

Pedestrian Scenario Design and Performance Assessment in Driving Simulations

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Abstract

This study is the start of a system to classify pedestrian scenarios with respect to drivers' reactions. Our aim is to help improve pedestrian safety by providing virtual scenarios that record driver responses to various pedestrian actions. In particular, we focus on developing scenarios that may be unsafe or impossible to test in a real-world environment. The four pedestrian scenarios implemented in this paper are a regulated crosswalk, a turning vehicle, an intersection dash, and a bus stop. Ten drivers were assessed for their reactions to the pedestrians by examining their speed profiles. From the perspective of the pedestrian, the safest scenario was the regulated crosswalk. The next safest was the turning vehicle scenario followed by the intersection dash. The most dangerous was the bus stop scenario, with the pedestrian being struck by every test subject. Our findings indicate that one key to pedestrian safety is visibility. In scenarios where the pedestrian is visible early and for a long period of time, safety is good. It is those scenarios in which the pedestrian is partially obstructed from view that a person's well being is in the greatest jeopardy. We need to design crossing facilities for pedestrians that will maximize the visibility of persons who want to cross.

Introduction

The National Highway Traffic Safety Administration reports that 4,749 pedestrians were killed in motor vehicle accidents in 2003, accounting for 11 percent of all motor vehicle related deaths that year [1]. The aim of this paper is to help improve pedestrian safety by providing virtual scenarios that test driver response to various pedestrian actions. In particular, we focus on developing scenarios that may be unsafe or impossible to test in a real-world environment. The scenarios involve pedestrians in urban areas and the testing of subjects for situation awareness, hazard detection, and decision-making.

Safe and efficient methodologies of studying pedestrian and driving behavior are receiving considerable attention. These complex driving behavior patterns may involve sensory, perceptual, decision-making, and response processes. Two approaches proposed in Kenneth R. Laughery's work are used in this study [2]. The first is an analytical approach required to help identify the variables involved in automobile driving. The second is to use experimental studies to determine the effects of specific combinations of these variables.

Computer simulations are considered the most ideal and powerful tool for town and traffic planning [3], offering both a flexible framework for construction of a model and a convenient device for objectively examining the effects of the variables in a driving task. For this particular study we have implemented a real-time urban environment with three-dimensional models and visual effects, contributing to a realistic and interactive driving experience.

Pedestrian Design

One goal of this project was to create a real-time interactive model to mimic pedestrian cross-walking behavior in the urban environment. This was accomplished through use of a triggering system.

There are two available triggers, traffic lights and the subject driver's vehicle. In the case of a pedestrian bound to a traffic light, he or she will start travel at a specified speed and direction once the light changes to the appropriate color. For the case of a pedestrian bound to the driver's vehicle, the pedestrian will start travel once the driver is within a certain distance.

The MD2 file format, originally developed for Quake 2, was used in this project for the pedestrian models. The models contain various animation cycles, two of which are idling and walking. For a stationary pedestrian, an idling animation is preferred over a static model because in real-life, a human is never completely still. Once the pedestrian's trigger is activated, the animation is switched to the walking cycle. A horizontal

translation is applied as the animation takes places, giving the appearance of proper movement.

Scenario Design

There are four pedestrian scenarios implemented in this simulation, three of which are taken from the Turner-Fairbank Highway Research Center (TFHRC) findings on common pedestrian accidents involving the elderly [4]. They deal with intersections, vehicle turning, and bus stops. In addition to the scenarios suggested by the TFHRC, a properly marked crosswalk was also added to the simulation. The four scenarios were conducted consecutively in the same run for each test subject, taking approximately five minutes. In all scenarios, the driver's performance was measured in terms of the distance to the pedestrian and the vehicle's speed.

Crosswalk Scenario

The first scenario involves a pedestrian traversing a crosswalk labeled with a *yield-to-pedestrians* sign (see Figures 1 and 2). The pedestrian's action is triggered when the driver is within 225 feet, initiating a walking speed of 1.15 ft/sec. Unlike later scenarios, in this situation a quick response from the driver is not necessary because of ample notice given by the signs and street markings.

