A Virtual Driving Environment for Connected Vehicles Collision Avoidance Based on Human Factors

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Abstract

Technologies such as connected vehicles are now considered as promising Intelligent Transportation Systems (ITS) solutions for smart cities to ensure less congestion and fewer accidents. By being constantly informed about the road states and potential accidents, connected vehicles drivers are able to take appropriate actions in order to avoid such accidents. Taking into account human factor in the process of driver’s warning has proved to be crucial for achieving the goal of this technology with respect to road safety. An empirical study based on human factors is then necessary to identify appropriate models of interaction with the drivers. We present in this paper the design and development of a testing environment based on the virtual reality (VR) technology. Our approach is based on a scenario based design for cooperative driving using the dissemination of information between vehicle drivers. The VR environment is based on immersive technologies using a head mounted display (nVisor SX 60 from NVIS, Cube3 motion tracker from Intersense and a Logitech steering wheel and pedals kit). Our tool is used to specify and test different scenarios in order to establish associations between driver behavior and responses to warnings in order to avoid collisions in real time.
1. Introduction

Connected vehicles are considered as promising solutions for smart cities to ensure less congestion and fewer accidents. Different technical means are defined for continuous interactions with drivers. In the category of connected vehicles, drivers are informed about the road states and receive warning messages in order to take decisions and trigger appropriate actions to avoid accidents and collisions [1]. We emphasize in our study the impact of the behavior of different driver on their decisions to avoid collisions. Faced with the consequences that can have uniform warning messages to all drivers, our goal is to establish associations between interactions between drivers and connected vehicles and the driver’s behaviors. Thus, different driver’s reactions must be known first to provide more efficient feedback.

We present in this paper a methodology and a tool for a virtual driving environment that will enable experiments allowing to collect data on different drivers reactions and associated reaction time. We will consider two categories of drivers, stressed drivers and unstressed ones.

This paper is organized as follows. In Section 2 we present an overview of the research on connected vehicles and their applications for road safety. Section 3 presents our methodology for the design of a virtual environment for conducting experiments to analyze drivers reactions in the context of connected vehicles for road safety. The description of the characteristics of our experimental tool is presented in Section 4. Section 5 provides conclusions of the paper and future research directions for defining adaptive interactions between connected vehicles and drivers based on drivers’ behaviors.

2 Background on connected vehicles research

2.1 Overview on connected vehicles

The connected vehicles technology is characterized by vehicles equipped with increasingly sophisticated devices used for communication, localization and environment perceptions, such as those presented in Figure 1. Connected vehicles are considered in different applications in the context of Intelligent Transportation Systems (ITS). Such applications are often based on a network of inter-vehicular communications called VANET (Vehicular Ad-hoc Networks) [1]. When dealing with connected vehicles, complex problems have to be solved to optimize transport network services such as congestion management.
Connected vehicles can be classified into two main categories: autonomous and non-autonomous vehicles. The latter are characterized by the presence of drivers with a new driving context that features continuous acquisition of information from their vehicle devices and other vehicles in the vicinity, and transmitted to the driver. Thus, driving these vehicles consists also of continuously receiving and processing information.

2.2 Background on connected vehicles research activities

Many research activities are carried out in the context of connected vehicles, such as solving complex problems and finding optimum solutions for inter-vehicular communications like routing and medium access control \[1,2\], real-time processing of disseminated information and the accuracy of fleet vehicles localization \[3\]. There still remain many challenges to solve research problems related to connected vehicles.

There are many emergent applications requiring connected vehicles, especially traffic congestion control, road safety based on cooperative behavior, and evacuation in case of emergencies. These applications reinforce the case for connected vehicles research activities, especially considering the inter-vehicular communications.

In this work, we consider a road safety application based on inter-vehicular information dissemination. In the context on non-autonomous connected vehicles, the driver must take real-time decisions in response to the warnings related to collision risks. Thus, the driver's behavior greatly affects the decision to be taken. Some research activities on road safety that take into account human factors were reported in the literature \[4\]. However, these are primarily concerned with the analysis of data related to accidents. Associations were then established
between diver’s characteristics, such as their age, and the occurrence of accidents as well as their severity level.

### 2.3 Role of human factors in connected vehicles for road safety

In this paper, we consider the problem of road safety optimization in the context of connected vehicles taking into account collaborative driving based on information dissemination. With non-autonomous vehicles, drivers must be able to make decisions and trigger real-time actions following alerts representing potential collision occurrences.

