MODEL GENERATION AND APPLICATION IN MEDICAL DOMAIN

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1. Introduction

3D model of real object can be generated using many different algorithms: surface measurement (large number of points measured with dot probe or laser, etc.), building the model from ground up and others. One possible method is creation of a model based on similar model (base model) and at least two images (input images) of a real object. When generating the model, expert knowledge of the real object is also used (Figure 1).
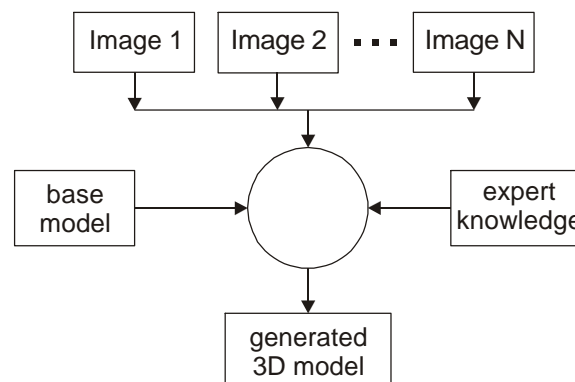

Figure 1. Alghoritm for creating 3D models

The input images, base model and parameters for creation of new model are defined in input file.

2. Sources for model creation

3D model is created from the following sources: two or more input images, base model and expert knowledge about new (and base) model. All sources are defined in input file, which holds parameters for creating new model. It is divided into three sections (input images, base model and final model), which are defined with tags: `model`, `base`, and `images`. Sections are separated with a line `#end`. Input images are defined with image data (pixels) and orientation in space using three angles. Image data is specified as PGM data (included in input file or as separate file). Models are defined as list of surfaces, each defined as a cloud of structured or unstructured points or as VRML file (included in input file or as separate file).

The origin of input images can be from variety of sources: photographs, sketches, computer made images from CT, MRI and X-ray images, etc. If needed, images are scanned and converted into appropriate format. Prior the use of images, they are converted into ASCII PGM format as this is the

only format that the application can process. For the propose of this article we will use two orthogonal X-ray images, positioned in main coordinate system.

Base model is 3D model which is the base for creating the new model. Usually base model represent the general shape of the model to be generated. The quality of the base model has large influence on the quality of the generated model.

Expert knowledge more precisely defines the property of the model to create. It mainly holds more precise definitions of the shape of the model. Expert knowledge is primary used in phase of defining (calculating) initially (primary) positions of cross sections on input images and base model. With the help of expert knowledge, the result number of cross section can be reduces and thus allowing to do more accurate model generation in same time.

3. Creation of model

Creation of model is done in following steps: prepare input images, generate position of cross sections and generation of model surface using one of two presented methods.

3.1 Prepare the input images and base model

First step in model generation is extracting the information from input images. The main information on the input images are outlines, which are used for defining the dimensions of the cross sections of final model. Extracting the outlines is performed with edge detection [Francois 2001, Barckhardt 2000]. In the article we will assume that images are black and white and the object on images is white and background is black. Outlines are converted into polylines and smoothed (reducing the number of points in polyline) to better represent the edge between object and surrounding [Mulmuley 1993, Guéziec 2000]. For calculation of scale factors, projections of the base model are calculated. Projections are calculated to the planes of input images (one projection for every input image) and are presented with outline.

3.2 Calculation of cross sections

Next step in generation of model is calculation of cross sections, which are used as the basement for model creation.

3.2.1 Initial positions of cross sections

Initial positions of cross sections are calculated for each input image and for base model separately (Figure 2). The expert knowledge is used to find the best positions of cross sections. The aim in using the expert knowledge is to reduce the number of cross sections as their number is directly associated with the time required to generate the model. Calculated positions (distances) are relative to the size of image or model in the sampling direction (the length of the image of model is 1 – Figure 2).
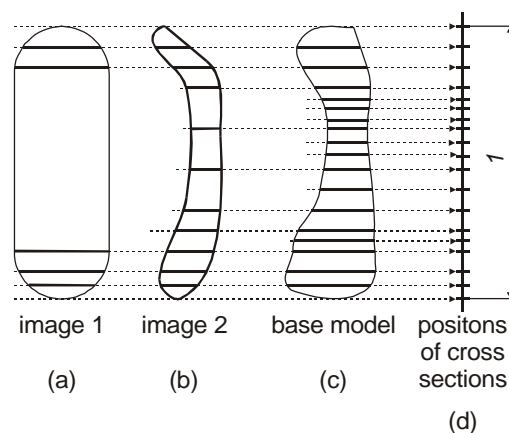

image 1   image 2   base model   positons of cross sections

(a)   (b)   (c)   (d)

Figure 2. Creation of united positions

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3.2.2 Generation of united cross section positions

To be able to construct the model, calculated positions of the input images and base model are used to create the united positions of cross sections. The separated lists of positions are jointed into one single list of positions of cross sections (Figure 2, image d).

