Peter Alexander Kopciak / Patrick Kolar / Daniela Hellmann / Shadja El Aeraky /Matthias Dollfuss

Virtual Reality Driving Simulator Prototype for Teaching Situational Awareness in Traffic

103 - Recent Advances in Multimedia Processing, Organization and Visualization beyond Domains and Disciplines

Abstract

Modern-day driving schools in Austria are using theoretical tests and a practical driving exam to ensure a person is fit to drive on the streets. Students have to learn these skills by driving with a teacher and taking lessons in a class. But many topics can only be covered in theory and not experienced in person beforehand. Those include very risky situations, like jaywalking, and situations that occur either infrequently or suddenly, such as clearing a lane for emergency vehicles ("Rettungsgasse") on a highway. In other fields, like piloting an aeroplane, a simulator is used to teach the needed skills in a cost efficient and safe way. Additionally, virtual reality is often used to fully immerse the user in the real world and to prepare him for action in the world. This project explores the possibilities of using a virtual reality driving simulator prototype to teach driving a car in a safe environment using cognitive learning methods and gamification. In contrast to existing (virtual) driving simulators, our prototype focuses on teaching situational awareness and is designed to be used in addition to classical driving schools. The student gains control of a vehicle which they can use to drive around a city. During this journey they have to reach a specific location and complete various objectives. As they drive they may be faced with various situations inspired by real world events, like fog or an unexpected encounter with a speeding vehicle. They have to quickly assess the situation and react in a responsible way. Throughout the session the student is assisted by Movado, a voiced computer system build into the virtual car. This assistant comments on the driving of the user, gives them information on their objectives and supports the user with abilities like making the car translucent or superimposing the worldview with arrows to help navigating the fictional city. We conducted user tests to assess the user's impression and experience of the simulator and how the user reacts during the experience in regard to cyber sickness. User feedback improved both the overall experience and acceptance of this new method.

Keywords:

virtual reality, driving simulator, driving school, gamification, education, edutainment, situational awareness

1. Introduction

Learning how to drive is a process which takes time and effort. People attend driving schools and pay for theoretical lessons to learn traffic laws, road signs, and how to behave on the streets during various situations. Afterwards, they pay for practical lessons to acquire the actual skill of driving a vehicle, including how to brake, how to turn, and how to park. Afterwards, they must use their theoretical knowledge in real world scenarios, react to other people's actions and drive in an imperfect world where mistakes can happen. Learning to drive well is a feat which comes from experience, practice, and hours spent on streets and highways. Some situations, like a crossing pedestrian, objects on the street, or a rescue alley require attention and a cool head. Billboards or fog can be distracting. All these things may be no problem for a seasoned driver, but someone who has just finished driving school may be overwhelmed at first. The majority of car accidents in Austria happen due to negligence, inexperience, overconfidence, failure to yield traffic, and driving too fast (Dietl / Pfeifer 2015: 14, 83). Similar to other fields, like flight training, we can use virtual reality to simulate critical moments during driving without harming the user or bystanders (Eckstein 1999: 8). One cannot learn everything in driving school lessons, and situational awareness can only be gained through experience. For this, we have developed a virtual reality driving software which ought to be an addition to established learning procedures in driving schools. With thorough simulation of different situations one can train and experience these moments first hand without the fear of making a fatal mistake. This new method, unlike classic approaches, provides interaction and enhances first person experience instead of theoretical distance (Dörner et al. 2013: 189). The prototype is subject to continuous change and development. Therefore, some things mentioned in this paper may change as this project is further developed and improved.

2. The Virtual Reality Driving Simulator

Using a steering wheel, pedals, a gear shift, and an Oculus Rift, one can drive a car in a fictive city and is able to look around freely employing virtual reality. The user is encouraged to adhere to traffic regulations and drive in a responsible manner. Faced with an objective, like getting to a place in the city or delivering items, the driver is set on a journey through the virtual world which they can explore on their own accord. This corresponds to two basic kinds of movement control in the virtual world: exploration or driving around without a specific aim, followed by a search assignment which is reaching a goal or point in the virtual world (Dörner et al. 2013: 170). With this quest mechanic, known from role-playing games, we enable virtual immersion and identification and, consequently we improve the student's sense of presence to make the experience as appealing as possible (Dörner et al. 2013: 60). Furthermore, immersion and personal engagement facilitate learning in virtual environments which can be achieved by presenting the user with a story, a purpose and tasks (Dede 2006). Using gamification metaphors we can lead the user and make the learning experience fun and entertaining. The actual learning process is not inherently visible to the user and is thus pushed into the background, following the principles of edutainment but leading to an efficient learning activity (Jayasinghe / Dharmaratne 2013: 1). Another aspect regarding immersion and learning quality is the employment of a spatial audio system to give the user detailed feedback about their surrounding environment and to mimic real world auditory perception, which aids presence and hinders cyber sickness (Warnecke / Bullinger 1993: 144). To provide the user with a familiar horizon and a reference point for gazing we implemented a very detailed skybox with high-definition clouds. This reduces visual conflict and increases comfort within the virtual world (Oculus VR, LLC 2016: 6). We refrained from displaying information at screen depth, in front of the view at a fixed position in the form of a heads-up display, to stay inside the narrative, and to prevent information overload, to reduce display cluttering and the number of necessary depth jumps, and to increase immersion (Schild / Masucha 2012: 4, 10).

