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Smoothing Module for Optimization Cranium Segmentation Using 3D Slicer

Gilang Argya Dyaksa[1,*], Nur Arfian[2], Herianto[3] and Lina Choridah[4], Yosef Agung Cahyanta[1]

[1]*Faculty Science & Technology, Sanata Dharma University, Indonesia*
[2]*Department of Anatomy, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia*
[3]*Department of Mechanical and Industrial Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia*
[4]*Department of Radiology, Faculty of Medicine, Public Health and Nursing, Yogyakarta, Indonesia*

Corresponding Author : gilangad@usd.ac.id

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Abstract

Anatomy is the most essential course in health and medical education to study parts of human body and also the function of it. Cadaver is a media used by medical student to study anatomical subject. Because of limited access to cadaver and also due to high prices, this situation makes it necessary to develope an alternative anatomical education media, one of them is the use 3D printing to produce anatomical models. Before 3D Print the cranium, it is necessary to do the segmentation process and often the segmentation result is not good enough and appear a lot of noises. The purpose of this research is to optimize a 3D cranium based on DICOM (digital imaging and communications in medicine) data processing using the smoothing modules on 3D Slicer. The method of this research is to process the Cranium DICOM data using 3D Slicer software by varying the 5 types of smoothing modules. The results with default parameter fill holes and median have better results compared to others. Kernel size variations are performed for smoothing module fill holes and medians. The result is fill holes get optimal segmentation results using a kernel size of 3 mm and the median is 5 mm

Keywords: anatomy, cranium, 3D slicer, smoothing module

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1 Introduction

Anatomical education is one of the most important courses to learn in the health and medical field [1]. Anatomy is studied using a body donor called cadavers. Cadavers can be obtained in several ways, such as direct donations from people who have agreed that they will donate their dead bodies to the university or the bodies of patients who died in hospitals but no family claiming their bodies [2].

The cadavers are high in price and the number of cadavers in university is limited [3]. Universitas Gadjah Mada (UGM) hasn't received any cadavers since 2001. These conditions are the reason for the development of anatomical education media, one of them is the use of 3-dimensional (3D) anatomical models.

Pandemic condition was also the reason for the development of anatomical education media using 3D technology due to the limited access to campus and the lab. 3D anatomical models provide an overview of anatomical structures more practically and are very useful for explaining some of the functions and relationships between anatomical structures. Anatomical education media using 3D models can reduce costs at the institution which is the costs for cadaver storage.

Because of this condition the development of medical advancement and 3D of anatomical model is the one of priority in this modern era [4]. One that is often done is multi modality 3D imaging technology and analysis of DICOM data using computer science and bio informatics. The purpose of this advance development is the medical workers can quickly see the visual of the patient body performed using CT or MRI then the results can be viewed in 3D and medical workers can diagnose patients. 3D imaging can also be used as a reference if the patient has defects or various medical disorders, which is important information in the medical field as a way to plan or determine procedures such as surgery that must be performed on patients [5].

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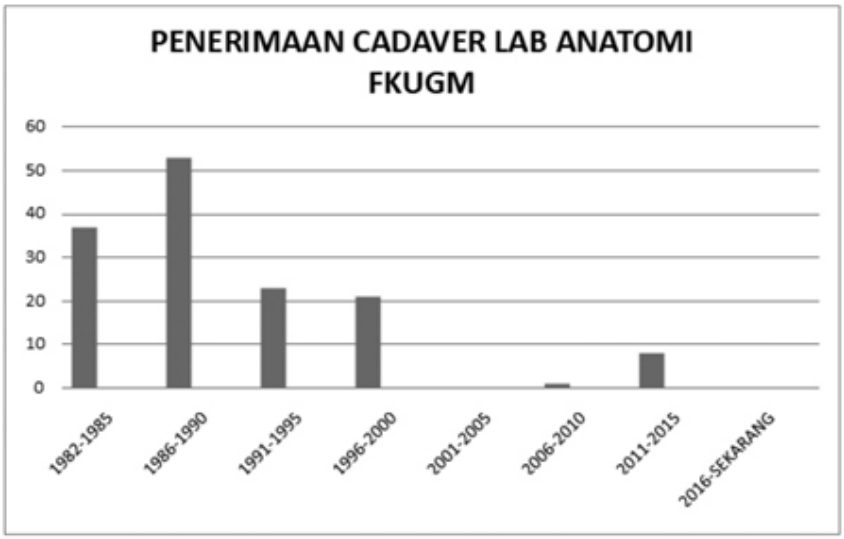


