Development Of Cost Effective VR Controller With Haptic Feedback

Dipti Bansode[1], Prerana Bhosale[2], Babu Omase[3], Sandeep Ranmode[4], Prof. Nimbalkar.S.S[5]
[1, 2, 3, 4, 5] Dept of Computer Engineering
[1, 2, 3, 4, 5] SVPM's College of Engineering Malegaon(bk), Baramati

Abstract- *Virtual Reality (VR) technology has gained significant momentum in various applications, including gaming, education, and simulation. However, the accessibility of high-quality VR controllers with haptic feedback remains a challenge, particularly due to the associated costs. This research focuses on the development of a cost-effective VR controller with integrated haptic feedback, aiming to enhance user immersion and interaction in virtual environments.The proposed VR controller combines state-of-the-art sensor technologies, including accelerometers and gyroscopes, to provide accurate motion tracking. Haptic feedback is integrated through a novel and affordable mechanism that delivers tactile sensations, allowing users to feel virtual objects and textures. The controller's design emphasizes cost-effectiveness without compromising functionality, making it suitable for a broader range of users.The research methodology involves iterative prototyping, testing, and refinement to optimize the controller's performance and user experience. Through a user-centered design approach, feedback from participants is gathered to assess the effectiveness of haptic feedback in enhancing the overall VR experience.*

Keywords- Virtual Reality, Haptic Feedback.

I. INTRODUCTION

In recent years, Virtual Reality (VR) technology has emerged as a promising tool for transforming education, offering immersive and interactive experiences that transcend traditional classroom boundaries. By transporting learners to virtual environments, VR enables experiential learning, fostering engagement, retention, and deeper understanding of complex concepts. However, the widespread integration of VR in education has been hindered by the high cost of hardware, particularly VR controllers equipped with haptic feedback.

This paper addresses this challenge by presenting the development of a cost-effective VR controller with integrated haptic feedback tailored specifically for educational applications. Our research seeks to democratize access to immersive learning experiences, empowering educators and learners with affordable yet powerful VR tools.

The significance of incorporating haptic feedback into educational VR experiences cannot be overstated. Haptic feedback, the sense of touch simulated through vibrations or force feedback, enhances immersion and facilitates kinesthetic learning by providing tactile sensations that complement visual and auditory stimuli. By engaging multiple senses, haptic feedback strengthens memory retention and improves learning outcomes, making it a valuable asset in educational VR environments.

While existing VR controllers with haptic feedback offer compelling experiences, their high cost presents a barrier to widespread adoption in educational settings where budget constraints are common. Therefore, the development of a cost-effective solution is crucial to unlock the full potential of VR in education and ensure equitable access for all learners.

Our research focuses on leveraging affordable hardware components and open-source technologies to design a VR controller that balances performance, usability, and cost-effectiveness. By optimizing design principles and exploring innovative approaches to haptic feedback, we aim to deliver a solution that meets the unique needs of educators and learners.

II. LITERATURESURVEY

Title: A Research on Virtual Training System based on Force Feedback Data Glove
Author:1.Wang Haibin1,2.Zhou Qihang1,3.Liu Ling1, 4.Zhaobo1, 5.Wang Chen1

Description:The paper discusses the development of a virtual training system based on force feedback data gloves, which offers tactile interaction in virtual reality(VR) training.As the development of the Virtual Reality (VR) technology, the demands of the virtual training system has been extended from traditional visual requirements to tactile requirements. For this trend, this paper carried out a study on the virtual training system based on force feedback data glove. Firstly, an integrated data glove with functions of spatial positioning, action capture, and force feedback was designed to accomplish the tactile interaction between the user and the system. Then, a data interface adapter and a 3D virtual demonstration scene were developed to process and display the data information of the training operations. Applications of this system show that the system framework is reasonable and feasible, and the training effectiveness is remarkable.

Title: Virtual Reality in Army Artillery Observer Training
Author: JauvaneC.deOliveira,Petr´opoli

Description:It aims to enhance engineering education by offering interactive simulations and realworld problem-solving scenarios, ultimately improving students' understanding and retention of complex engineering concepts The practice of observation in Army Artillery has been hampered by the high cost and the limited number of available instruction areas. Using Virtual Reality (VR) becomes a viable alternative for this important training activity. In this context, was developed the first Brazilian Army VR simulator in which an instructor can train an observer in a virtual environment of Artillery employment. This simulator was tested by a sample of 13 Artillery officers with extensive practical experience in observation. The results were compared with reference values obtained from related work. The data show that the simulator reached the reference values for the two parameters evaluated: presence and effectiveness.