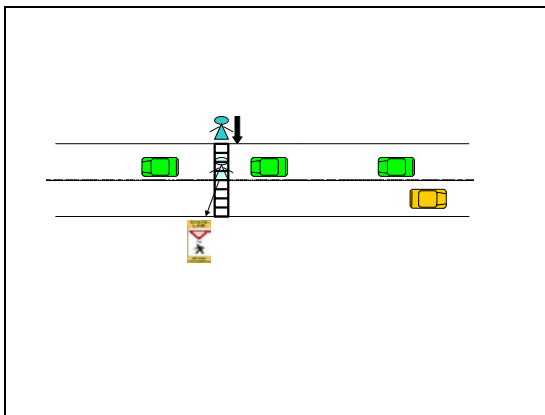


Figure 1: Crosswalk scenario



Figure 2: Crosswalk screenshot

Intersection Dash Scenario

For the second scenario, the subject driver is initially waiting at an intersection due to a red light (see Figures 3 and 4). The light changes to green and the driver enters the intersection only to find a pedestrian illegally crossing the street forcing the subject driver to stop again. The pedestrian starts crossing the street at a speed of 1.85 ft/sec when the driver comes within 65 feet.

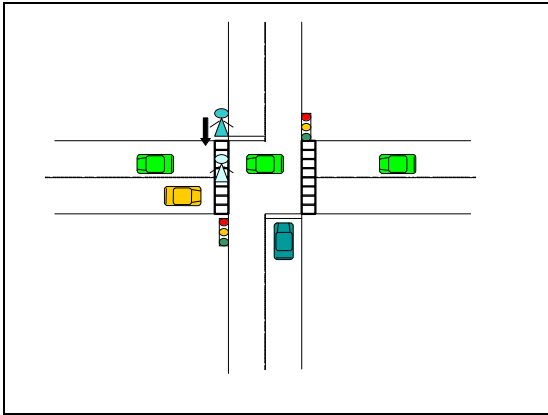


Figure 3: Intersection dash scenario



Figure 4: Intersection dash screenshot

Vehicle Turning Scenario

In the third scenario, a pedestrian crosses the street at a signaled intersection into the path of a driver making a left turn (see Figures 5 and 6). The pedestrian is triggered to walk at 1.85 ft/sec when the subject driver comes within 130 feet.

A left hand turn poses difficulty because of blind spots, which are inherent in simulations. Increasing the horizontal field of view, as well as use of a parabolic screen can minimize their effects. Such a screen was used in this simulation and the horizontal field of view was set to 30°.

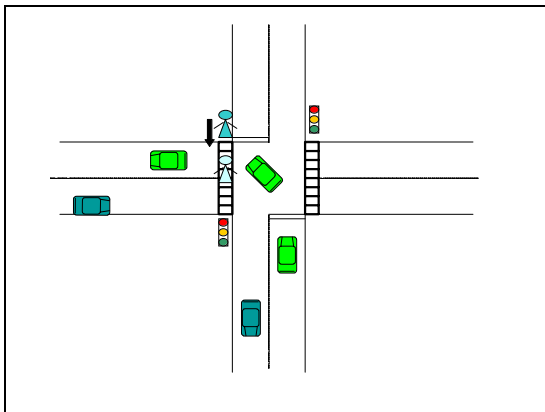


Figure 5: Vehicle turning scenario



Figure 6: Vehicle turning screenshot

Bus Stop Related Scenario

The fourth and final scenario is of a jaywalker initially obstructed from the driver's view by a bus (see Figures 7 and 8). The pedestrian will start walking at a speed of 1.15 ft/sec once the driver is within 130 feet. This travel takes place from right to left on a portion of road not marked as a crosswalk. However, there is a bus stop sign prior to the bus.

