Development of Automatic System for 3D Visualization of Biological Objects[1]

T. H. Choi, H. Hwang, C. S. Kim

Abstract: Nondestructive methods such as ultrasonic and magnetic resonance imaging systems have many advantages but still much expensive. And they do not give exact color information and may miss some details. If it is allowed to destruct some biological objects to get interior and exterior informations, constructing 3D image from a series of sliced sectional images gives more useful information with relatively low cost. In this paper, a PC based automatic 3D model generator was developed. The system was composed of three modules. The first module was the object handling and image acquisition module, which fed and sliced the object sequentially and maintains the paraffin cool to be in solid state and captures the sectional image consecutively. The second one was the system control and interface module, which controls actuators for feeding, slicing, and image capturing. And the last was the image processing and visualization module, which processed a series of acquired sectional images and generated 3D volumetric model. Handling module was composed of the gripper, which grasped and fed the object and the cutting device, which cuts the object by moving cutting edge forward and backward. Sliced sectional images were acquired and saved in a form of bitmap file. 2D sectional image files were segmented from the background paraffin and utilized to generate the 3D model. Once 3-D model was constructed on the computer, user could manipulated it with various transformation methods such as translation, rotation, scaling including arbitrary sectional view.

Keywords: Automatic 3D Contour Construction, Sectional Image Acquisition, Volumetric Model

Introduction

Ultrasonic and magnetic resonance imaging systems are used to visualize the interior state of biological objects without destruction. These nondestructive methods have many advantages but too much expensive. And they do not give exact color information and may miss some details. If it is allowed to destruct some biological objects to get the interior and exterior information, constructing 3D image from the series of the sliced sectional images gives more useful information with relatively low cost.

In this paper, a PC based automatic 3D graphic model generator was developed. The developed system was built with relatively low cost for the relatively small biological objects such as insect, plant stem, and so on.

Materials and Methods

1. System Architecture

The PC based automatic 3D graphic model generator was composed of three modules. One is object handling and image acquisition module, which feeds and slices an object sequentially and maintains the paraffin cool to be in solid state and captures the sectional image consecutively. The second is the system control and interface module, which controls actuators for image capturing, feeding, slicing, and the adjustment of slicing interval. And the last is the image processing and visualization module, which processes a series of acquired sectional images and generates 3D graphic model. The object handling and image acquisition module is a hardware part of the whole system and was composed of cooling system, feeding and grasping mechanism, slicing mechanism, and CCD color camera with lighting device.

Fig. 1 shows the overview of the object handling and image acquisition module. Fig. 2 shows a feeding mechanism using stepping motor. Cylindrical paraffin object was fed along the aluminum block by the step motor and grasped by the solenoid before being sliced. While the object was being grasped, the cutting device sliced the object by moving cutting edge forward and backward as shown in Fig. 3. Since a little clearance was required to feed the paraffin object, gripper was required to prevent uneven slicing. When the cutter began to slice the paraffin, the feeding clearance between paraffin cylinder and feeding guide caused the paraffin to be inclined because of the cutter force. Feeding guide was made of aluminum block with a drilled hole.