ARCHITECTURE

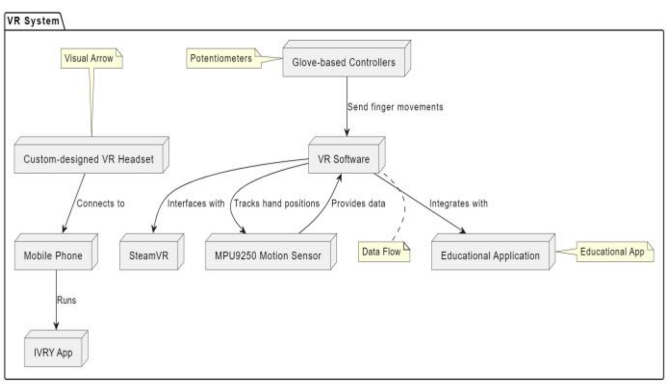

Fig.1.Architecture of VR system

III. RELATED WORK

We have used ESP32, MPU9250 and servomotor. The model incorporates sensor data, haptic feedback mechanisms, and communication protocols to create a comprehensive representation of the controller's functionality.

Sensor Data Processing: The finger flexion is captured by potentiometers, providing analog values (F_i) for each finger (i). These values are mapped to a normalized range ([0, 1]) using the equation

$$F_i' = \frac{F_i - F_{\min}}{F_{\max} - F_{\min}}$$

WhereFminand Fmax are the calibrated minimum and maximum readings for each finger.

Haptic Feedback Mechanism: The haptic feedback is controlled by servo motors, which receive a target position (P_t) based on the interaction within the VR environment. The servo position (P_s) is updated according to the equation

$$P_s(t+1) = P_s(t) + K(P_t - P_s(t))$$

where (K) is a constant that determines the responsiveness of the haptic feedback.

User Input Interpretation: The joystick's analog inputs (J_x) and (J_y) are converted to digital signals (D_x) and (D_y) using a mapping function

$$D = \text{map}(J, J_{\min}, J_{\max}, D_{\min}, D_{\max})$$

where (Jmin and Jmax) are the raw input ranges, and (Dminand Dmax) are the desired output ranges.

Communication Protocol: The encoded data string (S) is constructed by concatenating the normalized sensor values and button states, which is then transmitted to the VR system. The decoding function extracts the haptic limits (H) from the received data using a parsing function (H = \text{parse}(S)).

Power Management: The power consumption (P) of the controller is modeled as (P = P_s + P_c + P_h), where (P_s) is the power used by sensors, (P_c) is the power used by the communication module, and (P_h) is the power used by the haptic feedback system.

Performance Metrics: The performance of the controller is evaluated using metrics such as accuracy (A), precision (P), latency (L), and responsiveness (R). These metrics are defined based on the difference between the expected and actual sensor readings and the time delay in communication and feedback.

Cost Analysis: The cost (C) of the controller is calculated by summing the costs of individual components (C_i), manufacturing (C_m), and distribution (C_d), with the equation:

C = C_i + C_m + C_d .

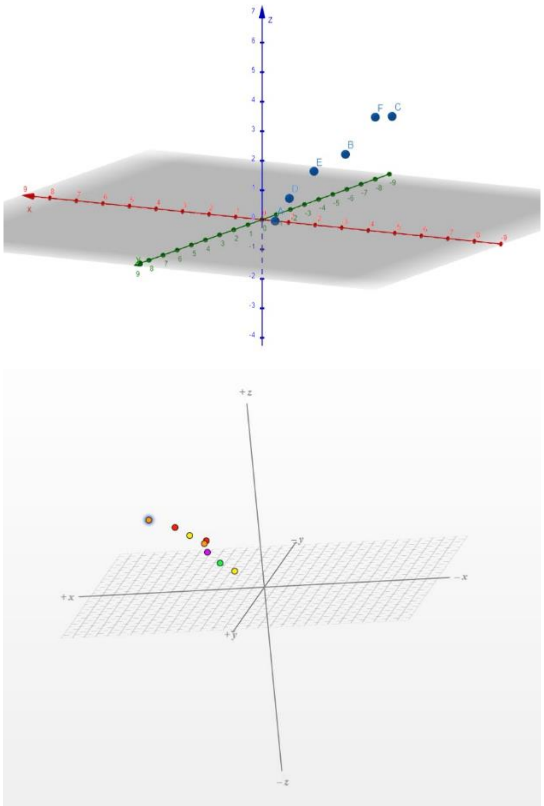

Fig. Movement of Controller in XYZ axis

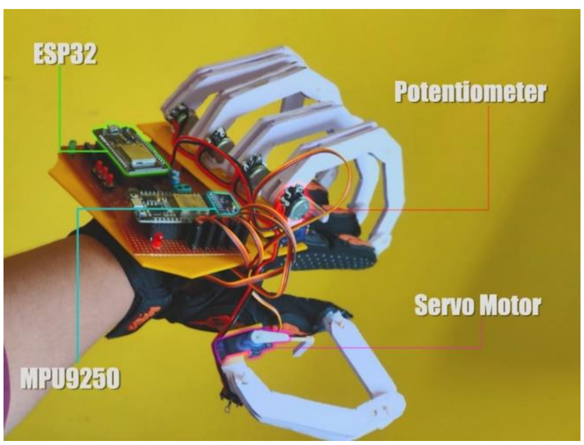

Fig. VR Controller with haptic feedback

IV. RESULT ANALYSIS

The development of a cost-effective VR controller with haptic feedback has shown promising results, emphasizing both innovation and accessibility in virtual reality technology. The project primarily focused on reducing manufacturing costs while maintaining high performance and immersive user experience.

