Impactful Resilient Infrastructure Science and Engineering (IRISE)

-Project Scope of Work-

(FY 2022-23 (IRISE Year 5) Annual Work Program)

SUMMARY PAGE

Project Title: A Novel Immersive Virtual Reality Platform for Health & Safety Training of Construction Workers

Person Submitting Proposal: Alessandro Fascetti

Proposed Funding Period: 10/01/2022 - 09/30/2024

Project Duration: 24 months

Project Cost: $ 220,371.14 ($113,365.53 for PennDOT, $107,005.61 Other IRISE Members)

PennDOT Work for Hire? No

Project Title: *A Novel Immersive Virtual Reality Platform for Health & Safety Training of Construction Workers*

Problem Statement: Effective Health and Safety (H&S) protocols are of the utmost importance in the infrastructure construction field, with mortality rates close to 10 deaths per 100,000 full-time equivalent workers in the industry (with the highest values pertaining to roofers and structural steel workers). Recent statistics show that approximately 20% of all the workplace fatalities in the US happen in construction sites. The National Safety Council (NSC) estimates that each fatality has an average cost of $1.42M for a company. In particular, the leading cause of highway construction worker injuries and fatalities is contact with construction vehicles, objects, and equipment. Notably, nearly half of all the deaths on construction sites happen within companies with 10 or fewer employees. This might be due to small companies having lower amounts of resources to develop and implement effective H&S measures and invest in training and health and safety hazard mitigation strategies.
Non-fatal injuries statistics show that one in every ten construction workers is subject to an injury every year, a value that is ~70% higher than in any other industry in the US. Also, workers in the 25-34 age range have the highest injury rate, which demonstrates how modern H&S protocols should focus on the younger generation of construction workers. According to the Center for Construction Research and Training (CPWR), "Better and more frequent training, regular inspections and regular health and safety meetings with construction supervisors result in lower costs, fewer lost-time injuries and more profits."

Project Objectives: The objective of this project would be to develop an interactive and immersive training platform using Virtual Reality (VR) to train construction workers, inspectors and other project site staff about the dangers caused by runovers, back overs, caught-in or -between, and struck-by accidents in the highway construction industry. The novel platform will immerse users into a detailed digital reproduction of a given construction site that will materialize a selected H&S training module in an immersive environment, while directing the users attention to observe and identify possible hazards. Such hazards will be randomly placed inside the simulation, where they will need to be identified by the users. This will bring a twofold advantage: 1) the reward scheme of the serious gaming environment will actively promote the workers' attention towards possible hazards on the construction site, 2) the users will also have the opportunity to familiarize themselves with the surrounding environment before they perform specific operations in the real world. Inexperience is, in fact, regarded as one of the compelling explanations for the higher injury rates among younger workers. Results of this project will provide novel, efficient tools to give construction operators the required level of training before they enter the construction site. The VR environment will actively engage construction operators in a rewarding serious gaming experience, accommodating effective learning experiences in an immersive virtual environment, while increasing learner motivation and monitoring gains in progress and learning.

Project Scope: The project will focus on developing a parametric VR training environment by means of the Unreal Engine platform. We will first analyze existing safety training procedures (e.g., the procedures developed by the National Work Zone Safety) and identify the operations that are best suited for being reproduced in a VR environment. We will then render the selected scene in a VR

environment, which will host and materialize the digital reproduction of the given construction operations, giving users the possibility to interact with Non-Playable Characters to simulate interactions among workers. The parametrization of the VR environment will allow for the contextual creation of different conditions for the simulations at each run, avoiding the possibility of users getting familiar with a static representation of the environment and therefore granting the required minimum level of engagement and attention at each test. The constructed VR training will serve as a testbed for the quantification of the effectiveness of advanced Health and Safety training for construction workers, allowing for the comparison between the traditional (existing) methodology and the generated VR experience. Moreover, we will also investigate the possibility of employing formal attention analysis metrics by means of new generation VR gear equipped with eye tracking technology. The proposed research will be carried out in close contact with the panel members (representing both the private and public sectors), to guarantee that its results will be meaningful and applicable to real-life cases.

