ABSTRACT

Educating the professional and technical workforce for the railway industry presents unique challenges. Safety concerns and limited accessibility to railway systems (e.g. track, maintenance facilities, etc.) present difficulties for hands-on education. Recreating this environment in a laboratory setting can be cost prohibitive and presents additional safety challenges in the University setting. To address these challenges, university educators are exploring the use of immersive learning technologies in the classroom. Virtual reality (VR) systems and computer simulation software are advancing rapidly to meet these education needs and also to facilitate remote learning. The Penn State Altoona Rail Transportation Engineering (RTE) program has recently developed a new TRAINS laboratory for Teaching Railway Applications through Immersive learning and Network Simulation. The TRAINS lab fosters immersive learning experiences, advances educational capabilities and increases student accessibility to railway engineering systems. This study explores the development and use of 360-degree virtual reality videos and immersive environments for railway engineering education. Best practices are presented for video development and content delivery. An assessment is made of current virtual reality systems and training simulators for railway education and recommendations are presented for industry and university applications. Use of immersive learning for K-12 education outreach is also considered. Finally, this study explores next steps for advancing immersive learning for railway education and suggests potential opportunities for collaboration with the private sector.

KEYWORDS: railway education, virtual reality, VR, immersive learning, 360-degree video, K-12, rail transportation engineering

INTRODUCTION

Railroads offer the safest, cleanest and most energy efficient form of surface transportation, and they will therefore play an essential role in meeting the global transportation demands of the future. Yet, despite these needs and the integral role of rail transportation across the globe, there are surprisingly few universities in North America that teach this discipline. Penn State Altoona currently offers the first and only accredited Bachelor of Science in Rail Transportation Engineering in the United States. Only a
handful of other US universities offer courses in rail transportation engineering. Thus, the need is great across North America to advance both the breadth and depth of rail transportation engineering education. However, it is not enough to simply add new educational programs. These programs must be focused on building leaders who will become the future engineers and managers equipped to design, build, operate and maintain the railway systems of the future.

The uniqueness of the RTE program at Penn State Altoona attracts students from all across the nation (and the world) with varied interests and backgrounds. These students will be leaders of a new generation of rail transportation engineers uniquely equipped for the specific challenges of a growing railroad industry. In order to best train these students, Penn State Altoona focuses on many hands-on educational experiences. These include in-depth practicum courses, field trips, technical conferences, undergraduate research, industry-based senior capstone projects, and internships. However, through the process of assessing the RTE curriculum, educators determined that there still existed educational gaps due inaccessibility challenges, safety concerns, and/or the lack of available infrastructure for certain elements of railway engineering (e.g. electrified rail systems, high-speed rail, maglev, etc.). As a result, Penn State Altoona has developed the TRAINS laboratory for Teaching Railway Applications through Immersive learning and Network Simulation. The TRAINS lab allows students to experience a diversity of railroad engineering environments across the world from a safe, accessible lab space. This lab includes the following: a virtual welder trainer, desktop locomotive simulator, 360-degree camera equipment, virtual reality headsets, high-end immersive learning platforms (e.g. HTC Vive and Oculus Rift), and a computer lab equipped with Rail Traffic Controller, the industry standard railroad dispatch simulation software. The TRAINS lab allows students to gain exposure to a variety of railway equipment and operations via a virtual immersive environment. Examples include: welding, locomotive operation, train operations, yard design, hump yard operations, etc. Much of the virtual reality video content used in the TRAINS lab was created by students using 360-degree cameras, both through course projects and funded research. Penn State received internal funding and sponsorship from Leica Geosystems to travel to Europe during May of 2018 to record 360-degree videos of European railway systems in Germany, Switzerland and Austria. Students then developed virtual reality videos using Adobe Premier software. These videos allow students to experience both freight and passenger train environments and understand the track, rolling stock, power supply, and other key elements from a virtual education platform. The educational videos also allow students from all over the world to take a “virtual field trip” and to learn about railroad freight and passenger infrastructure using the Penn State RTE public YouTube channel.