Figure 1. Graph of cadaver acceptance in the Department of Anatomy, Faculty of Medicine UGM since 1982 [3].

Analysis of CT results into 3D models can be done using open source software 3D Slicer that can perform medical image processing and visualization from DICOM Data and can be exported to 3D model mesh data such as STL and OBJ format [6]. 3D slicers are often used as a platform for developing and analyzing to produce prototype 3D models that suit clinical needs [7]. The result of prototype can be a 3D model or can be 3D printed to create a physical prototype of anatomical model.

In this reserach, we use 3D Slicer as a software for prototyping and development of cranium image analysis tools for clinical research applications and also provide an optimization using smoothing modules to make an optimal 3D model of anatomical model such as cranium that used in this research.

2 Methods

This research only using cranium as anatomical model and the method to segmentation the cranium data is accordance with research that has been done previously using the threshold technique [8].

- DICOM Data

DICOM CT-Scan 3D data of patients were obtained from the radiology department of the Faculty of Medicine, Public Health and Nursing (FKKMK) Universitas Gadjah Mada (UGM) - Central General Hospital (RSUP) dr. Sardjito.

- DICOM Viewer and segmentation

The DICOM file was processed using the DICOM Viewer and Segmentation software that is 3D Slicer. The software was used to view the DICOM file and segment it to obtain a region of interest for this research, the cranium. Threshold value that used in this research is 150 for the lower limit and the upper limit using the default value 2976. After the segmentation process, then the next step is to vary the smoothing module with the aim of eliminating some areas that are not included in the region of interest or can also be referred to as noise.

- Smoothing Modules

The smoothing module is located in the segment editor which main function is to smooth the area that has been segmented before. There are 5 types of smoothing modules that are median, opening, closing, gaussian, and joint smoothing [9]. Median is to removes small extrusions and fills small gaps while keeps smooth contours mostly unchanged. Applied to selected segment only. Opening is to removes object smaller than the specified kernel size. Closing is fills sharp corner and hole smaller than the specified kernel size. Gaussian has stronger smoothing for all object details, but tend to shrink the object. Joint smoothing is tend to preserving watertight between separate objects.

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After vary the 5 types of smoothing modules, 2 modules will be selected for the next step which is vary the kernel size to know the effect on the result of cranium segmentations. Kernel size is diameter of neighborhood that will considered around each voxel. In the 3D Slicer software documentation, it is explained that the greater the kernel size value, will makes the smoothing stronger and more details will be surpressed. In this study will vary 5 values of kernel size, that is 1, 2, 3, 4, and 5 mm with 3 mm is the default kernel size.

3 Results and Discussions

This research used 3D Slicer software for segmentation the cranium from DICOM data. This step used the same threshold value.

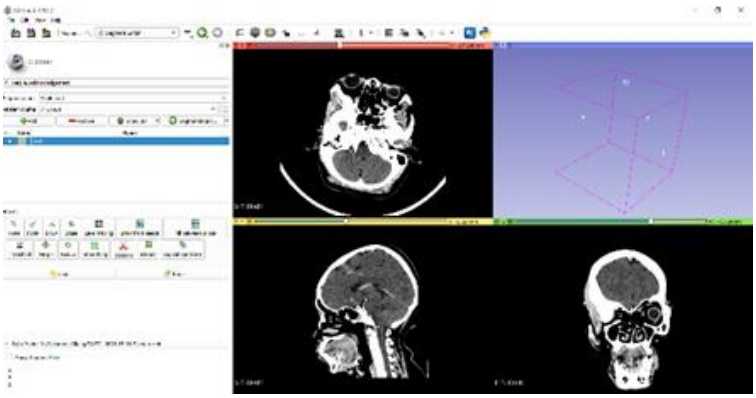


Figure 2. User interface of the first software.

