Harnessing AR/VR and Machine Intelligence for Oil & Gas Operational Safety and Security

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Funds Requested: $25,000.00

Overview

Virtual reality (VR) is a technology that uses wearable screens, such as VR headsets, to immerse the user in a synthetic 3-dimensional (3D) environment. On the other hand, augmented reality (AR) is a related technology that overlays elements of VR onto the real-world environment. The recent COVID-19 pandemic has accelerated the shift towards remote operations in essential services, prompting the exploration of VR and AR as crucial tools to provide seamless, immersive experiences akin to reality. VR is being adopted in a diverse range of applications such as military training [1, 2, 3], virtual education [4, 5, 6, 7, 8], personal financial systems [9, 10], flight simulations [11, 12], therapy [13, 14, 15, 16], and virtual remote teleoperation [17, 18, 19, 20, 21, 22, 23, 24].

Extended Reality (XR) serves as an encompassing term for a range of immersive technologies that merge physical and digital realms, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). XR holds immense potential to transform safety, security, and operational efficiency within the high-risk oil and gas industry. Catastrophic incidents in the upstream sector, often stemming from human errors, emphasize the need for a comprehensive interdisciplinary approach. A systematic examination of human behavior and its interaction with complex systems is imperative for accident prevention and the protection of drilling operations. While the establishment of the Human Performance Oil and Gas Group (HPOG) [25] signifies progress in integrating human factors into the industry, persistent gaps remain in effectively applying interdisciplinary knowledge. Our proposal aims to address these gaps by showcasing strategic implementations of XR to bolster safety outcomes and mitigate risks. Leveraging the state-of-the-art drilling and completion simulation facilities at the University of Wyoming, our proposal aims to demonstrate the significant impacts of these technologies.

The ***overarching goal*** of this project is to ***harness human interactions within an entended reality (XR)–based drilling environment to design adaptive safety and security modules that ensure secure access and safe working environment for human drilling operators***. Additionally, these modules will enable drilling simulations for predictive maintenance and real-time machine-assisted drilling operations, enhancing operational efficiency and safety protocols.

Proposed Research Goals

❶ **Enhance Safety and Security:** Develop mixed reality (XR) modules to bolster safety and security measures within the drilling industry, focusing on drilling operations & operators' safety and security. To accomplish this research goal, we will undertake the following tasks: ***Task 1: XR-Integration*** – Design modules for seamless integration of XR technologies into existing drilling systems, ensuring compatibility and functionality. ***Task 2: Human Behavior Analysis*** – Conduct a comprehensive study of human behavior and their interaction with drilling equipment and processes, pinpointing key factors contributing to safety incidents and operational inefficiencies. ***Task 3: Enable Assistive Operation using Machine Learning***– In this task, we will utilize insights from human behavior analysis to develop a predictive engine leveraging machine intelligence techniques. This engine will assist human drilling operators and be integrated within the developed XR module.

❷ **Conduct Safety and Security Risk Analysis:** Identify and mitigate potential risks associated with human errors by integrating XR-based solutions into drilling processes, thereby reducing the likelihood of catastrophic incidents. To accomplish this goal, we will undertake Task 4, and Task 5 detailed as follows. ***Task 4: Enhancing Safety by Proactive Monitoring*** – Employ AI-enhanced security cameras to detect signs of fatigue or distraction among personnel, enabling proactive interventions to prevent accidents. This application ensures operators maintain alertness, sustaining overall safety on the rig. ***Task 5: Secure Access Control*** – There is a need to restrict access to sensitive operations, such as blowout preventer activation, to authorized personnel only. In this task, we will develop behavioral biometric-based user and virtual asset authentication modules to ensure secure and authorized access to critical components.

❸ **Optimize Operational Efficiency:** To streamline drilling operations and cultivate a more efficient and productive work environment, we will implement XR-enabled adaptive safety modules. This endeavor will be supported by the following task: ***Task 6: Enhance Operator Efficiency*** – Enhancing training and monitoring procedures through mixed reality (XR) technology, we will overlay real-time data and intelligent alerts directly into the operator's field of vision. By delivering immediate, critical information, this approach aims to prevent errors and optimize performance. We will design an enhanced XR user interface to overlay essential data and critical alerts onto physical components, ensuring operators' attention is directed appropriately. Leveraging machine-learning techniques, we will analyze operator responses to alerts and employ predictive analysis to further enhance effectiveness.

