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RESEARCH SOME TECHNIQUES PROCESSING OBJECT AND APPLICATION SIMULATION IN MEDICAL

Abstract Doctoral Thesis of Computer Science

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Contents

Introduction

The world has witnessed many drastic changes and upheavals due to natural disasters, epidemics and wars leading to reduced human interaction, limited travel, study and work. Research to build virtual interactive applications in medicine to help share, train, evaluate and diagnose remotely [2, 20], which contributes to eliminating current problems. Besides, the rapid development of artificial intelligence, deep learning, virtual reality has become an indispensable part integrated in applications such as healthcare systems. However, the problem is to ensure safety when transmitting this data over the Internet. The approach of the thesis to solve this problem is to integrate cryptographic techniques as well as encryption and decryption algorithms [11, 21]. The research to solve the problem of simulating the human body and building applications for the study, study and practice of anatomy is a new issue for Vietnam, while there are requirements reality is posed. Within the scope of the research, the thesis focuses on the issues of interest: object processing techniques in medical simulation, 3D object optimization, image processing and image display based on technology. virtual reality 3D technology, the application of simulating the human body and encoding data on the transmission line. Therefore, the goal of the thesis is "*Research some techniques processing object and application simulation in medical*". The research topic is towards the simulation and representation of the complete virtual body and the security of medical information on the transmission line, specifically the thesis focuses on the following issues:

- First: Reviewing and developing techniques for 3D object processing, modeling, reconstruction techniques, surface simulation, and materials of the model. Evaluate and select appropriate and effective methods.
- Second: Researching and optimizing models, researching multi-user techniques in 3D virtual reality, researching virtual reality 3D simulation techniques from medical images (MRI, X-Ray, CT Scan).
- Third: Research on medical data encryption techniques in the process of transferring image data between devices.
- Fourth: On the technical basis, it is proposed to build and test a system of some parts of the human body such as: skeletal, muscular, digestive, circulatory, nervous, heart systems.

With the objectives of the thesis as above, in addition to the introduction and conclusion, the thesis is organized into 3 chapters:

- Chapter 1: Overview of object processing in medical simulation
- Chapter 2: Proposing some techniques for handling objects in medical simulation
- Chapter 3: Applying object processing techniques to build a virtual reality simulation system of the human body.

In chapter 1 introduces some basic knowledge, representation techniques for reconstruction, interaction on objects and approaches to object processing, overview of simulation and 3D simulation. Chapter 2 the thesis proposes a number of techniques: Effective RGB color selection for complex 3D object structures, techniques to improve the effectiveness of multi-user interaction in virtual reality, besides Producing techniques to enhance encryption of medical data in transit in IoT-based distributed systems. Chapter 3 is based on the techniques proposed above to build a simulation system of the human body for research and teaching of anatomy with analysis and comparison effectively through an experimental system.

The research results of the thesis contribute to supplementing and perfecting effective 3D object processing solutions applied to simulate virtual reality in medicine. Specifically, the thesis has 4 main contributions:

- Propose an effective RGB color selection technique for complex 3D object structures based on a combination of tagging and marking methods by selecting RGB color areas on the object structure in the scene graph system.
- Technical proposal to improve the efficiency of multi-user interaction in augmented reality with scenarios where users have the same geospatial and different geospatial.
- Proposing Memetic algorithm to enhance encryption of medical data on transmission in IoT-based distributed systems using Memetic algorithm combined with DWT transformation.
- Building a system that simulates the organ systems in the human body: skeletal, muscular, circulatory, nervous, respiratory, digestive, excretory, genitourinary systems, ...

Chapter 1

Overview of object processing in medical simulation

1.1 Simulation systems

Table 1.1: Compare the performance of simulation systems

Main features	Embedded System	Semi-Embedded System	Fully-Embedded System
Resolution	High	High	Medium
Perception of spatial extent	Low	Medium-High	High
Interactive abillity	Low	Medium-High	High
Field of Observation	Low	Medium	High
Latency	Low	Medium	Medium-High
Feeling present in AR/VR	No-Low	Medium-High	Medium-High

1.2 3D simulation in medicine

Up to now, the prominent field in medicine that has successfully applied simulation technology is Surgical Simulation [17] Based on computer graphics and simulation techniques, this medical training system consists of two basic parts: The three-dimensional interactive block is a virtual organism model that allows the user to perform manipulations. anatomy through virtual anatomy instruments; The two-way user interface block provides visual feedback from the model during anatomy as well as instructional information during the training session..

1.3 3D modeling and optimization principles

A 3D model [16] is a data structure that describes the 3D morphology of an object. There are two types of optimization problems in the field of 3D simulation. First, is optimal in terms of images. Second, is to optimize the number of grids.

1.4 Some techniques for performing and reproducing on 3D objects

There are two methods of representing three-dimensional objects: surface representation and spatial partitioning. To minimize the memory space of the model, one of the approaches is to minimize the number of model representation surfaces. In geometric modeling, smooth surfaces are often used to describe the surfaces of real objects. The most commonly used form is the fragment or parametric surface [5]. Most implicit surface reconstruction algorithms incorporate local implicit primitives to represent surfaces based on the idea developed by Blinn [18].

1.5 3D object interaction and multiple user perspectives

To ensure the accuracy of the interaction, it is necessary to analyze the user's position based on the virtual environment projection to ensure that the 3D object projection point is not distorted with the user's viewing position [6, 12]. Mapping between interactive components and devices is a big challenge. First, the user can observe the connection between the device and the virtual representation of the device from the point of view. Second, interactive devices track the user's hand movement and must visually respond to it.

