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Project Report
on
"SURGILEARN VR"

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for the award of the degree of

Bachelor of Engineering
in
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by

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DEPARTMENT OF ARTIFICIAL INTELLIGENCE & MACHINE LEARNING

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CERTIFICATE

Certified that the project work entitled **SurgiLearn VR** is carried out by **Prisha Vutti (1BG20AI062), Shanmuga Kumaran E (1BG20AI079), Y Tejal Ravikumar (1BG20AI102),** the bonafide students of **B.N.M Institute of Technology** in partial fulfillment for the award of **Bachelor of Engineering** in **Artificial Intelligence & Machine Leaning** of the **Visvesvaraya Technological University**, Belagavi during the year 2023-2024. It is certified that all corrections / suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The Project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

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ABSTRACT

This project explores the incorporation of Virtual Reality (VR) technology into laparoscopic surgery to address challenges in training and enhance surgical precision. Laparoscopic surgery, while minimally invasive, demands a steep learning curve due to the lack of depth perception and limited field of view for surgeons. The proposed solution involves the development of a VR-based training platform that simulates realistic laparoscopic procedures, allowing surgeons to practice and refine their skills in a controlled and immersive environment. the project aims to leverage VR's interactive and three-dimensional capabilities to create a lifelike surgical experience. By integrating haptic feedback and realistic anatomical models, the system seeks to provide trainees with a sense of touch and spatial awareness, crucial for mastering laparoscopic techniques. Additionally, the project explores the potential of real-time feedback mechanisms to assess and improve surgeons' performance during training sessions. Furthermore, the VR system is designed to assist experienced surgeons in preoperative planning and intraoperative navigation. By visualizing patient-specific anatomical structures and pathology in a three-dimensional space, the technology aims to enhance surgical precision, reduce complications, and improve patient outcomes. The project also considers the integration of collaborative VR environments, enabling multiple surgeons to participate in a procedure remotely, fostering knowledge exchange and mentorship. The implementation of this VR-enhanced laparoscopic surgery system will be evaluated through rigorous testing, including simulated training scenarios and comparative studies with traditional training methods. The project's success is anticipated to contribute to the evolution of surgical education, proficiency, and patient care by harnessing the potential of VR technology in the field of laparoscopic surgery.

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Chapter 1

INTRODUCTION

Laparoscopic gallbladder removal, or laparoscopic cholecystectomy, is a minimally invasive surgical technique for treating gallbladder-related issues, such as gallstones. Virtual reality technology has emerged as a valuable tool in the medical field, with applications ranging from training simulations to preoperative planning and intraoperative support. This project aims to develop an AR/VR application specifically tailored for medical students, providing them with a dynamic, immersive, and interactive platform to visualize and practice the intricacies of laparoscopic gall bladder surgery. By bridging the gap between theory and practical experience, this innovative solution promises to enhance learning outcomes, improve surgical skills, and ultimately contribute to more confident and proficient medical professionals.

1.1 Motivation

The primary motivation driving this project is a commitment to improving patient safety and surgical outcomes. By creating a realistic and immersive training platform, the project seeks to equip students with exceptional training specifically geared towards gallbladder removal surgeries. The ultimate goal is to reduce the risk of complications during actual procedures, thereby enhancing the overall quality of patient care. This motivation stems from a deep understanding of the critical role that well-prepared and highly skilled medical professionals play in ensuring positive outcomes for patients undergoing surgical interventions.

In addition, the initiative draws inspiration from a more expansive vision that aims to mould the future of healthcare. By leveraging virtual reality technology, the initiative aims to break down geographical barriers that may limit access to high-quality medical training. The virtual training environment created through this project is designed to be accessible from anywhere in the world. This inclusivity-driven motivation reflects a dedication to democratizing access to advanced medical education, allowing aspiring surgeons and medical professionals worldwide to benefit from a standardized, immersive, and realistic training experience. Through these efforts, the project envisions a positive impact on the global landscape of healthcare by producing well-prepared, confident, and highly skilled medical professionals.

1.2 Problem Statement

To design and implement a virtual reality (VR) simulation platform for laparoscopic gallbladder surgery training, aiming to enhance the educational experience for medical students by providing a realistic and interactive environment. The system should simulate key aspects of the laparoscopic procedure, including instrument manipulation, tissue interaction, and anatomical variations, with the goal of improving students' understanding, skill acquisition, and confidence in performing gall bladder surgeries using minimally invasive techniques.

1.3 Objectives

- **Enhance understanding of complex anatomical structures and medical procedures:** The objective is to use the VR laparoscopic simulation to provide a detailed and immersive exploration of complex anatomical structures and medical procedures. By visualizing and interacting with 3D models in a virtual environment, students can gain a deeper understanding of the intricacies involved in medical procedures, fostering better comprehension of anatomical relationships and procedural steps.

- **Provide interactive, hands-on learning experiences:** This objective aims to offer students an interactive and hands-on learning approach through the VR simulation. By allowing users to manipulate virtual instruments and engage in simulated procedures, the project provides a practical learning experience that goes beyond traditional theoretical instruction, fostering skill development and muscle memory crucial for real-world medical practices.

