Development of Immersive Vehicle Simulator for Aircraft Ground Support Equipment Training as a Vocational Training Program

Yongjae Park(✉), Yonghyun Park, and Hyungsook Kim

Department of Human Arts and Technology, Inha University, Incheon, Korea
{mayamind, yhpark81, khsook12}@inha.ac.kr

Abstract. Due to the increase in the number of flights and passengers at Korea's airports, there is an urgent need for airport personnel. A demand survey showed that the number of airport ramp services personnel was insufficient for the increasing amount of air traffic. Free access to various parts of the airport is difficult due to the security system, which limits on-the-job training. The purpose of this study was to develop an immersive vehicle simulator that can be used as a vocational training system to assist airport ramp agents in training to understand the process of performing the job and to master ground handling services before using the actual equipment at the airport. To aid in the development of this simulation, focus group interviews were conducted with ramp service personnel engaged in ground handling services, and the requirements for the position were identified. The simulator is largely divided into three parts: a hardware platform, a simulator software, and vocational training educational simulation content. To enhance the immersion of the experience, a display device was installed on the front and rear of the vehicle simulator. The software environment replicates the actual design of the Incheon airport, incorporates a 3D model of an actual vehicle and is simulated with the UNITY program. The simulator was used for vocational training in concert with the developed training program. Additionally, we collected feedback from trainees who participated in the vocational training program and identified necessary improvements to the hardware and software.

Keywords: Virtual reality systems for learning · Immersive vehicle simulator · Aircraft ground support equipment · Vocational training program

1 Introduction

Over the past several years, an increasing number of immersive virtual environment experiences have become available for both educational and entertainment purposes.

Participants in entertainment experiences now number in the hundreds of millions, yet adoption in educational settings remains limited [1].

In this paper, we will discuss the development of immersive simulation for training airport ramp agents. International airports are complex systems that require efficient operation and the coordination of all departments. Related research include the development of scheduling solutions to efficiently manage the work of airport ground

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crews [2], the study of aircraft coordination simulation and education to improve student understanding of aircraft coordination [9], and Cessna 172 Aircraft Simulation studies on virtual training [10].

In the past few years, the common direction of research on educational simulation development for airport-related work has been the construction of immersive environments. Focused research is being conducted to construct environments in which users can be immersed in various situations through the combination of hardware and software according to the characteristics of each field, along with a training environment configured using virtual reality (VR) and augmented reality. However, it is difficult to find simulations developed to replicate the work of airport ramp agents for educational purposes related to vocational training. The demand for such research is high for the personnel at Incheon International Airport.

Since its opening in 2001, Incheon International Airport has grown steadily to become an international hub airport and has developed into the world's seventh largest international airport and the world's third largest international freight airport. The Incheon airport has been ranked No. 1 in the International Airport Service Quality (ASQ) for 12 consecutive years and the number of passengers at the airport has surpassed 62 million per year. The third phase of the airport construction project was recently completed and Incheon International Airport successfully opened a second passenger terminal on January 18, 2018. With the addition of the new terminal, Incheon International Airport covers a total land area of 22,397,000 m^2, with three runways, two passenger terminals, 3,085,000 m^2 of passenger moorings and 1,155,000 m^2 of cargo moorings [3].

According to the 2017 aeronautical statistics for airport use in Korea, 850,214 flights, 143,331,106 passengers and 4,611,766 tons of cargo pass through Korean airports annually [4], with the number of passengers increasing by about seven million every year. In 2017, Incheon Airport had the highest amount of passenger traffic in Korea, accounting for 44% of the total number of passengers at all airports nationwide. According to a statistical survey from Korea's national statistics portal, the number of employees required for the airport passenger industry is increasing annually. From 2017 onward, it is estimated that between 2,000 and 2,500 additional aviation crews, comprising four to five percent of existing employees, will be needed [5]. Thus, it is more urgent than ever to train agents capable of airport ramp service.