BACKGROUND

According to Cochrane, virtual reality (VR) “involves the use of a computer to create an interactive immersive experience via some form of head mounted display (HMD) unit, such that the user feels part of the virtual or simulated environment” [1]. The current study considers two basic forms of virtual reality: 1) computer-generated virtual environments and 2) 360-degree images or videos. Virtual environments can take the form of two-dimensional or three-dimensional visualization of a computer-generated environment. Examples of virtual environments include equipment simulators, welder trainers, video games, and avatar-based virtual communities. Virtual environments often require higher computing power and specialized equipment to allow for more advanced human-computer interface. Another form of virtual reality is 360-degree images or videos of actual physical environments (e.g. Google Street View). This type of virtual reality is best viewed in an immersive setting using a VR headset that displays the image in 360 degrees, allowing the user to look up, down, left, or right and view what an observer would see if they were actually standing at that location in real life.

Industry Applications of VR and Simulation

Over the past two decades, virtual reality has been integrated into a variety of professional workplaces, industrial settings and academia. Some examples include education, entertainment, healthcare, retail, and military/law enforcement, and manufacturing. In many cases, this technology is used for employee training purposes. Some industries have also developed consumer-based platforms to allow customers to attend events or to take virtual tours of engineering designs or real estate.
A study by Berg and Vance shows that virtual reality has proven effective in a variety of environments [2]. This study surveyed the use of virtual reality at twenty different industrial locations including: aerospace, agricultural, automotive, construction, consumer goods, energy, and military industries. Other studies have assessed virtual reality systems in the medical field [3], engineering design [4], and transportation engineering [5]. A brief survey of virtual reality applications for various industries is provided in Table 1.

**TABLE 1. Examples of Virtual Reality Applications for Various Industries**

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>AREA</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
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</tr>
<tr>
<td>Power / Energy</td>
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<td>Rail Transportation</td>
<td>Infrastructure Design, Railway At-Grade Crossing Safety</td>
<td>Virtual walkthrough of civil infrastructure projects and railway stations, 360-degree videos of railway at-grade crossings</td>
</tr>
</tbody>
</table>

Companies within the railroad industry have begun to adopt virtual reality as well. For example, the engineering consulting company TranSystems now creates a 3D virtual representation of their civil engineering designs (e.g. a bridge or port facility) [6]. This allows TranSystems to showcase their designs to the customer in the form of a virtual walk-through, facilitating better communication and coordination on the design. Another example is found in a study by Cozens, conducted in Wales, that explored the source of passenger fears in train stations [7]. Participants were asked to wear a virtual reality headset and take a virtual “walk” through a station, pointing out where and why they felt uneasy. This data is being used to better design stations in order to help increase rail ridership. Finally, some US Class I railroads use virtual simulation systems for training purposes. Examples of these systems include locomotive simulators to train new locomotive engineers and tablet-based virtual freight car airbrake inspection training that teaches new car inspectors how to properly inspect a train. While these simulation programs used by railroads do not require the use of an HMD unit, they do offer a form of virtual reality training.

**EDUCATIONAL APPLICATIONS OF VR TECHNOLOGY**

As in the professional workplace, virtual reality has also found its way into both K-12 classrooms and universities. Examples can be found throughout all grades and in many different subjects and disciplines. These virtual reality applications allow students to learn in a more cost effective and often more realistic learning environments than what has typically be available in the classroom.