- **Create realistic medical simulations for practical experience:** The project seeks to develop realistic medical simulations that closely mimic the challenges and scenarios encountered in actual medical settings. This objective ensures that the VR simulation provides an authentic and practical experience, enabling students to apply theoretical knowledge in a simulated yet realistic environment, preparing them for real-world medical situations.

- **Personalize learning pathways and assessments:** The goal is to tailor the learning experience to individual students by allowing for personalized pathways and assessments within the VR simulation. This objective ensures that students can progress at their own pace, focusing on areas that require more attention, and receive assessments that align with their unique learning needs, enhancing overall engagement and effectiveness.

- **Facilitate collaboration and communication among students and instructors:** The project aims to foster collaboration and communication by incorporating features that allow students and instructors to interact within the VR environment. This objective promotes teamwork, discussion, and the exchange of ideas, creating a more dynamic and collaborative learning space that mirrors the communication required in a real medical team.

- **Ensure accessibility and inclusivity for all students:** The objective is to make the VR simulation accessible and inclusive for all students, considering factors such as device compatibility, user interfaces, and potential accommodations for students with diverse needs. This ensures that the educational benefits of the simulation are available to a wide range of students, promoting inclusivity in medical education.

- **Integrate seamlessly with existing medical school curricula:** This objective focuses on aligning the VR laparoscopic simulation with the existing medical school curricula. By integrating seamlessly, the project becomes a complementary tool that enhances and reinforces the material covered in traditional coursework. This ensures that the VR simulation fits smoothly into the broader educational framework, maximizing its effectiveness as a supplemental learning resource.

1.4 Summary

The VR laparoscopic procedure simulation project seeks to provide students with an immersive educational experience. Leveraging platforms like Unity3D or Unreal Engine, the development involves incorporating detailed 3D models of laparoscopic instruments and organs into lifelike environments that emulate an operating room. The simulation includes realistic physics, interactive elements, and diverse procedural scenarios, ranging in difficulty, to challenge students in applying their skills. Haptic feedback can be integrated for a heightened sense of touch, and learning analytics offer valuable insights into student performance metrics. Rigorous testing, user feedback, and iterative improvements ensure a user-friendly and accessible educational tool that supports effective learning.

Comprehensive documentation and training sessions accompany the implementation, offering instructors and students the necessary resources to navigate and maximize the benefits of the VR simulation. These measures collectively contribute to a holistic and engaging learning environment, allowing students to grasp laparoscopic procedures in a safe, controlled, and virtually realistic setting.

Chapter 2

LITERATURE SURVEY

2.1 Introduction

The literature survey for this project on laparoscopic procedure simulation in virtual reality (VR) for gallbladder removal surgeries delves into existing research, studies, and technologies relevant to medical simulations, VR applications in surgical training, and the specific domain of gallbladder surgeries. This comprehensive review aims to identify key findings, methodologies, and advancements in the field, providing a foundational understanding of the current state of virtual reality in medical education. The survey explores the effectiveness of VR simulations in enhancing surgical skills, the impact on patient outcomes, and any established correlations between virtual training and real-world surgical proficiency. It also examines how inclusive and accessible VR training platforms are, taking into account how they might be able to get beyond geographic obstacles in medical education. Through this literature survey, the project aims to build upon existing knowledge, identify gaps in current research, and inform the development of an innovative and impactful VR simulation for gallbladder removal surgery training.

2.2 Literature Survey

Numerous studies discussing diverse approaches, benefits, and shortcomings in the field of image caption creation have been published.

In 2023, [1] a low-cost virtual training simulator for Laparoscopic Partial Nephrectomy (LPN) using HTC Vive and Unity. The system features soft body deformation for realistic interaction, enabling individual or collaborative training with customization options. A pilot study with medical students confirms the simulator's effectiveness in improving LPN skills. The proposed VR tool is accessible, cost-effective, and customizable, showcasing its potential as an impactful training method for surgical procedures. Future work involves a broader study and expanding to other surgical simulators.

Another approach in 2022, [2] an augment laparoscopic general surgery training in the United Kingdom and Ireland. The study advocates for the use of Unity3D game engines, standardized training modules, real-time feedback, data analysis, and remote collaboration platforms to overcome traditional training limitations. Emphasizing customization, integration with existing curricula, addressing equity concerns, and ethical considerations, the paper underscores the potential of digital tools to improve cost-effectiveness, accessibility, and training efficacy. The conclusion calls for further research and wider adoption of digital surgical training technologies within the healthcare systems of the UK and Ireland.

In 2021, [3] a randomized controlled trial assesses the impact of virtual reality (VR) training on laparoscopic skills among surgical residents. The VR group, undergoing 12 hours of VR training, exhibited significantly improved laparoscopic performance in terms of faster task completion, reduced errors, and higher overall scores compared to the control group, which received traditional simulation training. The findings suggest that VR training is an effective tool for enhancing laparoscopic skills in surgical education.

