# A Computer-Aided Visualization System for Orthodontic Treatment

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***Abstract*— This system present a feasibility of computer-aided diagnosis, planning and simulation for orthodontic treatment. In the Visualization Toolkit (VTK) and Microsoft Foundation Classes (MFC) integrated environment, a flexible, friendly and functional interface for orthodontic treatment was designed. The methods of how to integrate VTK and MFC in different system are described, and the three-dimensional model of the dentition is reconstructed by using marching-cubes (MC) algorithms. Finally, the three-dimensional model for rendering and interaction is also introduced.**

***Index Terms*— Computer-aided; visualized system; Orthodontics.**

## I. INTRODUCTION

In orthodontic treatment, the treatment diagnosis and planning are two significant factors. Conventionally, in clinic, orthodontists performs treatment diagnosis and planning by measuring and operating dentition on plaster casts. The plaster cast based treatment strategy is costly, time-consuming and the accuracy is not satisfying. In addition, the plaster cast provides only the model of the crown part and misses the root part which is essential in orthodontic treatment. Currently, dental computed tomography (CT) imaging has been increasingly employed to orthodontic treatment as it provide clinicians through information of tooth. Using the dental CT images, three dimensional (3D) digital tooth model can be reconstructed. Orthodontists can perform treatment diagnosis and planning through manipulating the 3D digital tooth model in a computer-aided visualized system interface, thereby realize digital treatment strategy, which has the advantages of high efficiency and accuracy. However, there are only few such computer-aided visualized system for orthodontic treatment [1-4]. Existing commercial computer-aided medical system including MIMICS (Materialise NV, Belgium), 3D DOCTOR (Able Software, Lexington), and Invivo5 (Anatomage, California) cannot reconstruct 3D dentition model effectively nor provide clinists 3D visualization interface of orthodontic treatment diagnosis and planning.

In this paper, a 3D computer-aided visualization system for orthodontic treatment was developed. This system has integrated these functions including two dimensional (2D) CT images displaying, 3D digital tooth model reconstructing, rendering, interaction and measuring. Using this system, orthodontists can perform orthodontic treatment diagnosis and planning, and arching wire designing in a visualized interface. The 3D digital tooth model was reconstructed from CT images applying the method proposed in our previous work. Model rendering, interaction and measuring were implemented based on visualization toolkit (VTK)[5]. Visualized interface of the system was developed based on Microsoft foundation classes (MFC).

## II. CLINICAL REQUIREMENT AND SYSTEM FUNCTION ANALYSIS

### A. *Doctor-patient communication*

Orthodontist-patient relationships have significant effects on the success of orthodontic treatment. Orthodontic treatment a science of great flexibility, which malocclusion can vary greatly, each patient has different requirements for appearance. Orthodontic treatment which produce the perfect occlusal relationship does not necessarily make the patient the best satisfaction. Orthodontic doctors focus on the function of treatment with a subjective evaluation. Once the aesthetic perception of orthodontists inconsistent with the patient's perception, the results may make it difficult for patient to accept. Even function improved, patients may ultimately not satisfied with the results of the information.

Orthodontics treatment requires not only the implementation of the doctors who make the patients' teeth, dental arch,

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jaws, and the relationship between cranial and maxillofacial coordinated, but also to meet the psychological requirements of patient and family. So orthodontists when making treatment plan should fully understand the patients understanding of facial beauty and expectations of planning result, considering facial beauty and favorable occlusal relationships comprehensively, so as to obtain treatment outcomes of both patient and physician satisfaction.

This computer-aided visualized system with a flexible, friendly and functional interface can provide two-dimensional sheet series and realistic three-dimensional images for orthodontic treatment. The orthodontist can use computerized imaging to predict the outcome of treatment, so they now has a powerful and reasonably accurate communication tool to compare and contrast for the patient the potential outcomes of various treatment alternatives. Computer imaging to simulate the probable treatment outcomes can facilitate communication about these alternatives by eliminating misconceptions. Through this system, the patient can be intuitive to observe their teeth and understand the nature of their conditions and the proposed treatment plan or procedure to be performed that will be used to improve their condition. Patients can negotiate with the orthodontist to choose their own satisfactory treatment options.

