Volume manipulation using CUT and PASTE operations and its applications

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1 Introduction

With the advent of the aging society, knee and hip joint diseases have increased rapidly in recently, and both Total Knee Arthroplasty (TKA) and Total Hip Arthroplasty (THA) surgery are increasing. TKA and THA are surgical techniques that replace the artificial component (assortment of implant) with knee and hip joint, respectively. The conventional preoperative planning uses inferior limb X-ray images (Two-Dimensional Computed Radiography images: 2D CR). That's because X-ray film image in standing position contains the information required for preoperative planning. Therefore, the techniques and experiences of the surgeon cause a large difference for precise position of implant and cutting bone plane, volume of cutting bone, and so on. In order to solve the problems and to support the surgeon in a preoperative planning of TKA and THA, we have developed a 3D based surgical planning system on a personal computer. The system manipulates 3D templates of TKA and THA components, and cut and paste bone precisely on three-dimensional (3D) Computed Tomography (CT) image. In this paper, we have described the detail of interactive cutting and pasting functions for 3D image, and we have applied them into our 3D based surgical planning system. We also evaluate our manipulation techniques by using several CT image of patients.

2 Multi-volume operation for 3D image

Simultaneous processing of CT and MR images, which are different modality, is often used in clinical fields. CT can visualize bones, such as a femur (thighbone) and a tibia, but it is difficult to visualize cartilage (soft bones) in knee joint. Since MRI can visualize cartilage region, both CT and MR images will be utilized for preoperative planning of surgery. The conventional 3D image processing manipulates a single 3D image. However, the advent of 64-bit OS (Operating System), and the improvements of CPU (Central Processor Unit) and GPU (Graphics Processor Unit), and large-capacity memory on CPU, make it possible to manipulate multiple 3D image simultaneously on a personal computer.

2.1   CUT operations using stroke

Commonly, a display monitor is used to deal with 3D objects in 3D space. However, it is difficult and time consuming task to place 3D objects in 3D space on a display monitor. Therefore, we propose a tablet-based method to place 3D objects in 3D space. We utilize the directed line, we called stroke, on the screen, and define the CUT surface in 3D space on a display monitor. The image region is partitioned by the plane enclosed in the line which gave the direction. The direction of line, we called stroke, represents the normal direction of cut plane, which is positive or not. Here, we show several examples in the operation. Front and back sides of the cut surface are defined by the direction of the arrow (arranged in order of ①→②), as shown in the figs 1 and 2.
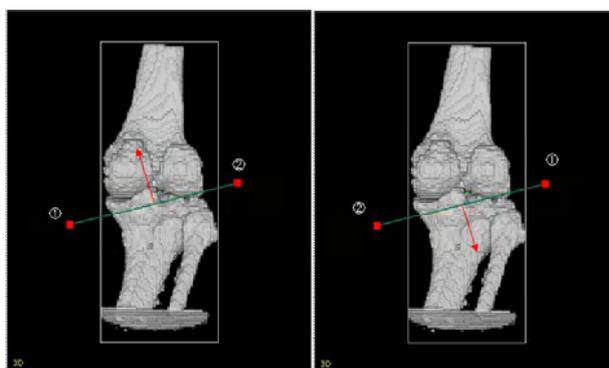

Fig. 1 Placement (case A)   Fig. 2 Placement (case B)

If cut surface is single, the results shown in Figure 3 will be same, regardless of the front and back sides of the cut surface. If the number of cut surface is two or more, the results will be changed by a combination of front and back sides of each cut surface. Also, the size of the cut surface will be treated as an extension that is present (dotted line in Figure 4) on the display even shorter. Processing in the two cut surfaces is that we divide into two separate regions, which are the region enclosed by the front side of the faces, and other region. If two of the cut surface, the direction of each segment in the stroke, you can specify the area to be cut.
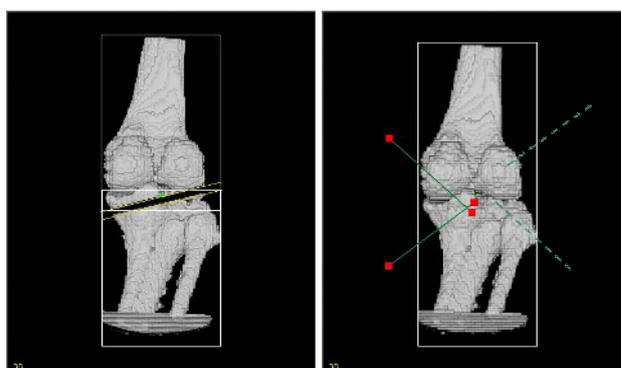