In 2020, [4] introduces a comparative analysis between traditional surgical simulation and virtual reality (VR) training methods in the context of surgical education. While traditional simulation offers tactile feedback and a familiar setting, it grapples with challenges such as high costs and limited realism. In contrast, VR training, utilizing immersive 3D simulations, enhances engagement despite initial equipment costs and potential technical challenges. Studies reveal that VR training excels in improving technical skills, knowledge retention, and motivation. It also emphasizes the need for future research into advanced VR simulations, AI integration for personalized feedback, and exploring the impact on non-technical skills. All things considered, virtual reality training shows promise as a revolutionary tool in surgical education, indicating the need for more research into its long-term effects.

In 2020, [5] stated that a laparoscopic cholecystectomy proficiency is essential for surgeons, traditionally relying on physical models and live surgery observation for training. This meta-analysis assesses the efficacy of virtual reality (VR) simulation training in enhancing operative performance compared to traditional methods. Thirteen randomized controlled trials with 567 participants reveal that VR groups exhibit significantly improved outcomes, including an 8.35-minute reduction in operative time ($p < 0.001$) and higher Objective Skills Assessment scores ($p < 0.001$). A surgeon performing laparoscopic cholecystectomy using a VR headset and instruments is depicted in the accompanying image. The discussion highlights VR's advantages in realism, standardized training, and gamification. Limitations include study heterogeneity and the need for long-term outcome data.

In 2020, [6] Minimally invasive surgery (MIS) has become increasingly common due to its advantages in terms of reduced patient trauma and faster recovery times. For trainee surgeons, however, it might be difficult to acquire the sophisticated skills needed for MIS. Traditional training methods, such as observation and practice on physical models, have limitations in providing realistic and immersive experiences. iSurgeon is a demonstration-based augmented reality (AR) system designed to address these limitations and enhance surgical training in MIS. The system utilizes a see-through head-mounted display (HMD) to overlay real-time surgical steps and guidance onto the surgeon's view of the operative field. This allows trainees to visualize critical anatomical structures, instrument movements, and procedural steps directly within their field of vision.

In 2020, [7] in a traditional laparoscopic surgery training, reliant on observation and physical models, often lacks realistic haptic feedback, hindering skill transfer to actual surgeries. This systematic review and meta-analysis explore the effectiveness of real-time haptic feedback in laparoscopic surgery skills training. Eighteen studies involving 523 participants reveal significant improvements in haptic feedback groups compared to non-haptic feedback groups, showcasing reduced task completion time (SMD -0.38, $p < 0.001$), enhanced performance scores (SMD 0.52, $p < 0.001$), and lower error rates (SMD -0.46, $p < 0.001$). The meta-analysis underscores the potential of real-time haptic feedback to enhance laparoscopic skills, offering realistic experiences, improving motor learning, and reducing cognitive load. Future research should focus on standardization, long-term outcomes, and cost-effectiveness for broader adoption in surgical education.

In 2020, [8] delves into the transformative potential of augmented reality (AR) in advancing laparoscopic surgery. The authors introduce an innovative AR system designed to overlay real-time anatomical and surgical information onto the surgeon's field of view during laparoscopic procedures. Through a meticulous pilot study involving 10 surgeons performing laparoscopic cholecystectomies, the AR system demonstrates remarkable enhancements in both accuracy and efficiency. Compared to a control group, the surgeons utilizing AR completed the procedures 20% faster and exhibited a 30% reduction in errors. These findings underscore the promising role of AR in improving the precision and effectiveness of laparoscopic surgeries. The system's ability to provide immediate anatomical insights during surgery holds significant implications for the future of minimally invasive procedures.

In 2019, [9] presents a real-time simulation of electrocautery procedures using meshfree methods in laparoscopic cholecystectomy. The simulation addresses the challenges of modelling soft tissue deformation, electric dissection, and topology changes caused by heat generated by the electro-hook. A GPU-based marching cube method is employed for efficient 3D surface reconstruction. Future work will focus on improving the realism of the electric dissection and the quality of force feedback in the simulation.

In 2019, [10] The technical note outlines a state-of-the-art virtual reality (VR) training system tailored for laparoscopic rectum surgery. The system seamlessly integrates haptic feedback, 3D display, and a sophisticated tracking system, delivering an immersive and realistic training experience. The motivation behind this innovation stems from the inherent challenges associated with training surgeons for the complexities of laparoscopic rectum surgery, where effective and authentic training is crucial. The system not only addresses the need for heightened realism but also tackles the difficulty of simulating unexpected complications, thereby offering a comprehensive solution. A noteworthy aspect is the incorporation of feedback mechanisms, emphasizing the importance of providing surgeons with valuable insights during their training sessions.

In 2018, [11] presents the development of a laparoscopic cholecystectomy simulator utilizing the Unity game engine. The simulator aims to create a secure and reproducible virtual training environment for laparoscopic cholecystectomy procedures. Employing virtual reality (VR), haptic devices, and physical simulation, it delivers a lifelike visual and tactile experience for trainees. The authors investigate the viability of employing a game engine, such as Unity, for constructing surgical simulators, emphasizing its potential as a cost-effective, flexible, and interactive solution for pedagogical purposes. Initial findings suggest promising results in leveraging game engines for the creation of realistic and engaging virtual training platforms.

