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Research Paper

An In-depth Analysis of Rendered Models using Blender

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A B S T R A C T

The research investigated the efficiency of a novel virtual reality (VR) method for anatomy education utilizing a web application designed for virtual dissection. This platform encompasses various features, including virtual dissection, quizzes, a chat forum, and direct messaging, transforming it into a virtual dissection classroom. To evaluate the efficiency of the virtual reality system we compared the web application with other existing web applications using parameters such as Accuracy, Precision, Jaccard index, Dice co-efficient, Processing time, and user rating. From the result obtained from the research in comparing the rendered models from this research with models from other work, the rendered models were able to achieve a Jaccard index of 0.93 and a dice coefficient of 0.94. It also achieved a remarkable average processing time of 15 seconds and a high user rating of 4.5.

INTRODUCTION

In earlier times, the widespread practice of dissecting the human body served as a fundamental method for gaining a deeper understanding of anatomy and advancing medical knowledge [1]. Anatomical dissection is a deliberate and systematic examination of human tissues and organs through the physical act of cutting along specific body planes, regions, and organs. This process allows for the identification, definition, and exploration of various structures, ultimately enhancing the learning experience [2]. In contemporary times, while the frequency of such dissections has diminished, their relevance persists in addressing everyday clinical inquiries and providing valuable insights to support surgical practices [3].

The growing number of medical students and the limited availability of cadavers have resulted in a decline in anatomy education through human cadaveric dissection. As a consequence, new and inventive teaching and learning methods have emerged to enhance students' understanding of anatomy [4]. One such method that has gained popularity is the use of virtual reality (VR) technology.

Virtual reality (VR) is a computer-generated, three-dimensional virtual environment that allows users to interact with it [5]. This immersive experience is typically accessed through a computer capable of displaying 3D information via a display. The display can be in the form of isolated screens or a wearable device, such as a head-mounted display (HMD) [6]

This study examined the efficiency of the Virtual Dissection System (VDS), a virtual reality web application for anatomical dissection developed as a result of this research. The paper also presented a comparative analysis of this system against other existing dissection applications. Performance metrics such as accuracy, precision, Jaccard index, dice coefficient, and processing time.

In order to provide a comprehensive understanding of the novelty of this work, this session will delve into a detailed discussion of related works. This will shed further light on the significance and originality of this research.

The paper is structured into four sections. It commences with a literature review covering existing virtual dissection applications and their methodologies. Subsequently, the methodology employed in this research is delineated. Following that, the outcomes and discussions are presented. Lastly, the paper concludes with a summary and outlines directions for future work.

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In a study by [7], a virtual anatomy system was developed to address the challenges associated with learning anatomy, such as the scarcity of anatomical specimens and the limitations of dissection techniques that can alter the shape and position of anatomical structures. This system was created using high-resolution thin-sectional anatomical images from the Chinese Visible Human dataset, encompassing both male and female anatomical structures.

In this study the methodology which was stated was not clearly explained and it becomes difficult for other researchers to replicate or build upon this work, without a clear understanding of how the study was conducted, it becomes difficult to assess the validity and reliability of the findings.

In their study, [8] designed and implemented a virtual reality gaming system known as Cognitive Arenas. This game was developed using Unity, a comprehensive environment that integrates several sophisticated elements, including the PhysX physics engine, the Mechanim animation system, a self-contained terrain editor, and many other features. Unity seamlessly interfaces with the Monodevelop code editor, enabling transparent compilation of any changes made in Monodevelop by Unity's C# or Javascript compilers. These changes are then seamlessly incorporated into the game, ensuring a smooth development process. Any compilation errors are conveniently displayed in the Unity console window. Furthermore, Unity was also responsible for rendering and provided the necessary scripting for asset tracking. The models used in the game were imported into 3ds Max using the. FBX format. The game developments had a shader, physics engine, network, terrain manipulation, audio, video and animation.

One limitation of this design is that the models were solely rendered without any texturing, resulting in a significantly reduced level of realism for the models.

[9] conducted a study on the utilization of digital virtual simulation (DVS) as a supplementary tool for teaching anatomy. DVS offers students three-dimensional (3D) stereoscopic images and precise anatomical structures, enhancing the learning experience. A study was conducted to assess the effectiveness of digital virtual simulation (DVS) as a method of teaching theoretical knowledge and practical skills in the field of anatomy. The study involved administering questionnaires to a total of 60 students, which included tests on memorization of anatomical structures, self-learning abilities, scientific thinking abilities, and operating skills.

The findings from the survey revealed that the conventional teaching method, when supplemented by DVS, proved to be a superior option compared to the conventional method alone. This suggests that incorporating digital virtual simulation into anatomy education can greatly enhance the learning experience. The application of digital virtual simulation holds great potential in supplementing the teaching of gross anatomy.

