PROTOTYPE AUTOMATIC SYSTEM FOR CONSTRUCTING 3D INTERIOR AND EXTERIOR IMAGE OF BIOLOGICAL OBJECTS+

T. H. Choi [1], H. Hwang [1], C. S. Kim [2]

[1] Robotics & Vision Lab., Dept. of Bio-Mechatronic Engineering,
Faculty of Life Science & Technology, Sungkyunkwan University,
Kyungki-do, Suwon-si, Changan-gu 440-746, KOREA
[2] Dept. of Bio-Resource Mechanical Eng., Faculty of Bio-Resource Systems
Engineering, College of Agriculture, Chonbuk University,
Chonju-si, 561-756, KOREA
hhwang@yurim.skku.ac.kr

ABSTRACT

Ultrasonic and magnetic resonance imaging systems are used to visualize the interior states of biological objects. 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, PC based automatic 3D model generator was developed. The system was composed of three modules. One is the object handling and image acquisition module, which feeds and slices objects 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 feeding, slicing, and image capturing. And the last is the image processing and visualization module, which processes a series of acquired sectional images and generates 3D graphic model. The handling module was composed of the gripper, which grasps and feeds 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 the form of bitmap file. The 3D model was generated to obtain the volumetric information using these 2D sectional image files after being segmented from the background paraffin. 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.

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

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

MATERIALS AND METHODS

2.1 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 objects 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 & Image acquisition module is hardware parts of the whole system and was composed of

1. Cooling system
2. Feeding and grasping mechanism
3. Cutting force measuring system
4. Slicing mechanism
5. CCD color camera and light source

Fig.1 showed the overview of the object handling and image acquisition module. Fig. 2 showed 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 as shown in Fig. 3. While the object was being grasped, the cutting device sliced the object by moving cutting edge forward and backward as shown in Fig. 4. 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. The load cell was mounted to measure the cutting force. And slicing interval was set as 0.5mm.

The image acquisition system was composed of the CCD color camera(Pulnix TMC-74), frame grabber(Matrox Meteor-II), 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 & visualization module is a software part of whole system and was composed of image processing part and 3D visualization part.

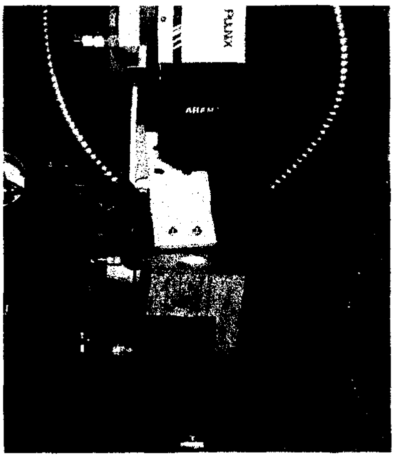

Fig. 1 Object handling and image acquisition module.

Sliced sectional images were acquired and saved in the form of bitmap file. The 3D model was generated to obtain the volumetric information using these 2D sectional image files after being segmented from the background paraffin. The 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 omputer, user could manipulate it with various transformation methods such as translation, rotation, scaling including arbitrary sectional view.

Fig. 5 showed 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 slicing a biological object merged in paraffin. The image acquisition module grabs the sliced sectional images and sends it to the image processing and visualization module. The image processing and visualization module extracts 2D information from the raw images and generate 3D volumetric model using extracted 2D information.

Fig. 6 showed the developed system control software as an system control and interface module. Fig. 7 showed the developed image acquisition and processing module.

2.2 Manipulating Sequence and Experiment

Fig. 8 showed the overall sequence of the system 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 et al.,1992) based on morphology and textures are executed to obtain 2D feature information. And finally, volumetric 3D model is generated.

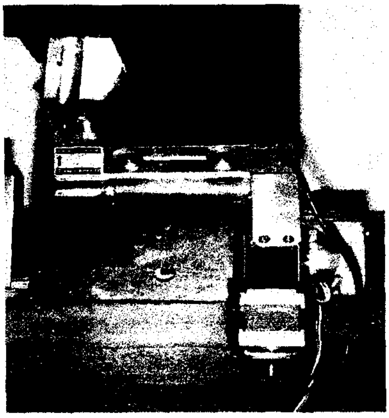

Fig. 2 Step motor driven feeding mechanism. with load cell.

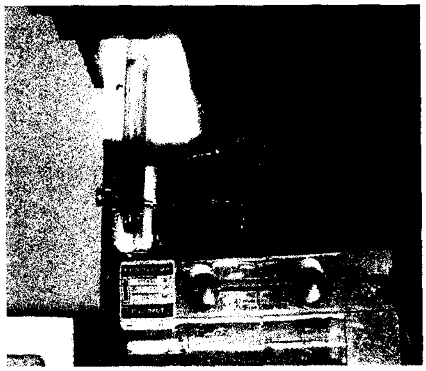

Fig. 3 Grasping mechanism mounted

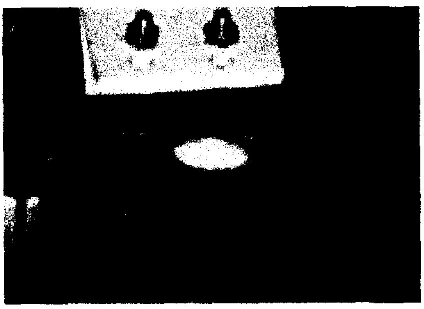

Fig. 4 Cutting mechanism with moving knife.