3.2.3 Calculation of cross sections

With generated list of united positions of cross sections the cross sections for input images and base model are calculated [Bu-Quing 1992]. They represent the input data for process of generating the new model surfaces. Cross section of the input image is presented with line and cross section of the base model is presented with polylines. Polylines are result of intersection between base model and plane of cross section (Figure 3).
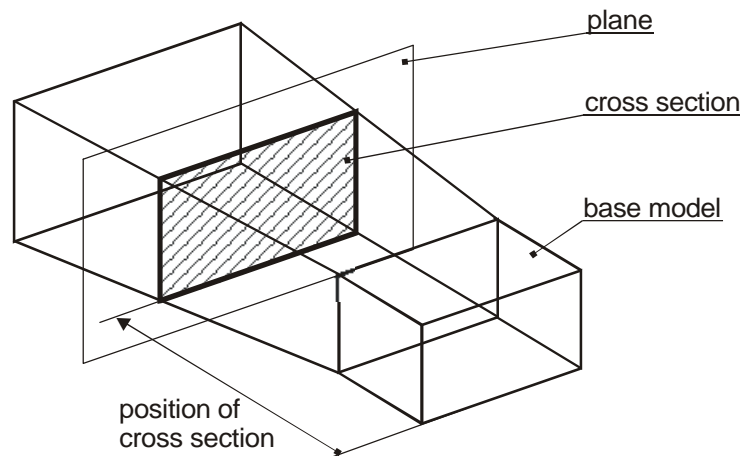

Figure 3. Defining the cross section on base model

3.3 Generation of model surfaces

Surfaces for new model are defined with set of points and patches Figure 4). The points and patches of surfaces can be generated in two ways: generation of new points and patches or recalculating the coordinates of points and using patches of base model. In both algorithm the topology of model (number of surfaces) of base and new model is the same.
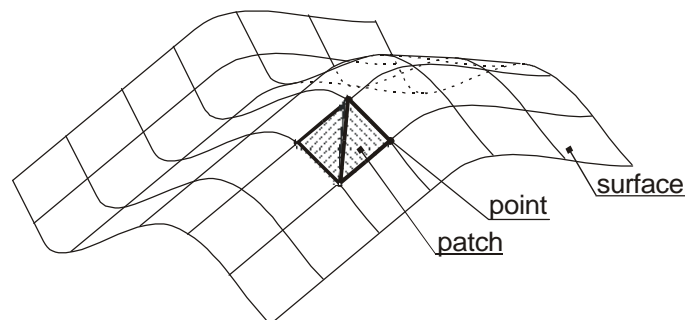

Figure 4. Surface of model

3.3.1 Generation of new points and patches

The usual way of creating the surface of new model is to generate the surface from ground up - generating new geometry (coordinates of points) and topology (relation between patches and points). Generated points and cross section share the same plane. The cross sections of input images are used to construct the bounding frame of new cross section. The points in the cross section of the base model are scaled using newly constructed bounding frame and giving points for polyline of new cross section (Figure 5).
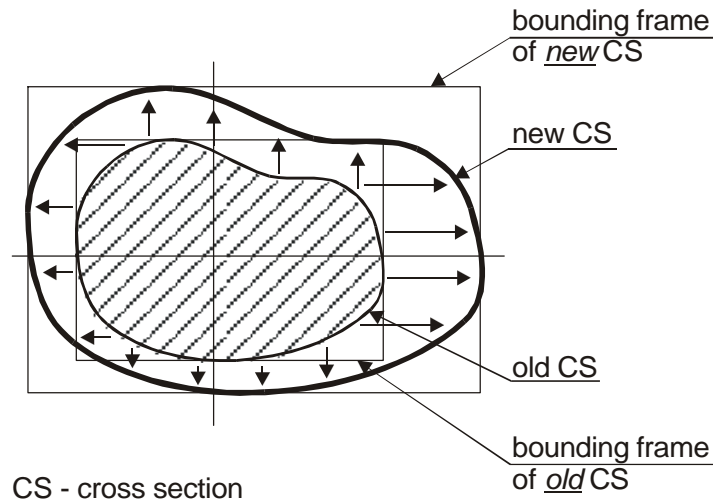
Figure 5. Generation of cross section of new model

Resulting points of new surfaces are structured and they only lie on the planes of cross sections. Patches are made after generating points. The patch is constructed from 3 close points (two points from same cross section and one from first next cross section).

The generated patches have no relation to the patches of the base model, which is advantage in case when the quality of base model is pure. The size of created model is defined with number of selected cross sections (from input file or automatic) and number of points on each section.

