follows: the techniques of ICP, DCT and RF used in the study are explained in Section 2. Section 3 covers the steps involved in aligning the 3D models, segmentation and transforming them into depth images within the proposed system for gender determination from tooth models. Section 4 describes the data set used and the experimental results. Section 5 discusses the advantages and disadvantages of the proposed system with reference to the literature. Finally, conclusions are drawn in Section 6.

2. Materials and methods

A system was devised for the purpose of fully-automatic gender determination from the 3D digital maxillary tooth plaster models of individuals; the steps involved are illustrated in Fig. 1 below.

The first step of the system involves obtaining 3D digital models of maxillary tooth plasters. The obtained models were aligned by selecting a reference model and using ICP. Following this, the aligned models were segmented and transformed to 2.5D depth images. Local DCT was applied to these depth images, and the features to be used for classification were derived. Gender determination was performed after the obtained features had been classified using the RF algorithm.

2.1. Iterative closest point algorithm

The ICP algorithm was developed by Besl and McKay in 1992 [13]. This algorithm finds the most appropriate match between point clouds and estimates the proper rotation and translation values based on this match. The input and output for the ICP algorithm are as follows:

Input:

- $P=\{P_i\}$; aligned cloud of points, $i = 1,2,\ldots,N_p$
- $X=\{X_i\}$; model cloud of points, $i = 1,2,\ldots,N_x$

Output: (R,t); Transformation that aligns P with X (R: Rotation, t: Translation)

This algorithm consists of two steps. First, the closest distance between two point clouds is estimated. The motion is predicted based on the corresponding points in the second step.

The closest Euclidean distance between the points is estimated in the first step, as shown in Eq. (1). The cloud of closest points for the P cloud, Y, is estimated as shown in Eq. (2).

$$d(p,x) = \|p - x\|^2 \tag{1}$$

$$Y_{i,k} = c(P_{i,k}) = X| \min_{x\in X} \quad d(P_{i,k}, x) \tag{2}$$

After the closest distance is found, the rotation (R_k) and translation (t_k) values are estimated; these can minimise the squared error function of the matched points ($p_{i,0}$, $y_{i,k}$) as shown in Eqs. (3) and (4).

$$e(R_k,t_k) = \frac{1}{N_p}\sum_{i=1}^{N_p}\left\|y_{i,k} - (R_k(p_{i,0}) + t_k)\right\|^2 \tag{3}$$

$$e_k = \min_{R_k,t_k} e(R_k,t_k) \tag{4}$$