1.6 Security for data 3D objects

Medical data exchange has now become a regular event of daily life in many hospitals. However, the problem is to ensure safety when transmitting this data over the Internet. Although the `https` protocol has been equipped with security techniques, medical data transmission systems still need a secure method in the IoT environment [1, 4, 19]. The approach to solving this problem is to integrate encryption techniques to avoid intrusions and unauthorized access to the system [11, 15, 21]

Chapter 2

Proposing some techniques for object processing in medical simulation

2.1 Efficient RGB color selection technique for complex 3D object structures

2.1.1 Current problem

Graphics objects are reproduced pixel by pixel to produce the final image on the screen. With complex objects, pixels require thousands of calculations and function calls to be plotted.

2.1.2 Propose an effective RGB color selection model for complex 3D object structure in scene graph system

The proposed method is described in 06 steps in Fig 2.1:

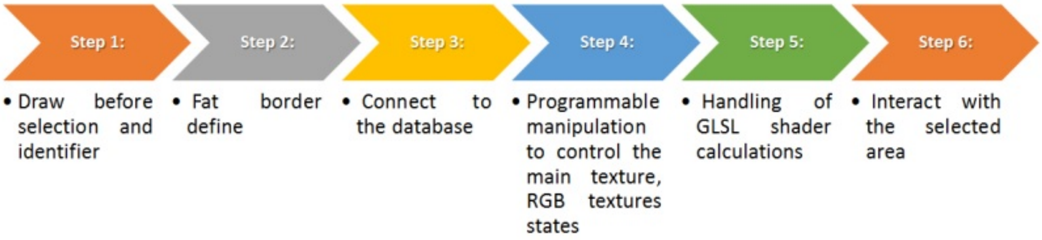

FIGURE 2.1: Effective RGB color selection technique for complex 3D objects.

2.1.3 Experimental results and evaluation

Experiments were carried out on Anatomy Now software system. The proposed method is applied on both static and dynamic 3D objects.

2.1.3.1 Experiment 1: Evaluate the performance of pixel writing operations

Experimental results are compared and evaluated on the following parameters: Average frame rate (FPS), GPU utilization rate (%) and CPU (%), GPU dedicated memory, GPU system memory and GPU committed memory. From the experimental results, the average rasterization speed is always between 44.02 and 60.01, average GPU usage is 9.35%, average CPU is 10.58%, average GPU-specific memory is 1.26 GB, GPU system average memory is 78.38 MB, and GPU committed memory average is 1,186 GB. The results clearly show the advantages of the proposed solution.

TABLE 2.1: Compare and evaluate the pixel write performance of the proposed method

System	Average FPS	GPU (%)	CPU (%)	GPU Dedicated	GPU System	Commited GPU Memory
Skeletal system - ligament	60.01	8.59	7.98	1.01 GB	83.3 MB	1018.8 MB
Respiratory system	59.22	8.84	9.4	1.1 GB	81.4 MB	1.0 GB
Cardio-vascular system	44.02	6.83	12.49	1.2 GB	72.8 MB	1.0 GB
Excretory and genital system	50.5	9.11	9.28	1.2 GB	81.1 MB	1.1 GB
Muscular system	47.62	12.59	12.29	1.8 GB	75.1 MB	1.7 GB
Digestive system	48.68	11.16	10.82	1.4 GB	81.4 MB	1.4 GB
Nervous system	43.52	7.03	12.49	1.2 GB	70.8 MB	1.2 GB
Endocrine system	49.69	10.68	9.89	1.2 GB	81.2 MB	1.1 GB
Means	**50.4075**	**9.35375**	**10.58**	**1.26375**	**78.3875**	**1.186865**

2.1.3.2 Experiment 2: Evaluating the effect on complex 3D objects

The measurements performed show that the proposed method is very good when applied on complex objects, see Table 2.2.

TABLE 2.2: Compare and evaluate FPS benchmarks on human anatomy systems

Character	Solutions	Speed of Rasterization(FPS)
1	Normal Rasterizer	16.1822
2	Incremental Rasterizer	27.0873
3	Block-based Rasterizer	34.9521
4	Non-Optimized GPU implementation	45.1296
5	Our method	**50.4075**
6	Optimized GPU implementation	112.2538

2.2 Techniques to enhance the effectiveness of multi-user interaction in augmented reality

2.2.1 Current problem

The world has witnessed many drastic changes and upheavals due to natural disasters, epidemics and wars leading to reduced human interaction and travel restrictions. Building shareable, virtual interactive applications can help with remote training, assessment, and diagnostics [2, 20]. The interactive environment can also be used for inter-institutional consultations anytime and anywhere

2.2.2 Technical proposal for improving the effectiveness of multi-user interaction in collaborative augmented reality for medical anatomy training

The main goal of this proposal is to develop an application of human anatomy (*AnatomyNow*) for teaching and training in anatomy..

2.2.2.1 Multi-user architecture in augmented reality

The thesis research considers two cases for anatomically multi-AR interaction: 1) Different users in the same physical space; 2) Different users and different geospatial.

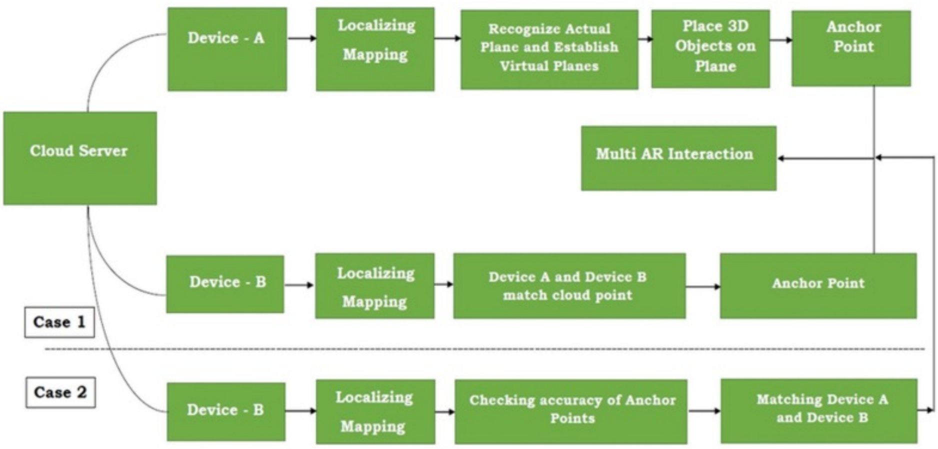

FIGURE 2.2: Augmented reality multi-user architecture

Case 1: **Many different users with the same physical space**. In this case, all devices observe 3D objects placed in a physical location. For example, placing a virtual body on the floor or table can be done as Figure 2.3,