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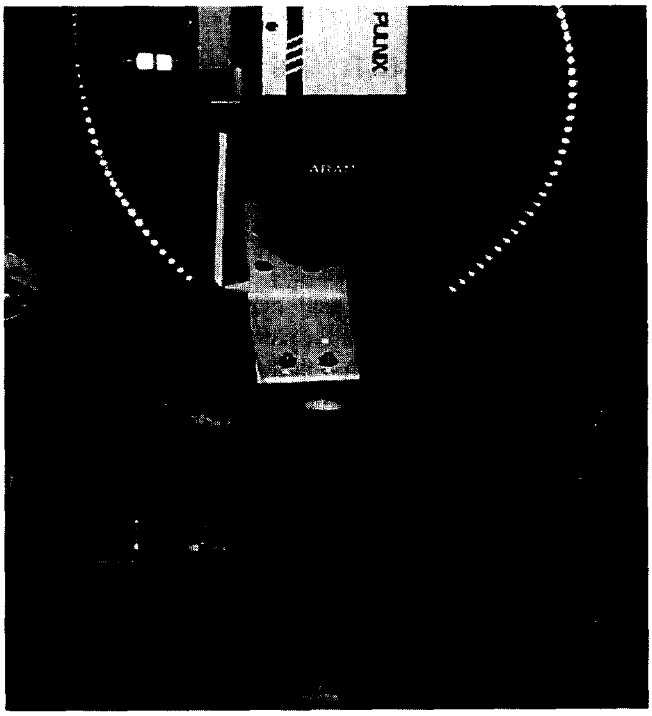

Fig. 1 Object handling and image acquisition module.

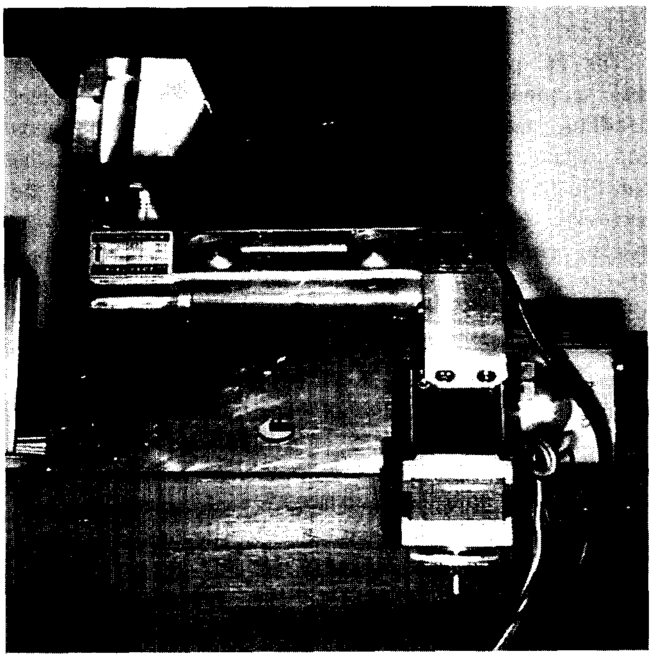

Fig. 2 Feeding mechanism driven via step motor.

The image acquisition system was composed of the CCD color camera (TMC-74, Pulnix), frame grabber (Meteor-II, Matrox), and fiber optic tungsten halogen lighting device.

The image processing and visualization module extracted 2D information from the sliced sectional images and generated 3D volumetric model from the series of extracted 2D information. The image processing and visualization module is the software part of whole system and was composed of image processing and 3D visualization parts. Sliced sectional images were acquired and saved in the form of bitmap file. 3D model was generated to obtain the volumetric information using these 2D sectional image files after being segmented from the background paraffin. Visualization toolkit 2.0 (Kitware Inc., USA) was used to visualize 3D model. Once 3-D model was constructed on the computer, user could manipulate it with various transformation methods such as translation, rotation, scaling including arbitrary sectional view.

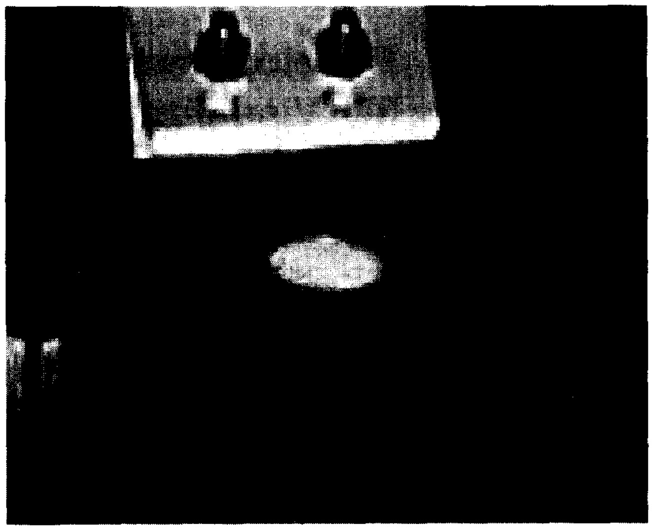

Fig. 3 Cutting mechanism with the moving knife.

