IBR (Image Based Rendering) complex for virtual simulation dental-jaw system

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Abstract

Development virtual systems for biomechanic simulation of anatomic organs is an interesting and promising direction in development diagnostic and prognostic medical complexes. Applicability of such systems depends on ability to provide fast, exact and rather cheap from the point of view of computing expenses generation of a computer model of a physical object (system) and its visualization in the form of the interactive three-dimensional drawing. To solve the above problems, it is convenient to use methods for the reconstruction of complicated, high specified three-dimensional scenes by processing of data flows received from sensors. Such methods have the general name Image Based Rendering (IBR) [1]. The presented work covers the questions connected with the diagnostic virtual simulation of the dental-jaw system.

1. INTRODUCTION

Development of high-grade program for simulation modeling dental-jaw system of a patient has base value for the diagnostics and treatment of an orthopedic pathology. Reception of exact dynamic imitation dental-jaw system is directly connected with the solution of quality problems of the functional analysis of occlusion and articulation.

Movings of the bottom jaw have a complicated organization and trajectory. Analogue diagnostic devices (Fig. 1) do not quite precisely simulate topology of interdental mutual relations, taking into account all individual factors in an oral cavity of the patient, because they represent the dynamic (biomechanical) processes arising at articulation too simplistically.

Such devices (systems) do not allow the researcher to consider excursions of teeth in the dental-alveolar ligament, resulting from the application to teeth of forces acting in various directions because in similar simulating systems, plaster models of the jaws which physical properties are not equivalent to properties of object of the original are analyzed.

At the same time, those skilled in the art are needed in objective knowledge of contacts between teeth(Fig. 2). Disputes concerning number and an arrangement of the contact sites necessary for maintenance of stability of a separate tooth are proceed(Fig. 3). The followers of some occlusion concepts consider that it is necessary to adhere to specific model of plural contacts for each tooth [2].

In case of premature contacts of dental tubercle slopes, displacements of teeth, the absence of dental tubercles or their irrational inclinations, normal dental tubercle-fissure rations and their stability are broken, i.e. the balanced occlusion is broken.

Such infringements have an effect on neurovascular mechanisms of periodontium. However, the realization of the approach of modeling specific plural contacts for each tooth assumes accuracy of studies of gnathologic positions, which in practice is not quite provided with analogue devices.

Figure 1: A general view of the analogue diagnostic system (regulated articulator) with plaster models.

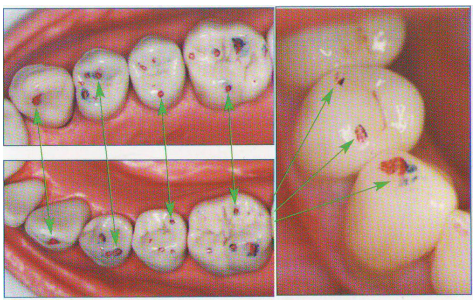

Figure 2: Contact points on the teeth.

2. COMPUTER DESIGN

In computer modeling, including for creation of virtual interactive dynamic models of material objects (systems of objects), the digital data flows containing data on physical objects are used.

In a broad sense, a computer model includes all knots, final elements, properties of a material, real constants, boundary conditions depending on transformation of a spatial configuration of an object (system), which are used to display (simulate) a physical system. Design of a "virtual" model in this context implies the visualization of a mathematical model of the real material object (system) in the form of the interactive computer three-dimensional drawing.

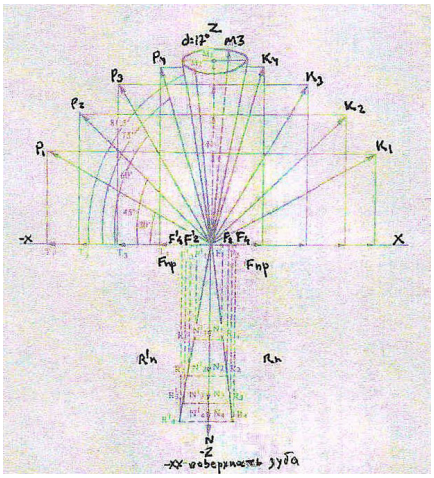

Figure 3: Scheme of actions of chewing loading on occlusive surface of a tooth.
P, K, M traction forces: N1, N2, N3, N4 normal components; F1, F2, F3, F4 friction forces; R1, R2, R3, R4 full reactions (Rn). [3]

In the simulated system, an auxiliary artificial model (not the interesting object itself), which is in some objective conformity with a cognizable object is directly studied, capable to replace it in certain relations, giving the information on the object, when it is studied, that is, as well as in case of any modeling, the computer model describes the studied object not completely. However, the logicality and formality of computer models allow to reveal the major factors defining properties of a studied object, in particular, to investigate the response of a modeled physical system to alteration of its parameters and initial conditions [4].