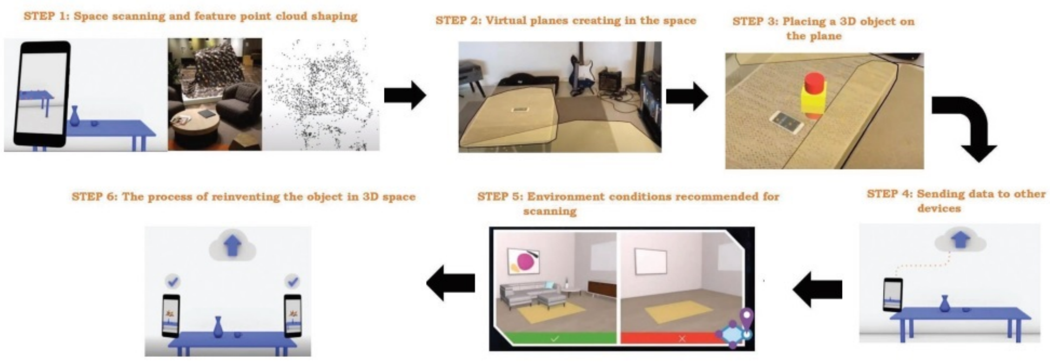

FIGURE 2.3: Detailed model for different multi-user systems in the same physical space

Case 2: Many different users, different physical space. In this case, users participating in AR share the experience and are geographically distant from each other and the process is similar to case 1. The difference is that when device B scans the surrounding space, the The accuracy of the anchor point depends on the fact that the area around device B has been designed to coincide with the position of device A..

2.2.2.2 Multi-user sharing technique

Multi-user sharing is done through two steps: Create space from the original device and share that space with other devices. The proposed AR interactive space sharing technique is illustrated in Fig 2.4.

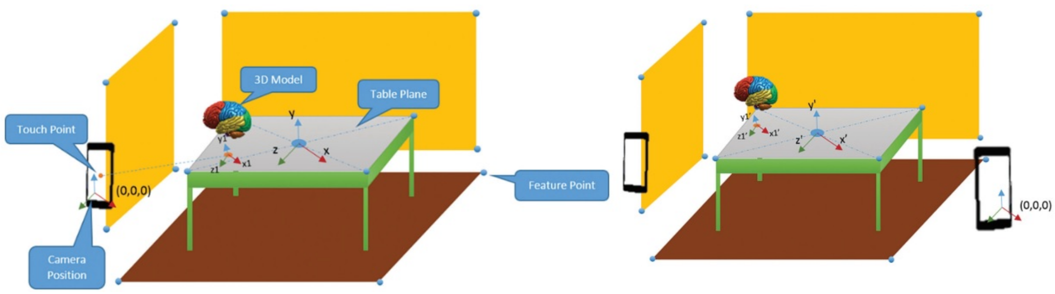

FIGURE 2.4: Make space from the head device and space for other devices

2.2.2.3 Techniques to interact AR with multiple devices

Figure 2.5 illustrating the workflow of multi-device AR interaction.

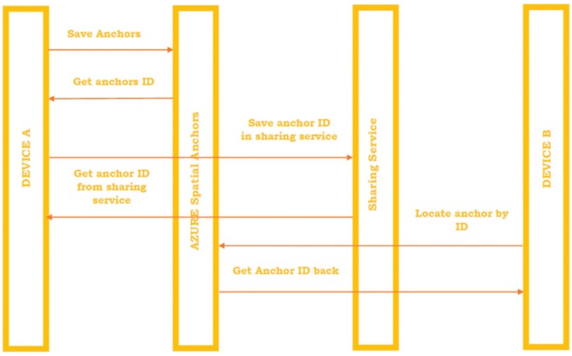

FIGURE 2.5: AR workflow that interacts with multiple devices

2.2.3 Experimental results and evaluation

2.2.3.1 Experimental results

The participants' experience was measured on a Likert scale from 1 to 5. On the Likert scale, 1 represents the most negative experience and 5 represents the most positive experience. Table 2.3 shows AnatomyNow's analysis in HoloLens.

TABLE 2.3: Analysis of different AnatomyNow user groups using HoloLens

Group participation	Data Latency between devices	Distance and exact position between models in different equipment
Group 1	4	5
Group 2	4	4
Group 3	3	4
Group 4	5	4
Group 5	4	4

2.2.3.2 Analyze and evaluate experimental results

TABLE 2.4: Analyze and compare the proposed solution with other solutions

Author	HoloLens approach and results
Maniam and partner (2019) [14]	- Developing MR application for bilateral temporal bone anatomy - Displace the vertices, widen the surface for easy drilling of the temporal bone - Only support one direction drilling, high dissection error rate
Huang and partner (2019) [10]	- Comparison table between VR and AR used in anatomy - Image generator based on position and displacement, labeling. - Camera controller rotate and switch on AR - VR performance is better than AR but there is lag in AR models
Vergen and partner (2020) [9]	- AR anatomy app developed for healthcare system - Controlling and directing the trajectory of the battery in anatomical 3D simulation - Latency in AR models is high
Our Solution (2021) [13]	- Application development for training, teaching anatomy - Color-based interactive 3D objects, pin system for sharing angles camera rotation and orbit - Low latency between devices - Accurate display of AR model position relative to other methods

2.3 Enhanced encryption of medical data in transit in IoT-based distributed systems

2.3.1 Current problem

IoT plays an important role in connecting sensor devices in an integrated communication environment between the real and virtual worlds through distributed systems [7]. The problem is to ensure safety when transmitting this data over the Internet. In this section, the PhD student will propose a security model for the transmission of medical data using the Memetic algorithm..