At airports, a variety of ground handling services are required to load and unload passenger cargo as it enters and leaves the aircraft. The functions of ground handling agents have a very significant impact on timely execution of the flight network by the air carrier. The main tasks of ground handling agents consist of taking care of the aircraft before and after the flight, specifically, handling passengers, baggage and the aircraft [6]. According to the results of a survey of company personnel demands regarding airport ground handling services [7], the personnel for the ramp service is insufficient for completing the aforementioned services. It has since been confirmed that few staff members are capable of performing the duties of aircraft marshaling, towing with pushback tractors, and luggage handling with Belt Loaders and baggage carts.

Ground handling is one of the most important processes at the airport and is directly related to the operation of the aircraft. Efficient management and the competitiveness of ground handling services are both business assets and a survival strategy for airlines. In particular, ground handling accounts for a large portion of cargo transportation services and these services should be differentiated. According to the current guidelines, operating companies are selected based on the criteria set out in the International Air Transport Association (IATA) Ground Handling Agreement regardless of the nature of the airport or the size of the airline. There is no standardization of the method for selecting a ground operation company to complement the work of the airline. Consequently, these companies are selected according to the judgment of each airline. Different selection strategies are required taking into consideration the business area of the airline, the passengers and cargo, and the airport situation of the ground operator [8].

Based on the results of a demand survey, the Inha University Institute of Advanced Human Resource Development (IAHRD) developed a 160-h training program to educate airside ramp service agents who can immediately apply the training to their work. Due to the nature of the job, many occupations require the use of specialized equipment. Therefore, it is necessary to practice rather than learn theoretical concepts in order to develop the skills to use the equipment. However, the security system of the airport and the characteristics of specialized equipment make practice difficult. Not only is the airport's airside ramp difficult to access, but the equipment required for practice is specialized and can only be used at the airport. Therefore, a virtual simulator is needed to help trainees indirectly experience the work of an airside ramp services agent by facilitating practical training for the use of specialized equipment.

The purpose of this study is to develop immersive equipment for airport ramp agent trainees to help them understand the process of performing the job and to learn the ground handling services tasks before using the actual equipment at the airport. This equipment will be used for vocational training to train the ground handling services personnel needed at Incheon International Airport and was developed to be adaptable to other airports of similar size. Therefore, this study contributes to a practical environment that can be used universally in vocational training education so that airport ramp agents can utilize the equipment necessary for their job in a virtual environment.

2 Related Work

Research related to the development of ground handling services equipment was difficult to find. Studies on the development of simulation equipment in the aeronautical field that combine hardware and software similar to this study are described below.

2.1 Aircraft Handling Simulator

The report titled "Creating an Aircraft Handling Qualities Simulator for the USAF Test Pilot School" [9] contains a description of aircraft coordination simulation equipment and training programs designed to improve the understanding of aircraft handling for students at the USAF Test Pilot School. The equipment used in the study included hardware from the actual equipment located in a separate laboratory where users could practice. The hardware configuration consisted of a Cockpit & Cockpit Inceptor Control (stick, rudder pedals, throttles), five displays, Image Generator, Image Driver Generator, Control Room, Master Sim, and Backup. For the purpose of general purpose aircraft coordination, the software included basic controls or a display with general purpose GUI, and the simulation software was configured to select and practice the operation of various aircrafts. The goal of the simulator is to enable instructors and students to easily create lesson plans that include the characteristics of various aircrafts.