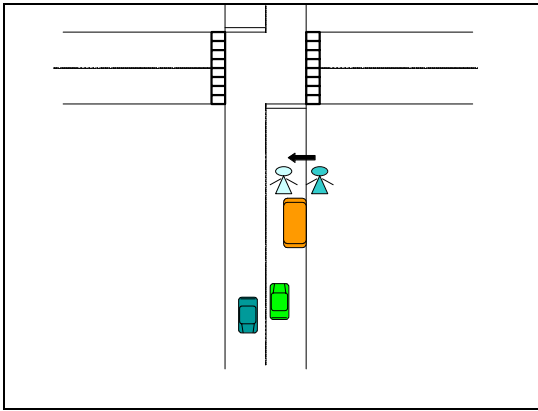


Figure 7: Bus stop scenario



Figure 8: Bus stop screenshot

Testing Methodology

The test subjects were comprised of ten Northeastern Engineering students, six males and four females, all with a minimum of one year driving experience, good vision, and between the ages of 18 and 36. Prior to the test, each subject participated in a practice session (without any active scenarios) to become familiar with the virtual environment and the path of travel. There were no reports of motion sickness. Subjects were instructed to obey standard traffic rules, signage, and to drive safely. All subjects were paid for their participation in this study.

Technology

The driving simulator is located in the Virtual Environments Laboratory and is comprised of four main components: the vehicle, computer, projection system, and screen. The vehicle is the front end of a 1991 Dodge Caravan, featuring interactive vehicle components, including: seat belts, force feedback steering wheel, brake and gas pedals, and a digital speedometer. The simulation is powered by an Alienware computer housing an Intel Pentium 4 3.4 GHz processor and an NVIDIA GeForce 6800 Ultra video card. The rendered scene is sent to a high-resolution projector and is displayed on a parabolic screen running at a resolution of 1024 x 768 with a 30° horizontal field of view.

All these elements contribute to the creation of a realistic driving environment and provide a powerful visualization tool for evaluating human performance.

Results

The results are shown as a series of graphs depicting speed profiles (distance vs. speed) in Figures 9, 10, 11, and 12.

Each pair of graphs represents one of the four scenarios. The location of the pedestrian is marked as dashed vertical line. The graph on the left highlights the speed profiles of the drivers who made complete stops before reaching the pedestrian, while the graph on the right is the average speed profile of those drivers who did not make complete stops prior to reaching the pedestrian. The variance in deceleration patterns is due to the differences in how subjects deal with time-to-collision (TTC) and breaking [5]. Because not all drivers decelerate at the same location, stops are represented as dips in the average speed profile. The deeper dips represent drivers making complete stops while the shallow dips represent drivers not fully stopping.

Crosswalk Scenario

The graphs of the crosswalk scenario are an excellent example of what the speed profile should be for a well-marked crosswalk. Eight out of ten drivers came to a gradual stop about 40 feet before the crosswalk (see Figure 9a). The other two drivers slowed down slightly when approaching the crosswalk, collided with the pedestrian, and then sped up and continued on (see Figure 9b).

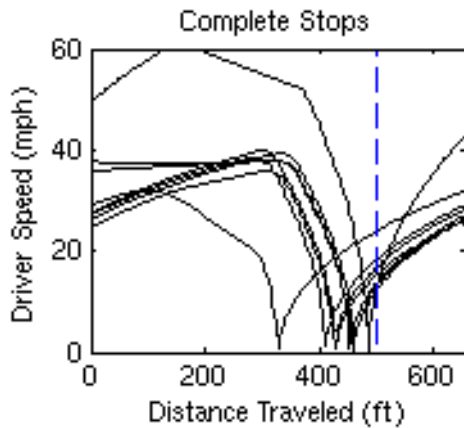


Figure 9a: Crosswalk scenario; speed profiles of those who made complete stops before reaching the pedestrian