**K-12 Applications**

One example of Virtual Reality being used in elementary education is Nearpod VR. Nearpod VR allows students to take Virtual field trips to better understand new environments. Nearpod VR uses 360 images and videos to give students a visual understanding of what they are learning about. One virtual field trip Nearpod VR offers is a “trip” of the ancient Mayan ruins where students can explore the different ruins.
while also learning about Mayan culture and history [8]. Google Expeditions is another similar example that allows students in elementary schools to take virtual group field trips using only a smartphone and a cardboard viewer headset, called Google Cardboard. Another example of Virtual Reality in education is the use of 360-degree still images and 360-degree videos from news sources. In one case, a social studies teacher used a 360-degree video from the Huffington Post pertaining to the Syrian refugee crisis. The 360-degree videos that the students watched using VR headsets allowed the students to see the world through the eyes of a Syrian Refugee and helped them better understand the situation as a first-person observer [8]. Virtual Reality has been used in high school education as well. For example, the VFrog™ program allows high school students to virtually dissect and explore the internal anatomy of a frog [9]. The application offers real-life animal physiology education to schools that may not be able to afford expensive equipment, materials and lab space required for a real-life dissection. This technology also caters to students who may have strong opposition to dissection due to personal reasons [10].

University Applications

Virtual Reality has also found a place in higher education and is being used in universities around the world. These applications much like the K-12 programs allow students to learn in a visual manner to better comprehend topics and experience “field trips” that would normally be impossible. The Arizona State University recently launched a new Virtual Reality Lab program for some of their biology courses. The VR labs allow students to perform labs without the use of brick-and-mortar laboratory spaces. Through the online course and VR lab applications, the university has been able to increase the number of students who can take biology labs without building more lab space. The VR labs are also helpful for providing students with experiences that a physical laboratory would not allow due to cost or safety concerns. These experiences include taking a blood sample to test glucose levels and virtual field trips to other professional labs across the country [11]. Another example is the Jiangnan University in Japan, that has developed a 3D Virtual Reality program to help its Mechanical and Manufacturing Engineering students better understand engines and their components. The program uses interactive exploded diagrams to show students the pieces of a 3D model engine [12].

Applications at Pennsylvania State University

Penn State University now offers a variety of virtual reality education experiences. Several examples are provided below:

- Virtual field trips for environmental science courses using mixed virtual reality which combines 360-degree images with 3D modeling [13]. These field trips offer students the ability to visit locations that would be impractical and/or cost prohibitive otherwise.
- Second language vocabulary learning. VR programs such as iVR Zoo and iVR Kitchen help student learn vocabulary through an interactive virtual environment (such as a kitchen or zoo). Students use a controller to click on different objects to hear a correct pronunciation of the object. Initial feedback has been very positive [14].
- The forestry department is using VR and modeling and visualization techniques to give students a better understanding of how human impacts and forest management decisions can affect forest health. These videos show students the possible effects that human decisions can have on an environment using a simulated forest that places students right in the middle of the changes [15].
- Industrial Engineering faculty developed a VR program that places students in a virtual manufacturing system, allowing them to visualize all the components in the system in a way not previously possible. Students can also manipulate the manufacturing process and observe the effects on the whole system [16].
- The TRAINS lab at Penn State Altoona offers virtual welding training to teach students the basics of SMAW and GMAW welding, a PTC Prime Locomotive Simulator that allows students to gain locomotive engineer training applicable for PTC Systems, 360-degree educational videos for various railroad environments, and a virtual environment program for studying railroad yard operations (Figure 1).
FIGURE 1: Photos of TRAINS lab at Penn State Altoona including virtual reality stations and computer simulation lab (a), Virtual welder trainer (b).

Other Uses in Railroad Education

The applications of VR in Railroad Education are limited, however as the technology increases in popularity, more educators will likely begin using VR for railway education. Current applications, outside Penn State University have focused on railway safety. In the United Kingdom, Motion Rail Ltd. has developed a VR program aimed at teaching children the importance on railroad safety. The program a virtual railway environment and allows students walk across a railroad at-grade crossing in order to learn how to safely cross the tracks [17]. In the Canada, Operation Lifesaver (a railroad safety organization) has created several 360-degree videos that demonstrate the dangers of disobeying railroad signs in a dramatic fashion. These videos give the viewer a first-person view of crossing train tracks in an unsafe manner and the serious repercussions. Some videos have also been developed with the goal of reducing railway collisions with all-terrain vehicles [18].