2.3.2 Propose a Memetic algorithm to encrypt medical data in transit in IoT-based distributed systems

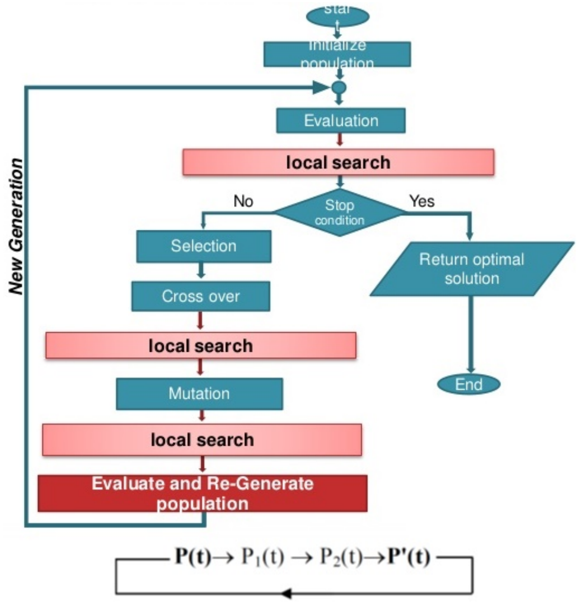

FIGURE 2.6: Evolution of populations in the Memetic algorithm

The Memetic algorithm is described as follows:

Algorithm 2.1 . Memetic Algorithm

Input: Problem, Parameters, Constraints

Output: Ind* (Best Individual)

BEGIN

$Population \leftarrow Init_{Pop}$ (Parameters, Constraints)

Repeat

$Fitness \leftarrow f\,(Population)\,;$

$Pop_{Cross} \leftarrow Crossover\,(Population)\,;$

$Pop_{Mut} \leftarrow Mutation\,(Pop_{Cross})\,;$

$Population \leftarrow LocalSearch\,(Pop_{Mut})\,;$

Until (*Termination Criteria Satisfied*);

END

2.3.3 Memetic algorithm encrypts data

The medical image coding scheme using the Memetic algorithm is described as follows::

Algorithm 2.2 . Memetic algorithm encrypts data

Input: Raw Text File.

Output: Enc_{Text}

BEGIN

Convert the raw text into ASCII Values $Values = ASCII\,(text)$;

Transform the ASCII values in the respective binary form with the base 10:

$$Values_{Bin} = Binary\,(Values)\,;$$

The Binary Values are split into 8 bits/block: $N = \frac{Length(Values_{Bin})}{8}$;

Blocks stored in $S_1, S_2, .., S_N$

$j = 1$;

foreach i = 1 **to** N **do**

$S_i = Values_{Bin}\,(j : j{+}7)\,;$

$j = j{+}8$;

endfor

Repeat

Pseudorandom number generated for every two blocks from S_i and the mod of S_i with 4 will be the choice of crossover operation. 0-One Point Crossover; 1-Two Point Crossover; 2-Uniform Crossover; 3-Multi Point Crossover;

Applying Crossover: $foreach\ i = 1 : \frac{|Pop|}{2}\ do\ C_i = Crossover(P_1, P_2, Pse)$;

Applying Mutation: $foreach\ i = 1 : \frac{|Pop|}{2}\ do\ C_i = Mutation(P_i)$;

Until (*Termination condition satisfied*);

Transform the Binary values in respective ASCII Values: $R_{ASCII} = ASCII\,(Values_{Bin})$;

Convert the ASCII to text $Enc_{Text} = Text\,(R_{ASCII})$;

END

2.3.3.1 Procedure for hiding information using DWT

Figure 2.7 shows the image hiding process where it shows the decomposition of image C with dimensions $N \times M$. They are further subdivided into four sub-components, namely the HH, HL, LH and LL frequency bands (L: *Low* and H: *High*).

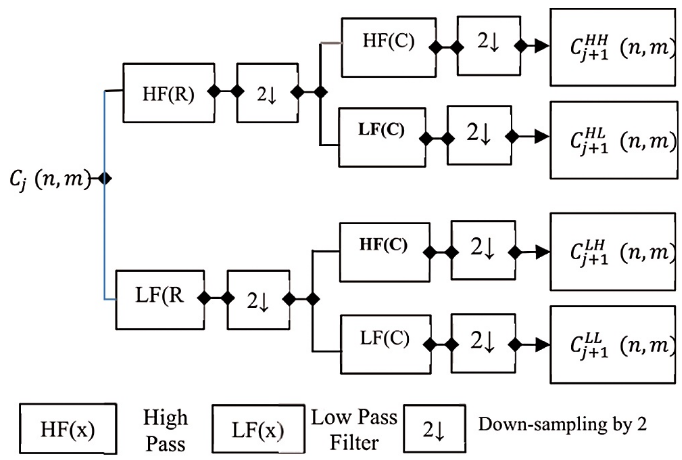

FIGURE 2.7: DWT-2L Separation Process

When the information is extracted from the image, the encrypted text is deleted, the cover image is recreated using IDWT2 for both the second and first stages. The details of the implementation process are shown in Fig 2.8.