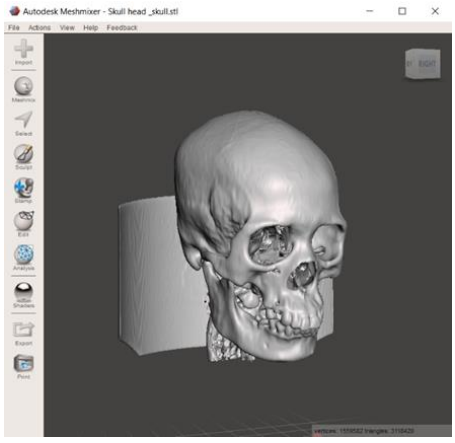


Figure 3. Segmentation output

The user interface of the first software is shown in Fig. 2. This software can show three planes commonly used by the medical officer to view CT imaging results,

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namely axial, sagittal, and coronal, shown as the red, yellow, and green in window tabs. After opening the DICOM file, segmentation was carried out to determine the region of interest.

The segmentations result showed in Fig. 3 is segmentation without using smoothing module. Next will be discussed the results of segmentation using smoothing modules which will be shown in 2 views that is coronal plane and sagittal plane.

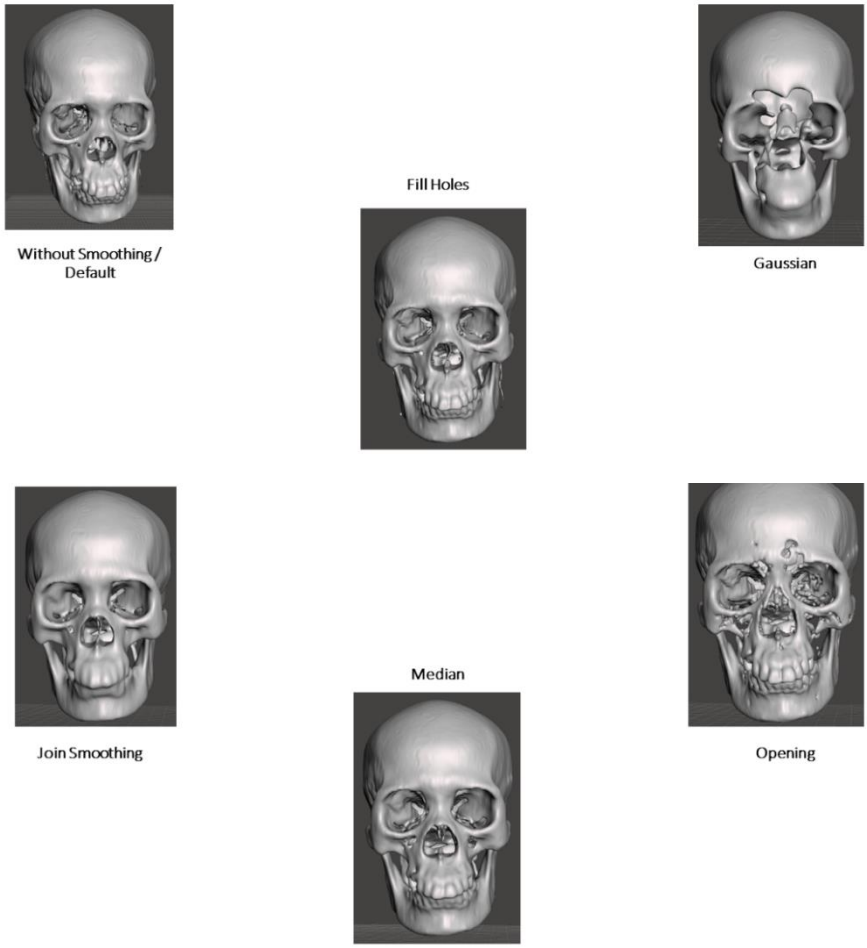


Figure 4. Segmentation using smoothing module coronal plane

The results of segmentation using smoothing modules can be seen in Fig. 4 for coronal plane and Fig. 5 for sagittal plane. When viewed from the coronal plane Gaussian has poor results because many details are missing such as in the frontal and maxilla. Opening also has poor results because some parts are perforated and include removing details from the cranium. Join smoothing has quite good results but in the