TRAIN'S LAB AT PENN STATE ALTOONA

Penn State Altoona has recently developed a virtual learning lab, entitled TRAINS (Teaching Railway Applications through Immersive learning and Network Simulation). Equipment for this lab was purchased through a grant from the National Railroad Construction and Maintenance Association (NRCMA) and donations from PS Technology and Norfolk Southern Corp. The Virtual Reality equipment offered in the lab includes two different types of VR headsets (high end and standalone), an Apolo WeldTrainer, a desktop locomotive simulator from PS Technology, and a 360-degree camera. Below is a more detailed list of this technology, followed by photos of the TRAINS lab and VR technologies (Figures 2 & 3).

High End Headsets

The lab currently offers two different brands of high-end VR headsets, the Oculus Rift and the HTC Vive Pro. Both of these headsets require the use of motion sensors, which are placed on the ceiling in a dedicated area. These headsets are used for experiencing virtual reality environments such as Unity as well as railroad-specific applications using the SteamVR software platform. Using the Google Earth VR application, students can experience an in-depth study of railroad classification yards and stations.
Standalone Headsets

The TRAINS lab has three different type of standalone VR headsets: Google Daydream, Oculus Go, and Gear VR w/ Samsung Galaxy Note 8. The Google Daydream and Oculus Go are complete standalone systems that do not require an accompanying smartphone. The Gear VR systems require a separate smartphone (e.g. Samsung Galaxy Note 8) that is inserted into the headset. All of these basic headsets can be easily set up and do not require any motion sensors, allowing them to be used outside of the lab and making them ideal for K-12 outreach programs. These headsets are mainly used for experiencing 360-degree videos and taking virtual field trips.

Apolo WeldTrainer

The Apolo WeldTrainer is a 3D modeled welding simulator used to teach the basics of welding. The program uses Carl ZEISS HD OLED 3D glasses placed inside a welder’s mask to replicate a real welding experience. The program can replicate SMAW and GMAW (MIG) welding. The program can simulate the process of welding beads on plates, fillet welds, butt welds and pipe welding. The software program identifies user errors in real time and can help the user if they are experiencing difficulty in their welding abilities [19]. Penn State students use this system to develop their skills and learn basic welding safety prior to performing actual welding in a physical lab space.

PS Technology- PTC Prime Locomotive Simulator

The PS Technology- PTC Prime Locomotive simulator is a full locomotive simulator that is used to train railroad employees on how to operate a locomotive equipped with Positive Train Control. The simulator has a complete locomotive desktop control stand and two touchscreen monitors that display a locomotive dashboard and a view from the cab [20]. Although this is not a true virtual reality system (because it does not include an HMD), this simulator offers a unique training experience for students that falls within the scope of the TRAINS lab.

360-Degree Camera

Both the TRAINS lab and the Penn State Altoona Library offer Nikon KeyMission 360 Cameras for filming the 360-degree videos. The camera features two opposite facing wide angle lenses to allow for full 360-degree coverage. Along with the camera are several accessories that help with filming including a tripod, a monopod (a one-legged camera stand especially useful for filming 360-degree videos because the legs of the stand will not appear in the video), and micro SD cards for extra memory.

FIGURE 2: RTE students using the standalone VR headsets (a) and students from the Penn State AREMA student chapter using Locomotive Simulator from PS Technologies and the HTC Vive (b).
FIGURE 3. Placement of a 360-degree camera and tripod at a hump yard near Vienna, Austria (a) and students setting up the 360-degree camera inside a railcar at Curry Rail Services in Hollidaysburg, PA (b).