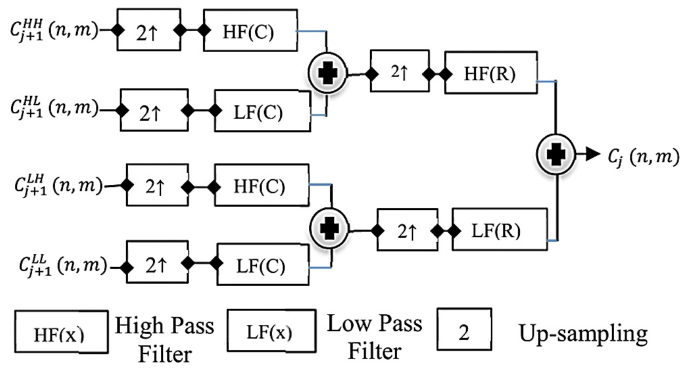

FIGURE 2.8: Synthesis of DWT-2L

2.3.3.2 Procedure for obtaining confidential information

This process refers to converting an encrypted message into its original text form. Reverse engineering applies to encryption methods. The key used by the sender to decrypt the encrypted message must be used by the receiver.

Algorithm 2.3 . Memetic algorithm decrypts data

Input: Encrypted Text

Output: Dec_{Text}

BEGIN

Convert the Encrypted Text into ASCII Values: $Values = ASCII\,(text)$;

Transform the ASCII values in the respective binary form with the base 10:

$$Value_{Bin}^{Enc} = Binary\,(Enc_{Values})\,;$$

The Binary Values split into 8 bits/block: $Enc_N = \frac{Length(Value_{Bin}^{Enc})}{8}$;

Blocks stored in $S_1, S_2, .., S_N$

$j = 1$;

foreach i = 1 **to** N **do**

$S_i = Values_{Bin}\,(j : j{+}7)$, $j = j{+}8$;

endfor

Repeat

Applying Mutation blocks: $foreach\ i = 1 :|\ Blocks\ |\ do\ C_i = Mutation(P_i)$;

Applying Mutation: $foreach\ i = 1 :|\ Blocks\ |\ do\ Crossover(P_1, P_2, Pse)$;

Until (*Termination condition satisfied*);

Transform the Binary values in respective ASCII Values: $F_{ASCII} = ASCII\left(Values_{Bin}^{Enc}\right)$;

Convert the ASCII to text $Dec_{Text} = Text\,(F_{ASCII})$;

END

2.3.4 Experimental results and evaluation

Table 2.5: Comparison of peak signal-to-noise ratio and mean squared error for color images

Image	Text Size (byte)	PSNR DWT-2L	PSNR DWT-1L	MSE DWT-2L	MSE DWT-1L
Image (1)	15	58.22	57.97	0.22	0.2
	30	55.25	54.41	0.37	0.44
	45	52.81	51.8	0.49	0.66
	55	53.06	51.05	0.48	0.76
	100	53.78	48.06	0.41	1.42
	128	52.37	47.89	0.61	1.69
	256	52.68	44.78	0.51	3.27
Image (2)	15	58.24	57.29	0.22	0.24
	30	55.43	53.71	0.37	0.42
	45	53.48	51.88	0.52	0.65
	55	53.83	50.81	0.48	0.73
	100	53.5	48.66	0.46	1.44
	128	52.62	47.39	0.6	1.66
	256	53.58	44.7	0.5	3.25
Image (3)	15	57.27	57.62	0.22	0.22
	30	54.6	53.31	0.38	0.44
	45	53.16	51.83	0.52	0.66
	55	53.59	51.1	0.51	0.74
	100	54	48.68	0.44	1.44
	128	51.76	47.22	0.63	1.68
	256	52.66	44.66	0.54	3.3
Image (4)	15	58.36	55.94	0.24	0.25
	30	55.32	53.32	0.28	0.49
	45	54.38	51.22	0.45	0.68
	55	53.58	50.54	0.42	0.85
	100	55.24	48.3	0.32	1.44
	128	53.74	47.62	0.53	1.77
	256	53.06	44.23	0.47	3.47
Image (5)	15	58.55	56.37	0.2	0.22
	30	57.44	54.28	0.37	0.29
	45	54.93	53.23	0.43	0.52
	55	53.29	52.09	0.45	3.01
	100	53.8	54.42	30.07	1.06
	128	54.54	52.79	0.53	2.76
	256	51.99	50.11	0.48	3.18

To evaluate the change of the color image histogram before and after applying the algorithm, the researcher compares the results between the high and small packet sizes in Fig. 2.9. Experimental results show that DWT 2L improves by 9.51% and DWT-1L improves by 22.75%.