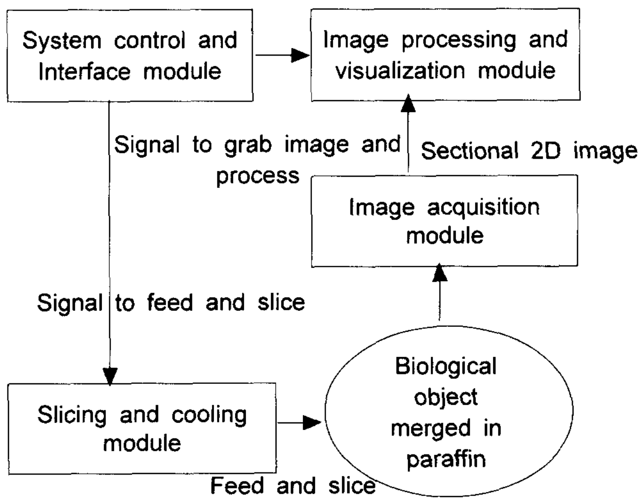

Fig. 4 Block diagram of functional architecture.

Fig. 4 shows the overall functional architecture of the developed system. The system control and interface module sends control signals to other two modules. The slicing and cooling module feeds and slices a biological object merged in paraffin. The image acquisition module grabs the sliced sectional images and sends them to the image processing and

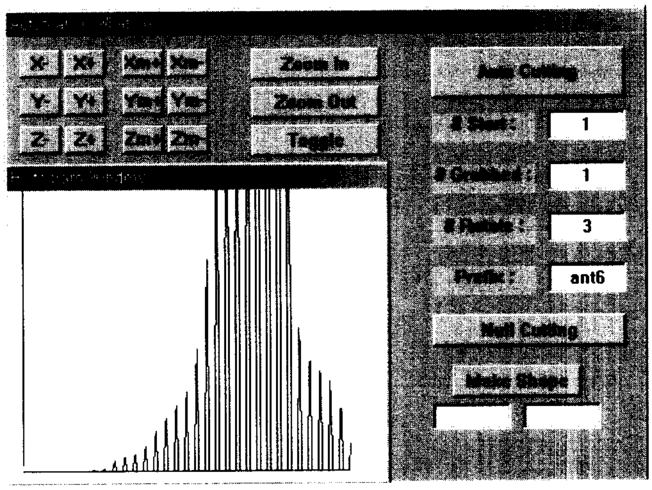

Fig. 5 System control and interface module.