VIDEO COLLECTION METHODOLOGY

The process of capturing 360-degree videos is relatively simple and straightforward. Required equipment includes a 360-degree camera and tripod/monopod or flexible camera mount. Penn State Altoona has purchased several of the Nikon KeyMission 360 cameras for video capture purposes. This 360-degree camera is relatively inexpensive (~$500) and produces fairly good quality videos. Higher quality cameras are available and may be purchased in the future by Penn State. This model was chosen due to its cost effectiveness and ease of use, taking into consideration that the primary users would be undergraduate students. In order to take a 360-degree still image or video, the user positions the camera in the location of interest, typically at eye level, presses a button on the top of the camera, and walks away to a safe location. In order to achieve optimal results, lighting is the most important consideration. Locations outside in the daylight are best. Images or videos can be captured indoors as well, but it is best to find locations that are well lit. Precautions should also be taken so that the camera is not quickly moved or jerked during filming, as this could create the potential for motion sickness for the viewer. Students have discovered that it is best to develop a storyboard for their video prior to filming, so that all important locations are filmed while on-site. Training should be provided to ensure that students are aware of all safety hazards and that proper safety procedures are followed, especially when filming at industrial sites, including railroad locations. Prior to filming, proper permissions must be secured. When working with railroad organizations, written permission is often required.

PROCESSING OF VIDEOS

The goal in developing 360-degree videos for the TRAINS lab was to create an entertaining video that also captures the viewers’ attention while maximizing educational content in a short amount of time. Before editing the videos, students receive training from Penn State Media Commons in order to learn the basics of editing 360-degree videos in the Adobe Premiere Pro software. These sessions teach students how to use video editing tools, manipulate raw video data, and practice editing using a sample video. After the required training, the video creation process begins by returning to the storyboard and creating a detailed plan for the video. The storyboard provides an outline for how the students would like to present the footage and provides a simple “plot line” that the designer can follow. Next, the video clips are imported into the editing software, trimmed and placed into the correct order according to the storyboard. Video formatting and coloring is then modified and additional aesthetic enhancements are made. Students conduct additional research to add educational content to the videos. Using online resources, contacting companies at filming locations and other course materials the students gather all the required information. Based on this additional research, supplemental photos, 2-D videos or charts are added to give the viewer a better understanding or a closer view of an object discussed in the video. Finally,
narration is recorded and music added. Videos are typically limited to 4-5 minutes in length in order to not exceed the attention span of the viewer.

RESULTS

In May of 2018 three students and one faculty from the RTE program along with an Instructional Designer from Penn State Altoona visited Germany, Switzerland, and Austria as part of a data collection trip. The goal of the trip was to record a variety of educational 360-degree videos of European railway sites. In the fall semester of 2018 students edited these videos into educational content. The topics covered in these videos are the Deutsche Bahn pantograph testing facility, the Munich train station, a hump yard in Austria, the Semmering Mountain Line, the Rheineck-Walzenhausen Mountain railroad, the Leica showroom, and the Hagerbach Test Gallery. Other videos were also created of SEPTA operations in Philadelphia, PA in 2018 and the Everett Railroad in Hollidaysburg, PA in 2019. These videos were created by student groups as part of the RTE 303, Railroad Operations & Safety course at Penn State Altoona. All of these videos can be viewed on the publicly available Penn State RTE YouTube channel. Future work will involve the creation of an interconnected virtual tour that allows students to jump between locations as they explore different railway sites and locations.

Cautions and Potential Problems

While Virtual Reality has many benefits, it is important to consider some of the cautions and potential problems in using VR in the classroom. The first concern is related to camera placement when filming VR videos. Penn State has tested a variety of filming methods using 360-cameras and experimented with placing cameras in a variety of locations including on the locomotive running board, inside a locomotive cab, on the knuckle of a coupler, and below the rails inside the gage of the tracks. While these camera angles provide unique visual experiences, situational awareness for real-world settings should be considered. Students must receive extensive safety training prior to filming, proper permissions must be granted, and procedures followed when on site, including a railroad flagman, if necessary. Additionally, viewers should be cautioned not to attempt to recreate any videos and to maintain a safe distance from all trains and railway tracks. Another potential challenge with VR technology is related to user interface. It is the educator’s responsibility to properly demonstrate to the students how to use VR technology, and without the proper training the educator and student may be unable to use the VR technology to its maximum potential [21]. Without proper training and demonstration, students may become impatient or frustrated with the technology, hindering the learning process.