3.3.2 Calculation of new coordinates of points

The alternative way of creating surface of new model is using the surface topology of base model and newly generated geometry data (coordinates of points). The algorithm for recalculating the coordiantes of points of new model is:

```
for all points {
  - create cross section (CS) through current point and calculate
    its position
  - find two neighbour CS (one on each side; indexes i and i+1 on
    Figure 5.) from the list of unified CS
  - calculate scale factor for current CS from the neighbour CS
    using linear interpolation (Figure 5.)
  - scale the coordinate of current point
}
```
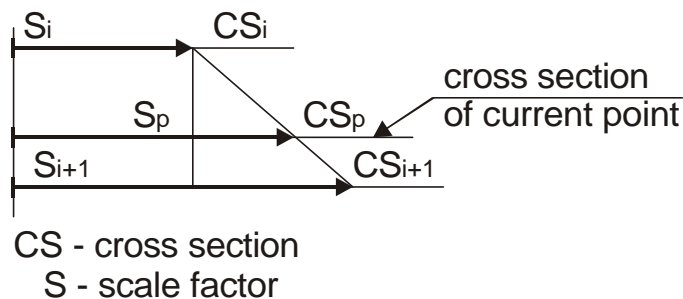

Figure 6. Calculation of scale factor for CS of current point

3.4 Model presentation

The representation of the model is done with list of points and patches. The number of patches depends on values defined in input file and (in some cases) on the quality of base model (depends on

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the way the model was created).

The presentation of graphical information is done using VTK library. VTK library is oriented towards easy displaying large amounts of scalar and vector data. Data can be organised in clouds (cloud of points and patches) or streams (stream of vector data). It relay on OpenGL for displaying the model and can take advantage of hardware (graphical card capable of 3D hardware acceleration). The graphical transformations (translation, rotation, scale) and different view modes (wireframe, hidden lines, shade) are integrated in VTK library and thus available in application.

4. Application from medical field

The practical representation of model generation is from medical field. The input images are defines with two orthogonal X-ray images and base model is model of bone (Femur). Figure 7. shows the content of actual window of application. It includes two input images, base model (foot) and generated model of foot.
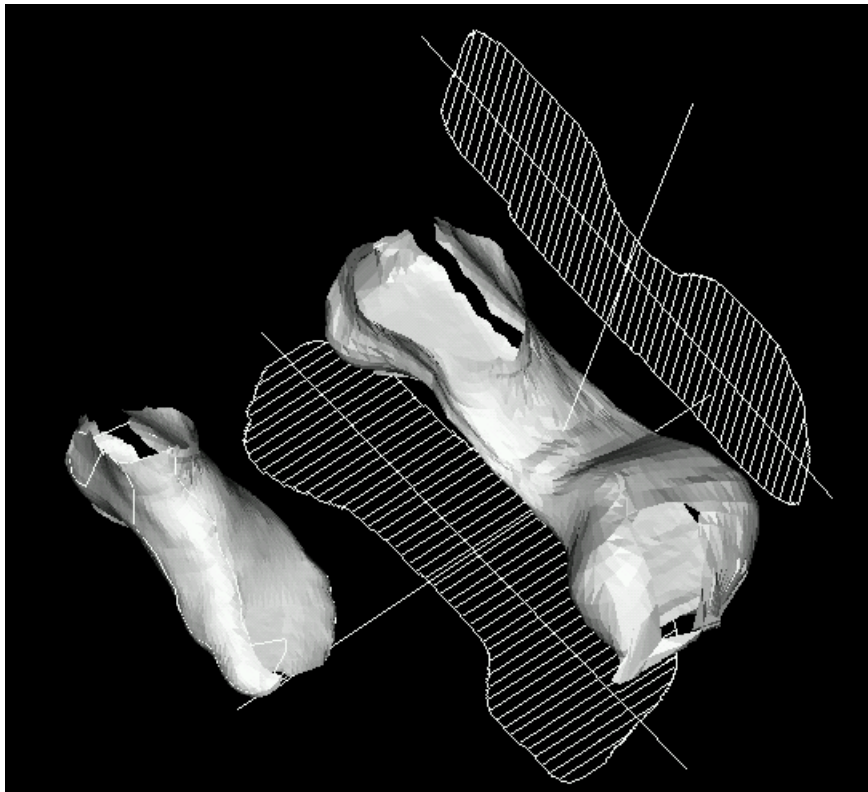

Figure 7. Contents of actual output window of program

5. Conclusions

The represented model generation has limitation, because the generation of the model heavily depends on the quality, number and position of the input images of a real object. The method cannot replace the model, generated from series of CT images. It represents the possibility of faster and cost effective representation of a real patient before any surgery or decision takes place.

With minor update, the represented method can be used to support making the tailor made prothesis. With generated 3D model of a real patient, it is possible to determine the required size and shape of prothesis without surgery, which results in greater number of successfully made surgeries.

References

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