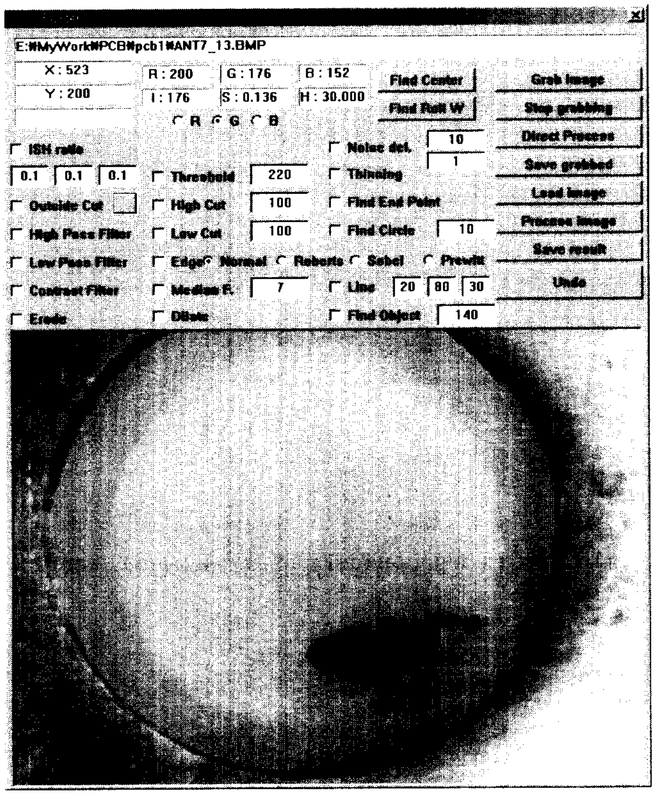

Fig. 6 Image acquisition and processing module.

visualization module. The image processing and visualization module extracts 2D information from the raw images and generates 3D volumetric model using extracted 2D information.

Fig. 5 shows the developed system control software as a system control and interface module. Fig. 6 shows the developed image acquisition and processing module.

2. Manipulating Sequence and Experiment

Fig. 7 shows the overall sequence of the system

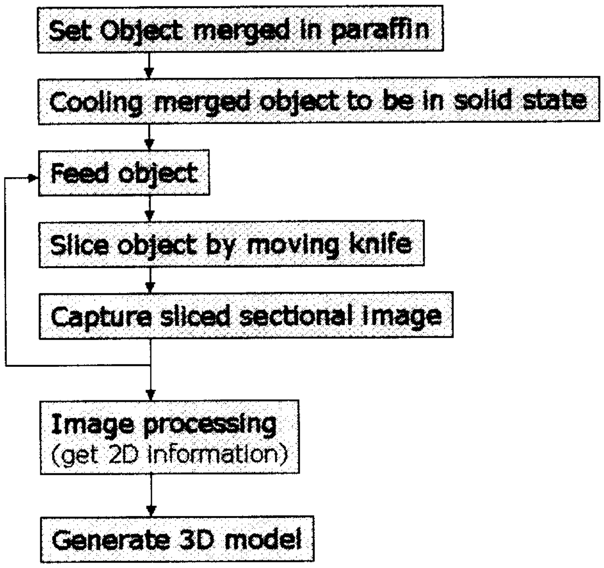

Fig. 7. Block diagram of manipulating sequence.

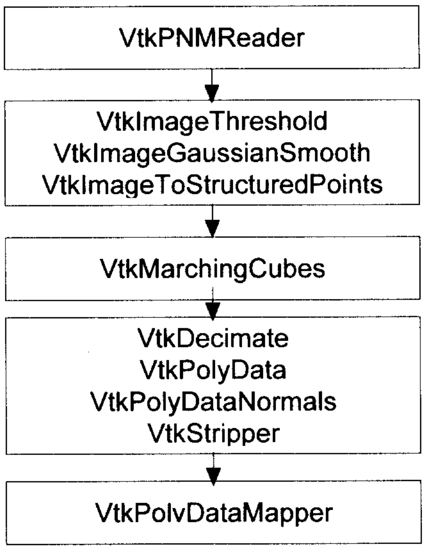

Fig. 8 Process diagram of isosurface construction.