Accessibility limitations and safety concerns should also be considered. While VR is generally easy to use by most of the public, some people may have difficulty using VR headsets (e.g. those with vision and hearing disabilities). Challenges can also arise for users who wear glasses or are prone to motion sickness. As a result, VR headsets should be selected that will accommodate students with glasses (larger models such as the Google Daydream standalone, or HTC Vive may be best), and viewing time should be limited to allow for breaks every 10-15 minutes. The VR headsets and equipment can also present other safety hazards. Some VR headsets require a wired connection to a desktop computer. If the VR system requires the user to move frequently around the viewing space the wires could trip the user and cause harm to them and others in the area. Another danger is the environment in which the VR headsets are being used. The area in which VR headsets are used should be clear of all obstructions, or users should be seated in a sturdy chair with a low center of gravity that can easily spin a full 360 degrees. A final caution to consider is the effect of VR on young children. Some VR headsets do have a minimum age rating. For example, the Oculus Rift system has a manufacturer recommendation limiting use to children over thirteen years of age. Other systems may not provide a stated limitation, but consideration should be made for how these headsets can affect young children, and it may be best to seek parental permission prior to using VR for K-12 education programs. Some concerns have also been raised that exposure to video screens in close proximity over long periods of time could affect a child’s vision. Other concerns have been suggested pertaining to mental health risks, body neglect, privacy, and behavioral changes [22, 23]. Research is ongoing to determine on how to best use virtual reality while maintaining the highest health, safety and ethical standards.
Best Practices and Recommendations

A study by Spiegel puts forth some recommendation on how to best utilize virtual reality for educational and training purposes. First is the adoption of a rating system and minimum age requirement for virtual reality products [22]. This would be similar to a rating system for video games or movies. This study argues that mental and physical risks involved with immersive environments are much higher than that of a typical video game environment and therefore a minimum age should be established [22]. Another recommendation is related to personal data and intellectual property. Users of a virtual reality systems may be asked to share personal information with the software host– in educational settings student personal information must be protected. If users are designing videos or aspects of a virtual world, ownership of this content should be considered. Spiegel suggests that laws should be enacted to determine who owns user data and intellectual property for these platforms [22]. Since most of these legal issues have not yet been tested in court it is recommended that schools and companies create internal policies to address user data and intellectual property [24].

CONCLUSIONS

This preliminary study offers a survey of applications for virtual reality across various industries and academic settings. Compared to other industries, the railroad industry has been relatively slow to adopt virtual reality systems. However, due to cost and safety benefits, railroads have begun to explore the use of virtual reality for training purposes. Currently, most of this training occurs using simulators and tablet-based online training, but virtual reality training using Head Mounted Display (HDM) units may be a logical next step to improve the effectiveness of training programs. Railway consulting companies are now using virtual reality systems to improve the design process and streamline communication between designers and customers. Railway safety organizations have begun using virtual reality videos to educate the public on railway/highway at-grade crossing safety. Finally, educators at Penn State Altoona have established the TRAINS lab that incorporates virtual reality and simulation systems to foster immersive learning and exposure to railway system across the US and the world. As technology advances and virtual reality systems become more affordable, it is expected that VR will grow in use both in academia and in the private sector.