2.2 Cessna 172 Aircraft Simulator

The study "Development of a Cessna 172 Aircraft Simulator with a Glassless Open-type VR Screen for Virtual Training" [10] was conducted for pilot flight simulations based on the Cessna 172 model, which is widely used for the training of aircraft pilots around the world. The simulator provides virtual training for piloting and aircraft instrument operation procedures. The content used in this simulator was developed using the PREPAR3D engine program provided by Lockheed Martin, which includes a physical interface to express the physical aspects of the aircraft. The equipment is largely divided into three parts: a simulator interface, a simulator operating software, and pilot training educational simulation content. The display utilizes a Glassless Open-type VR Screen instead of a regular monitor, which is a positive factor for practitioners to improve immersive experiences during pilot exercises. This simulator has been certified by the Ministry of Land for Grade A training for flight simulation equipment, which is the same as the Flight Simulator Level C of the Federal Aviation Administration (FAA). The efficacy of the aircraft simulator was verified for Cessna 172 aircraft virtual simulation training through two field trials with a group of experts in VR and aviation related fields.

3 Simulator Requirements (Development Process)

In order to develop virtual simulation training equipment, focus group interviews were conducted 3 times with ramp services agents currently performing ground handling services (Table 1).

Table 1. Development requirements for ground handling services

Necessary task	Marshaling	Tug Car	Loader	Belt Loader	Aircraft Tractor
Job description	Guide the aircraft in and out of the parking position	Move cargo from the warehouse to the airplane or the plane to the warehouse	Move cargo from the aircraft to the ground or from the ground to the aircraft	Move cargo from the aircraft to the ground or from the ground to the aircraft	Tow aircraft
Requirements	• Hardware production based on various vehicle operating environments and user interfaces. • Marshaling: Implementing a situation in which the aircraft reacts in real time to movement signals from the marshal to induce parking. • Tug Car – Implementation of Tug Car backward interface for connection with Tug Car and Dolly – Implementation of a display device that allows trainees to check the situation behind simulation training – Implementation of a hardware experience that allows the user to feel the movement of the vehicle when driving in the airport • Loader – Implementation of a realistic user interface (with up and down movement of the chair) reflecting the characteristics of the equipment – Describing in detail the moment of contact between the aircraft and the Loader • Aircraft Tractor: Representation of the connection between the tractor and the Tow-bar • Simulation of the Tug Car in which the process is similar to that of work at the airport • Development of the working environment by simulating day, night, and rainy weather • Implementation of unexpected situations due to obstruction or collision with the progress route of other vehicles during work • Assessment of the students' practice and ranking announcement system				

4 Configuration

4.1 Hardware

According to the results of the demand survey, most of the simulation work required by the company was related to the operation of special equipment. In order to implement the simulation in accordance with the requirements of the company, a universal hardware structure capable of presenting a common interface for different vehicles was required. The hardware platform largely consists of display devices, a controller, a frame, and a six-axis motor. The displays consist of two 42-in. monitors used to represent the front and rear views. The controller consists of a cockpit chair, steering wheel, transmission, brake pedal, accelerator pedal and option buttons. The frame is custom made using steel. In order to increase the immersion feeling by conveying physical movements in various situations to the driver, an electric motor composed of six axes is used as the base of the whole equipment (Fig. 1).