Fig. 3 Results (1)   Fig. 4 Extended lines
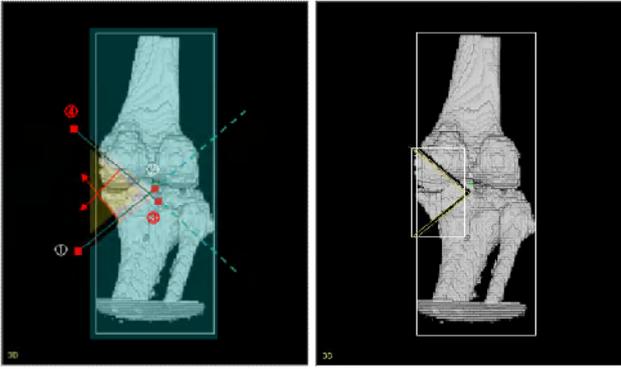
Fig. 5 Two cut planes (1) Fig. 6 Results (2)
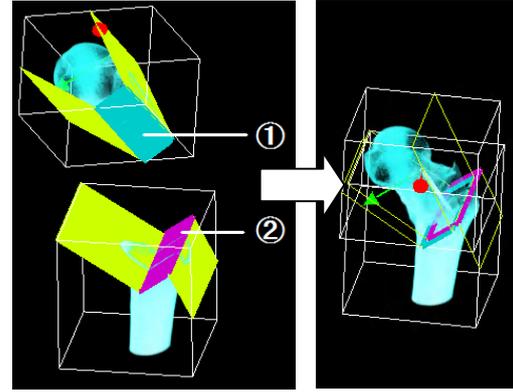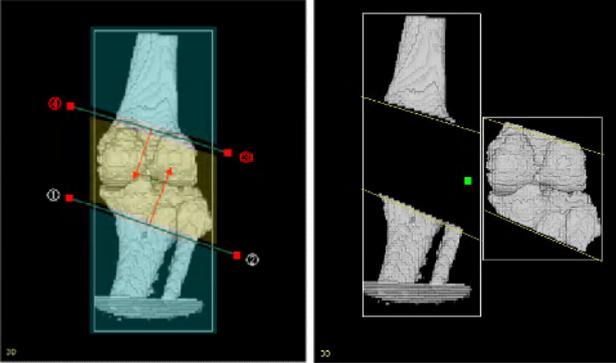
Fig. 7 Two cut planes (2) Fig. 8 Results (3)
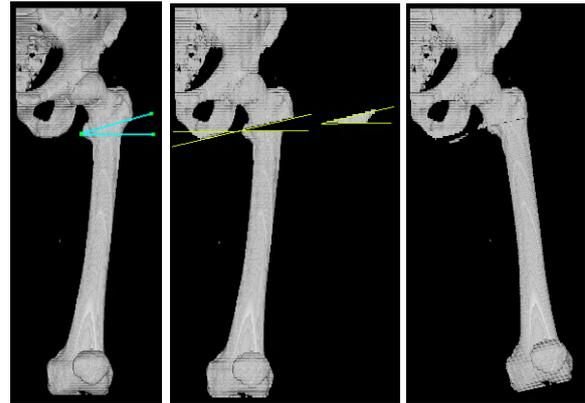
2.2 PASTE operation

PASTE operation has the ability to place two planes on the same plane. For example, the two cut surfaces of the image volume are pasted. This feature is used when both images need to connect each other, precisely. In our system, the user select two cut surfaces interactively, and the first cut surface is re-located on the second cut surface. After the placement, the volume image with first cut surface can be moved and rotated horizontally on other surface (Figure 9).

3 3D based surgical planning system

Our 3D based surgical planning system manipulates a multi-volume data, and we have developed cut and paste operations to improve the accuracy of surgical procedures. In addition, we have supported several functions, such as DICOM image loader, volume rendering, image segmentation, implant placement (3D Templating), drawing auxiliary lines, for assistance with preoperative planning.

Our goal is that the whole procedure for the preoperative planning will be done within 30 to 40 minutes. Therefore, our system, unlike traditional CAD systems and CG system, has been designed and implemented to allow, cut, move, rotate objects with intuitive mouse-only operation. The mouse is suited to intuitive operations for rotation and movement on a screen. Each subset of several images is selected by the mouse, and the selected images can be moved and rotated interactively. Figure 10 shows the simulation results of the posterior rotational osteotomy in clinical fields.

Our 3D based surgical system has been written by VC++ and OpenGL on Windows families, and our volume rendering utilizes 3D texture function of OpenGL [2]. The gray-scaled image has converted to color image, and stored as 3D texture memory, and displayed by GPU.

Fig. 9 PASTE operation

Fig. 10 CUT and PASTE operations for 3D image

4 Conclusion

The exact and efficient surgery planning increases the Quality Of Life (QOL) of the patients, and reduces the burden of surgeons for the entire artificial joint surgery procedures. Our system manipulate 3D image directly, and CUT and PASTE operations are very powerful tool for surgeons.

In this paper, we have described the detail of interactive cutting and pasting functions for 3D image, and we have implemented these functions into our 3D based surgical planning system.

The surgeons have evaluated ease of use of the manipulation techniques by using several CT images of patients for TKA and THA surgery. They have also used to several complicated osteotomy surgery, such as the posterior rotational osteotomy for the non-traumatic osteonecrosis of the femoral head.

Acknowledgements

References

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