

# ORTHODONTIC DATA ACQUISITION AND VISUALIZATION

*P. Dvořák\*, A. Procházka\*, M. Kašparová\*\* and T. Dostálková\*\**

(\*) Institute of Chemical Technology, Department of Computing and Control Engineering

(\*\*) 2nd Medical Faculty, Charles University, Department of Paediatric Stomatology

## Abstract

The three-dimensional mathematical modelling is a very efficient tool for the volumetric objects modelling and analysis. The paper presents the application of these methods in orthodontics as it is able to replace standard plaster casts by images of scanned objects. Geometric morphometrics represents a new approach to multi-dimensional data modelling both in medicine and engineering. Data acquisition enabling to transform physical model to its three-dimensional mathematical representation include the use of 3D scanners, multi-camera systems but also special methods based on multi-pictures composition. The paper is devoted to one of these methods, calibration of the three-dimensional mathematical model and possibilities of resulting surface visualization. The goal of such a modelling is in objects detection and classification, shape determination and evaluation of important measures. The paper describes the technique of data acquisition and export of resulting data into the MATLAB environment. The proposed algorithm is devoted to the three-dimensional data interpolation and selection of specific object components for their further analysis and processing. The graphical user interface is proposed to simplify the whole process and to present the surface plot of the dental arch.

## 1 Introduction

The tree-dimensional modelling is very important in many technical and biomedical areas providing significant tools for efficient visualization and numerical analysis of space objects. The paper is devoted to analysis of such methods in orthodontics [3, 4, 2, 7] and analysis of the dental objects. Fig. 1 presents the triangular surface plot of the dental arch studied further.



Figure 1: Result of the dental arch mathematical computer modelling using the triangular surface plot

## 2 Orthodontic Data Processing

Dental casts play an important role in the diagnosis and treatment planning in prosthodontics and orthodontics. Although plaster casts present golden standard in treatment planning, not only in orthodontics, replacement of plaster dental casts can be advantageous especially in saving space in storage areas, efficiency of having patient records accessible through computer, in possibility to share the models with other specialists needed during the therapy and possibility of accurate measurements and use of diagnosis setups.

With the present-day knowledge, study cast analysis as a whole is often considered to have a limited diagnostic value. A new method of computer imaging and measurements on a dental stone cast is a ubiquitous tool in dentistry and aids in the recording of precise information required for treatment as well as its evaluation. It can be used in forensic dentistry too.

## 3 Data Acquisition

The latest 3D scanning technology is used for data acquisition. It allows dental technicians to quickly, precisely and easily scan dental models. In the Motol University Hospital, they use three-dimensional Sirona's inEos Blue desktop scanner with innovative Bluecam technology, which utilizes short-wavelength visible blue light to facilitate flexible recording options, resulting in substantially faster scanning and precise 3D digital models. inEos Blue enables better control to determine what we want to record, allowing us to process 3D digital models with unprecedented precision and speed. During the scanning process, we utilize an automatic image capture function that allows free movement of the dental model in any direction, providing complete control of the angle of the scan. It is very important to keep a few basic rules when scanning the model. Fig. 2 presents the main problem of a badly scanned model. The model on Fig. 2 was scanned in wrong angles, some areas of the model were not captured and they had to be substituted by calculated vertical areas. These areas are marked by red color.