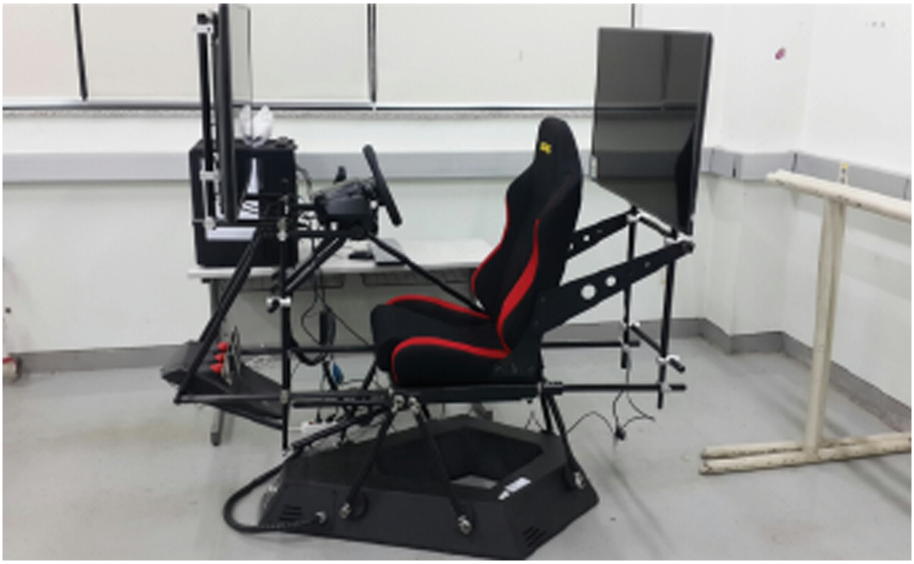

Fig. 1. Simulation hardware architecture

4.2 Computer

High polygon modeling data was used for realistic representation of the airport's overall virtual space and 3D object configuration. The following computer hardware specifications are required for real-time rendering including physical environments: Intel i7-4790 3.6 GHz quad-core CPU, 32 GB memory, Geforce GTX 980 4 GB graphics card, 500 GB SSD drive, and Windows 7 64 bit operating system. However, since the software was designed to arbitrarily adjust the 3D graphics resolution considering various platforms, there should be no problems using it on a computer with lower specifications than those proposed above.

4.3 Software

We created 3D objects for the terrain, buildings, structures, vehicles, cargo, and aircrafts that can be seen in the ramp area of the airport. We simulated real-time operations that may occur for inbound and outbound freight at airports using the Unity program. In detail, the character representing the ramp services agent was dressed in an outfit with the same design as the actual work outfit, and each vehicle was modeled in 3D based on the actual vehicle operating in the field. In addition, the physical environment such as slippery road surfaces, changes in braking distance, changes in illumination, etc., which can occur at nighttime or in rainy weather, was also represented to better reflect the characteristic and differences in the work depending on weather changes due to the nature of work performed outside. Six electric motor shafts were used to replicate a realistic driving experience by moving the driver's seat in real time in response to the driver's manipulation of the direction of the vehicle, collision of the vehicle, and up and down movement of the equipment. In order to evaluate the students, an evaluation system was developed to show individual points and rankings taking into consideration the operating time and the delay time due to equipment malfunction. The displayed view can be selectively changed between the first and third person perspectives in the middle of the practice session according to the situation, and the basic resolution for the display is set to 1920 × 1080 (Fig. 2).

