*3D surface scanning*
*facial features analysis*

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# COMPUTER SYSTEM FOR THE ANALYSIS OF FACIAL FEATURES BASED ON 3D SURFACE SCANS

Development of 3D scanning techniques provides new possibilities in supporting orthodontics diagnosis. The article describes the implementation and functions of the computer system for facial feature analysis based on 3D surface scans of patient head. The system contains functions derived form traditional facial feature analysis like landmarks acquisition, measurements of distances, inclinations and proportions of the face. Beyond, it enables the analysis of multiple scans, using the registration based on user determined coordinate system.

## 1. INTRODUCTION

Facial esthetics as a symbol of attractiveness and success plays a crucial role in everyday life [5]. Even slight distortions in facial proportions are regarded as a kind of stamp and are the main reason for beginning a therapy[1,4]. Moreover, improvement of facial esthetics is the most expected result of therapy, it is more important than reduction of other factors, connected with serious malformations in the facial and oral area of the skull, like difficulties in chewing and speaking. Therefore, analysis of the facial features is a basic examination performed intuitively by the doctor. More objective examinations use calipers or measurements made on photographs [6]. Both approaches are tiresome and inaccurate.

Development of 3D imaging provides new possibilities in supporting orthodontics diagnosis and evaluation of treatment results. The reconstruction of facial surfaces can be done using data acquired from CT and MRI [2], but as an auxiliary result can not be the motivation for performing those invasive examinations. Therefore, a 3D photograph of a patient, yielded from noninvasive laser scanning can be a very useful alternative for performing facial features analysis in orthodontic diagnosis [3,7].

Complex software designed for 3D medical imaging is usually a part of CT or MRI systems and as such it is not always available for each orthodontist. On the other, hand highly specialized computer programs designed for technical applications (e.g. AutoCad, RapidForm) can also, after some modifications, be used for medical purposes, especially for facial feature analysis[6]. But

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specialized program designed for facial feature analysis is still expected. This program should be rather simple (like most programs for cephalometric analysis) and not very expensive.

The paper develops presented in [6] aspects connected with designing methods of computerized analysis of the facial features relied on 3D surface scans. Furthermore, it deals with implementing the computer system: the list of functions resulting from traditional facial feature analysis is described, then new functions facilitating the analysis in 3D are developed, possibilities given by 3D registration of scans are exploited. The accuracy of measurements is estimated and exemplary analyses are illustrated.

## 2. ASSUMPTIONS FOR COMPUTERIZED ANALYSIS OF THE FACIAL FEATURES

The aim of the computer program is to support the system of 3D scanning of patient's face, described in [7]. Scans taken from several viewpoints, properly registered and merged [8], are, as a result of examination, delivered to a physician and also to a patient. Therefore, there is a need to enable simple visualization of the 3D scans for a patient and also to assure a tool for measurements, documentation purposes and statistical examinations for specialists. Some assumption for such a system were already presented in [6], but as this work is logical continuation, some of them will be now briefly recollected.

The starting point for designing a system is traditional analysis of the facial features, performed by specialists on the photographs. Examination is carried out in standardized position. Recommended is the emplacement of head in the Frankfurt (eyes-ears) plane. Enface, and both lateral views are considered [6]. Identified landmarks and reference lines are used for further measurements The conclusions of the facial feature analysis are based on comparison of distances and angles, and proportions. As all those entities defined for 2D analysis, now have to be redefined for 3D procedures.

Although some artists attempted to define harmonious proportions of the face (e.g. Leaonardo da Vinci, Albrecht Dürer) [1,5], but up till now there is no established norm, which can be used in the analysis of the facial features. Hence program should make it possible to define new measurement values and to perform proper statistics for analyzed population.

## 3. SYSTEM FUNCTIONS' SPECIFICATION

The prototype computer system for analysis of the facial features based on 3D scans consists of the following functions: visualization, landmarks acquisition, reference coordinate determining, measurements, database functions. These functions are briefly described below.

### 3.1. VISUALIZATION AND SIMPLE ACTIONS

The aim of the visualization module is to provide to a physician functions similar to procedures that are undertaken during the examination. Besides the rendering of surfaces of a scan application has the ability to perform simple operations like: rotation, movement, zoom in and out. There is a possibility to apply quick positioning of the scan and to rotate it by an arbitrary angle around chosen axis, which is very important in visual asymmetry estimation (fig. 1.). Additionally to examine a few of scans simultaneously, the application can display several shells. The visibility and transparency of each shell is optional. Perspective and orthogonal views are available at every stages of analysis Visualization of additional reference geometry and description notes is enabled.

Fig. 1. Rotating 25 degrees around OX axis.

Another visualization function is connected with observation of profile lines generated by intersection of a shell with a reference plane (fig. 2.).