This system provides a platform for the acquisition and analysis of images that the orthodontist can use to reposition the patient before treatment.

A scanner is described which acquires the CT images, then this interface can present three orthogonal planes (sagittal plane, coronal plane, transverse plane). Blend slider is used to superimpose one image over another with consideration to the image's scales and positional alignments. The blend slider supports dissolving from one single image to the other to help orthodontist get information from different plane.

When acquiring two-dimensional images series of the dentition, they can be registered to each other to reconstruct a complete three-dimensional virtual model of the dentition. And obtain dentition position in the three-dimensional coordinate system. Individual tooth objects are also obtained from the three-dimensional model.

With the three-dimensional model, orthodontist can observe patients teeth and how they arranged together from any angle. This treatment planning system provides virtual simulation tools that allow orthodontist to move and rotate dental model in the three-dimensional visualization interface. Orthodontist plan, adjust, simulate the morphology of the patient's dentition and make the most effective plan to meet patients unique treatment needs.

### *B. Computer-aid treatment planning*

Orthodontic treatment planning is defined as determining a orthodontic treatment plan to quantify the whole process, including three aspects: 1) CT image input stage of processing2) Orthodontists on treatment options include dental crowding parameters, tooth movement and direction of movement of data requirements and their implementation3) Plan confirmation and the inspection during the implementation of the program and the error analysis, etc.

Obviously the planning process should be a continuous process for the entire treatment process to quantify and optimize. Obtaining the patient's anatomy and the input data is one of the main involved the treatment plan. Data acquisition mode and its integrity directly affect the design of treatment. Importation and reconstruction of three-dimensional CT data of the anatomical structure in the coordinate system, determine the relationship between each of the teeth and dental. Orthodontist gets dental crowding parameters by observing and calculating, then determine whether the patient clinical tooth extraction is needed. In the process of orthodontic planning, orthodontist move and rotate dental model in the three-dimensional visualization interface to plan, adjust, and simulate the morphology of the patient's dentition. Simulate the teeth straightening process to design the treatment plan, and tailored design braces for patients.

### *C. Appliance design*

Orthodontic treatment system is both a complex computer-aided measurement and analysis system that need a solid oral medical knowledge and extensive clinical trials. Therefore in the process of system research and development, for the realization of humanity, intelligent operation, and other functions, software development using the object-oriented development method, to the module partition must be clear and can reflect the needs of users. Function Divided into import/export, three-dimensional reconstruction, orthodontic planning and archwire orthodontic and parameter design, and a low degree of coupling between the levels, can reduce the interaction between modules to ensure the smooth progress of the system design.

## III. VISUALIZATION SYSTEM DESIGN AND IMPLEMENTATION

### *A. User interface design based on VTK and MFC*

VTK, which has powerful functions of image processing and data visualization, is widely used for developing a 2D or 3D visualization system in the medical field. It is an open-source, portable, object-oriented software system for 3D computer graphics, visualization, and image processing [5]. However, as VTK lacks of practical and flexible user interfaces (UI), other graphical user interface (GUI) toolkits is needed to help VTK to construct a practical system for 3D data visualization or image processing. MFC is a complete set of c++ application frameworks, and has a powerful UI development ability, thus is widely used to develop professional software. Considering the advantages of VTK and MFC, the computer-aided visualization system for orthodontic treatment introduced in this paper was developed based on the combination of the two programming.

This system is based on a MFC single document engineering [6]. In the UI of the system, there are four sub-windows to display images or graphics, i.e. one 3D dentil model rendering window and three 2D image display windows to display CT images in sagittal plane, coronal plane, and transverse plane respectively. Using a separate class to encapsulate three-dimensional reconstruction. Due to the program structure of the three orthogonal faces are similar, we can use a class to encapsulate the pipeline. The three sub-windows for 2D image display are implemented using one class as they have almost the same function. While the sub-window for 3D model rendering is implemented using another class. The class encapsulation structure of the image/graph display sub-windows is shown is Fig. 1.