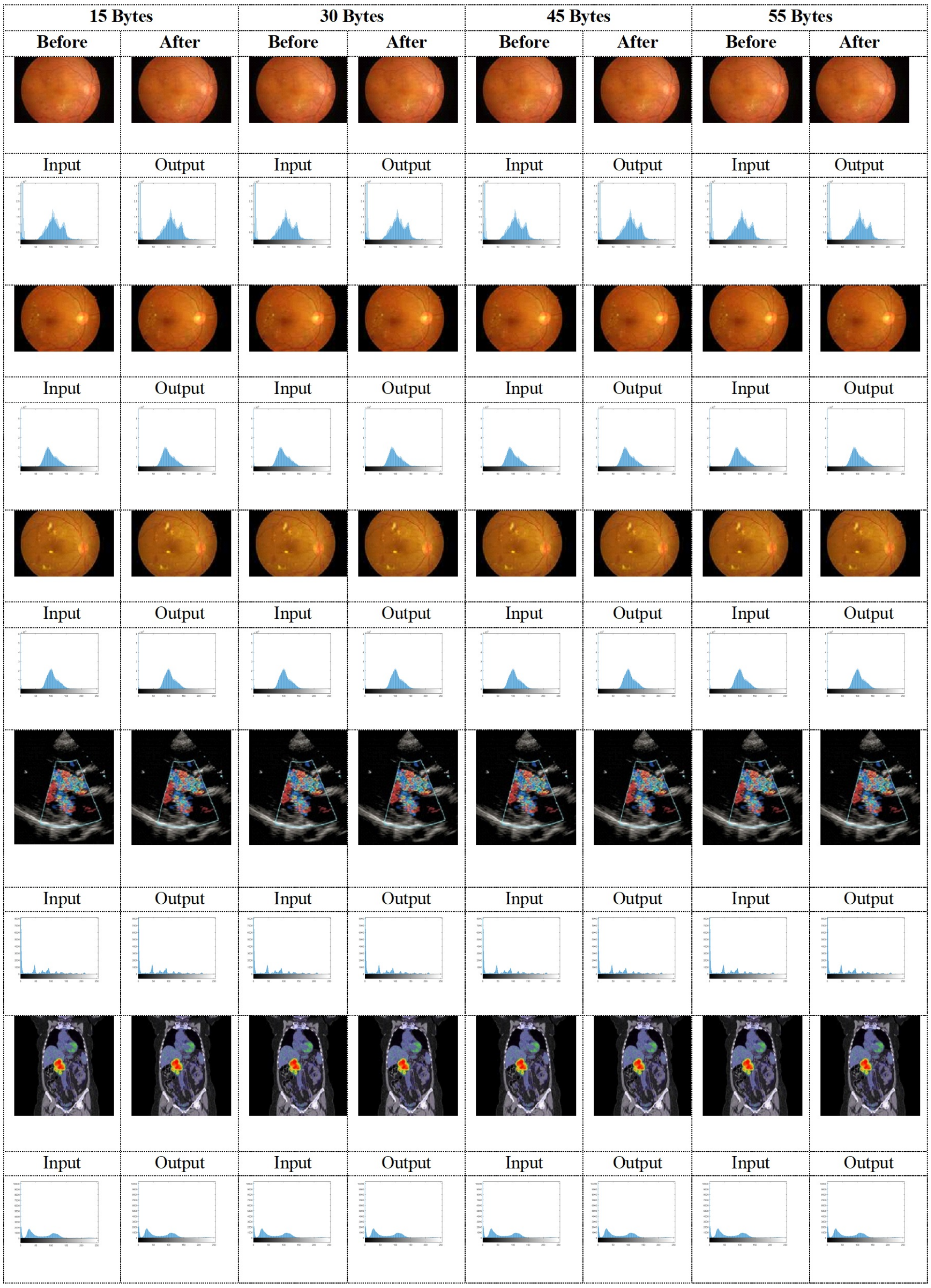

FIGURE 2.9: Histogram comparison of color images before and after applying Memetic algorithm with text sizes (15, 30, 45, 55 Byte)

Table 2.6: Comparison of peak signal-to-noise ratio and mean squared error for grayscale

Image	Text Size (byte)	PSNR DWT-2L	PSNR DWT- 1L	MSE DWT-2L	MSE DWT- 1L
Image (1)	15	57.53	56.9	0.23	0.24
	30	55.33	53.4	0.33	0.45
	45	52.7	51.43	0.53	0.68
	55	52.87	51.43	0.49	0.78
	100	54.37	48.49	0.44	1.46
	128	52.01	47.27	0.61	1.68
	256	52.69	44.55	0.55	3.23
Image (2)	15	57.5	56.62	0.24	0.24
	30	55	53.35	0.34	0.45
	45	52.78	51.81	0.53	0.69
	55	52.8	50.66	0.49	0.78
	100	53.73	47.75	0.45	1.47
	128	51.81	47.84	0.61	1.69
	256	52.55	44.36	0.53	3.29
Image (3)	15	57.87	57.07	0.21	0.24
	30	54.8	53.57	0.35	0.47
	45	52.69	51.35	0.53	0.67
	55	53.01	51.2	0.5	0.81
	100	53.76	47.86	0.39	1.45
	128	52.27	47.92	0.63	1.68
	256	52.66	44.73	0.53	3.23
Image (4)	15	58.23	55.56	0.22	0.3
	30	55.89	53.15	0.32	0.56
	45	55.2	51.36	0.42	0.73
	55	53.47	50.61	0.42	0.85
	100	54.92	48.04	0.36	1.43
	128	52.67	47.05	0.54	1.79
	256	53.1	43.79	0.49	3.53
Image (5)	15	57.55	55.33	0.2	0.31
	30	54.62	53.19	0.34	0.53
	45	54.03	51.01	0.52	0.73
	55	53.38	50.14	0.48	0.92
	100	55.15	49.11	0.42	1.13
	128	52.23	49.33	0.64	1.17
	256	53.06	46.35	0.53	2.17

To evaluate the variation of the color image histogram before and after applying the algorithm with different text sizes. The experimental results show that between the high and small packet sizes, DWT 2L shows an improvement of 8.41% and DWT 1L is 21.70%.

Table 2.7 shows that the proposed method achieves better PSNR values with less MSE when compared with other algorithms in the existing methods.

Table 2.7: Comparison of PSNR and MSE values between Memetic and other methods

Paradigm	Peak signal ratio on noise(PSNR)	Overall error average (MSE)
Anwar and partner [3]	56.76	0.1338
AES & RSA [8]	57.02	0.1288
Suggested Memetic Algorithm	58.32	0.1195

2.4 Summary

In Chapter 2, the thesis has proposed a number of techniques for processing 3D objects in the medical data simulation system. Specifically, one is to propose an effective RGB color selection technique for complex 3D object structures; Second, propose techniques to improve the effectiveness of multi-user interaction in augmented reality with scenarios where users have the same geospatial and different geospatial; Third, propose a technique to strengthen the encryption of medical data on the transmission line in IoT-based distributed systems. These techniques play a very important role in object processing and application simulation in medicine to help teach on the e-learning system presented in Chapter 3.

Chapter 3

Apply some object processing techniques to build a virtual reality simulation system of the human body

3.1 Current status of teaching anatomy and approaches

In the context of education and training under "Content-oriented" becomes inadequate and appears many disadvantages. Besides, knowledge of clinical anatomy is one of the most basic and important subjects for health students. This subject requires direct study on human corpses, but through the survey, most students approach the subject mainly through models, pictures, 2D images and templates or using foreign software [13]. On the basis of the development of computer hardware, computer graphics techniques and Virtual Reality, the medical training system on virtual patients has gradually become a reality, reducing the dilemmas of patients this field. This highly interactive training method has many advantages over traditional methods such as practicing on plastic models or on real patients..