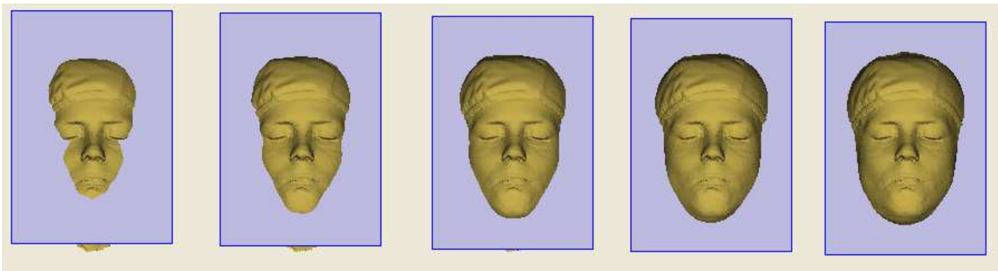

Fig. 2. Observation of profile lines generated by parallel plane to the orbital one.

### 3.2. LANDMARK IDENTIFICATION

A hundred years of cephalometry results with landmarks approach to every orthodontic analysis. The unquestionable advantage of this approach is underlying solution of homology problem. Landmarks with the same label correspond within temporal images of a single patient or within images of a group of patients. Landmarks are bases both for determining reference coordinate system and for further measurements. Actually landmarks identification can be done by a qualified user semi-automatically - by the mouse clicking. During landmarks localization other functions as moving, rotating, magnifying, quick positioning etc., are available. It is important because not all landmarks, which can be identified on photographs or directly on a patient face, are simple to be localized on 3D scans. Localization of some landmarks of face profile requires iterative adjustment while viewing direction is changed. Difficulties of some landmarks localization are the main reason why the list of landmarks can be extended when some new 3D landmarks are defined or redefined. There are also attempts to localize landmarks automatically [9]

### 3.3. COORDINATE SYSTEM AND PLANES

Defining a reference coordinate system is one of the first step in facial feature analysis. It enables quick positioning of scans – aligning then in standardized (frontal or lateral) projection (fig. 3,4.). Equally important, is also a possibility to superimposition (register) multiple scans in common coordinate system. The exact definition of the coordinate system belongs to physicians, but a program must be prepared to determine this coordinate system basing on localized landmarks. It is necessary then to implement the plane parameters calculation , basing on three or four landmarks, determine the plane perpendicular to the other, finally move those planes along chosen directions, which is connected with possibility of changing the origin of the coordinate system Creating new coordinate system requires all points of the scan to be adequately transformed. Besides, normal vectors, planes, landmarks and measurements have to be transformed as well. Transformation parameters can be calculated as angles between normal vectors of two of the fixed planes and suitable planes of the global Cartesian coordinate system. Axes of rotation are calculated as cross products of them. Finally the translation vector have to be calculated, so that intersection of the planes coincides the origin.

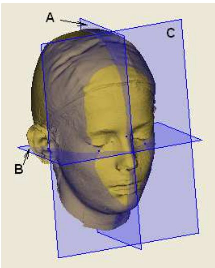


Fig. 3.Exemplary coordinate system

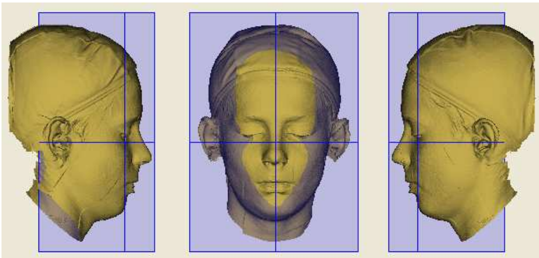

Fig. 4. Positioning of a scan

### 3.4. BASIC MEASURMENTS

Features, that can be assessed in our system are: distances between landmarks, distances between landmarks and reference planes, inclination between vectors, and between vectors and reference planes, differences between distances and proportions (fig. 5,6.). The list of measured features is open and can be easily extended by the user. When the plane correspond to the plane of symmetry then distances between even landmarks and the plane can be used to evaluate degree of the facial asymmetry.