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teeth the details are lost. If from the coronal view, the median and fill holes have the best results among other smoothing modules.

Move to Sagittal View, Gaussian and Opening still have poor results, especially some parts of the cranium that disappear so that the anatomy parts is not very clear. Join smoothing has quite good results as well, but especially in the ethmoid part the cranium loses a lot of parts so it loses a lot of detail.

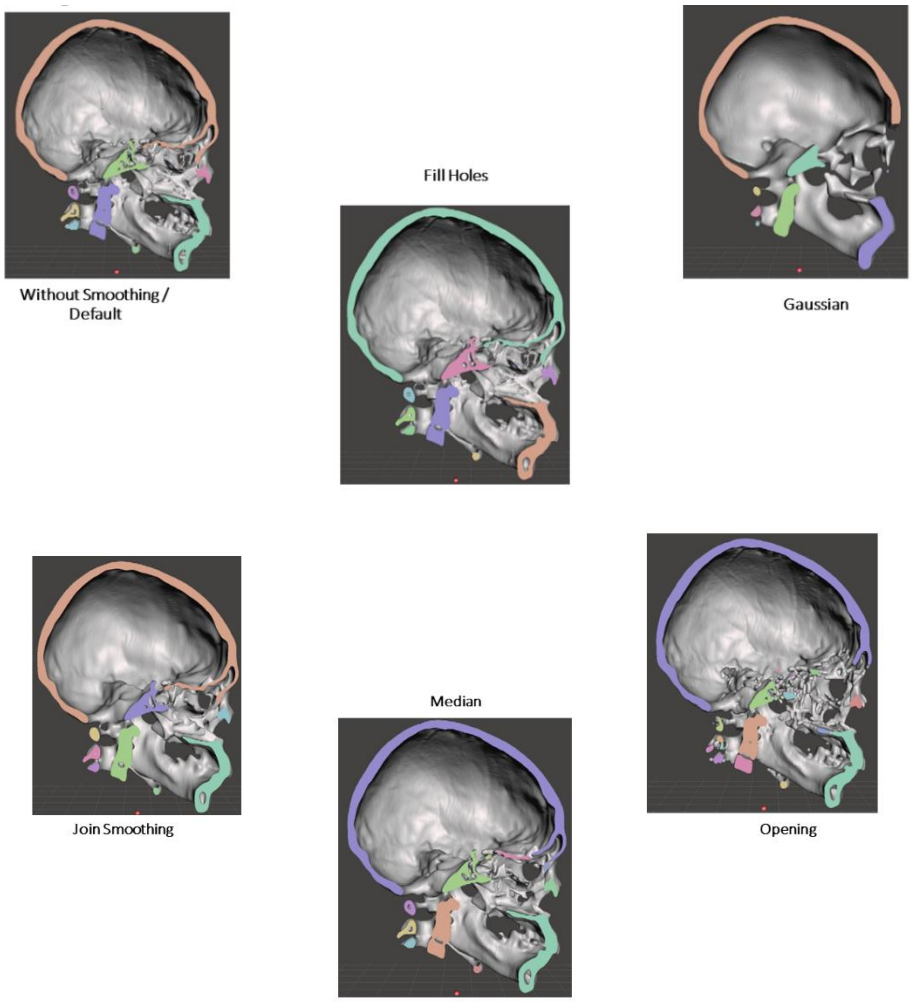


Figure 5. Segmentation using smoothing module sagittal plane

Comparison of segmentation results without smoothing module and smoothing module fill holes is shown in Fig. 6. If using fill holes, the result is that many cavities in a bone become more closed. In addition, there are also many parts of the cranium that are connected better using this module and can be seen around the occipital and sphenoid have quite good detailed results.