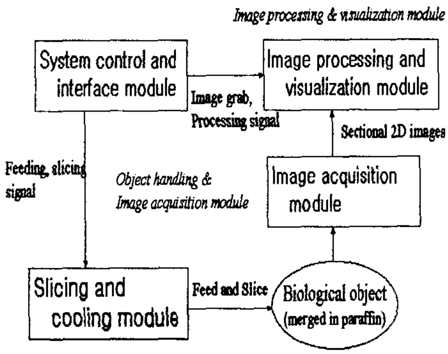

Fig. 5 Block diagram of functional architecture.

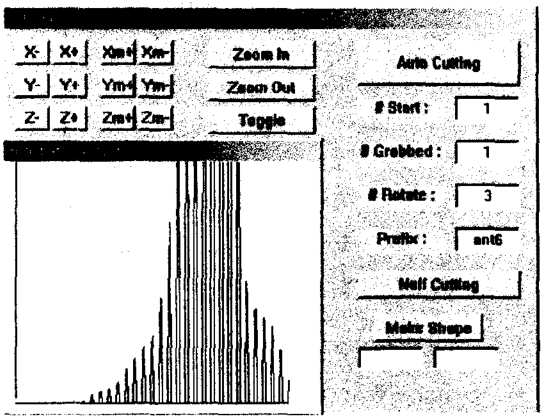

Fig. 6 System control and interface module.

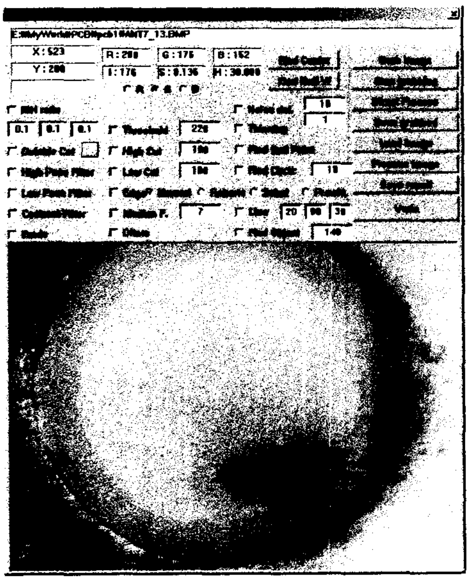

Fig. 7 Image acquisition and processing module.

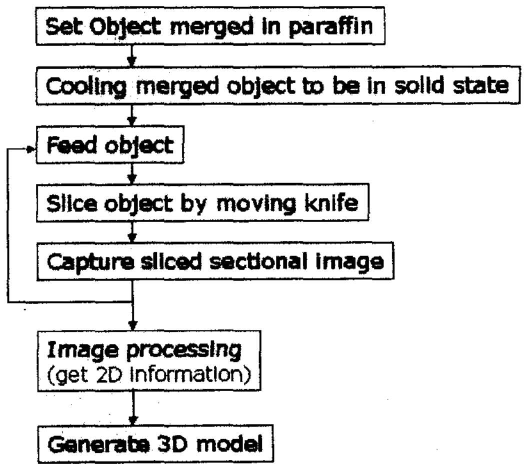

Fig. 8 Block diagram of manipulating sequence.

The visualization toolkit library(Schroeder, 1998a,b) and MS Visual C++(Petzold,C. and P. Yao,1996, Neider et al.,1996)was utilized to program on-line module. 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 3D volumetric model. Color sectional images were transformed to gray scale image first. 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. 9 and 10 showed the sampled sliced image of an ant and the extracted boundary of an ant respectively. Fig. 11 showed the wire frame image of an ant. 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. 12.

Though the inside structure of an ant such as organs from the sectional raw images, 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.

The visualization toolkit library gave 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.

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 feeds and slices objects sequentially and maintains the paraffin cool to be in solid state while being sliced. Another module was for the system control and interface, which controls feeding and slicing mechanism including the adjustment of slicing interval. And the other one was the imaging and visualization module, which acquires 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 the interior and exterior information, constructing 3D image from the series of the sliced sectional images gave more useful information with relatively low cost. From this point of view, the developed system can 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.

Fig. 9 Sampled sliced sectional image of an ant.

Fig. 10 Extracted boundary of the sectional image of an ant.

Fig. 11 Wire frame graphical image of ant.

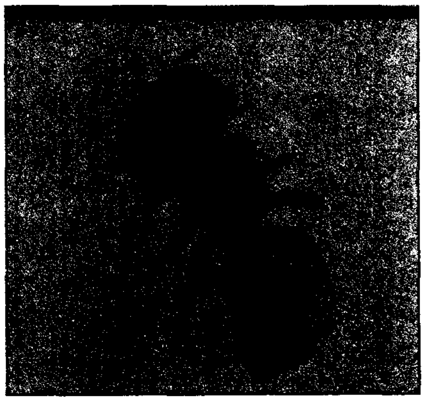

Fig. 12 Rendered 3D model of an ant.

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