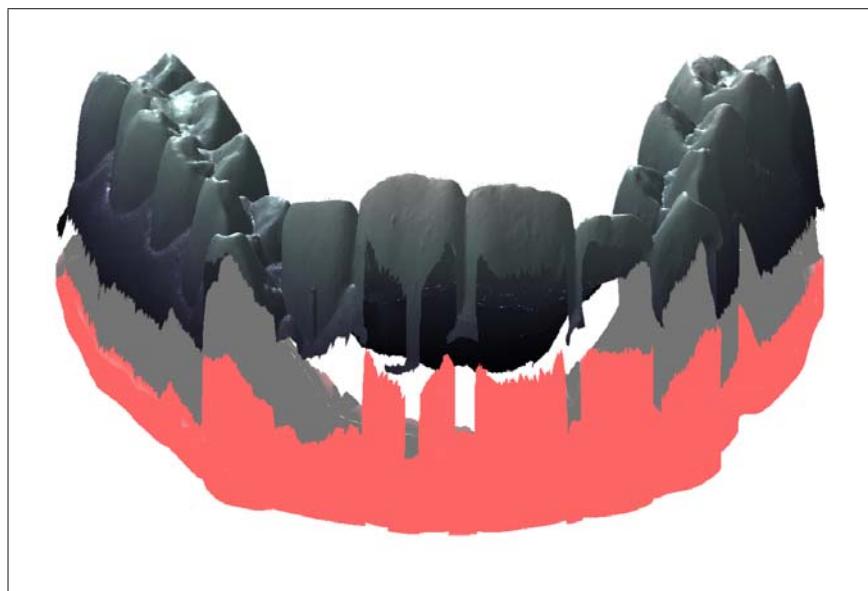


Figure 2: Missing areas of the model caused by bad scanning

Scanner inEos Blue can export scans in the STL (stereolithography) file format, giving labs the flexibility to work with the files in third party design software. STL files contain a list of triangles (defined as sets of vertices), which are used for rapid prototyping and modeling 3D objects. It is possible to load the exported STL file to MATLAB software. After successful loading of the STL file to MATLAB, we get these variables:

- $v$  - contains the vertices for all triangles [ $3*n \times 3$ ]
- $f$  - contains the vertex lists defining each triangle face [ $n \times 3$ ]
- $n$  - contains the normals for each triangle face [ $n \times 3$ ]
- $c$  - is optional and contains color rgb data in 5 bits [ $n \times 3$ ]
- $Stitle$  - contains the title of the specified stl file [1 x 80]

## 4 Three-Dimensional Data Interpolation

The two-dimensional interpolation between observed values for non-uniform distribution of their independent variables is a common problem both in engineering and medicine. Fig. 3 illustrates such a situation for simulated data values forming triangles in the space. These triangles resulting from the Delaunay triangulation [6, 1] presented in Fig. 4 form the basis for interpolation of these values in the given region. It is obvious that this triangulation have different solutions and the selection of the optimal set of triangles form a separate problem [1] closely related to Voronoi polygons.

There are various interpolation techniques that can be used to obtain numerical values of the model surface coordinates including

- the simple nearest neighbour method providing results in Fig. 11 for the given set of simulated values
- the linear interpolation with selected results in Fig. 12
- the cubic interpolation with selected results in Fig. 12 as well

While the nearest neighbour method uses the Euclidian distance to find the nearest observed value to each point in the defined by coordinates in the  $xy$  plane further methods provide much better results and allow better visualization and both subjective and numerical analysis of the object surface.

Linear interpolation is based upon the definition of the plane defined by each triangle defined by points  $P_1 = [x_1, y_1, z_1]$ ,  $P_2 = [x_2, y_2, z_2]$ ,  $P_3 = [x_3, y_3, z_3]$ . For each set of such values it is possible to find coefficients of relation

$$Ax + By + Cz + 1 = 0 \quad (1)$$

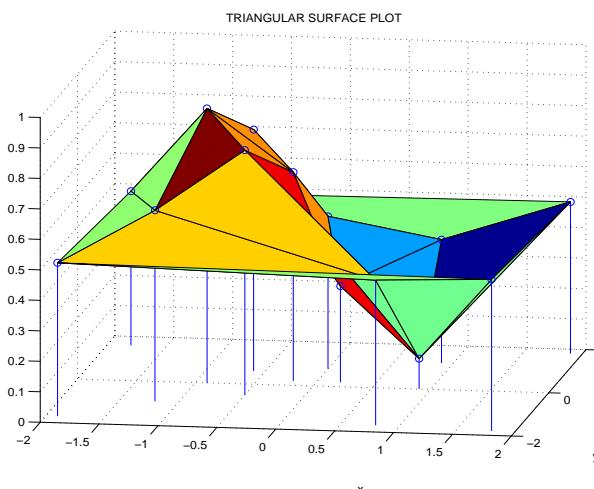


Figure 3: The simulated data set and its triangular surface plot related to the Delaunay triangulation