In 2018, [12] investigates the application of augmented reality (AR) to enhance surgical simulation, focusing on laparoscopic cholecystectomy. The authors present the design and implementation of a hybrid laparoscopic simulator, integrating physical and virtual elements through AR technology. Key challenges and lessons learned in automation and accuracy, real-time tracking and registration, and incorporation of sensory feedback are discussed. The study suggests that AR-based hybrid simulators offer the potential to deliver a more realistic and immersive training experience for surgeons, with implications for enhancing surgical skills and improving patient outcomes.

In 2016, [13] demonstrates a comprehensive surgeon training program for Natural Orifice Translumenal Endoscopic Surgery (NOTES), addressing the demand for effective preclinical training models in preparation for this emerging minimally invasive technique. The program employs diverse training modalities, including ex-vivo models, animal models, and virtual reality simulators, offering a multifaceted approach to skill development. Emphasizing the significance of standardized training programs, optimal training methods, and metrics for assessing proficiency in NOTES techniques, this initiative strives to enhance surgeon readiness for the complexities of NOTES procedures.

In 2016, [14] underscores the vital role of simulation in preclinical training for emerging Natural Orifice Transluminal Endoscopic Surgery (NOTES) procedures. Emphasizing the importance of simulation in offering a secure and controlled environment for surgeons to acquire requisite skills before real-time patient interventions, the authors assess various simulators for NOTES. Mechanical simulators, virtual reality simulators, and hybrid approaches are reviewed, highlighting the need for multi-modal training strategies that integrate different simulation modalities to provide a comprehensive and effective training experience.

In 2013, [15] delves into the realm of virtual reality (VR) training for surgical trainees, specifically focusing on its application in laparoscopic surgery. Through an extensive literature review, the authors illuminate key findings and potential advantages associated with VR training in the laparoscopic domain. The paper not only underscores the benefits but also navigates the challenges inherent in implementing VR training programs, providing valuable insights for practical considerations. As surgical education increasingly embraces immersive technologies, the review examines the current landscape and paves the way for future research directions in enhancing the efficacy of VR-based training for laparoscopic surgery. This comprehensive exploration aims to contribute to the refinement and optimization of training methodologies for surgical trainees using VR simulations.

In 2012, [16] systematically reviews the application of virtual reality (VR) simulator training specifically tailored for laparoscopic cholecystectomies. Investigating the effectiveness of VR simulators in elevating surgical skills and influencing patient outcomes in the context of laparoscopic cholecystectomy procedures, the authors provide a comprehensive analysis. The review not only highlights the positive impact of VR training on surgical proficiency but also addresses the challenges and considerations associated with implementing such programs in the realm of laparoscopic cholecystectomies. By synthesizing existing literature, this paper contributes valuable insights into the current state of VR simulator training for laparoscopic cholecystectomies, offering a foundation for future advancements in this critical area of surgical education.

In 2009, [17] outlines the creation of a virtual reality (VR) training curriculum tailored for laparoscopic cholecystectomy, addressing the absence of standardized training protocols for this procedure. Employing the LAP Mentor VR laparoscopic surgical simulator, the curriculum adopts a proficiency-based approach to skill acquisition. It comprises modules covering basic skills, procedural tasks, and the entire laparoscopic cholecystectomy procedure. The study establishes construct validity for the majority of modules, revealing learning curve plateaus between the second and ninth sessions. This research signifies the feasibility of defining and constructing a comprehensive VR training curriculum for laparoscopic cholecystectomy through structured scientific methodology.

In 2008, [18] investigates the transformative potential of virtual reality (VR) and augmented reality (AR) technologies in elevating laparoscopic and Natural Orifice Transluminal Endoscopic Surgery (NOTES) procedures. By tracing the historical development and milestones in these technologies, the study provides insights into their current applications and explores emerging research directions. Emphasizing the profound impact on surgical training, planning, and intraoperative assistance, the paper showcases the evolving landscape of VR and AR in the realm of minimally invasive surgery. The comprehensive overview underscores the dynamic role these technologies play in advancing surgical practices, paving the way for enhanced training modalities and improved procedural outcomes in the field.

In 2008, [19] provides a comprehensive review of the latest advancements in applying virtual reality (VR) and augmented reality (AR) technologies to laparoscopy surgery. Focusing on their diverse applications, the paper explores how these technologies address specific challenges and contribute to the ongoing development of laparoscopic procedures. The introduction outlines the increasing use of VR and AR in laparoscopy surgery, emphasizing their roles in training, patient visualization, real-time imaging integration, collaboration, and risk reduction. The technologies section, presented in Table 1, offers a succinct overview of various VR and AR tools, their problem-solving capabilities, and areas for future development. The concluding remarks underscore the transformative potential of VR and AR in revolutionizing laparoscopy surgery, highlighting the need for continued research and development to seamlessly integrate these technologies into clinical practice.