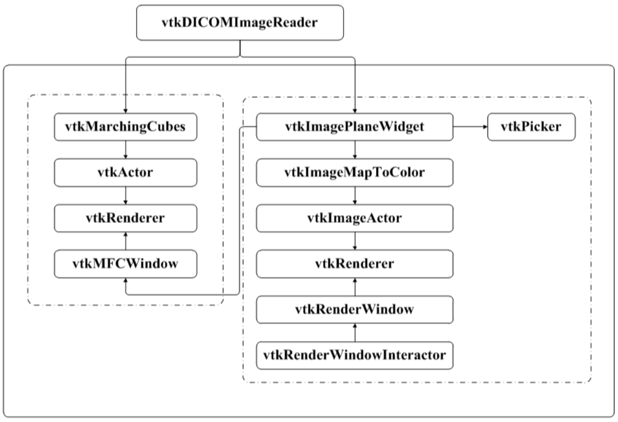


Fig. 1. Class encapsulation structure of image/graph display windows. The left Dotted box is the class to encapsulate the window for 3D model rendering. The right Dotted box is the class to encapsulate the windows for 2D images display.

### *B. 3D tooth model reconstruction*

This system uses the Marching Cubes (MC) algorithm to achieve a three-dimensional reconstruction of the tooth surface. MC is a computer algorithm, published in the 1987 DIGGRAPH proceedings by Lorensen and Cline, for extracting a polygonal mesh of an isosurface from a three-dimensional scalar field (also called voxels) [7,8]. In this algorithm, the user needs to specify a threshold value. Voxels which have the same intensities with the threshold are extracted to reconstruct the isosurface. Because the intensities of neighboring teeth and surrounding jaw bones are approximate, using MC directly to reconstruct the individual tooth surface is impossible. This system reconstructs the individual 3D tooth model from segmented images which were obtained using the segmentation method developed in our previous work. After the segmentation, each individual tooth is distinguished by assigning different gray levels. In the surface rendering stage, by setting appropriate threshold, isosurface of each tooth is extracted [9,10].

### *C. 3D model rendering and interaction*

There are two models in VTK three-dimensional scene, one is used for three-dimensional objects Widget model of operation, the other is in the scene shows the data model. But in widget model is unable to touch their own message response function to control the data model because itself is in a three-dimensional scene, in order to achieve this goal, we need to set up a bridge in the middle of it and the data model, this bridge is achieved through command mode callback. It is like a drive, intercepted messages retrieved from view, and then drive widget model to the data model. At the same time there is an Observer module data model to observe and update to reflect the state of the external data model.

In the course of the three-dimensional measurement function realization, VtkPicker class belongs to the widget model, while the object to be measured VtkObject it belongs data model. When the parameter vtkpicker update, the observer object through the update interface to update of data, also because of the update is an abstract interface, the implementation will be defined by the user. Users only see scenes in VtkPicker and VtkObject, mouse and keyboard messages intercepted by the operating system are implemented by callback functions of the command mode, which is to achieve the interactive measurement of three-dimensional model.

When the scene is fixed, rotating and translating the camera around the scene, pan rotation and translation can be achieved throughout the dentition; When the camera is fixed, the upper and lower dentitions total nodes rotate around a straight line which passed through the scene, then Upper and lower dentition rotate around a fixed axis can be realized. Thus simulating the upper and lower dental occlusion process; when the scene summary points, upper and lower dentition nodes and cameras are all fixed, a single tooth model around its node rotation and translation. So as to realize the orthodontic treatment planning and simulation. When the model of a single tooth orthodontic simulation operations such as rotation and translation, in order to prevent crossing with other dental model, the model must be added during the collision detection.

Interactive three-dimensional model measured position by a mouse click, the user picked up the desired point on the three-dimensional object, and transform it into the coordinate values of the world coordinate system. At the same point can be picked up to be fine-tuned according to the operation of the keyboard, and finally through the formula output measurement results on the pane.