Task Statements:

The objectives of this project will be realized through the completion of the following tasks:

Task A: Review of current practices in H&S training and selection of a training module to be implemented in the VR environment.

Current practices in H&S training will be reviewed to identify opportunities for the materialization of one specific training module in the VR environment. The specific training will be selected based on the operations that are best suited for being reproduced in a VR environment, as well as input from the Project Panel and recent injury statistics (to identify the relevance of the training). Representative construction site layouts will be selected based on the identified training program.
The experimental design (Task B) will leverage such information to define a meaningful parametrization of the VR space, in terms of interactions with computer-controlled agents and construction equipment.

Task B: Construction of a parametric VR environment.

A parametric VR environment will be constructed by means of the Unreal Engine (UE4.25). Several instances of the selected construction site will be rendered in the 3D environment. The Playable Character (PC, i.e., the user undergoing training) will be able to navigate the environment freely and interact with Non-Playable Characters (NPCs, i.e., the computer-controlled agents) and will be asked to recognize safety hazards while completing specific training tasks. The spatial distribution and frequency of hazards will be fully customizable to allow for different levels of training and to accommodate users with different technological backgrounds. The environment architecture (developed by means of block programming in the Unreal Engine) will be based on parametric design, allowing for the creation of different layouts and simulations at each execution, avoiding the possibility of users getting familiar with a fixed representation of the site and therefore granting the required minimum level of engagement and attention at each test.

Task C: Trial training, training materials and instructor's manual.

The environment created in the previous Task will be used to deliver the selected training case study to a number of selected subjects, including one or more construction workers and engineering graduate students. Each training session will be monitored and recorded. Results will be used to test the proposed approach by means of exit interviews, and perform detailed analysis of the expected knowledge retention granted by the adoption of the VR training. Results from this task also have the potential to inform more advanced attention analysis techniques, such as gaze tracking, and enable further research in the future. A comprehensive set of training manuals will also be developed in this phase, to ensure efficient transfer of the technology.

Task D: Draft final report.

A draft final report containing suggestions and guidelines for best practices in the creation of immersive environments for H&S training will be prepared. Such guidelines will define the optimal levels of detail to be included in the simulations as a function of the specific training conditions (i.e., hands-on or theoretical), as well as the required interactions between the VR users and the agents in the simulations, effectively allowing for more efficient virtualization of training programs in the future.

Task E: Final report.

A Final Report taking into consideration comments that were received on the Draft Final Report will be prepared.

Deliverables:

1. Task A: Literature review on existing VR training programs and current H&S conventional programs. (6 months from the Notice to Proceed date)
2. Task B: Unreal Engine architecture for materialization of the construction sites used in the training program. (15 months from the Notice to Proceed date)
3. Task C: Training materials and an instructor's manual. (20 months from the Notice to Proceed date)
4. Task C: Recordings of the test training simulations (both the rendered simulations and a video feed of the participants will be recorded). (22 months from the Notice to Proceed date)
5. Task D: Draft final report and recommendations. (22 months from the Notice to Proceed date)
6. Task E: Final report and recommendations. (24 months from the Notice to Proceed date)

Key Personnel:

Principal Investigator: Alessandro Fascetti

Co-Principal Investigator: Lev Khazanovich

Other Personnel:

Grad Students: 1x Graduate Student

Undergrad Students: 1x Part-Time Student

Proposed Person-Hours by Task:

Team Member	Task A	Task B	Task C	Task D	Task E	Total
Alessandro Fascetti	60	120	90	60	30	360
Lev Khazanovich	60	120	90	60	30	360
Graduate Student	554	1109	832	227	50	2772
Undergraduate Student	100	230	320	-	-	650
Total	774	1579	1332	347	110	4142

Proposed Schedule:

Months	2022	2023				2024		
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Task A: ~6 months								
Task B: ~12 months								
Task C: ~9 months								
Task D: ~ 2months								
Task E: ~ 1 month								

Budget: The total project cost is $220,371.14.

Acknowledged By:

Alessandro Fascetti, Ph.D.
Principal Investigator