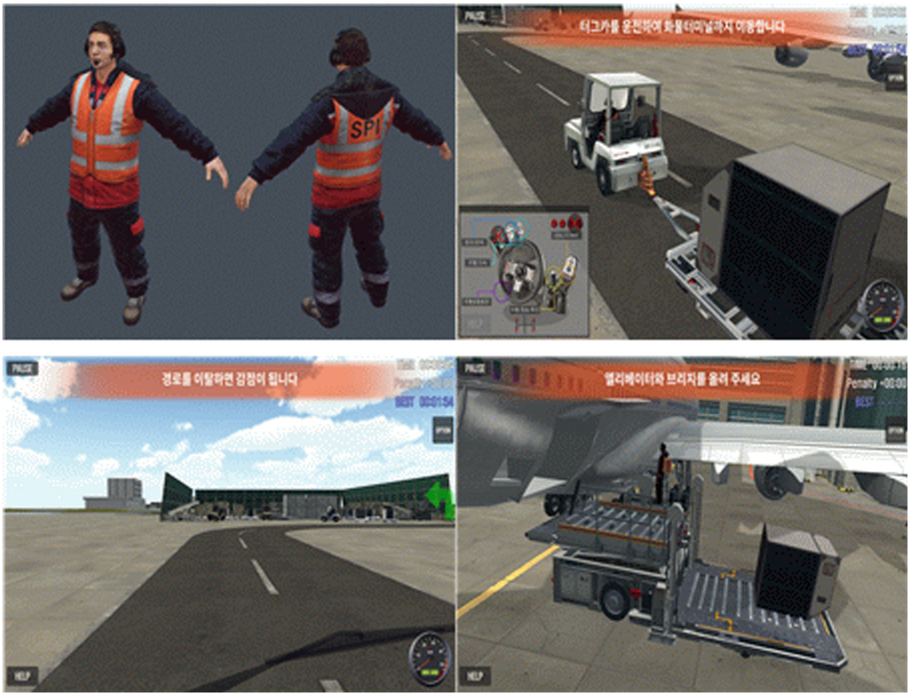

Fig. 2. Ramp services agent, Tug Car, and Loader driving screen shot

4.4 Ground Handling Equipment

For all vehicles that appear in the simulation, users can operate the transmission, accelerator pedal, and brake simultaneously, which are necessary for traveling (forward and backward). The crash response caused by external shock is transmitted to the cockpit. The main function of the Tug Car is driving and cargo transportation, which can be achieved by connecting up to three cargo containers. The exterior of the vehicle is modeled after a 3D object in the same form as the Toyota TD25. Due to the design of the vehicle, new ramp services agents experience difficulties connecting a Dolly to the Tug Car. Therefore, the simulation for connecting the Tug Car to a Dolly is presented through a driving interface that shows a backward view, similar to the situation in the field. The Loader is a device that comes into direct contact with the aircraft. The loader simulation has a function to learn the procedure and method of the Bridge Seesaw and the Elevator

Seesaw which are necessary to carry out the controlling practice in contact with the aircraft and the process of loading and unloading the cargo. Belt loader is a device that is mainly used to move small packages and it shows the situation to practice the procedures of operation of the equipment. Aircraft tractor is a device that pulls and moves the aircraft directly. The user can practice connecting the aircraft wheel and Aircraft Tractor to the Tow-bar, and also practice dragging and moving the aircraft (Figs. 3 and 4).