This paper was able to show the importance of Digital virtual simulation (DVS), however the process of combining DVS with the traditional teaching method of anatomy was not clearly stated. The potential challenges or limitations associated with combining DVS with traditional teaching methods was not addressed.

In a study carried out by [10] a virtual dissection table called Diva 3d was developed. This advanced system offers three-dimensional vector models of the human body, derived from anatomical slices obtained through an extensive series of cryosections from the renowned Visible Human Projects. These vectorial models offer a comprehensive representation of the human body, allowing for detailed analysis and exploration of its anatomical structures. By utilizing cryosection techniques, which involve freezing and slicing the body into thin sections. The learning of this method and its practical application were evaluated on a multicentric cohort of 86 people divided into 3 groups, according to the duration of their training (1, 2 or 3 days, respectively. Ninety-four percent of the subjects rated the device as excellent and would continue to use digital anatomy in their practice.

In a research carried out by [11] they designed a virtual reality simulator that was built on Unity a platform for game development, they meticulously crafted a captivating virtual environment and all models were created using Blender. The configurations in unity using the Oculus quest 2 controllers. The objects in the application adhere to the principles of physics, mirroring real-life behavior. A collider was implemented to prevent objects from passing through each other, ensuring a realistic experience. Rigid body scripts and C# scripts were developed and employed to govern object movement, incorporating fundamental principles such as Newton's force, gravity, and acceleration, thereby mimicking real-life physics. Furthermore, a dissection-specific pressure meter was developed, enabling students or doctors to simulate the dissection process authentically. This meter displays all the necessary parameters for dissection, enhancing the effectiveness of the learning experience for users. Their research showcases the potential of Unity and Blender and also highlights the importance of seamless integration with cutting-edge hardware like the Oculus Quest 2 controller.

The result of this research was a real time simulation of the human Thorax. This approach had a good simulation result however, this simulation is limited to only the human thorax, mainly focusing on the heart. While it provides valuable insights, it does not provide a comprehensive understanding of the entire human anatomy curriculum. Also, the simulation of the heart which was shown in the result was focused on only outer arteries and veins and did not give enough intricate details of the heart itself. Also, this is a research that has not been made available for use to the public.

METHOD

Modelling, Labelling, and Exporting

The models were all made on blender (Anatomy by region). Blender is a powerful tool that allows users to create amazing 3D models and graphics without paying for expensive software [12]. One of the major advantages of using Blender is its cost-effectiveness. Unlike other professional software that requires a significant financial investment, Blender is completely free to download and use. This accessibility democratizes 3D modeling

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and allows students, educators, and researchers, to explore the its use without any financial barriers. After modeling, the models were all labelled using data obtained from Clinically Oriented Anatomy, 8th edition. The models were then exported in. glb format into swift XR. Swift XR is a development solution that helps developers to effortlessly craft immersive and interactive 3D, AR, and VR experiences. It facilitates the seamless publication of model codes created within a web application [13].

In swift XR, the models code was published and then made ready for embedding into the web application that was designed.

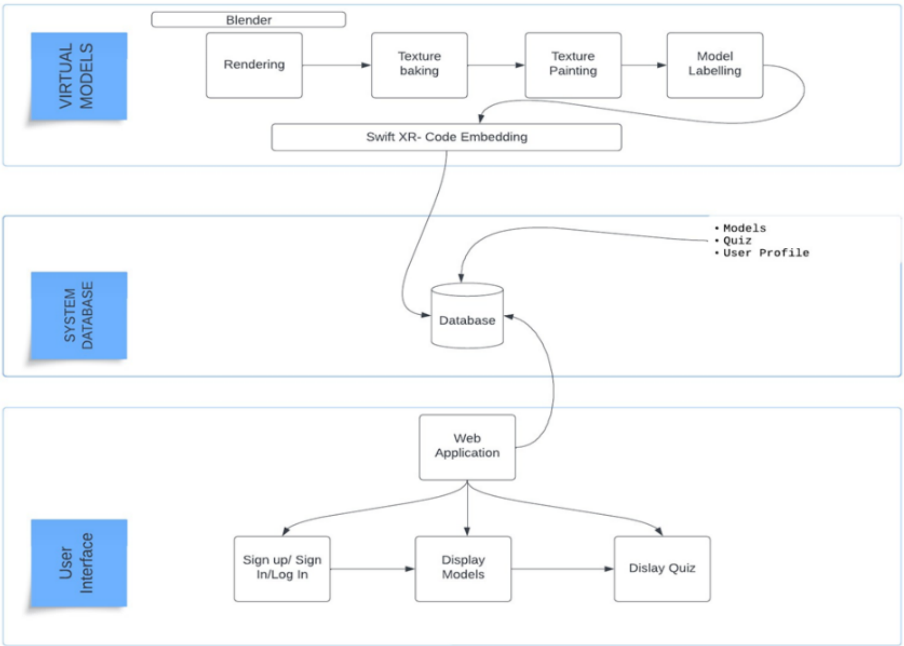

Figure 1: System block diagram.