Warning messages often require real-time reactions knowing that certain behaviors may require more response time, which can affect the quality of the supposed reactions to avoid collisions. Our objective is to study potential associations between the drivers reactions and the types of drivers behaviors especially whether they are stressed or calm.

### 3. Design methodology and tool for connected vehicles virtual driving

#### 3.1 Background on virtual driving simulators

There has been a great deal of research activities on virtual driving simulators. The main focus of these activities relates to driver’s training with an emphasis on road safety improvement in different situations such as driving in fog, etc [5], [6], [7]. While the human factor is considered in much research on virtual driving environment, most studies focus on characteristics such as age, gender, fatigue or alcohol use. However, these factors are rather considered in statistical analyzes to determine trends in certain drivers categories.

Many factors can lead to a collision [8], but the most important difference between a collision and a near-miss appears to be whether adequate evasive manoeuvres are initiated by the driver [9]. Several models have been proposed to represent adequate and inadequate driver behaviors [10] and, to be efficient, the integration of intelligent transport systems must take into account psychological variables, such as: (a) attention level, (b) information overload, (c) adequate interpretation of information provided by the system, (d) overreliance on the system’s ability to detect all potential risk situations, (e) increase in risk taking behaviors, etc. [10]. Interestingly, these five variables are highly influenced by stress and anxiety [11]. It is important to recognize that, in the sequence of events leading to a collision, the anxious driver of a connected vehicle may react in unexpected and unproductive manner. Adjusting the feedback provided to the driver and other connected vehicles based on the emotional state of the driver might reduce the likelihood of a collision. It is therefore important to document if there are differences in driving behaviors and the ability to avoid a collision when anxious and non-anxious drivers are receiving feedback from connected vehicles.
We aim to improve road safety based on triggering the most suitable actions by drivers to avoid collisions. This feature also represents a new aspect for existing studies related to driving in a virtual environment studies. In our study, the human factor is considered first to define our experimental scenarios. Then, it will be considered further to evaluate the quality of driver reactions when they perceive collisions warnings.

3.2 New virtual driving for collective driving

We propose in this paper an approach that will consider the driver’s behavior using the concept of cooperative behavior. Owing to the equipment installed in connected vehicles, drivers can receive risk situations such as a precrash detected according to the traffic model [12]. Since the traffic model can change within 5 minutes, it becomes necessary to trigger actions by drivers to prevent potential collisions.

We aim in our study to establish associations between drivers’ behavior and their reactions to collision warnings that can come from their own vehicles or transmitted by other vehicles. The first step in our approach is to design and develop a tool for virtual cooperative driving. Our tools will be used to realize the experiment in order to study the behavior of human factors. Data to be collected will cover different categories of driver’s.

Our empirical study will use experimental data in order to identify and compare calm and anxious driver’s reactions to alerts related to potential collisions. The driver’s responses will be modeled according to different parameters such as direction, speed, braking time, steering wheel angle and response time in general.

3.3 Methodology for virtual driving experiments based on scenarios

In order to design our virtual experiment tool, we proceed first by defining its architecture based on software and hardware components for data processing and virtual driving. The architectural design is based on a set of scenarios representative of situations from the cooperative behavior based on connected vehicles for road safety. Several events triggering alerts collisions are also considered in our design scenarios. Thus, the perception of the content of warning about potential collisions is one of the capabilities of the operation of these vehicles. We consider in this paper a set of attributes such as those presented in Table 1 to define our experimental scenarios.
<table>
<thead>
<tr>
<th>Attribut</th>
<th>Catégories possibles</th>
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<tbody>
<tr>
<td>Human Factor</td>
<td>Age, behavior</td>
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<td>Road network infrastructure</td>
<td>Intersection, Roundabout and multiple exposure routes</td>
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<td>Traffic</td>
<td>Balanced, predictable congestion</td>
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<td>prévisible, non predictable congestion</td>
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**Tableau 1**: Scenarios attributes and categories

For each category of attributes, we define potential values which can be either boolean or located in data interval. Figure 2 shows a tree structure representing scenarios attributes. Based on this tree structure, we will build a knowledge representation such as decision tree to be used by the processing techniques in order to identify different driver’s reaction classes.