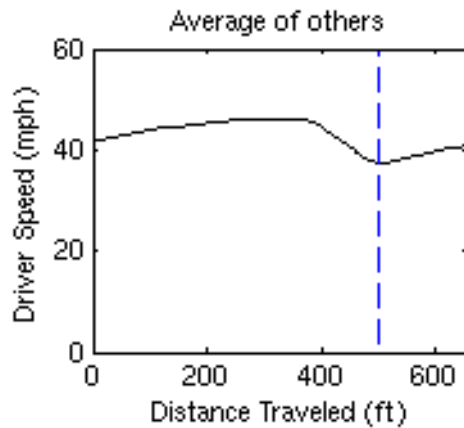


Figure 9b: Crosswalk scenario; average speed profile of those who did not stop before reaching the pedestrian

Intersection Dash Scenario

The intersection dash is a slightly more interesting scenario. These graphs have two dips: the first represents the driver waiting at the red light and the second is the driver stopping midway through the intersection when a pedestrian illegally crosses the street. Six out of ten drivers stopped before reaching the pedestrian, coming to rest at a distance of 65 feet in front of the crosswalk (see Figure 10a). The other four drivers sped through the red light at the intersection and hit the pedestrian without stopping (see Figure 10b).

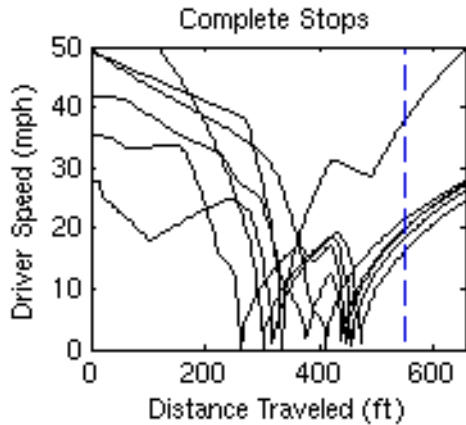


Figure 10a: Intersection dash scenario; speed profiles of those who made complete stops before reaching the pedestrian

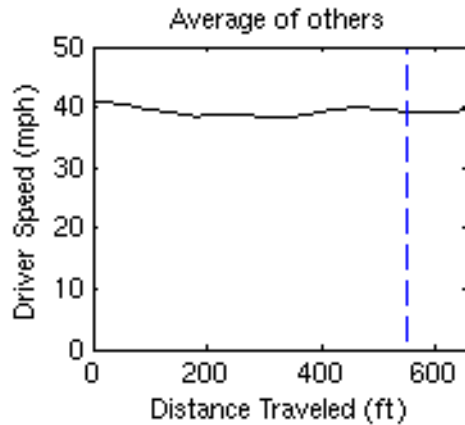


Figure 10b: Intersection dash scenario; average speed profile of those who did not stop before reaching the pedestrian

Vehicle Turning Scenario

The vehicle turning scenario had a high number of drivers who successfully stopped for the pedestrian. Six out of ten drivers stopped before reaching the pedestrian at an average distance of 30 feet away (see Figure 11a). The remaining drivers slowed down to about 25 MPH at a distance of 100 feet away from the pedestrian, thereby allowing for a successful crossing but without the subjects coming to a complete stop (see Figure 11b).

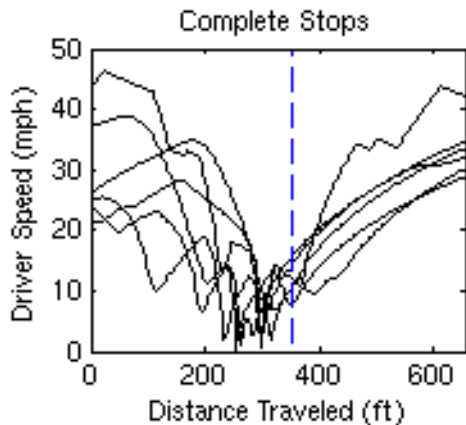


Figure 11a: Vehicle turning scenario; speed profiles of those who made complete stops before reaching the pedestrian