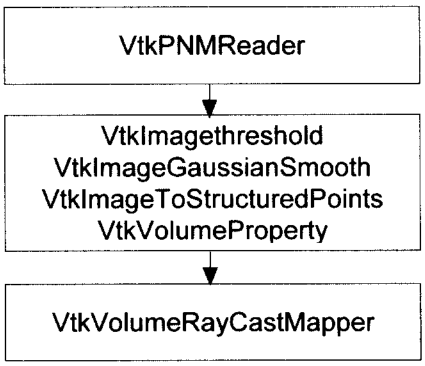

Fig. 9 Process diagram of volume rendering.

manipulation. First, the biological object was put into the aluminum paraffin holder filled with the liquid paraffin and sample holder was put into the refrigerator to make the liquid paraffin to be solid. After taking off the frozen solid paraffin from the sample holder, cylindrical shaped paraffin was fed by 0.2mm~0.5mm using stepping motor and sliced by moving knife back and forth. While the paraffin being sliced, the cutting force was measured simultaneously using load cell. And the sliced sectional image was captured using color CCD camera, frame Grabber and micro zoom lens. After whole sectional images are captured, 2D image processing algorithms (Gonzales and Woods, 1992) based on morphology and textures are executed to obtain 2D feature information. And finally, volumetric 3D model is generated.

The visualization toolkit library (Schroeder, 1998a,b) and MS Visual C++ (Petzold and Yao, 1996; Neider et al., 1996) was utilized to program on-line module. The visualization toolkit library gives many advantages to visualize 3D model by way of handling some parameters such as pixel sampling rate, smooth factor, Gaussian standard deviation, decimate reduction, etc. Fig. 8 shows the process diagrams of isosurface generation. Process to generate volumetric model is shown in fig. 9.

Once 3D model has been created on the PC, the object is manipulated with various viewing transformations such as translation, rotation, scale and arbitrary sectional view. An ant was used for the experiment. The length of paraffin to be sliced was about 12mm. And the number of slice was 35 (0.34 mm thickness per each slice).

Results and Discussion

Because of the difficulty in segmenting color details of the sectional view in this paper, pseudo color was used instead of real color to generate the 3D volumetric model. Color sectional images were transformed to gray scale image at the first stage. And a series of image processing algorithms such as binarization, segmentation, noise reduction, boundary extraction and so on were applied to extract 2D features. Fig. 10 and Fig. 11 show the sampled sliced image of an ant and the extracted boundary of an ant, respectively. Fig. 12 shows the wire frame image of an ant.

To extract the wire frame image from the raw sectional images, a sequence of image processing algorithms such as segmentation, blob analysis etc was applied. First, a region of the interest (ROI) was specified to restrict the processing area and to speed up processing. Within the ROI, ant was separated from the paraffin background using color threshold in the HSI plane. And small image blobs were eliminated from the threshold image to reduce the noise effect.

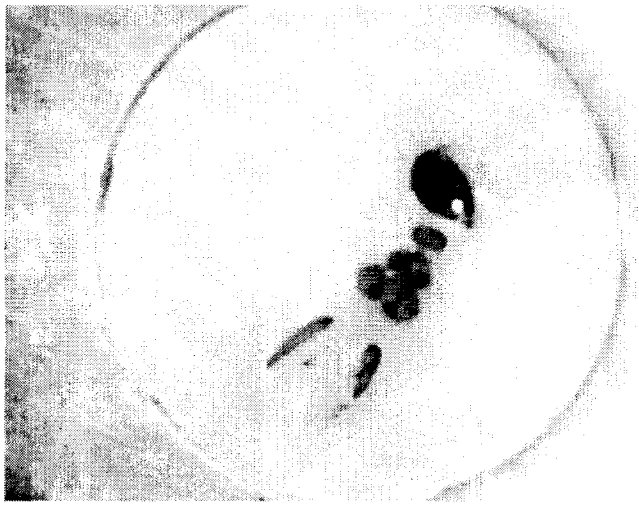

Fig. 10 Sampled sliced sectional image of an ant.

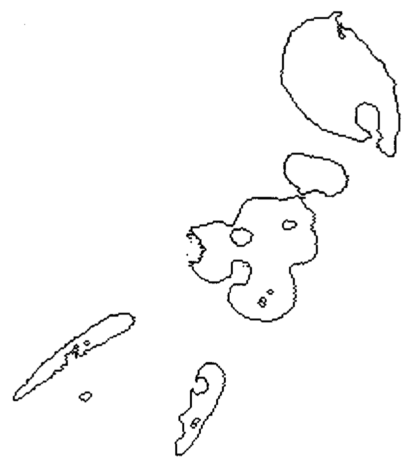

Fig. 11 Extracted boundary of the sectional image of an ant.