❹ **Advance Interdisciplinary Collaboration:** Foster collaboration among various disciplines, including petroleum engineering, human factors, and computer science, to devise holistic solutions tailored to the unique challenges of the oil and gas sector. The proposal emphasizes extensive participation from the entire multidisciplinary team, ensuring that diverse expertise is leveraged effectively to address complex industry challenges.

What are the expected short-term and long-term impacts?

There will be several long-term impacts: (1) the prototype study conducted in this proposal will enable us to develop a larger proposal for external funding (see the following section for our plan for obtaining external funds);(2) the proposed XR-based drilling simulation system will provide an improved level of safety and security to drilling operators; and (3) education and training – The developed tools will be useful in education and training for future engineers in oil and gas industry.

Research Plan beyond this Proposal and Potential Funding Sources

In this project, we aim to conduct an initial prototype analysis for the proposed XR-based drilling simulation, focusing on safety and security functionalities. This analysis will involve gathering data from 10 volunteer participants to develop, and evaluate the effectiveness and usability of the prototype. The PI team has engaged in discussions with ***Drilling Systems LLC*** regarding the proposed research, and the company has expressed keen interest. Subsequently, we plan to develop a comprehensive proposal to seek external funding from Drilling Systems LLC. Additionally, we intend to explore other potential funding sources such as the NSF Cyber-Human Systems (CHS) program and the Department of Energy (DoE) to support the expansion and further development of our research efforts.

Funds Needed: (\$10,000+\$8,800+\$3,600+\$1,600+\$1,000=\$25,000)

Senior Personnel's Salaries including Fringe (\$10,000)

We are requesting funds for senior personnel's (i.e. PI team) salary support towards their efforts during the summer months to conduct the proposed study and develop a proposal for external funding. A modest amount of funds \$10,000 will be used for senior personnel's summer efforts.

Effort spent on the project but not compensated for within the academic year is deemed to be included within the senior personnel's regular institutional duties.

Graduate/Undergraduate Student's Salaries including Fringe (\$8,800)

We are requesting funds to support a part-time graduate student's salary for one semester of the project. The students will perform project-related research and development activities as assigned by the PI team. Salaries for any undergraduate students working on the project on hourly effort will be adjusted according to the college's standard hourly pay rate.

Research Equipment (\$3,600)

Funds are requested to acquire a dedicated AR/VR headset for Drilling Simulation research, and a couple of Inertial Measurement Units IMUs (i.e. motion sensors), that will be utilized for development, testing, and data acquisition. We will also utilize the existing AR/VR devices available in the PI's labs to test multi-user scenarios. The dedicated headset will be utilized for deployment and testing of the developed system in the Drilling Simulation lab.

Human Subjects Study (\$1,600)

An incentive cost of \$1,600 is requested to be used towards payments for the human subjects study to recruit 20 volunteer participants. The existing Drilling Simulator in conjunction with the AR/VR-based simulator will be utilized to conduct these user studies. Co-PI-Elshehabi has extensive experience conducting studies with the drilling simulator and PI-Shukla has experience conducting human subjects studies with AR/VR and wearable sensors. As a part of this human subjects drilling behavior data collection study, user experience, and perception surveys will also be conducted for security perception and usability analysis. These surveys will also be used to estimate qualitative and quantitative measures of the effectiveness of the system. For each user, the data will be collected in four different sessions with at least two weeks between two consecutive sessions. Each data collection session will take $\approx$ two hours and each volunteer participant will be compensated with a gift amount of \$80 for their participation in the data collection experiments after completion of all four data collection sessions. We are preparing the IRB application for the human subject study to collect preliminary data for initial prototype analysis with the drilling simulator.

Materials and Supplies (\$1,000)

A modest amount of \$1,000 has been included for miscellaneous supplies needed to do the proposed research and development as outlined in the project goals. Material and supplies cost includes any publication/travel cost to disseminate the research findings to the research community, external funding agency, and beyond.

Appendix A - References Cited

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