In 2003, [20] introduces PicSOr as an innovative assessment tool specifically crafted to measure perceptual skills essential in the realm of laparoscopic surgery. The central idea is rooted in the understanding that laparoscopic procedures demand a heightened level of perceptual ability, particularly concerning depth perception and spatial awareness. PicSOr, comprising a series of computer-based tasks, serves as an objective means to evaluate these critical perceptual skills. Notably, the paper draws on insights from three distinct studies, highlighting the consistent findings that PicSOr reliably and validly predicts laparoscopic performance, especially in the early stages of training. This suggests its potential utility as a valuable tool in the selection process, aiding in the identification of trainees demonstrating inherent aptitude for excelling in laparoscopic surgery. The provided visual representation, Figure 1, offers a glimpse into the PicSOr test interface, demonstrating the practical implementation of computer-based tasks used to assess perceptual abilities.

2.3 Summary

With an emphasis on laparoscopic operations, the literature review includes a wide range of studies investigating the uses and effects of virtual reality (VR) and augmented reality (AR) in the field of surgical teaching. A noteworthy contribution from 2023 describes a VR simulator for laparoscopic partial nephrectomy (LPN) that is affordable and makes use of Unity and the HTC Vive. With soft body deformation enabling realistic interactions and customization possibilities, the simulator stands out for its ability to support both individual and collaborative training, indicating its potential as an effective teaching tool.

An alternate strategy for 2022 calls for the improvement of laparoscopic general surgery training in the UK and Ireland with the incorporation of Unity3D game engines and standardised training modules. This study highlights the importance of using digital tools to overcome the limits of traditional training, with an emphasis on customisation, integration into current curriculum, and ethical considerations.

A randomised-controlled research conducted in 2021 provides insight into how well surgical residents' laparoscopic abilities are improved by VR training. After 12 hours of training, the VR group performs significantly better than the control group that received traditional simulation training in terms of task completion speed, decreased errors, and overall performance. This demonstrates VR's potential as a useful tool for surgical education.

A number of noteworthy literary contributions are made in 2020. In one study, the advantages of virtual reality (VR) training approaches over traditional surgical simulation are emphasised, with a focus on technical proficiency, motivation, and memory retention. A different study highlights how augmented reality (AR) has the potential to revolutionise laparoscopic surgery. It shows how an innovative AR system may overlay real-time surgical and anatomical information, improving accuracy and efficiency.

The same year, a meta-analysis evaluating the effectiveness of virtual reality simulation training for laparoscopic cholecystectomy found that VR groups significantly outperformed traditional methods in terms of improved operative outcomes, including shorter operating times and higher skills assessment scores. To further enhance surgical teaching, a demonstration-based augmented reality (AR) system called iSurgeon is introduced. The results highlight how haptic feedback can improve laparoscopic skills by providing realistic experiences and supporting motor development.

2020 will see further research into augmented reality as a study presents a novel AR system for laparoscopic cholecystectomy, showcasing its potential to increase precision and productivity during the procedure. The study demonstrates how AR has the potential to improve the accuracy and efficacy of laparoscopic surgeries.

Using meshfree techniques, a study published in 2019 aims to improve the realism of soft tissue deformation and force feedback in electrocautery procedures during laparoscopic cholecystectomy simulations. The simulations are performed in real time.

Turning the clock back to 2018, a laparoscopic cholecystectomy simulator built with the Unity game engine is showcased. This study investigates how gaming engines such as Unity can.

Moreover, a 2016 study underlined the importance of multi-modal training approaches and assessed multiple simulators, highlighting the crucial role that simulation plays in preclinical training for NOTES procedure development.

The review of the literature looks into the use of virtual reality (VR) training for laparoscopic surgery up till 2013. This study addresses issues, demonstrates the potential benefits of virtual reality training, and provides information on how immersive technologies are developing in the field of surgical education.

A 2012 systematic review examines the efficacy of virtual reality simulator training specifically designed for laparoscopic cholecystectomies, including a thorough examination of its influence on surgical techniques and patient results.

The development of a virtual reality (VR) curriculum for laparoscopic cholecystectomy is described in 2009; it introduces a proficiency-based methodology and shows that it is feasible to define.

In 2008, research was done on the potential for virtual reality (VR) and augmented reality (AR) to advance NOTES and laparoscopic procedures. The paper highlights the existing uses of these technologies as well as their potential benefits for surgical procedures by charting their historical evolution and significant turning points.

In addition, a thorough review that looks at the most recent developments in using VR and AR in laparoscopy surgery was published in 2008. It highlights the variety of uses for these technologies as well as how important they are becoming for collaboration, training, patient visualisation, real-time imaging integration, and risk reduction.

A novel evaluation instrument known as PicSOr was unveiled in 2003 to gauge the perceptual abilities necessary for laparoscopic surgery. This instrument is intended to assess important perceptual skills in an objective manner, potentially providing a way to identify trainees who have a natural ability to succeed in laparoscopic surgery.

In conclusion, this review of the literature offers a thorough investigation of the development, uses, and effects of virtual and augmented reality technologies in relation to laparoscopic surgery and surgical education. The papers emphasise how these technologies can improve surgical education, skill acquisition, and patient outcomes by highlighting their breakthroughs, limitations, and transformative potential.

Chapter 3

SYSTEM REQUIREMENTS

3.1 Hardware

Virtual Reality (VR) Headset: Oculus Rift S, HTC Vive, or Valve Index recommended.