2.1. Situations and Scenarios

As the user drives in the city and is focused on his quest they may be faced with various scenarios and situations. Like in the real world, one is not able to prepare for the onset of specific circumstances but has to react properly and quickly. This leads to higher "replayability" and encourages exploration. As an example, the user may find himself in a foggy part of the city (see Figure 1) and is warned to pay attention and drive slower due to the reduced line of sight. They may pass a construction site and if they, despite bad visual conditions, have driven too fast, they might crash or cause an accident. One may hear the distant sirens of a fire brigade and later at an intersection a fire engine may drive past the user, ignoring all traffic lights. This is a typical moment where immediate reaction is required to avoid a collision.

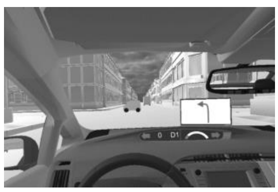
2.2. Movado the Assistant

The user is assisted by Movado, a computer assistant system and driving instructor. Movado is represented as a smiley face displayed on a monitor placed on the dashboard. It speaks to the user and can change its facial expression. Movado introduces the user to the controls and to the possibilities of virtual reality and makes the user aware of their mirrors and speedometer. Movado will give feedback on mistakes and achievements or provide information on progress towards the main goal. During situations it may offer assistance and information. By using Movado as an intradiegetic device, we can share extradiegetic knowledge, instructions or advice, and activate various supporting systems to aid the driver inside the narrative context of our world and thus hinder the breakdown of immersion (Schild et al. 2013: 170). As an example, Movado can make the car translucent to offer increased visibility of the surroundings and the exact positioning of the wheels (see *Figure 2*).

2.3. Navigation Through the City

Movado can help the user find a way through the city. Depending on the user's preference, it can act like a classic navigation system announcing the next turn and displaying an arrow on its screen (see *Figure 4*). Alternatively, it may place floating arrows inside the cyber world. (see *Figure 3*). This can be combined with a line on the street, which may be followed to the destination (Sherman / Craig 2002: 336). Checkpoints act as landmarks at specific places in the world, which fade when the player is in proximity or passes the previous checkpoint (Oliveira / Araujo 2012: 326).



From Left to Right: Figure 1: A Fog Situation with reduced sight; Figure 2: Movado makes the car translucent; Figure 3: Arrows are placed in the city; Figure 4: Movado shows the next turn

3. Technological Aspects and Development

One of our major challenges throughout the project was software performance and maintaining a constant frame rate at 75 fps. A low frame rate could induce simulator sickness by not providing enough frames per second and if the frame rate didn't match the refresh rate (75Hz) of the Oculus Rift DK2 we would have flickering and screen tearing (Kolasinski 1995: 31). During development we applied various techniques to increase performance, reduce CPU load and the amount of micro stutters. For instance, we were reducing memory allocations when instantiating new objects by pooling and recycling objects for reuse, accessing objects with tag references created at the start of the game and generally improving programming structures within Unity modules. We resorted to batching by grouping geometry together so it may be drawn with just one API call; baking the meshes by combining all static and immobile meshes to one object; baking textures, shadows and vertex colours into the models; and occlusion culling to reduce rendering of objects which were obstructed by other objects. With all these measures MotEx is now capable of running at 75 fps while simulating 20 AI agents which behave in accordance to traffic rules and use PhysX WheelColliders and raycasts to avoid collision with objects (running on Windows 7 with Intel Core i7-920 [Q4 2008], 3GB DDR3-1066 RAM and GeForce GTX 970 4GB).

4. The User Experience

We developed the software with an agile mind-set and in an iterative process. We conducted many smaller scale tests on new features to gain insight into potential problems. We exhibited our software at various locations and performed three user experience and usability tests. With the feedback from our target group (15 – 25 years old), we improved our concept (Dörner et al. 2013: 178-186). We also tested for the occurrence of cyber sickness and simulator sickness which could pose a problem for some people (Dörner et al. 2013: 70). Testing began in an early stage of development, and we continuously improved the software based on user feedback.

4.1. The First User Test – Acceptance of Virtual Reality

Stage of Development: The user drove in a fictional parking lot. The experience was timed at about 2 to 3 minutes. They collected coins, had to evade a sudden cloud of smoke, drove a zigzag course with pylons and then maneuvered into a parking space.

Objectives: We wanted to recognize design flaws as early as possible, find out how users would react to our idea, and how they would react to virtual reality in respect to dizziness and nausea.

Design and Participants: Participants (n=55) were questioned about their sociodemographic background before being allowed to use the software. Their performance was measured during driving. Afterwards, each participant was questioned about his experience. All questions were conducted without intervention from any team member by handing the participant a tablet with a questionnaire. 87% of participants were in our designated target group.