3.2 Applying 3D object processing techniques to build a human body simulation system

The simulation system is built towards the application of 3D virtual reality technology to visually and accurately simulate the Vietnamese human body with a 1:1 ratio with a full range of organ systems allowing direct interaction continue in 3D space. Support system, serving teaching, learning and research in the field of health sciences to reach career goals, able to work in a dynamic and fast-changing new world.

3.3 Analyze and compare the effectiveness of the experimental system

3.3.1 Architectural design and experimental object selection

The experimental process was conducted on 135 students randomly selected from 03 medical training universities.

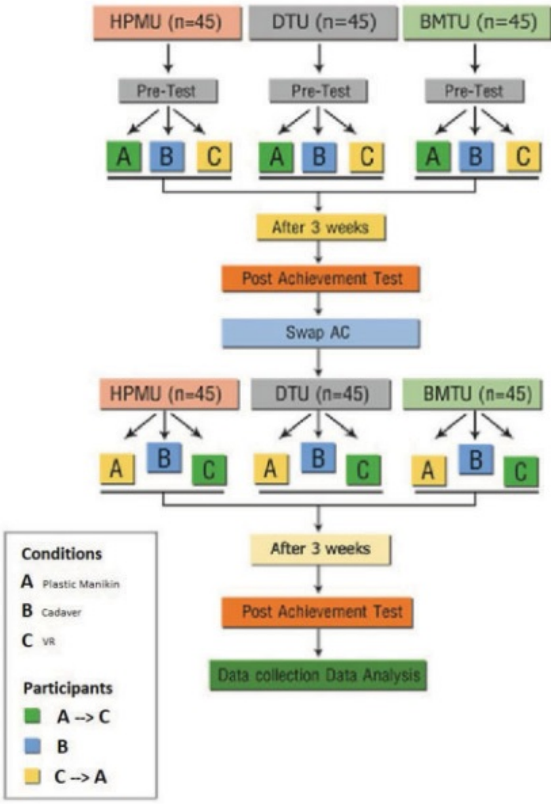

FIGURE 3.1: Architectural design of experimental survey

45 students from each school were randomly divided into 3 groups A, B and C. Group A studied anatomy by means of plastic models. Group B learns on corpses. Group C learned 3D simulation method. After the end of 03 weeks of study, there will be a knowledge test to assess the students' acquisition level.

3.3.2 Analyze experimental results

The test results show the scores of each group as follows:

- Group A (studying with the plastic model observation method) has the lowest score of 5.81 (HPMU: $M = 5,67$; DTU: $M = 5,97$; BMTU: $M = 5,80$);
- Group B (corpse) $M = 6,69$ (HPMU: $M = 6,70$; DTU: $M = 6,60$; BMTU: $M = 6,77$)
- Group C (VR) highest score $M = 7,74$ (HPMU: $M = 7,934$; DTU: $M = 7,68$; BMTU: $M = 7.63$).

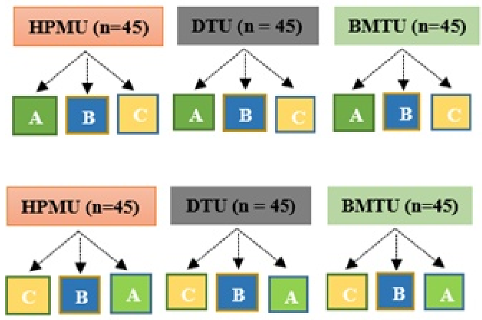

FIGURE 3.2: Swap the learning method of group A to group C

After the results of the test are available, the practice session is completed by an independent assessment unit. Then do the learning method swap from $A \rightarrow C$. The obtained results showed that the group that studied by 3D simulation method improved their scores significantly. This research result contributes to affirm that with the current conditions of Vietnam's medical training universities, it is effective to bring virtual reality technology into teaching.

3.4 Summary

In this chapter, the graduate student applied the object processing techniques proposed in chapter 2 to build a test system that simulates parts of the human body such as: skeletal system, muscle, digestive, circulatory, nervous, heart. The PhD student has also implemented this application into the training course in anatomy at some universities. The comparison, evaluation and testing of the system's effectiveness between experimental groups and control groups shows the effectiveness of the system compared to learning by slides and plastic models. The system can be used on many device platforms, helping to save costs of purchasing and maintaining models, pictures, and templates. The system is the foundation for developing projects on medical simulation, proceeding to apply technology for remote medical examination and treatment (*Telemedicine*)

Conclusion

In the thesis, the author presented the results of the medical virtual reality simulation model, the problem model and the 3D model optimization principle. The thesis focuses on analyzing and evaluating recent 3D object processing approaches including: optimal approach to the surface of triangle mesh, quadrilateral mesh, smoothing surface of surf, lighting, object shading and surface smoothing. 3D object interaction. From those analyzes, the PhD student proposes a number of techniques for processing 3D objects and deploying the application of virtual reality technology to build a simulation system of some parts of the Vietnamese human body to help with teaching, training and research in medicine. Along with that, the PhD student proposed a number of medical imaging techniques based on deep learning and multi-user interaction combined with encoding medical data on the transmission line in IoT systems.

1. Contributions of this doctoral thesis

The research results of the thesis are meaningful in supplementing and perfecting techniques for processing and optimizing complex 3D objects, applying virtual reality simulation in the medical field. Specifically, the new contributions of the thesis research process are as follows:

1) Propose an effective RGB color selection technique for complex 3D object structures based on a combination of tagging and marking methods by selecting an RGB color area on the object structure. From the RGB color codes proceed ID tagging and the creation of relational tables that store relevant information about specific areas of the anatomy. Using the entire set of color values (R, G, B) to define a set of anatomical regions helps to define multiple overlapping areas of an object for efficient representation of complex objects, and more clearly.
2) Technical proposal to improve the efficiency of multi-user interaction in augmented reality with scenarios where users have the same geospatial and different geospatial. The solution is to identify, mark the pins and interactive positions on 3D objects to set the color area and interactive position under

different views of multiple users on the same object. The proposed technique allows many interactions to be performed simultaneously on many different devices with many people using it with low latency and accurately displays the virtual reality model location.