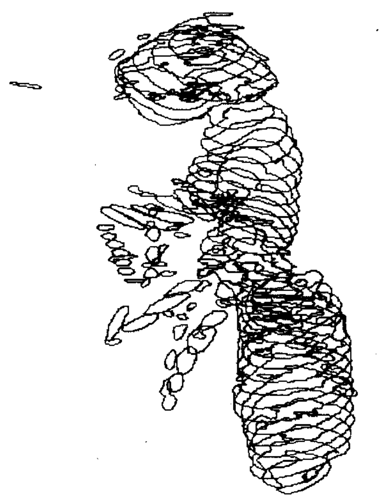

Fig. 12 Wire frame graphical image of ant.

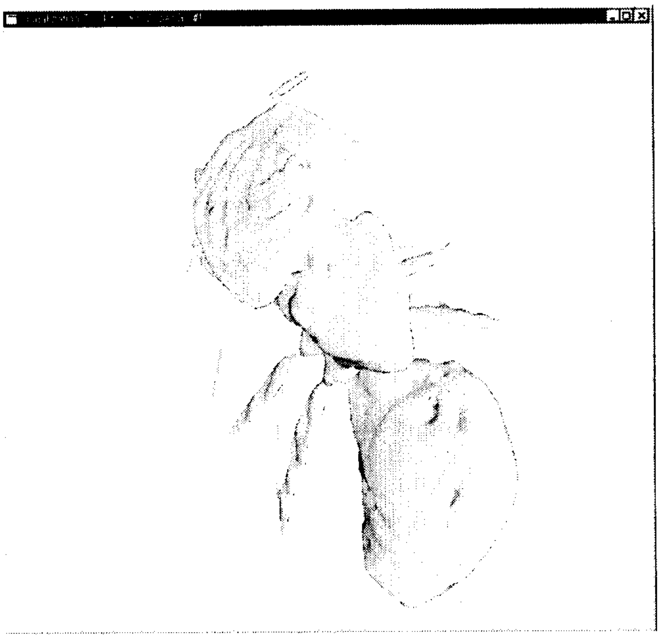

Fig. 13 Rendered 3D model of an ant.

Then, boundaries were extracted from the segmented image using edge detection method, and spatial coordinates of resulting boundary were saved to the computer memory. A series of 2D boundary information extracted from the sectional images was transformed as a form of graphical array. Finally, whole rendered 3D model was generated as shown in Fig. 13.

Though the inside structure of an ant such as organs from the sectional raw images was investigated, it was relatively difficult to separate inside organs in this experiment. To separate the inside organs of an ant details of the structure from the magnified image was required. And biological knowledge of ant organ should also be required. The color and shape variation of the captured image was too vague to distinguish inside organ of an ant. Visualizing interior structure of a biological object using real color information is still under development.

Conclusions

An automatic 3D graphic model generating system was developed. The system worked successfully with an ant, which has a relatively complex shape. The developed system was composed of three modules. One was the slicing and cooling module, which fed and sliced objects sequentially and maintained the paraffin cool to be in solid state while being sliced. Another module was for the system control and interface, which controlled the feeding and slicing mechanism including the adjustment of slicing interval. And the other one was the imaging and visualization module, which acquired the images of sliced section of the object via color imaging system and generates 3D model.

If biological object is allowed to destruct to get interior and exterior information, constructing 3D image from the series of the sliced sectional images could give more useful information with relatively low cost. From this point of view, the developed system could be utilized efficiently to model the inside structure and behavior of internal organ of a biological object and to model complex outside 3D contour of a biological object.

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