Results: 93% were very positive about the experience, and 67% would like or would have liked to use MotEx during driving school. 9% experienced nausea and 18% experienced mild discomfort. 67% had no problem in navigating or controlling the car, and 64% were actively scanning the screen. 14% did not have a driving license, and 14% were in driving school at the time. During testing, users mentioned that they missed mirrors and would like better sound feedback and more realistic acceleration. They mentioned that the pylons were too small and that they “lagged” (performance issues).

4.2. The Second User Test – Virtual Driving Exam

Stage of Development: We reproduced the parking lot of an actual driving school with the corresponding practical driving exam. Students were required to drive slalom, pass a narrow spot, maneuver into and out of a parking space while looking (“Drei S Blick”) for other cars. Afterwards, they were required to park in a garage, then make a U-turn and accelerate to 40 km/h, and finally stop before a designated line. We implemented a spatial sound system, mirrors and a computer voice (acting as a driving teacher) which told the user what to do next.

Objectives: We wanted to test how our implemented features and changes since the last test would affect the user experience and how younger people would respond to our software.

Design and Participants: Similar to the previous test, participants (n=54) were questioned before and after the experience through a questionnaire on a tablet without intervention of team members. Unlike the previous test, participants wore headphones and were guided through the track by a computer voice. The performance of the virtual driving exam was measured inside the software. 31% of the participants were in the 15-25 year old age group, and 48% were in the 5-14 age group.

Results: 96% were very positive about the experience, and 74% would like to or would have liked to use MotEx during driving school. 4% experienced nausea, and 11% experienced mild discomfort. 72% had no problem in controlling the car or navigating the course. Participants were satisfied with sound feedback but mentioned that the computer voice was talking too much and too slowly. Feedback revealed that the mirrors needed to be adjusted and objects appeared too small; traffic signs and the finishing line were not as visible as we had hoped. 36% did not have driver licenses, and 32% were in driving school at the time. Acceleration was better, but the braking distance seemed off. This time there were almost no performance issues.

4.3. The Third User Test – Navigating Through a City

Stage of Development: We replicated the city of St. Pölten with traffics lights, road markings, environment, low poly buildings and trees. A majority of dynamic shadow had been removed for performance reasons. We implemented an AI system with cars which navigate traffic, adhere to traffic regulations and react to the player car. At this point we changed the concept of our software. Instead of offering the same services as driving schools, we focused on providing an addition to existing driving school learning procedures.

Objectives: Just as before, we wanted to test how users would react to our new features and if the development of the project was focused in the right direction. Another important aspect of the user test was to observe how players would drive in a city and how they would react to the AI. Participants would drive approximately 10 minutes while guided by floating arrows.

Design and Participants: The participants (n=34) were, as before, questioned before and after the experience in the simulator. 72% were in our designated target group of 15 – 25.

Results: 100% of our participants were very positive, and 78% would like to or would have liked to use MotEx during driving school. 3% experienced nausea and 16% mild discomfort. 14% did not have a driving license. Participants paid attention to surrounding simulated drivers, although they were still speeding due to lack of awareness of their velocity. Overall they were not hindered or dissatisfied with the presence of the AI cars. Participants liked to simply drive around while exploring the city.

5. ConclusionWe developed a virtual reality driving school simulator to help students learn how to drive and prepare them for real world traffic and situations. At first we tried to simulate actual driving schools and learning procedures, but we found out that there is a demand for learning specific skills which could not be taught during traditional learning procedures. Our concept changed to teaching experience and situational awareness as a complimentary learning offer to existing driving school learning procedures. We focused more on the gamification and edutainment aspect of the software experience. The users can learn how to behave during various situations while navigating a fictional city and following a special quest. These situations happen at random without warning. The users are accompanied by a virtual computer assistant inside the car which serves as a driving teacher, feedback system and narrative device for storytelling and virtual reality display techniques (like superimposing a path) without breaking immersion. With an agile mind-set and by staying in touch with our target group's trough user experience and usability testing we were continuously developing and improving features. Like most virtual reality simulators before us, we ran into issues with cyber sickness, motion sickness and simulator sickness. By improving programming structure and unity module design, reducing CPU load, minimizing draw calls and baking meshes we could improve performance to a point where our prototype would run at 75 fps while deploying 20 AI agents using PhysX WheelColliders, raycasts while adhering to traffic rules and traffic priority. We introduced a high-definition skybox, a spatial audio system and refrained from displaying too much information on screen-depth to stay inside the narrative and to hinder the breaking of immersion. As we improved our software, performance and concept, people were more likely to use and enjoy the experience. We have now implemented a new navigational concept, inspired by traditional real life navigational systems and combined it with arrows, checkpoints and lines, similar to those existing solutions in virtual games. This feature and the general current state of development, including the assistant and new situations, will need further tests for acceptance and usability. Furthermore, we plan to improve the AI so that it may react better to the user car, initiate various manoeuvres and force specific situations. This, combined with randomizing the occurrence of other situations, will yield a more dynamic learning experience.

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