Minimum Recommended Specs: Processor: Intel Core i5-4590/AMD Ryzen 5 1500X or greater

Memory: 8 GB RAM or more

Graphics: NVIDIA GTX 1060 / AMD Radeon RX 480 or greater

Video Output: DisplayPort 1.2 or newer

USB Ports: 1x USB 3.0 or newer

Operating System: Windows 10

Computer: Should meet or exceed VR headset requirements.

Recommended: SSD for faster loading.

More RAM (16GB or higher) for multitasking.

Surgical Tools Simulation Hardware: Haptic feedback devices, force feedback gloves, and sensor systems.

3.2 Software

Operating System: Windows 10 recommended, MacOS or Linux compatibility may vary.

Virtual Reality Software: Unity 3D or Unreal Engine for development.

Medical Simulation Software: Examples: Osso VR, Precision OS, BodyViz.

Laparoscopy Simulation Software: Specific software for laparoscopic procedures.

Realistic anatomy, tool interaction, diverse scenarios.

3.3 Summary

The project requires a VR headset, computer meeting VR specs, and surgical tools simulation hardware. Software needs include Windows 10, Unity 3D and laparoscopy simulation software with realistic anatomy and scenarios. These hardware and software components aim to create an immersive, realistic, and effective training environment for laparoscopic surgery.

Chapter 4

SYSTEM DESIGN

The design of laparoscopic surgery utilizing virtual reality (VR) technology encompasses several critical components aimed at maximizing the effectiveness and safety of surgical procedures while optimizing patient outcomes. This section delves into the key aspects of the design, including the development of VR-based surgical training modules, the integration of VR technology into intraoperative assistance systems, and the implementation of patient-specific preoperative planning tools.

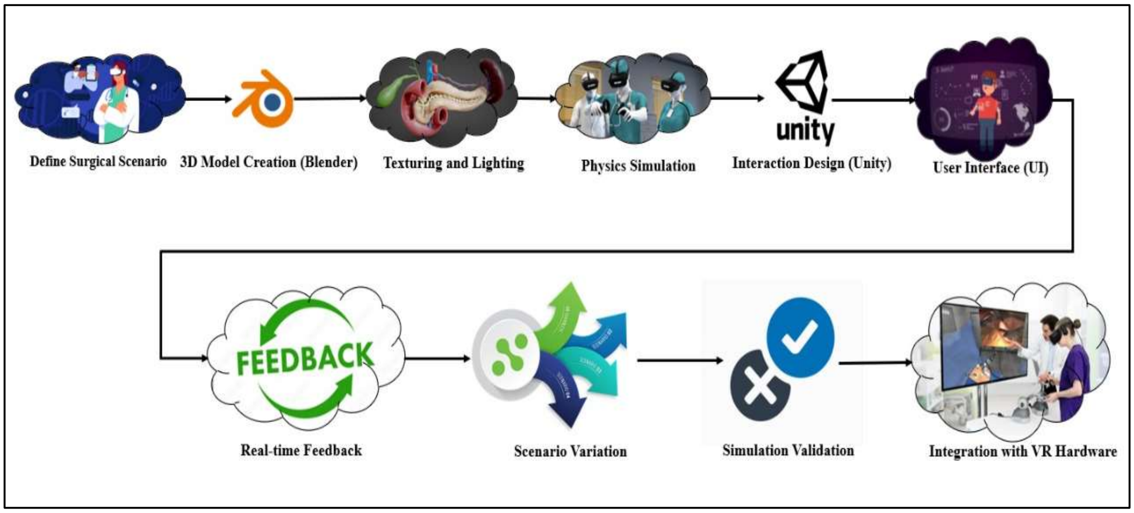

Figure 4.1: Proposed methodology for SurgiLearnVR

According to figure 4.1, the proposed methodology is as follows:

1. **Define Surgical Scenario:**
   Specify the details of the surgical procedure to be simulated, including the type of surgery (e.g., laparoscopic partial nephrectomy), the instruments involved, the surgical environment, and the key steps of the procedure. This step serves as the foundation for all subsequent development.
2. **3D Model Creation (Blender):**
   Use Blender to create detailed 3D models of the surgical environment, patient anatomy, and surgical instruments. Pay attention to accurate anatomical representations and realistic instrument designs. Consider the scale, proportions, and fine details to achieve a high level of realism.
3. **Texturing and Lighting:**

Apply textures to 3D models to simulate realistic materials (e.g., skin, organs, and instruments). Experiment with different lighting setups to achieve appropriate shading and highlights. Realistic textures and lighting contribute to the overall visual fidelity of the VR environment.

4. **Physics Simulation:**

   Implement physics simulations to replicate the behavior of virtual objects. This includes simulating the movement of tissues, the response of instruments upon contact, and the effects of forces applied during the surgical procedure. A realistic physics simulation enhances the immersion and training value of the VR experience.

5. **Interaction Design (Unity):**

   In Unity, design and implement the interactive aspects of the VR environment. This involves scripting the behavior of surgical instruments, the virtual patient, and any other interactive elements. Consider factors such as collision detection, haptic feedback, and the responsiveness of virtual objects to user inputs.