3) Proposing a Memetic algorithm to enhance encryption of medical data in transit in IoT-based distributed systems using Memetic algorithm combined with DWT transformation. The results of the proposed algorithm are evaluated using performance metrics such as PSNR, MSE, SSIM, correlation, SC and BER which show the efficiency of the proposed algorithm compared to the existing methods. When comparing the histogram of the covered messages and the original message both in color and grayscale images, there is not much deviation in the PSNR values, which indicates that the proposed algorithm works well. in the encoding and decoding process. Therefore, security concerns in the healthcare system through IoT are highly secure and safe..
4) Applying the above techniques to build a simulation system of the human body. The system provides an interface that allows the user to manipulate to observe the images of the parts that can be searched and looked up information through the sample information.

2. Ability of extension

The issues mentioned in the thesis cover a lot of content, for each content presented in each chapter, it is possible to find issues that can be used to propose content as a research direction. for the next projects. That shows the openness of the issues mentioned by the PhD student in the thesis. Some open directions of the thesis that can be further researched are:

1) Research efficient algorithms for surface smoothing of complex 3D objects based on optimal compression of model meshes. Especially the shading algorithms based on unreliable input data.
2) Researching algorithms to optimize multi-view navigation from multi-users in a 3D environment. Optimizing the technique of sharing multi-user models on the same space and different geospatial.
3) Research effective 3D object encryption algorithms to compress data and increase security when transferring data between devices.

List of publications of the author related to the thesis

[1] **Chung Van Le**, Trinh Hiep Hoa, Nguyen Minh Duc, Vikram Puri, Nguyen Tung Sanh, Dac-Nhuong Le (2021), Design and Development of Collaborative AR System for Anatomy Training, Intelligent Automation & Soft Computing, vol. 27, no. 3, pp.853-871, ISSN 1079-8587 (**SCIE IF 1.647**).
`DOI: 10.32604/iasc.2021.013732`

[2] Srinath Doss, Jothi Paranthaman, Suseendran G, Akila D, Souvik Pal, Balaganesh. D, **Chung Le Van**, Dac-Nhuong Le (2021), *Memetic Optimization with Cryptographic Encryption for Secure Medical Data Transmission in IoT-based Distributed Systems*, Computers, Materials & Continua, vol. 66, no. 2, pp. 1577-1594, ISSN: 1546-2218 (**SCIE IF 3.772)**. (*Corresponding author*)
`DOI:10.32604/cmc.2020.012379`

[3] **Chung Le Van**, Gia Nhu Nguyen, Tri Huu Nguyen, Tung Sanh Nguyen, Dac-Nhuong Le (2020), *An Effective RGB Color Selection for Complex 3D Object Structure in Scene Graph Systems*, International Journal of Electrical and Computer Engineering, vol.10, no. 6, pp. 5951-5964. ISSN 2088-8708. (**Scopus Q2**).
`DOI:10.11591/ijece.v10i6.pp5951-5964`.

[4] **Chung Van Le**, Gia Nhu Nguyen, Tung Sanh Nguyen, Tri Huu Nguyen, Dac-Nhuong Le (2020), *Applying 3D VR Technology for Human Body Simulation to Teaching, Learning and Studying*, Emerging Extended Reality Technologies for Industry 4.0: Early Experiences with Conception, Design, Implementation, Evaluation and Deployment, pp.17-28. John Wiley & Sons. ISBN 978-1119654636. (Book Chapter)
`DOI:10.1002/9781119654674.ch2`

[5] **Chung Van Le**, Jolanda G. Tromp, Vikram Puri (2018), *Using 3D Simulation in Medical Education: A Comparative Test of Teaching Anatomy Using Virtual Reality*, Emerging Technologies for Health and Medicine: Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0, pp.12-21. John Wiley & Sons. ISBN: 978-1-119-50981-3. (Book Chapter)
`DOI: 10.1002/9781119509875.ch2`

[6] Jolanda G. Tromp, **Chung Van Le**, Le Nguyen Bao, Dac-Nhuong Le (2018). *Massively Multi-User Online Social Virtual Reality Systems: Ethical Issues and Risks for Long-Term Use.* In Social Networks Science: Design, Implementation, Security, and Challenges, pp. 131-149. Springer. (**Scopus**)
`DOI: 10.1007/978-3-319-90059-9_7`

Some other publications

[1] **Chung Van Le**, Vikram Puri, Nguyen Thanh Thao, Dac-Nhuong Le (2021), *Detecting Lumbar implant and Diagnosing Scoliosis from Vietnamese X-Ray Imaging using the Pre-Trained API Models and Transfer Learning*, Computers, Materials & Continua, vol. 66, no. 1, pp. 17-33, ISSN: 1546-2218 (**SCIE IF 3.772**). `DOI:10.32604/cmc.2020.013125`

[2] Jolanda G. Tromp, Dac-Nhuong Le, **Chung Van Le** (2020). Emerging Extended Reality Technologies for Industry 4.0: Early Experiences with Conception, Design, Implementation, Evaluation and Deployment. John Wiley & Sons. ISBN 978-1119654636. (Book Editor)
`DOI: 10.1002/9781119654674`

[3] Dac-Nhuong Le, **Chung Van Le**, Jolanda G. Tromp, Nguyen Gia Nhu (2018). *Emerging Technologies for Health and Medicine: Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0.* John Wiley & Sons. ISBN: 978-1-119-50987-5. (Book Editor)
`DOI: 10.1002/9781119509875`

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