FUTURE WORK

As educators at Penn State have begun to implement VR technology in the classroom, several areas of future work have been identified. First, RTE faculty plans to continue growing a virtual library of 360-degree educational videos to be made publicly available. Feedback from students and faculty have indicated that the 360-degree videos are a useful teaching tool that give students knowledge of railway environments, especially those that are not easily accessible. In order to improve the resolution and audio quality of videos, new, higher quality 360-degree cameras will need to be purchased. Penn State Altoona will also need to work with railroads, transit authorities, and railway construction firms to identify locations and gain permission to film new 360-degree videos in unique settings that will foster student learning.

Next, to further develop railway education using virtual reality, new computer-generated virtual environments will need to be created. Although 360-degree videos offer the most immediately applicable form of virtual reality education, from a pedagogical standpoint, virtual environments provide even greater educational value. Through the use of a virtual world, students could conduct field laboratory sessions to measure track geometry, inspect rail or vehicle defects, explore the inner workings of a locomotive, troubleshoot signals systems, inspect a bridge or a variety of other tasks. Development of these computer-generated virtual worlds is costly, due to the time required by computer programmers to design the environments. This provides a potential area of future collaboration between academia and the private sector. As railroads or engineering design companies develop CAD drawings of railway vehicles or infrastructure these drawings could be converted into components in a virtual reality educational program. In this way, students could explore actual railway infrastructure or vehicles and manipulate aspects of the environment in order to understand how it is designed, inspected and maintained. Sharing of this information can also lead to the development of augmented reality systems that allow users to interact with the physical world and receive information and visual feedback via a virtual reality headset,
smartphone, or tablet. As more companies and universities grow in the use of virtual reality systems, greater collaboration will be possible.

ACKNOWLEDGEMENTS

The authors would like to thank the National Railroad Construction and Maintenance Association (NRCMA), PS Technology and Norfolk Southern Corp. for providing funding and in-kind support for acquisition of virtual reality and simulation equipment for the TRAINS lab at Penn State Altoona. The authors would also like to thank Leica Geosystems for providing travel funding to record 360-degree videos of railway systems in Europe in 2018. Finally, we would like to acknowledge the Penn State Altoona Office of Research for providing funding to hire undergraduate research assistants.

REFERENCES


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Immersive Learning Using Virtual Reality Systems for Railway Education

Bryan Schlake, Michael Begany, and Colin Seitz
Penn State Altoona
Rail Transportation Engineering Program
Overview

• Introduction
• Virtual Reality (VR) Background
  • Use of VR in Other Industries
  • K-12 and University Applications
  • Railway-specific Education
• TRAINS Lab at Penn State Altoona
• 360-degree Video Development
  • Methodology
  • Results
  • Recommendations
• Conclusions
• Future Work
Introduction

• Rail Transportation Engineering (RTE) at Penn State Altoona
• Hands-on education
  • Practicum courses
  • Field trips & conferences
  • Research projects
• Need for Immersive Learning and Virtual Reality (VR)
• Teaching Railway Applications through Immersive learning and Network Simulation (TRAINS lab)
Virtual Reality (VR) Background

**Definition:** “Virtual Reality involves the use of a computer to create an interactive immersive experience via some form of... display unit, such that the user feels part of the virtual or simulated environment” (Cochrane)

**Types:**

1) Computer generated virtual environments
   
   *Pros:* Almost any type of environment can be created  
   *Cons:* High cost to design environments

2) 360-degree images or videos (e.g. Google Street View)
   
   *Pros:* Easy to collect and process photos/videos  
   *Cons:* Environments limited by accessibility
## Industry Applications for VR

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</tbody>
</table>
Current uses in Railroad Education

• **Motion Rail Ltd. - United Kingdom:**
  Railway safety VR programs for children & workers

• **Operation Lifesaver - Canada:**
  360-degree videos demonstrate the dangers of walking or riding snowmobiles or all-terrain vehicles around railroad tracks
Other Educational Applications of VR

