






Virtual Zoomorphic Accessories for Enhancing Perception of Vehicle Dynamics in Real-Time

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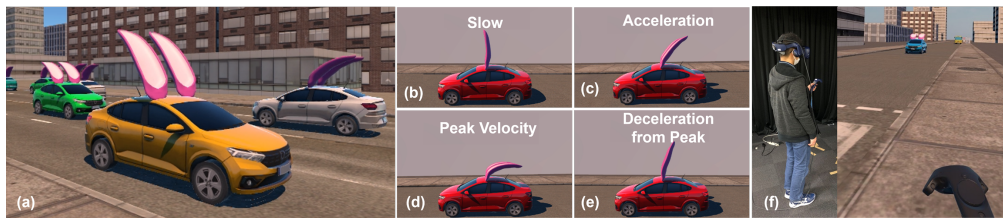


Figure 1: The proposed system enhances the understanding of moving objects' behavior in outdoor augmented reality using zoomorphic accessories. Its features include (a) method simulation on cars, (b) upright ears when the car is slow/stopped, (c) ears that tilt at 20 km/h, (d) a significant bend in ears at 60 km/h, and (e) ears that indicate sudden deceleration. (f) shows a participant in the experiment on vehicle braking judgments.

Abstract

This research introduces virtual zoomorphic accessories, inspired by the animation principle of “follow-through and overlapping action,” to enhance pedestrian comprehension of vehicle speed. We employed dynamic rabbit ear-like accessories on vehicles as a visual representation. The animation offers pedestrians an intuitive sense of the vehicle's speed. We conducted an experiment using accessories that visualize speed in videos. The results indicate that such animated zoomorphic accessories can bolster understanding of vehicle behavior.

CCS Concepts

• **Visualization** → Information Visualization; • **Interaction** → Human-Computer Interfaces; • **Virtual Environments** → Augmented Reality;

1. Introduction

Animation, through its exaggerated movements, uniquely enriches expression, as highlighted by Disney's twelve basic principles established in 1995 [TJT95]. These principles, along with related studies like [GDO08], show that animation not only animates characters but also clarifies on-screen behaviors for viewers. Our research leverages these exaggerated movements to help users better understand physical phenomena. Cars and other vehicles are typical examples of moving objects for which a clear understanding of speed and acceleration is highly beneficial. There is research on external Human-Machine Interfaces (eHMIs) to communicate the movements of self-driving cars to pedestrians [PLC*21, THG*22]. Our study ventures to use animation effects to clarify the behavior of all vehicles, not just autonomous ones, for pedestrians. Using the “follow-through and overlapping action” animation principle,

we developed a virtual eHMI featuring a zoomorphic design. We added animated rabbit ears to cars to indicate speed. This integration aimed to clarify car behavior for both pedestrians and drivers. Our experiment showed that this approach improved the pedestrians' understanding of vehicle dynamics.

2. Ear Design

We propose two types of ears used as accessories to visualize object speed and acceleration. The ears in the “Visualization of Speed” type indicate speed by changing their inclination. As the speed increases, so does their inclination, but they stand almost vertically when the speed is low.

In the “Visualization of Speed and Acceleration” type, the ears lean backward when the speed is positive. Their inclination be-

comes more significant with positive and high acceleration but returns to a vertical orientation when the acceleration is negative. This type of visualization can convey the driver's intention to yield the right-of-way to pedestrians more effectively, particularly at a crosswalk. If the driver plans to stop and yield, they will brake to decelerate and stop safely before the crosswalk. At this moment, the ears stand up noticeably from a tilted position, making it clear to pedestrians that the car is decelerating. Cars with these ears clearly visualize the driver's intent to slow down and yield more distinctly than cars without them.

3. Experiment

In this study, we tested the effectiveness of the “follow-through and overlapping action” principle in a virtual environment to understand the behavior of moving vehicles. It was a video-based test visualizing only car speed. It aimed to see if “speed-visualizing ears” enhanced pedestrians' accuracy in estimating the speed of approaching vehicles. The study procedures were reviewed and approved by the Institutional Review Board (IRB) at the authors' institute.

3.1. Setup

24 university students (22 males and 2 females) participated in the online experiment, with each session taking on average eight minutes to complete via a web survey. The participants were divided into two distinct groups, A and B, for the experiment. In the core of the experiment, every participant was required to watch a total of 16 videos, with 8 of them featuring cars with ears and 8 without ears, to visualize and estimate the car's speed after viewing each video. Initially, participants were shown a reference video lasting 1 minute and 31 seconds, displaying cars with ears indicating their speeds to familiarize them with the speed perception. This reference video showcased several cars moving at varied speeds. Following this, participants proceeded to watch 16 videos of a single car from 16 different vantage points in a virtual environment, estimating the car's speed in each. Videos were alternated between groups; cars with ears for Group A were shown without ears to Group B and vice versa, ensuring a comparative analysis.

3.2. Results

As mentioned earlier, the 16 video pairs used for measurement were taken from different locations, resulting in different viewing angles of the cars. Therefore, the viewing angles of the cars were classified into four categories: front, rear, right, and left, each at 90-degree intervals. Additionally, each video had two variations: with ears and without ears. A Wilcoxon rank-sum test was conducted to examine the errors between the true speed and the estimated speed. The test revealed statistically significant differences in the average error between the two conditions; with and without ears. Figure 2 shows a subset of videos with statistically significant differences and their box plots.

4. Discussion

In the experiment, two of the 16 video pairs, shown in Figure 2, exhibited statistically significant differences. Cars with ears yielded

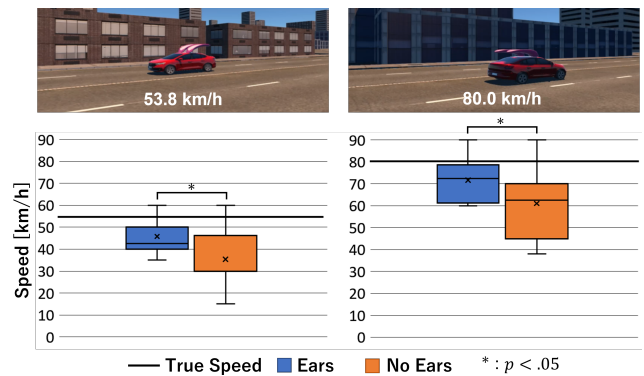


Figure 2: Results from the experiment showing significant differences in speed estimation in Video 10 at 53.8km/h (left) and in Video 7 at 80.0km/h (right) are presented above their corresponding box plots.

more accurate speed estimations, especially when viewed from the side. When categorizing the 16 video pairs based on speed, with eight classified as low-speed and the other eight as high-speed, these two video pairs were classified as high-speed. Therefore, the effectiveness of the ears appears to be more pronounced when the cars are viewed from the side and when the speed is higher. The remaining 14 video pairs showed no statistically significant differences, indicating that ears do not negatively impact speed estimation. These results suggest that ears or similar modifications can enhance the understanding of car behavior, though further evaluation is needed. However, the obtained results support the notion that ears or other zoomorphic modifications can be beneficial in understanding the behavior of cars.

5. Conclusion

In this study, we designed an augmentation to promote pedestrian understanding of car behavior by attaching rabbit ear-like attachments to vehicles, utilizing the animation principle of “follow-through and overlapping action.” We evaluated the usefulness of these augmentations through an experiment. In this experiment, the results suggest that cars with ears visualizing speed tend to yield more accurate pedestrian speed estimation than cars without ears.

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