![Figure 2: Tree structure for scenarios attributes](image_url)

We also define a set of events that represent situations of collisions risks considering our scenarios based on the combination of the previous attributes categories and their values. Examples of events are presented by pedestrian crossing spontaneously, cars passing at close distance, late lane change, etc.
4. Virtual Driving Tool for Connected Vehicles Warning Scenarios

4.1 General architecture of virtual environment components

Our experimentation tool for the virtual collective driving is defined by numerous components defined to represent our scenarios categories defined in Section 3. The overall architecture of our tool is characterized by two main subsystems: 1) The subsystem of connected vehicles and 2) the subsystem of the road infrastructure. Figure 3 illustrates the interface defining the virtual driving environment components.

Figure 3 Virtual Driving Environment Components Interface

1. Connected vehicles sub-system

The main components that characterize the connected vehicles sub-system are a camera sensor to collect images, communications devices to transmit information to other vehicles [13]. In our simulation model, we represent components that model drivers environment perceptions through specific signs representing the messages received by the camera sensors.

2. The road infrastructure sub-system

The infrastructure components representing the locations of the virtual driving are represented by roads, intersections, etc. The generic architecture of our tool illustrates the components of the subsystem.
4.2 Static and dynamic models of our experimental tool

The static model of the connected vehicles subsystem is based on several sub-components such as the speedometer, pedal, throttle, etc. The interior rear view mirror can map the images of transmissions sensors while the outside mirror can locate the vehicle relative to the current traffic. The model of the road network infrastructure is represented by a map with components representing city roads such as crossroads, intersections. For our model, we consider a closed quadrangle with a park in the center to simulate city driving. The dynamic model is based on the integration of hardware with software programs. This model enables the operation of our scenarios presented in Section 3.

![Image](image.png)

**Figure 4.** Scenario based experimentation on an event correlation

Regarding the connected vehicles sub-system, we have incorporated a software model with driving equipment made by Logitech (WingMan Formula Force wheel Gp [14] which includes a steering device with two pedals. The VR environment is based on immersive technologies using a head mounted display (nVisor SX 60 from NVIS) and a motion tracker (Cube³ from Intersense). The virtual environment was designed with 3DStudio Max (from Autodesk) and the real time 3D rendering and interactions with the environment was programmed with Virtools from 3Dvia (working with the Virtools engine [15]). The software part of this model defines a set of features suitable for our scenarios. It also enables to generate warning events representing messages between connected vehicles that require decisions making and actions triggering in order to avoid collisions.

Models that allow operation of the vehicle such as the acceleration and the deceleration are also defined. These models take into account the mass and the power of the car. Thus, it is possible to carry experiments based on smaller or more powerful vehicles.

In the roads infrastructure sub-system, traffic lights are programmable according to the scenarios requirements. Also, information panels are based on numerous messages as defined in the scenarios considered for our experiments. Various events are also programmed to trigger the
transmission of warnings such as vehicle sudden braking, a pedestrian crossing spontaneously and the correlations of similar events, as illustrated in Figure 4

5. Conclusions and future directions

The connected vehicle technology is a promising approach that addresses the problem of road safety. In this context, existing research activities are more focused on issues related to communications that transmit warnings signals between vehicles and drivers.

In this paper, we considered in particular the importance of human factors in the context of non-autonomous connected vehicles. Since driver’s behavior is also considered as a factor that can cause accidents, it is important to take into account different behaviors in the interactions between connected vehicles and drivers. Our goal is to find the associations that may exist between driver’s behavior, such as stress, accidents antecedents, etc., and their reactions to warnings in the situation of cooperative driving.

Our approach is based on the design and development of an experiment environment of cooperative driving in order to collect data representing the driver reactions. Our design methodology is based on scenarios representing different situations that may lead to collisions and possible interactions between connected vehicles and drivers. Our experiment tool is suitable for cooperative driving and can be extended to support additional scenarios.

Further experiments based on our virtual driving tool are in progress. They will allow us to collect data representing different driver reactions. As future directions for our current study, we will consider artificial intelligence techniques, such as data mining to establish associations between responses to different scenarios and the behavior of the driver. Then, we will define a technique to adapt warnings associated with each scenario according to driver behaviors. Our main goal is to maximize the effectiveness of driver decisions and reactions to the warnings related to potential collisions.

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6. References


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