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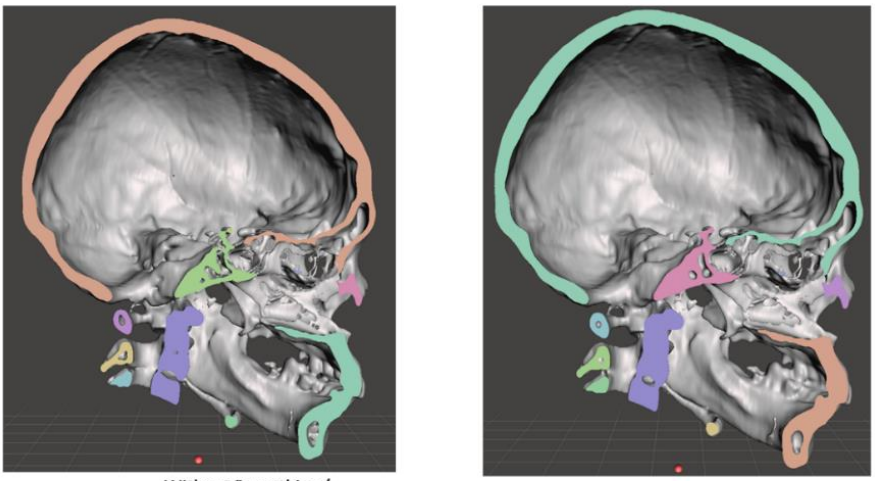


Figure 6. Segmentation using smoothing module default (left) and fill holes (right)

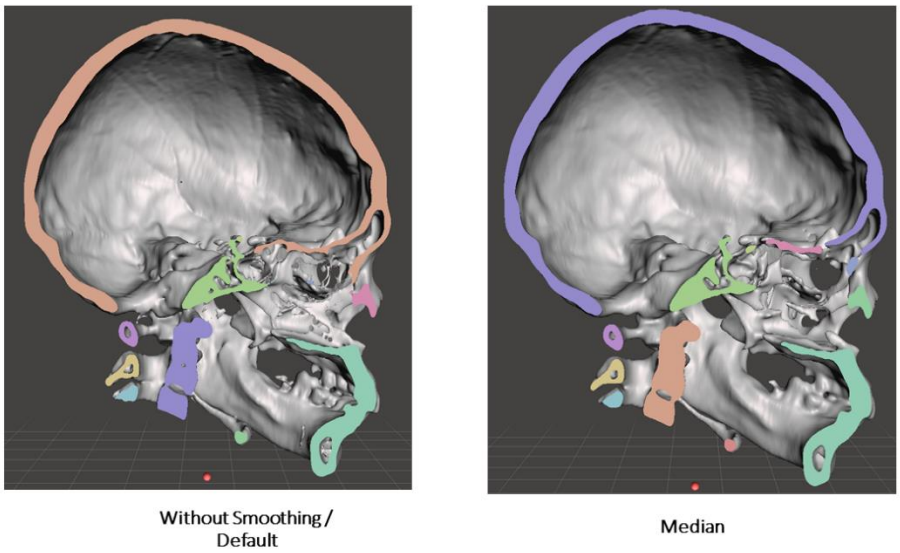


Figure 7. Segmentation using smoothing module default (left) and Median (right)

If it use the median smoothing module that can be seen in Fig. 7, the result is almost similar to fill holes, which close several cavities in the bone and can join several separate parts if segmented without using a smoothing module. But in certain parts there are several parts disconnected such as around the frontal and sphenoid.

As a decision in this first step of experiment, smoothing module fill holes and medians will be selected to proceed to the second experimental step, which is to vary

the kernel size of these two smoothing modules to find out the effect to the cranium segmentation.