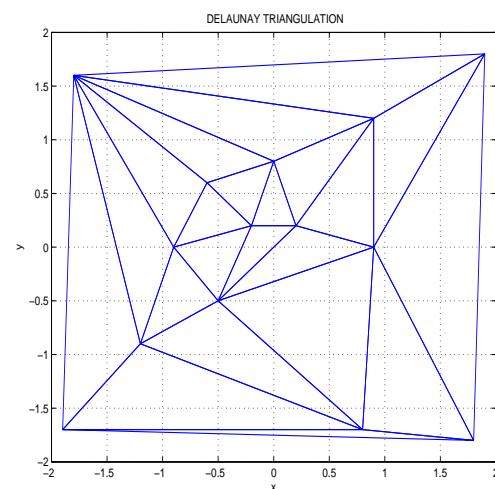


Figure 4: Delaunay triangulation and the interpolated area segmentation for the given data set

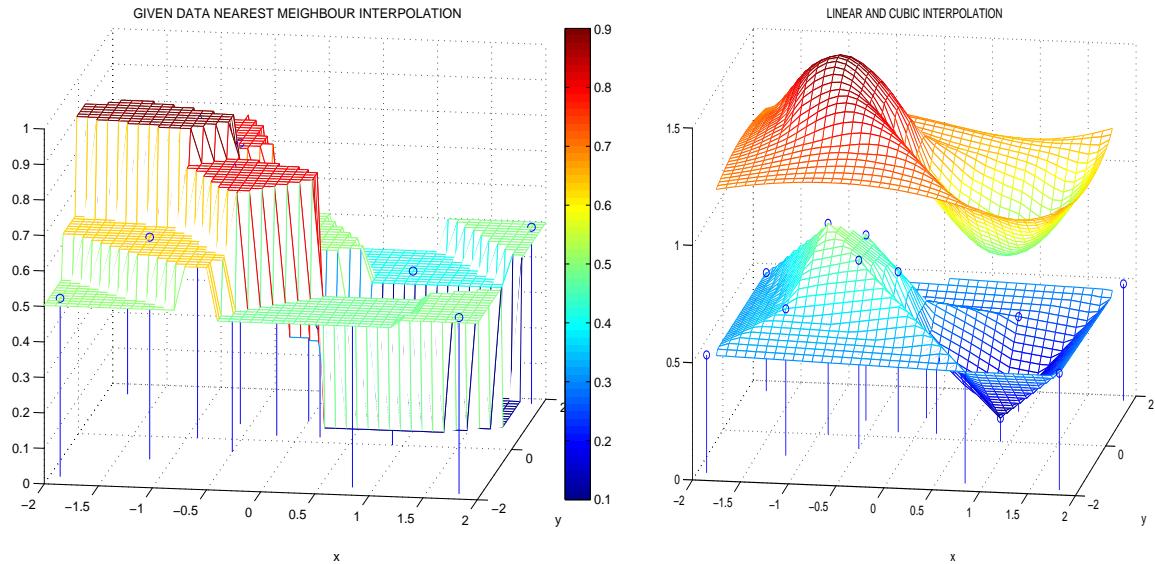


Figure 5: Simulated data distribution and their nearest neighbour interpolation

Figure 6: Linear and cubic interpolation of the simulated data set

defining the plane and the to find the z-coordinate for any point within this triangle. This methods is presented in Fig. 7.