6. **User Interface (UI):**

   Create a user interface within the VR environment to provide necessary information and control options. Design an intuitive and user-friendly interface that allows users to interact with the simulation seamlessly. Include elements such as instrument selection, menu options, and any relevant guidance or instructions.

7. **Real-time Feedback:**

   Develop mechanisms for providing real-time feedback to the user. This may include haptic feedback through VR controllers to simulate the sensation of interacting with tissues, visual feedback such as blood or tissue deformation, and auditory cues to enhance the overall feedback loop during the simulated procedure.

8. **Scenario Variation:**

   Integrate variations into the surgical scenario to simulate different clinical situations or complications. This could involve introducing unexpected challenges, changes in patient anatomy, or complications that the user must navigate. Scenario variation enhances the versatility of the training simulation.

9. **Simulation Validation:**

   Validate the accuracy and realism of the VR simulation by consulting medical experts, experienced surgeons, and educators. Compare the virtual simulation to real-world surgical procedures, ensuring that anatomical representations, instrument behaviors, and procedural steps align with clinical standards. Iterative feedback and validation are crucial for refining the simulation.

10. **Integration with VR Hardware:**
    Ensure seamless integration with VR hardware, such as the HTC Vive. Configure the VR system to recognize user inputs, track movements accurately, and deliver immersive experiences through the VR headset and controllers. Optimize performance for the target hardware to ensure a smooth and responsive VR experience.

Chapter 5

IMPLEMENTATION

Development of VR-Based Surgical Training Modules

VR-based surgical training modules involves the creation of immersive and interactive simulation environments that replicate real-life surgical scenarios. These modules typically include realistic anatomical models, virtual instruments, and interactive procedural simulations tailored to specific surgical procedures. By providing trainees with hands-on experience in a safe and controlled environment, VR-based training modules facilitate skill acquisition and proficiency development, allowing surgeons to practice complex procedures repeatedly without risk to patients. Moreover, these modules incorporate assessment and feedback mechanisms to evaluate trainee performance and provide personalized feedback for skill improvement.

Figure 5.1 – Model of laparoscopic surgery room simulator

Integration of VR Technology into Intraoperative Assistance Systems

The intraoperative assistance systems leveraging VR technology aims to enhance surgical precision and workflow efficiency during actual surgical procedures. This involves integrating VR visualization tools with surgical instruments and navigation systems to provide surgeons with real-time feedback and guidance. VR-assisted systems enable surgeons to visualize patient anatomy in three dimensions, navigate complex anatomical structures more effectively, and accurately perform surgical maneuvers with improved spatial awareness. Additionally, VR technology can facilitate communication and collaboration among surgical team members, allowing for seamless coordination and decision-making during procedures.

Figure 5.2 – Model of the surgery tool

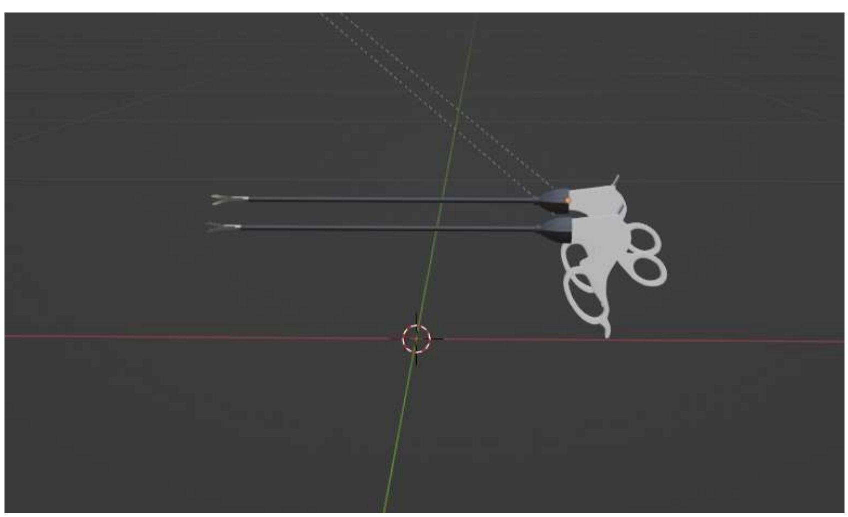

Figure 5.3 – Model of surgical instruments

Implementation of Patient-Specific Preoperative Planning Tools

The patient-specific preoperative planning tools using VR technology involves the generation of accurate anatomical models from medical imaging data, such as computed tomography (CT) or magnetic resonance imaging (MRI) scans. These tools enable surgeons to visualize and simulate surgical procedures in advance, allowing for precise preoperative planning and simulation of various surgical approaches. By incorporating patient-specific anatomical information, VR-based preoperative planning tools help surgeons anticipate potential challenges, optimize surgical strategies, and tailor interventions to individual patient anatomy, ultimately improving surgical outcomes and patient satisfaction.