System System specification measurement for Performance evaluation

For the purpose of this research a high-definition Lenovo Think book 14 G2 ITL core i7 was used to render the images and also to test run for the processing time of each of the rendered models. Table 1 and 2 give in detail the specification of the system offering detailed information that is crucial for understanding its functionality and capabilities.

Table 1: Device specifications of system used

S/N	Device Specification	Result
1	Processor	11th Gen Intel(R) Core (TM) i7-1165G7 @ 2.80GHz 2.80 GHz
2	Installed RAM	8.00 GB
3	System Type	64-bit operating system, x64-based processor

Table 2: Window Specifications of system used

S/N	Device Specification	Result
1	Edition	Windows 11 Pro
2	Version	21H2
3	OS build	22000.856

Dataset Description

The data used for labelling the models was obtained from the renowned resource, Clinically Oriented Anatomy, 8th edition [14]. Clinically Oriented Anatomy is a highly regarded and widely used resource in the field of medical education. This anatomy textbook provides a detailed and comprehensive understanding of human anatomy, focusing on its clinical relevance. Medical professionals, students, and educators often turn to this resource to enhance their knowledge of anatomical structures and their clinical implications. The book offers in-depth explanations of various anatomical regions, emphasizing the functional aspects of the body's structures and their significance in a clinical context.

Evaluation Metrics for Models

The evaluation metrics used for the comparison of the models are explained in details below:

- **Accuracy**: is an absence of bias. Accuracy refers to the extent to which a calculated or measured value aligns with the true value. It serves as a measure of the statistical error, which represents the disparity between the measured value and the actual value [15] For this research, the accuracy of the models was calculated in its effectiveness of identifying anatomical structures.

  The accuracy was calculated using the percentage error. To find the percent error, results of the measurement is subtracted from the accepted value and then divided by the accepted value. Then multiply the figure by 100.

$$\% \ Error = \frac{Measured \ Value - Actual \ Value}{Actual \ Value} X100 \quad (1)$$

- **Precision**: This is the proportion of correctly identified structures among all identified structures [16]. When evaluating precision, it is essential to consider both true positives (correctly identified structures) and false positives (incorrectly identified structures). By calculating the proportion of correctly identified structures among all identified structures, it is easy to access the system's ability to avoid false positives. The formula for calculating precision is given as;

$$P = \frac{TP}{TP+FP} \quad (2)$$

Where,
P is the precision of the model
TP is the True positive
FP is the False positive

A high precision value indicates that the system has a low rate of falsely identifying irrelevant or incorrect structures. This suggests that the system is reliable in accurately identifying the desired anatomical structures. On the other hand, a low precision value implies that there is a significant number of false positives

- **Jaccard Index (Intersection over Union, IoU):** The Jaccard index measures the similarity between two sets by calculating the intersection divided by the union of the sets [17]. In the context this research, it is used to assess how well the segmented regions by the model overlap with the ground truth regions. A higher Jaccard index indicates better overlap and is a measure of the model segmentation accuracy.

The formula for calculating Jaccard index is shown in is given as;

$$J(A, B) = \frac{(A \, n \, B)}{(A \, u \, B)} \quad (3)$$

Where,
J is the Jaccard index
A is the binary segmentation of the models
B is the size of the ground truth

- **Dice co-efficient**: The Dice coefficient is similar to the Jaccard index and measures the similarity or overlap between two sets. It is particularly useful for assessing the accuracy of binary segmentations of the models. It helps to assess the accuracy of binary segmentations of the models because it allows the comparison of the predicted segmentation with the ground truth segmentation. By evaluating the overlap between these two segmentations, it provides a means to quantitatively measure how well the model has captured the desired regions.

The dice co-efficient is calculated as twice the intersection of the sets divided by the sum of the sizes of the two sets. where A the binary segmentation and B is the size of the ground truth and this is mathematically expressed as;

$$DSC(A, B) = \frac{2 \, (A \, n \, B)}{(A \, u \, B)} = \frac{2 \, (TP)}{2(TP+FP+FN)} \quad (4)$$

Where,
DSC is Dice co-efficient
A is the binary segmentation of the models
B is the size of the ground truth
TP is True Positive
FP is False Positive
FN is False Negative

- **Processing Time**: The duration necessary for the rendered models to process and accurately identify structures. Processing time is calculated using the formula;

$$PT = \frac{(T)}{(IP)} \quad (5)$$

Where,
PT is the PT is the Processing Time (seconds per item).
T is the total amount of time (secs).
IP is the total amount of items processed