The results of cranium segmentation using smoothing module fill holes by varying the value of the kernel size can be seen in Fig. 8 for coronal view and Fig. 9 for sagittal view. When viewed from the coronal view for kernel size variations does not provide a significant difference.

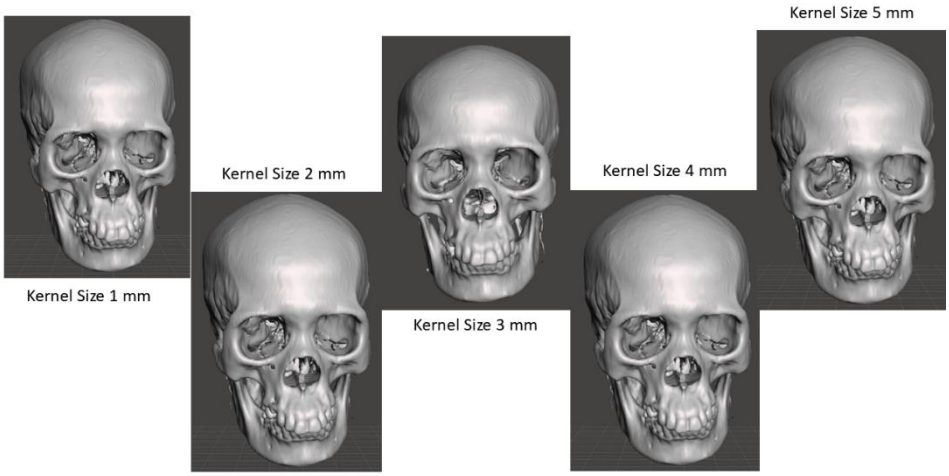


Figure 8. Segmentation using smoothing module fill hole coronal view.

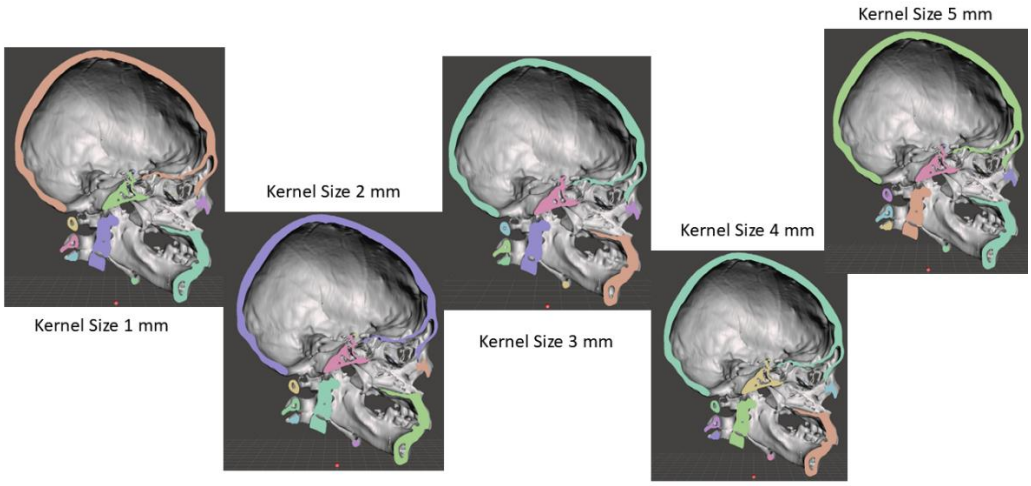


Figure 9. Segmentation using smoothing module fill hole sagittal view.

When viewed from the sagittal view in the kernel size range from 1 mm - 3 mm, in the spine and around the occipital the higher the value of the kernel size value, the cavity will be more closed and also in kernel size 3 (default value) still has a fairly good

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anatomical detail around the occipital compared to the kernel size of 1 mm and 2 mm. But in kernel sizes of 4 mm and 5 mm, anatomical details are reduced because the results are almost the same as kernel sizes of 1 mm and 2 mm characterized by cavities that expand back around the mandible, spine, and occipital. The best result of the kernel size variation in smoothing module fill holes is the kernel size of 3 mm.