## IV. Experiment

This system is running on a Lenovo M5400 computer (with Windows 7 operating system).The development environment is Visual Studio 2010, VTK5.10.1 is installed and made the necessary settings. By clicking menu options and selecting the folder can implement in the form of a set of files to read a DICOM image sequences.

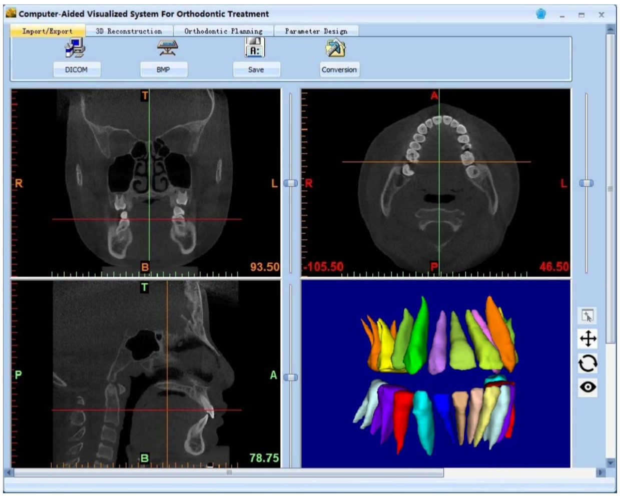


Fig. 2. User interface of the designed computer-aided visualization system for orthodontic treatment .

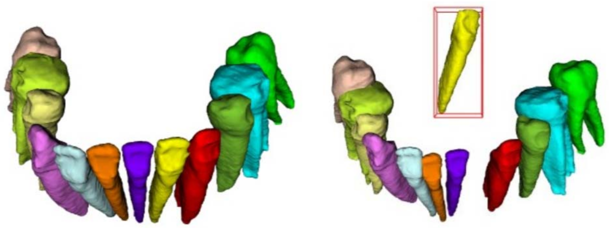

Fig. 3. Three-dimensional model rendering and interaction .

Fig. 2 shows the designed user interface of the computer-aided visualized system. It consists of a toolbar and image display panels. There are four panes in the interface to display three 2D image display planes (sagittal plane, coronal plane, transverse plane) (Top left, Bottom left, top right in Fig.2) and a 3D model rendering plane (Bottom right in Fig.2). In the 2D image display planes, user can select which CT slice to be displayed by dragging the slider at the right side of the image display plane. In the 3D model rendering plane, user can implement these operation including selecting measure dentition three-dimensional based on coordinate system. 3D model can also be selected to drag, rotate, and zoom by mouse operation.

As shown in the Fig.3, Three-dimensional model can be rendering and interact effectively. We can operate on the entire dentition, so as to effectively achieve human-computer interaction (left in the Fig.3). A single tooth model can also be can be selected separately to drag, rotate, and zoom by mouse operation (right in the Fig.3). Orthodontic can do orthodontic tooth arrangement planning (bottom in the Fig.3).

This paper briefly describes a visualization system of interactive, computer based orthodontist treatment. VTK integration with MFC, not only takes advantage of VTK powerful image processing and data visualization capabilities, but also effective use of the merits of MFC closely integrated with Windows and its rich interface development controls and resources. The data from the several frames are registered to each other to provide a complete three-dimensional virtual model of the dentition. Through rendering and interacting three-dimensional virtual model, orthodontists can plan, adjust, and simulate the morphology of the dentition directly and conveniently.

## V. CONCLUSIONS

This paper briefly describes a visualization system of interactive, computer based orthodontist treatment. VTK integration with MFC, not only takes advantage of VTK powerful image processing and data visualization capabilities, but also effective use of the merits of MFC closely integrated with Windows and its rich interface development controls and resources. The data from the several frames are registered to each other to provide a complete three-dimensional virtual model of the dentition. Through rendering and interacting three-dimensional virtual model, orthodontists can plan, adjust, and simulate the morphology of the dentition directly and conveniently.

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