Cubic interpolation provides better results of interpolation between points  $P_1 = [x_1, y_1, z_1]$ ,  $P_2 = [x_2, y_2, z_2]$ ,  $P_3 = [x_3, y_3, z_3]$  and  $P_4 = [x_4, y_4, z_4]$ . In the simplest case it is possible to find coefficients of relation

$$z = A \cdot (x - Sx)^2 + C \cdot (y - Sy)^2 \quad (2)$$

and the to find the z-coordinate for any point within this area according to results Fig. 8.

More sophisticated methods use the spline interpolation [5] but in each case it is necessary to solve problems of connection between separate surface areas to have smooth surface enough and to solve problems of extrapolation in some cases as well.

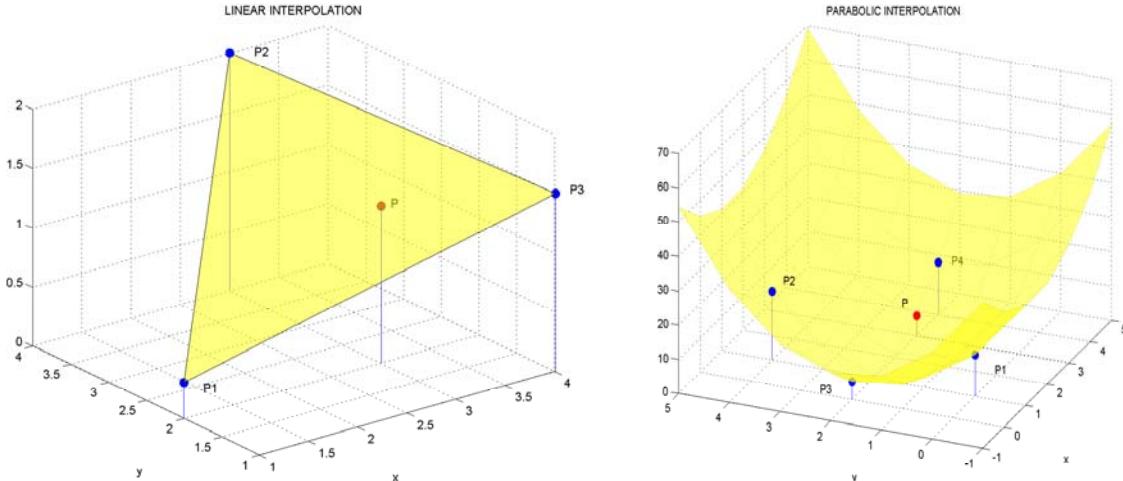


Figure 7: The plane defined by values  $P_1, P_2, P_3$  and the localization of value P

Figure 8: The parabolic surface defined by values  $P_1, P_2, P_3, P_4$  locating point P

## 5 Results of Data Visualization

Selected objects are presented on Figs 9 and 10 using the specified *colorbar* to define the space distribution.