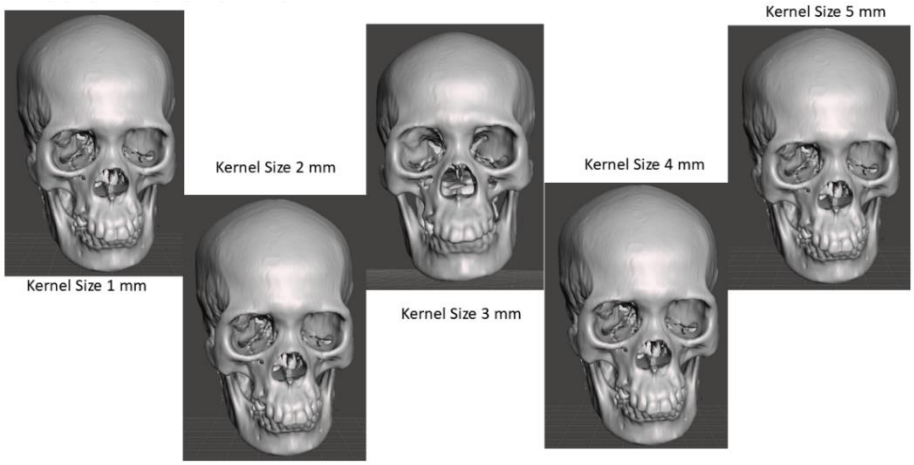


Figure 10. Segmentation using smoothing module median coronal view.

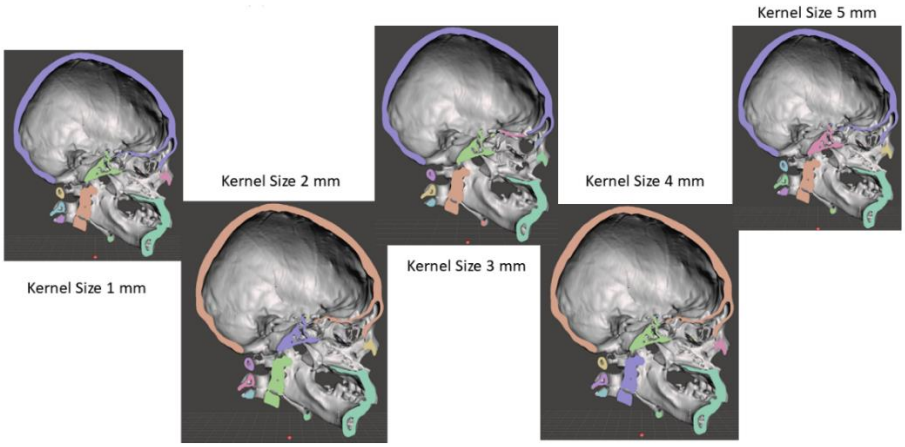


Figure 11. Segmentation using smoothing module median sagittal view.

The results of segmentation using the smoothing module median by varying the kernel size can be seen in Fig. 10 for coronal view and Fig. 11 for sagittal view. The coronal view median has a slight difference with fill holes, which is at the kernel size of 3 mm the segmentation results have a slight reduction in detail in the teeth. This reduction is not seen in any other kernel size other than 3 mm. When viewed in sagittal

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view, the results are almost similar to fill holes. The results at kernel sizes of 1 mm and 2 mm are similar to the results of kernel sizes of 4 mm and 5 mm. The default kernel size of 3 mm has different characteristics from other kernel sizes which can be seen in comparison with the kernel sizes of 2 mm and 4 mm which will be shown in more detail in Fig. 12.