The method of the imitation of dental-jaw system with the use of IBR methods allows:

- optimizing a process of the generation of a dynamic model since there are messages for economy of resources, i.e. the preliminary analysis of calculations with known analytical decisions or the received experimental data is not needed;
- achieving the maximum conformity of geometrical, spatial parameters of model during the different moments (phases) of changes to parameters of a physical prototype.

Such approach is characterized in that it offers the consumer (dentist, dentalprothetist) the possibility to carry out studies of a virtual biomechanical model of a dental-jaw system of an individual patient by computer processing the information and interactive interaction with such an object, including possibilities of input of experimental data for the subsequent calculations on the model. Accuracy of the calculations is provided due to:

- resolving possibilities of scanners and sensors which fix geometrical parameters of the original occlusive field and control points of the occlusion;
- inclusion model calculations of parameters of excursions of teeth, when loadings act in various directions, in the system;
- computing possibilities of vector geometry.

Carrying out research under the project Design of Virtual Dentofacial Models for the Purpose of Studying the Development of a Pathology and Selecting Procedures of the Treatment of Stomatologic Patients (the Russian Federal Property Fund, 07-07-00373) (Fig. 4) [5], our group has come to a conclusion about the possibility to design the system to solve the problem of designing a virtual biomechanical model of dental-jaw system in an individual patient by combining several devices of "gathering of the digital information", registering different physical phenomena [6].

This technical decision is protected by Russian useful model patent 80111, 27.01.2009, Hardware-software System of the Functional Analysis of Occlusion and articulation.

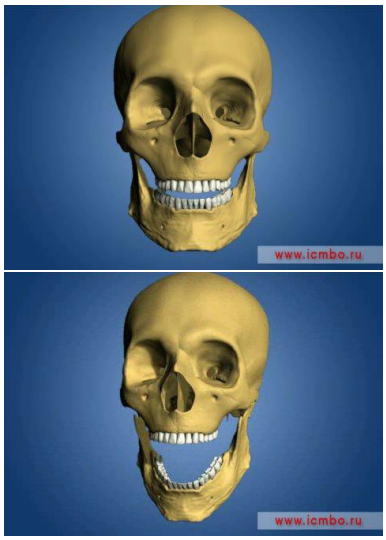

Figure 4: The screen shots of the test three-dimensional model of the skull, simulating articulation movements. The model is constructed on the basis of results of scanning of an anatomic preparation followed by the subsequent graphic processing.

3. IBR SYSTEM FOR 3D DENTAL-JAW CONTENTS

The aim of the work is provide a simulating system which allows increasing the accuracy of the functional analysis of occlusion and articulation.

The primary purpose of the hardware-software complex is the virtual simulation of the dental-jaw system of a patient for carrying out computation experiments to analyze system functions: research of the response of the modeled system to alteration of its parameters and initial conditions, comparison of results of the modeling to real behavior of the object-original.

The working out essence consists in transferring the digital information about defined gnathologic positions on a polygonal grid of three-dimensional model of the dental-jaw system of the patient. Using the data synthesized in such a way, and by means of the module of the solid-state modeling, it is possible to calculate and visualize a trajectory of movements of the bottom jaw at chewing, to define arising load on a teeth, to reveal contact points and fields on occlusive surfaces of teeth, taking into account excursions of teeth in the dental-alveolar apparatus.

During the development of the system used methods of mathematical modeling and statistical analysis of the data, three-dimensional computer visualization and technology of a virtual environment.

In our work, the method of mathematical modeling is used to calculate articulation movements. Processing digital data on co-ordinates of control points of occlusion fixed at certain movements of the bottom jaw is performed in the coordinate system of the three-

dimensional model.