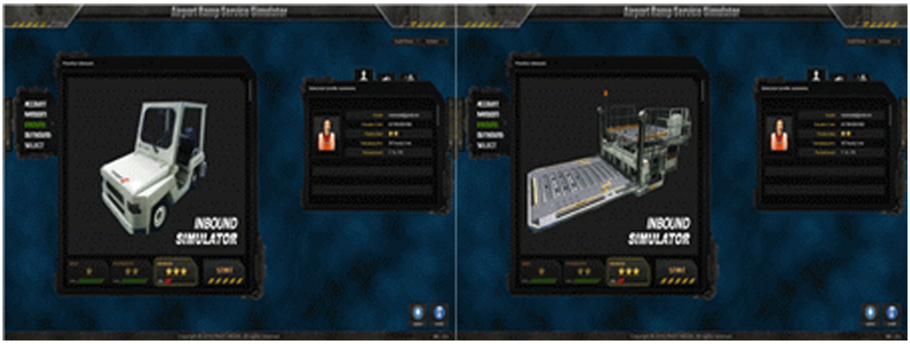

Fig. 3. Tug Car and Loader equipment screen shot

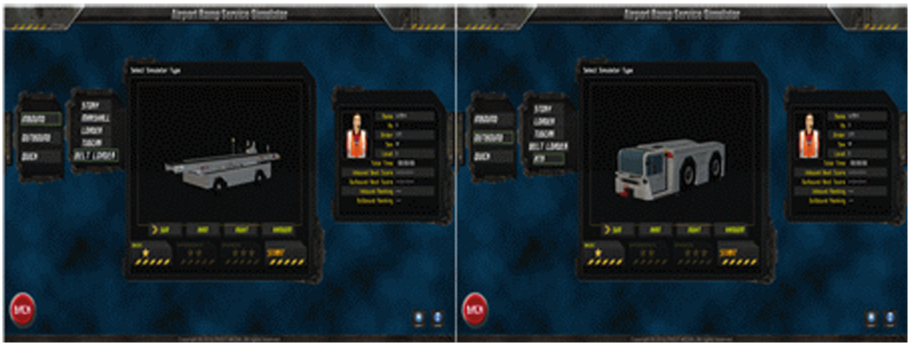

Fig. 4. Belt Loader and Aircraft Tractor equipment screen shot

5 Vocational Training Program

The Inha University Institute of Advanced Human Resource Development (IAHRD) developed a 160-h, 20 - day vocational training offline training program for 15 job seekers who wish to perform aircraft operations at airports such as Incheon Airport and Gimpo Airport. The main contents of the training program are utilization of the logistics information system, air transportation management, storage and unloading management, land transportation management, ramp operation safety and security education, ground moving support equipment operation training, air cargo handling and handling equipment operation training, training on aircraft towing and communication. The equipment training on campus is carried out using simulation equipment, and the last 6 days of the training program consist of practice using actual equipment at the Incheon Airport work site.

The practice sequence of this equipment is divided into inbound, outbound, and elective practice. Inbound practice is performed in the order of Marshalling, Loader, Belt Loader, Tug Car operation, and Cargo terminal movement starting from the time the aircraft lands, while the outbound process proceeds in the reverse order. If sudden and ad-hoc decisions need to be made while practicing with the equipment, the instructor will demonstrate the process and interact with the students to provide information that enhances the completeness of the education.

6 Results and Discussion

The Ramp Services Simulator developed according to these requirements was put into practice for education, and 49 students participated in the training program. After training with the simulator, the students completed a questionnaire. The results of the survey on the merits of simulator training are as follows. First, the 3D graphics environment created to be similar to the actual airport environment was realistic, which made the educational experience more immersive. Secondly, the vibrations and movements of the vehicle during the training were delivered to the cockpit and the steering wheel realistically. Third, the structure of the airport in the educational content and the moving line for the car were similar to those at the actual airport, so the users were able to adapt quickly to the actual work.

The disadvantages of simulation education according to the students are as follows. Only some aspects of airport operations were simulated; therefore the students could not practice with all the equipment they needed for the work. Additionally, it was inconvenient that the equipment was so bulky that practice was only possible in a specific room. Lastly, it was not possible for the students to practice for the desired amount of time.

Evaluation of the students' participation in the practice revealed two areas that required improvements. First, in order to better represent the comprehensive work of a ramp services agent, it is necessary to reorganize the existing simulation content to express all aspects of the actual work. Second, the hardware platform requires various improvements for convenient use of the equipment. For example, if the display method is implemented in a VR environment using a head mounted display instead of a monitor, the user will be able to experience various tasks in a narrower space. This will make it possible to create a simplified program that enables the user to experience the simulation with no time or space restrictions. We expect this to be possible.

After the development was completed, the students provided feedback on their experiences for technical improvement. First, when there was a collision between vehicles during operation and sudden decision making was required, the implementation of collision considering various physical environments was found to be insufficient. This situation was attributed to the lack of exception processing information that can be generated during driving. Second, in one section of the simulation, animation of the linking action between mechanical parts of the equipment was not expressed accurately. This was because mechanical drawings of the equipment were unavailable and the simulation was created using photographs of the equipment as a reference. Consequently, simulation of the connection of parts of the equipment was inaccurate. Third, the expression of reactions such as the speed of movement according to the cargo weight and the physical force experienced when the cargo is moved or loaded were insufficient. As the airport's security system provides limited information, data on how to handle various exceptions was unavailable.

7 Conclusion

The proposed simulator equipment is displayed in the equipment room at the Inha University Institute of Advanced Human Resource Development. Individuals undergoing vocational training and students in the airport ramp training program are using the equipment and providing feedback to help improve the product. We also continue research on UX/UI improvements based on ongoing user experience. We plan to complement the software and add content to provide similar educational content for a variety of industries. To improve the quality of vocational training in various fields that require experiential training and to improve the academic achievement of students, it is necessary to increase the universal utilization of these types of simulation equipment. In order to do this, it is necessary to continue research to expand the platform environment to multi-platform environments such as VR or online and to develop new content.

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