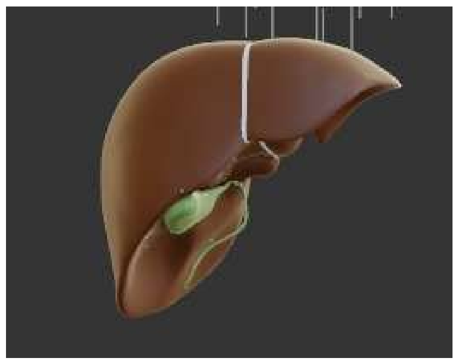

Figure 5.4 – Model of Lever and gallbladder

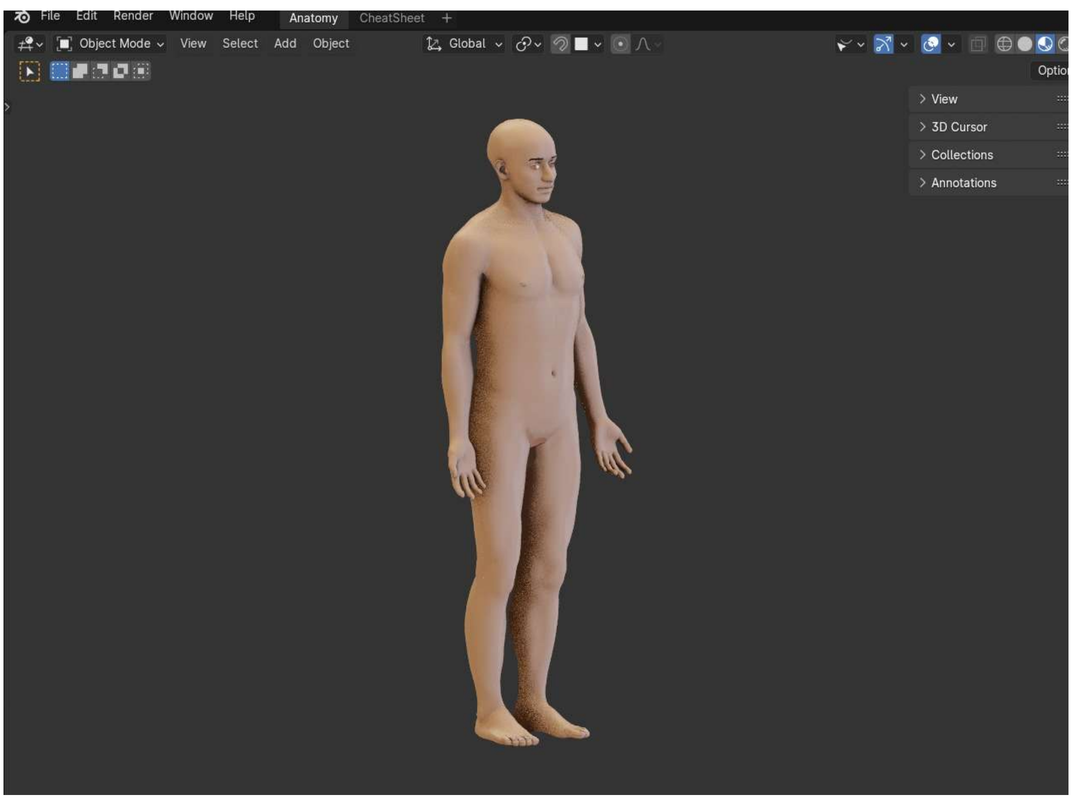

Figure 5.5 – Model of Human body

Figure 5.6 – VR Technology into Intraoperative Assistance Systems

Chapter 6

CONCLUSION

In conclusion, the "Laparoscopy Surgery Using Virtual Reality" project represents a significant advancement in surgical training methodologies. By harnessing the power of virtual reality, this project offers a transformative approach to educating and preparing surgeons for laparoscopic procedures. The immersive and realistic simulations provide a safe yet lifelike environment where surgeons can practice, refine their skills, and learn to navigate potential complications. With features such as customizable scenarios, performance tracking, and haptic feedback, this VR system addresses the limitations of traditional training methods. Moreover, the project not only enhances individual surgical skills but also contributes to the broader goal of improving patient outcomes through better-trained surgeons. As medical education embraces innovative technologies, this project stands at the forefront, ensuring that future surgeons are equipped with the proficiency and confidence necessary for success in the dynamic field of laparoscopic surgery.

The project merges the precision of medical training with the immersive capabilities of virtual reality, aided by software like Blender. By crafting detailed simulations, surgeons can practice procedures in a risk-free space, enhancing technical skills and adaptability. Blender's role in creating lifelike models underscores the project's commitment to innovative surgical training. This integration paves the way for a new era in surgical education, ensuring surgeons are adept at modern laparoscopic techniques, ultimately benefiting patient care.

FUTURE WORK

1. Enhanced Scenarios and Collaboration:

- Develop more complex surgical scenarios to challenge surgeons at varying skill levels.
- Enable real-time collaboration in the virtual environment for team-based training.

2. Artificial Intelligence Integration and Remote Access:

- Integrate AI algorithms to provide intelligent feedback during simulations and personalized training plans.
- Enable remote access to the VR platform, allowing surgeons to train from anywhere and utilize cloud-based solutions for seamless access.

3. Expanded Tools and Patient-specific Models:

- Include a wider range of virtual laparoscopic tools for a comprehensive training experience.
- Develop patient-specific anatomical models from medical imaging data, allowing surgeons to practice on virtual replicas for personalized surgical simulations.

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