The statistical analysis of the data was applied to research results of a series of laboratory-clinical tests in which result the rational sequence of actions for the determination of the gnathologic data which are necessary for the construction of a biomechanical model is revealed.

Both of the above methods make a basis of the system for the construction of the virtual simulation dental-jaw system of the patient.

The considered simulating system(Fig. 5) includes a block of digital data acquisition and means for the organization of the integrated information environment uniting all processes of life cycle of the useful model.

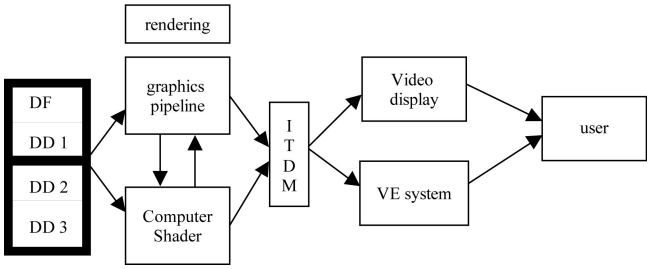

Figure 5: The schematic diagram of the basic stages of a technological chain of the construction of virtual simulation of the dental-jaw system with the use of IBR methods.
wherein:
DF flows of digital data on occlusive field geometry;
DD1, DD2, DD3 flows of digital data on occlusion points in different phases of articulation;
ITDM interactive three-dimensional dynamic model;
VE system a virtual environment system (an additional way of the interactive interaction with the model).

Since it is a question of virtual modeling a dynamic system, it was needed to solve the questions connected with the adaptation of the visualization technology under conditions of the given technological complex(Fig. 6).

A format of storage of results of the laser scanning STL had been chosen as the basic format for three-dimensional models. The specification of the format STL does not support entry of one top in several polygons, therefore at loading of the data the model is automatically converted from format STL into an indexed format.

To further form the texture co-ordinates fixed by sensors, their exact imposing on complex geometry of the three-dimensional model received as a result of scanning, some methods are approved.

Figure 6: Intermediate technological result: imposing of "a coordinate texture" on the test model.

The library of three-dimensional modeling OpenGL had been chosen as the base technology for the visualization module. The technology is the cross-platform decision and is optimized for the purpose of technical modeling. Further, the possibility to use the graphic API OpenGL Volumizer is considered. OpenGL Volumizer provides the interface of high level for OpenGL, resolves hardware rendering of the volume data to several GB [7].

4. CONCLUSION

he modern tendency of the application of information technologies in stomatology makes possible to predict rather fast development and introduction in practice of a method for studies of the dentofacial system, which method is based on processing digital data flows received from sensors so that the user can analyze a system function on the virtual simulator [8]. Principles of such information-modeling environment assume a considerable computing resource and actual reliability in comparison with analogue imitating devices.

5. REFERENCES

[1] Mc.Millan L.: An Image-Based Approach to Three-Dimensional Computer Graphics, Ph.D. Dissertation, UNC Computer Science Technical Report TR97-013, University of North Carolina, (April 1997).

[2] Klineberg I., Jagger R. G.: Occlusion and Clinical Practice: An Evidence-Based Approach, p. 160 ISBN-10 0723610924 (April 2004).

[3] Swartc A.D.: Biomechanics and occlusion of teeth. Medicine, p. 208, ISBN 5-225-01598-0, (1994). (in Russian)

[4] Novik I.B.: On the philosophical issues of cybernetic modeling. Znaniye, (1964). (in Russian)

[5] Lukyanov A. E., Klimenko S. V., Bobrov A. P., Smirnov A. G.: The method of scientific visualization as a tool for studying the development of maxillofacial pathology system and predicting the effects of medical interventions. Institute of Stomatology.-3(36), p.120-121, (2007). (in Russian)

[6] Smirnov A. G., Bobrov A. P., Kazansky I. P., Bulgakov M. G.: Hardware-software technique for the analysis of occlusion and articulation: general outlines of solutions. Journal "Research in Russia" ISSN 1819-4192.- 101/081013, p. 1110-1116, (2008). (in Russian)

[7] OpenGL Volumizer `http://www.sgi.com/products/software/volumizer/`

[8] Smirnov A. G.: Computer modeling in stomatology. Institute of Stomatology.-1(30), p.24-25, (April 2006). (in Russian)