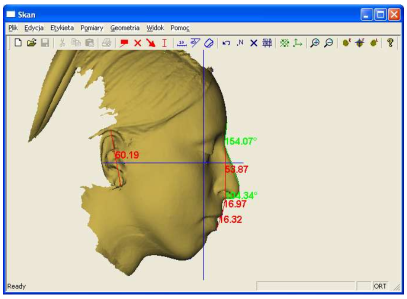


Fig. 5. Measurements

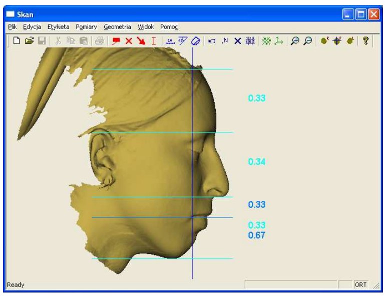


Fig. 6. Proportions of the face

### 3.5. MULTIPLE EXAMINATIONS ANALYSIS

Analysis of growth, evaluation of therapy results and intra-patient studies requires two or more scans to be compared. This comparison is available after a suitable registration of scans. The registration, used by our system, relies on the aligning reference coordinate systems, determined by the user, for each scan. After this aligning, differences between coordinates of landmarks, which have the same label in both scans, yields displacement vectors, which is a basis for further analysis of form change. Multiple scan analysis is connected with the implementation of additional functions. The visualization of registered scan needs the transparency option. Concurrent analysis of two scans requires the possibility of choosing the active scan. Each of the shells should have its own set of landmarks, measurements etc. so that it can be showed separately. Landmarks can be done only on one of shells simultaneously. That's the reason why the selection of the active scan is needed. Additionally, for each of the shells there should be available options like enabling or disabling its visibility, transparency, displaying measurements, landmarks etc. Figure 7 illustrates identified landmarks and two scans in the same coordinate system with calculated distances in mm between suitable landmarks.

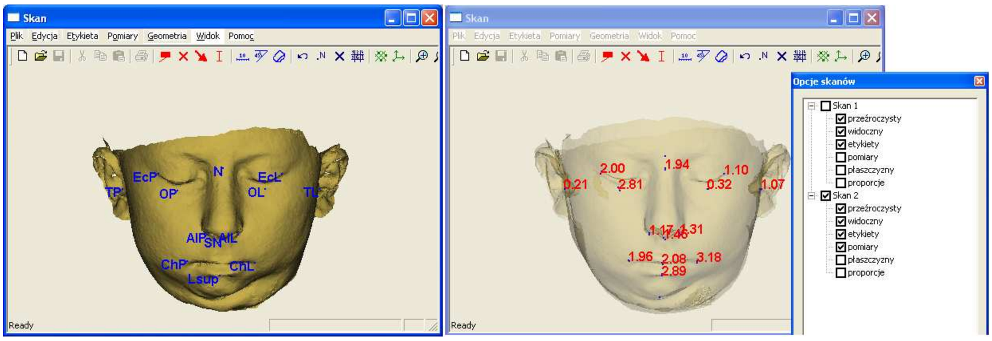


Fig. 7. Landmarks and scans in the same coordinate system with distances between landmarks

### 3.6. DATABASE FUNCTION

3d surface scans of heads are collected in the relational database. It also stores such data as dates of the examinations, patients' personal details, names and descriptions of the landmarks, coordinates of identified landmarks, lists of measured features, measurements and data, which are needed to recreate coordinate system.

## 4. ACCURACY AND EXAMPLARY ANALISIS

The accuracy of the measurements was estimated by comparing distances between landmarks, which were detected on the same scan in RapidForm and in our system (fig. 8.). Mean square differences is 0,53mm. Discrepancies may be caused by imprecise identifying landmarks, and simplification of the scan mesh. The average distance between original scan and decimated with reduction ratio 20% is about 0,01mm. Standard deviation is 0,06mm. Figure 9 illustrates the value of deviation between not simplified and simplified mesh of the scan.

Exemplary analysis is showed on the figures 5, 6 and 7. In the fig. 5. measured distances and angles are illustrated. Fig. 6. shows the proportions of the face, and fig. 7. shows differences between two examinations.

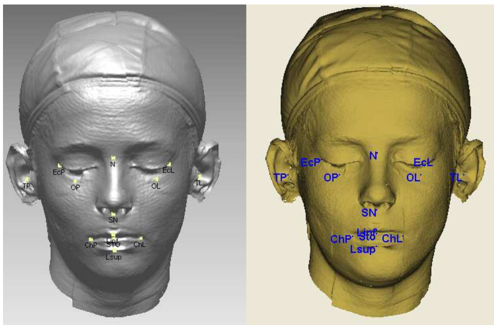


Fig. 8. Identified landmarks in RapidForm and our system

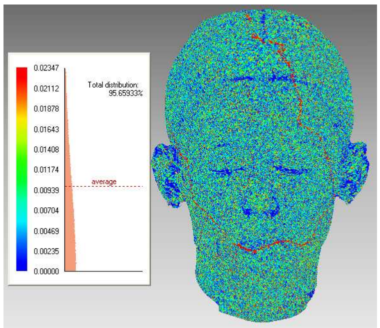


Fig. 9. Shell deviation for the simplified scan

## 5. CONCLUSIONS

The presented article describes the functions of computerized system for facial features analysis, based on 3D surface scans. Beyond the functions derived from and meeting the habits of prevailing orthodontic analysis, it provides new functionality connected with visualization and analysis of 3D structures, which results the possibility to establish new techniques and methods for orthodontics purposes. The main advantage of such a program is its simplicity and it's specialization for orthodontics analyses like coordinate system determining and quick positioning. Gathering landmarks and measurements makes it possible to create statistics. The program is being tested by specialists now, and will be used in a research project, which is aimed at studying growth norms for the population of children in Silesia.

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