• K-12 Education: Nearpod VR, Google Expeditions, VFrog™

• Universities (examples at PSU)
  • Geology: Virtual field trips
  • Biology: 2nd language vocab learning with iVR Zoo and iVR Kitchen
  • Forestry: VR and Modeling to visualize forest growth
  • Industrial Engineering: Manufacturing visualization & design
  • Rail Transportation Engineering: TRAINS lab at Altoona
TRAINS Lab at Penn State Altoona

**Immersive Learning**
- Apolo Virtual WeldTrainer
- High-end VR systems: Oculus Rift & HTC Vive (NRCMA grant)
- Standalone VR headsets: Gear VR, Oculus Go & Google Daydream headsets (NRCMA grant)
- 360-degree VR camera (NS Gift)

**Signals & Simulation**
- PLC signal station (Ansaldo-STS / Hitachi Gift)
- Locomotive & PTC Simulator, (PS Technology Gift)
- Computer Stations
  - Berkeley Simulation Software
  - Autodesk Civil 3D
  - PLC Simulator
TRAINS Lab at Penn State Altoona
HTC Vive  
Locomotive Simulator (PS Technology)  
Apolo WeldTrainer
360-Degree Video Development

• Nikon KeyMission 360
• Video collection trips:
  • Pennsylvania: Altoona, Philadelphia and Hollidaysburg
  • International: Germany, Switzerland and Austria
Video Processing

• Adobe Premier Pro Software Training

• Develop storyboards

• Add supplemental photos, 2D videos, and narration
<table>
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<th>Video Title</th>
<th>Duration</th>
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<tr>
<td>Hagerbach Test Gallery</td>
<td>5:34</td>
<td>Video of the Hagerbach Test Gallery</td>
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<tr>
<td>Leica Geosystems Showroom and Amberg Technologies</td>
<td>4:14</td>
<td>Video showcasing Leica Geosystems Showroom</td>
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<tr>
<td>Austrian Humpyard</td>
<td>5:12</td>
<td>Video of the Austrian Humpyard</td>
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<tr>
<td>Semmering Mountain Line 360 Ride</td>
<td>6:01</td>
<td>Video of the Semmering Mountain Line 360 Ride</td>
</tr>
<tr>
<td>Munich Central Train Station</td>
<td>3:02</td>
<td>Video of the Munich Central Train Station</td>
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<tr>
<td>Septa Virtual Tour 360 Video</td>
<td>10:22</td>
<td>Video of the Septa Virtual Tour 360</td>
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<td>Penn State - RTE 303 Term Project -- Fall 2017</td>
<td>10:27</td>
<td>Video of the Penn State - RTE 303 Term Project</td>
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<td>Deutsche Bahn Pantograph Test Stand</td>
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<td>Video of the Deutsche Bahn Pantograph Test Stand</td>
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<tr>
<td>PennState RTE 404 - Railroad Mechanical Practicum</td>
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<td>Video of the PennState RTE 404 - Railroad</td>
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<tr>
<td>RTE 303 Railroad Crossing Signals 101</td>
<td>9:57</td>
<td>Video of the RTE 303 Railroad Crossing Signals</td>
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<td>Austrian Humpyard</td>
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<td>Leica Geosystems Showroom and Amberg Technologies</td>
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</tr>
<tr>
<td>Rheineck-Walzenhausen Mountain Railroad</td>
<td>3:01</td>
<td>Video of the Rheineck-Walzenhausen Mountain Railroad</td>
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</tbody>
</table>
Conclusions & Recommendations

• VR provides an excellent medium for safe and affordable hands-on education

• Not an “end all be all” but provides a valuable compliment to physical labs

• Best practices for filming and viewing:
  • Safety and accessibility permissions
  • Safe viewing environment
  • Viewing time considerations
  • Age sensitivity
Future Work

• Grow virtual library for VR educational videos
• Purchase new higher resolution camera and audio equipment
• Identify new filming locations of interest and collect videos
• Partner with industry to create new computer-generated virtual environments
• Augmented reality
Acknowledgements

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Questions?