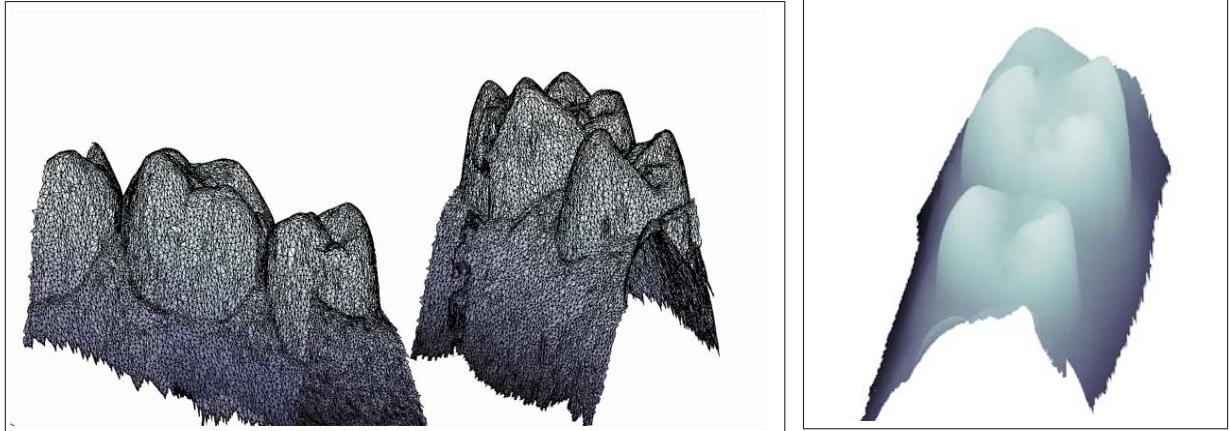


Figure 9: Triangular surface plot of the selected part of the dental arch

Figure 10: Shadow surface plot of the molar tooth

## 6 Conclusion

For further research of dental arch models it will be necessary to use the mathematical interpolation of the data set from STL file (which contains  $x$ ,  $y$ ,  $z$  coordinates of triangle vertices). There are various interpolation techniques that can be used to obtain numerical values of the model surface coordinates. The suitable one is the cubic interpolation method, which provides sufficiently smooth surface in appropriate time.

Figs 11 and 12 present results of cubic interpolation applied to selected details of model under the study. The cubic interpolation of the dental arch data set is much more suitable for further calculations and statistical evaluations of model parameters in comparison with original data obtained in the STL format.

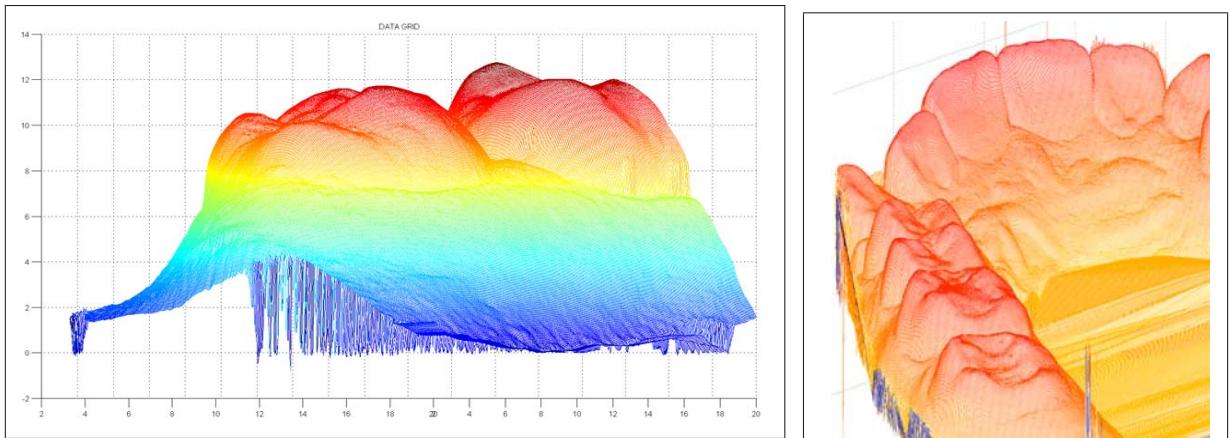


Figure 11: Cubic interpolation of the model (detail of molar tooth)

Figure 12: Cubic interpolation of the model

## 7 Acknowledgements

The work has been supported by the research grant of the Faculty of Chemical Engineering of the Institute of Chemical Technology, Prague No. MSM 6046137306.

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Ing. Petr Dvořák, Prof. Aleš Procházka  
Institute of Chemical Technology, Praha  
Department of Computing and Control Engineering  
Technická 1905, 166 28 Praha 6  
E-mail: Petr.Dvorak@vscht.cz, A.Prochazka@ieee.org

Magdaléna Kašparová and Tatjana Dostálková  
The 2nd Medical Faculty, Charles University  
Department of Paediatric Stomatolgy  
V Úvalu 84, 150 06 Prague 5, Czech Republic  
E-mail: Magdalena.Kasparova@fmotol.cz, Tatjana.Dostalova@fmotol.cz