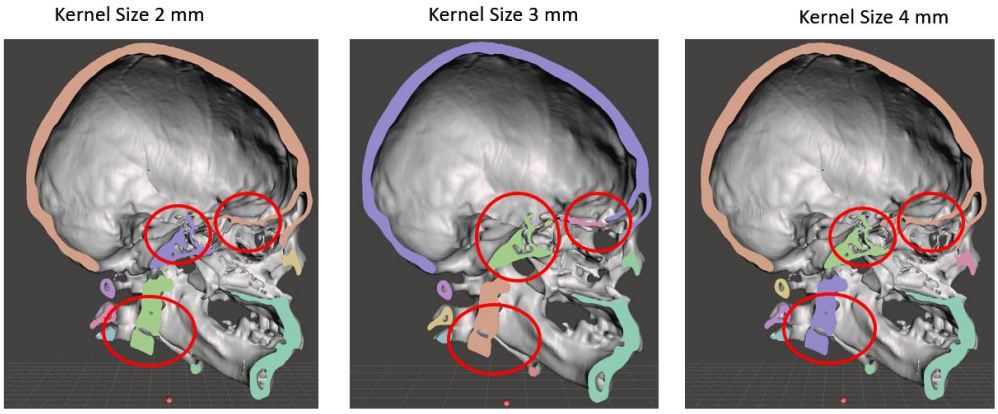


Figure 12. Comparison result median sagittal view.

Kernel size 3 mm has quite good segmentation results on the spine and occipital when compared to kernel sizes of 2 mm and 4 mm. But the 3 mm kernel size has disadvantages around the sphenoid parts that do not connect and where the segmentation results in kernel sizes 2 and 4 have better sphenoid results that connect compared to the 3 mm kernel size.

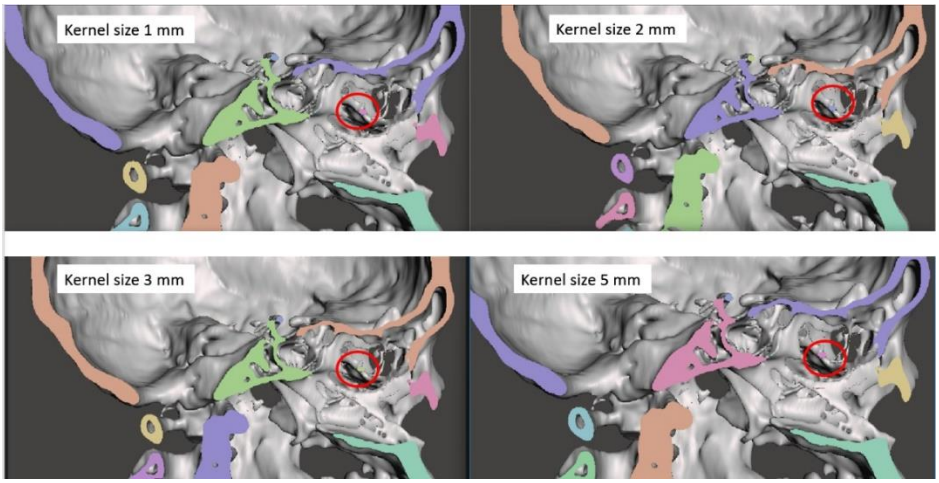


Figure 13. Comparison result median kernel size 1, 2, 4, 5 mm.

kernel size other than 3 mm also has other similarities that can be seen in Fig. 13, which both have details around the maxilla that are not found in the kernel size of 3 mm. Therefore, for the most optimal results 5 mm kernel size was chosen even though the results were almost the same as 1 mm, 2 mm, and 4 mm, but the 5 mm kernel size subjectively had more optimal results compared to others.

4 Conclusions

Studies on the effect of smoothing modules and kernel size have been presented on the results of cranium segmentation. The results of this study used 5 types of smoothing modules fill holes, gaussian, join smoothing, median, and opening smoothing. The results with default parameter fill holes and median have better results compared to others. Kernel size variations are performed for smoothing module fill holes and medians. The result is fill holes get optimal segmentation results using a kernel size of 3 mm and the median is 5 mm. This research is limited to its application to cranium segmentation only. The direction of future research is to conduct a study of the optimal smoothing module for each anatomy part such as the brain, heart, liver, and abdomen.

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