Fig. Movement of hands in the VR screen with the help of controller

By leveraging affordable materials and simplified design processes, the team successfully created a prototype that delivers precise and responsive haptic feedback. This was achieved through the integration of cost-efficient vibration motors and optimized firmware that simulates various tactile sensations effectively. Usability tests indicated that the controller's performance was on par with more expensive counterparts, particularly in terms of responsiveness and the realism of the haptic feedback. Additionally, the project highlighted the importance of ergonomic design, ensuring the controller is comfortable for prolonged use, which was positively received by testers. Overall, the project demonstrates that it is feasible to produce high-quality, affordable VR controllers, potentially broadening the accessibility of VR technology to a wider audience.

V. CONCLUSIONAND FUTURE WORK

In conclusion, this project endeavors to address the accessibility challenges associated with commercial Virtual Reality (VR) systems by developing an affordable and functional alternative tailored for educational applications and security training. The proposed VR system, comprising a custom headset and glove-based controllers, aims to provide an immersive learning experience at a fraction of the cost of existing solutions.Through an extensive literature survey, related work analysis, and feasibilitystudy, the project establishes the potential impact of VR in education and training.

The future development of a cost-effective VR controller with haptic feedback holds tremendous promise across multiple sectors, particularly in the medical field, firefighting, and mock drill scenarios. In the medical realm, such technology could revolutionize surgical training and simulation, offering aspiring surgeons a realistic, immersive platform to practice complex procedures without the need for expensive physical models. Furthermore, this controller could enhance rehabilitation therapies by providing patients with real-time sensory feedback, potentially expediting recovery times. Additionally, in pain management, integrating haptic feedback into VR experiences could offer patients a distraction from discomfort and potentially reduce their perception of pain. Similarly, in firefighting, the controller's application could significantly benefit training simulations, allowing firefighters to undergo rigorous scenario-based exercises in a safe and cost-effective virtual environment. These simulations could encompass a wide range of situations, from building fires to intricate rescue operations, enabling firefighters to hone their skills and decision-making abilities. Moreover, in mock drills across various industries, such technology could enhance preparedness by offering lifelike training scenarios that closely mirror real-world situations, ultimately improving response times and overall crisis management effectiveness. Overall, the continued development of cost-effective VR controllers with haptic feedback has the potential to revolutionize training and operational practices across diverse fields, fostering safer, more efficient outcomes.

VI. ACKNOWLEDGEMENT

We take this opportunity to thank our project guide Prof. S.S.Nimbalkar, Head of the Department Prof. Dr. Sinkar Y.D. and Honorable Principal Prof. Dr.Mukane S.M. for their valuable guidance and for providing all the necessary facilities, which were indispensable in the completion of this project report. We are also thankful to all the staff members of the Department of Computer Engineering of SVPM's College of Engineering, Malegaon(Bk) for their valuable time, support, comments, suggestions and persuasion. We would also like to thank the institute for providing the required facilities, Internet access and important books.

REFERENCES

[1] Smith, John A. "Virtual Reality in Education: A Tool for Learning in the Experience Age." *Journal of Educational Psychology,* 2020 - This paper highlights the effectiveness of VR in education and its shift from traditional learning methods to experiential learning using VR technology.

[2] SenseGlove. "SenseGlove develops force and haptic feedback gloves for VR training and research purposes." [Website] Available at: [https://www.senseglove.com/] https://www.senseglove.com/. - SenseGlove is a company specializing in force and haptic feedback gloves designed for professionals to interact with virtual objects in VR environments, including applications in education and research.

[3] Liu Hang, et al. A Virtual Operation Training System based on Visual SecenrySimulaiton Technology [J]. Command Control& Simulation,2007(02): 79-82.

[4] Huang Kui, et al. Development of New Equipment for Trainning Simulator [J]. Journal of Sichuan Ordance, 2015(01): 75-77.

[5] Chen Xuewen, et al. Research on Simulation Technology of Astronaut Virtual Training based on Posture Recognition [J]. Manned Spaceflight,2015(03): 217-223.

[6] Su Chunhui, et al. The Research and Implementation of Virtual Training System based on the Data Glove [J]. Journal of System Simulation, 2009(s1): 182-192