- **User rating**: User rating is important as it helps to provide valuable insights into the quality and functionality of a system. It also helps to identify specific strengths and weaknesses of the system. The user rating was calculated using the average rating calculation, which is given as;

$$AR = \frac{(1A \times 2B \times 3C \times 4D \times 3E)}{(R)} \quad (6)$$

Where,
AR is the average rating
a is the number of 1-star ratings
b is the number of 2-star ratings
c is the number of 3-star ratings
d is the number of 4-star ratings
e is the number of 5-star ratings
R is the total number of ratings

In summary, the algorithm for validating the proposed model for different regions of the model is as follows:

- Input: Rendered models in Blender.
- Output: Accuracy, precision, Jaccard index, and dice-co-efficient scores.
- The score was calculated using the X, Y, Z coordinates of the blender workspace.
- The binary segmentation was calculated at the point of the segmented rendering before texture painting was done
- The Jaccard index and dice co-efficient were calculated after texture baking using the X, Y, Z coordinates.
- The processing time was calculated by loading each model in the web application and getting the average it took for all the models to load. This approach allows to assess the efficiency of each model's loading process and identify any potential areas for improvement.
- For the survey the web application was given to students to use and a rating scale was added. By collecting ratings from multiple students who used the web application, an average or aggregate score was be calculated.

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RESULTS AND DISCUSSION

This section presents and discusses the obtained results from the rendered models, it also evaluates the efficiency of the rendered models and other existing models.
Table 3 shows the results of the metric evaluation of metric scores for all regions. The metrics used are Accuracy (A), Precision (P), Jaccard Index (JI), Dice Coefficient (DC), and Processing Time (PT). The table shows the results of the metric evaluation of metric scores for all regions. The metrics used are Accuracy (A), Precision (P), Jaccard Index (JI), Dice Coefficient (DC), and Prediction Time (PT).

Overall, the models perform well in all regions, with Accuracy scores above 97%. The Upper Limb and Male Thorax models have the highest Accuracy scores, while the Head and Neck model has the lowest Accuracy score. The Precision scores are also high for all models, above 0.90. The Precision score for the Female Thorax model is slightly lower than the other models, but it is still considered to be good. The Jaccard Index and Dice Coefficient scores are also high for all models, above 0.92. These metrics are used to measure the similarity between the predicted segmentation masks and the ground truth segmentation masks. A higher score indicates better similarity. The Processing Time scores are low for all models, below 15 seconds. This means that the models can process segmentation masks quickly. The high Accuracy, Precision, Jaccard Index, and Dice Coefficient scores indicate that the models are able to accurately identify and segment the different regions of the body. The low Processing Time scores indicate that the models are able to predict segmentation masks quickly.

Based on Table 4, VDS (which is the system implemented) has the best performance overall among the virtual dissection applications compared. It has the highest Jaccard Index and Dice coefficient, which are measures of similarity between two sets. VDS also has the fastest processing time and the highest user rating.

Table 3: Metric evaluation by metric score for all regions

S/N	Models	Metrics Score				
		A (100%)	P (1)	JI (1)	DC (1)	PT (secs)
1	Upper Limb	99	0.94	0.97	0.98	15
2	Lower Limb	98	0.97	0.92	0.93	10
3	Male Thorax	99	0.97	0.94	0.96	13
4	Female Thorax	99	0.95	0.85	0.87	15
5	Head and Neck	97	0.90	0.92	0.89	12
6	The Brain (Sagittal Cross Section)	99	0.99	0.98	0.99	17

Table 4: VDS performance evaluation in comparison with other virtual dissection application.

S/N	Web Application	Jaccard Index	Dice-co-efficient	Processing time	User rating
1	VDS	0.93	0.94	15secs	4.5
2	Anatomy 3D Atlas (2019)	N/A	N/A	20secs	3.2
3	3D Human Anatomy (2022)	N/A	N/A	30 secs	4.2
4	Visual Anatomy (2023)	N/A	N/A	35 secs	4.1
5	Organs 3D (2019)	0.42	0.3	19secs	1.0

CONCLUSIONS

The software was designed to provide a virtual dissection experience that closely mimics the real-life process of cadaver dissection. It includes detailed 3D models of human anatomy, which can be manipulated and explored from different angles and perspectives. From the result presented in section 4 in comparing the rendered models from this research with models from other work, the rendered models were able to achieve a Jaccard index of 0.93 and a dice coefficient of 0.94. It also achieved a remarkable average processing time of 15 seconds and a high user rating of 4.5.
Future work will explore applying Magnetic Resonance Imaging (MRI) to enhance the level of detail in the models.

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