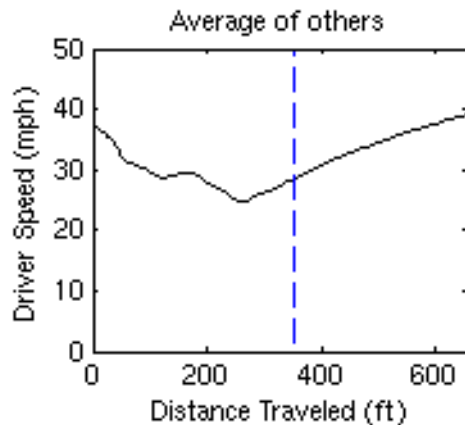


Figure 11b: Vehicle turning scenario; average speed profile of those who did not stop before reaching the pedestrian

Bus Stop Related Scenario

The bus stop scenario yielded the worst subject driver behavior with every driver striking the pedestrian. Four of the ten stopped within 25 feet after striking the pedestrian (see Figure 12a), while the other six only slowed down slightly and then resumed their speed of 40 MPH (see Figure 12b).

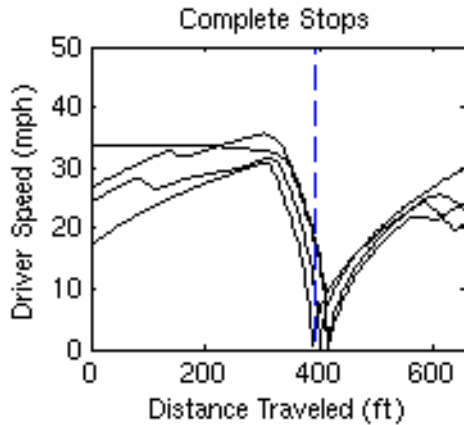


Figure 12a: Bus stop scenario; speed profiles of those who made complete stops within 25 feet after striking the pedestrian

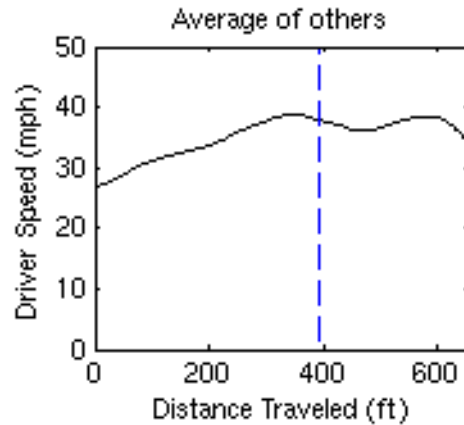


Figure 12b: Bus stop scenario; average speed profile of those who did not stop

Discussion and Conclusions

The safest scenario from the view of a pedestrian was the standard crosswalk with its large yield sign in the middle of the street. An interesting aspect of this scenario is that most drivers stopped fairly close to the pedestrian, indicating they were comfortable with the situation and knew the exact location of where they wanted to stop. This is unlike other scenarios where there is an emergency and the driver stops immediately. With the properly marked crosswalk, the driver has more time to approximate the TTC, which is the basis for determining when to start breaking [6].

The vehicle turning scenario was the next safest due in part to the extended visibility of the pedestrian as the driver makes the left turn. The pedestrian is in sight before the driver enters the intersection to the moment when he disappears after crossing the street.

The intersection dash can be considered unsafe since four drivers struck the pedestrian.

Finally the most dangerous was the bus stop scenario with none of the drivers stopping until after a collision with the pedestrian. This is attributed to the limited visibility of the pedestrian being blocked by the bus (see Figures 7 and 8).

The common thread running through the analysis of these scenarios is visibility. Signage and pedestrian visibility had the greatest affect on pedestrian safety in the scenarios above; pedestrians are safest when they can be seen. A possible area of future study is to relate safety to visibility.

References

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