Lecture Notes on Data Engineering and Communications Technologies 114

Mukesh Saraswat · Harish Sharma · K. Balachandran · Joong Hoon Kim · Jagdish Chand Bansal *Editors*

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K. Balachandran · Joong Hoon Kim ·
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Editors

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Preface

This proceedings contains the papers presented at the 2nd Congress on Intelligent Systems (CIS 2021), organized by CHRIST (Deemed to be University), Bengaluru, India, and Soft Computing Research Society during September 4–5, 2021. Congress on Intelligent Systems (CIS 2021) invited ideas, developments, applications, experiences, and evaluations in intelligent systems from academicians, research scholars, and scientists. The conference deliberation included topics specified within its scope. The conference offered a platform for bringing forward extensive research and literature across the arena of intelligent systems. It provided an overview of the upcoming technologies. CIS 2021 provided a platform for leading experts to share their perceptions, provide supervision, and address participants' interrogations and concerns. CIS 2021 received 370 research submissions from 35 different countries, viz., Algeria, Bangladesh, Burkina Faso, China, Egypt, Ethiopia, Finland, India, Indonesia, Iran, Iraq, Kenya, Korea, The Democratic People's Republic of Madagascar, Malaysia, Mauritius, Mexico, Morocco, Nigeria, Peru, Romania, Russia, Serbia, Slovakia, South Africa, Spain, Switzerland, Ukraine, United Arab Emirates, UK, USA, Uzbekistan, Vietnam. The papers included topics about advanced areas in technology, artificial intelligence, machine learning, and data science. After a rigorous peer review with the help of program committee members and more than 100 external reviewers, 135 papers were approved.

CIS 2021 is a flagship event of the Soft Computing Research Society, India. The conference was inaugurated by Fr. Dr. Abraham VM, Honorable Vice-Chancellor, CHRIST (Deemed to be University), Bangalore, and Chief Patron, CIS 2021. Other eminent dignitaries include Prof. Joong Hoon Kim, General Chair, CIS 2021; Fr. Joseph Varghese, Patron, CIS 2021; and Prof. K. Balachandran, General Chair, CIS 2021. The conference witnessed keynote addresses from eminent speakers, namely Prof. Xin-She Yang, Middlesex University, The Burroughs, Hendon, London; Prof. P. Nagabhushan, Indian Institute of Information Technology Allahabad; Prof. J. C. Bansal, South Asian University, New Delhi, India; Prof. Lipo Wang, Nanyang Technological University, Singapore; and Prof. Nishchal K. Verma, Indian Institute of

Technology Kanpur, India. The organizers wish to thank Mr. Aninda Bose, Senior Editor, Springer Nature, New Delhi, India, for the support and guidance.

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The Extraction of Automated Vehicles Traffic Accident Factors and Scenarios Using Real-World Data

MinHee Kang, Jaein Song, and Keeyeon Hwang

Abstract As automated vehicles (AVs) approach commercialization, the fact that the SAFETY problem becomes more concentrated is not controversial. Depending on this issue, the scenarios research that can ensure safety and are related to vehicle safety assessments are essential. In this paper, based on 'report of traffic collision involving an AVs' provided by California DMV (Department of Motor Vehicles), we extract the major factors for identifying AVs traffic accidents to derive basic AVs traffic accident scenarios by employing the random forest, one of the machine learning. As a result, we have found the importance of the pre-collision movement of neighboring vehicles to AVs and inferred that they are related to collision time (TTC). Based on these factors, we derived scenarios and confirm that AVs rear-end collisions of neighboring vehicles usually occur when AVs are ahead in passing, changing lanes, and merge situations. While most accident determinants and scenarios are expected to be similar to those between human driving vehicles (HVs), AVs are expected to reduce accident rates because 'AVs do not cause accidents.'

Keywords Automated vehicle · Real datasets · Traffic accident · Road safety · Traffic scenario · Machine learning

1 Introduction

AVs stand out in IT firms, unlike the traditional automobile manufacturing industry companies [1]. Especially, Waymo LLC preemptively is developing and occupying AVs technology and is being chased by the existing automobile manufacturing

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industry as a latecomer [2]. This is judged that the IT companies that deal with data first occupied the AVs technologies due to the software characteristics of the AVs. However, the SAFETY issue is spotlighted due to pedestrian fatal crashes in operating Uber's AVs in 2018 [3–5]. Also, by emerging the study that AVs have the probability of collision even in ideal conditions [6], commercialization of AVs has been delaying. Although AVs clearly will be to take root in our society, ultimately the safety issues will eventually draw more attention in the future [7]. According to the issues, the safety paradigm has been changing from a passive safety system in the past to an active safety system that can prevent various accidents in advance [8]. One method of the active safety system is the prevention of traffic accidents in advance by learning numerous situations [9, 10], even if countless traffic accidents occur in real traffic conditions [11]. Furthermore, the recently proposed method for AVs assessment is the scenarios with ensuring safety. According to Ulbrich et al. [12], a scenario is the temporal development between several scenes in a sequence of scenes, actions, and events, as well as goals and values, specified to characterize this temporal development. Namely, these scenario studies that directly involved in car safety assessment are essential [13–15] and ambiguity about scenarios should need to minimize [18]. Along with these features, diverse studies that use real data for extracting scenarios are being carried out [16–18]. This is more relevant with this new paradigm shift in test and validation [19]. For instance, Erdogan et al. [19] pointed out that proposed scenarios are mostly hand-driven or expert input for AVs safety assessment. The authors stated that a myriad of scenarios is expected to be presented, so it is alone would not be suitable. In order to supplement the limitation, they proposed multiple classification algorithms and effectively extracted scenarios. Also, Webb et al. [20] presented an approach and methodology for AVs safety scenario assessment to reduce accident fatalities through safety and trust driving. With regard to using real data, Schwall et al. [16] demonstrated the safety of AVs on urban roads based on actual Waymo driving data.

In this paper, we propose a 2-step scenario-building method to improve safety by alleviating ambiguity. This is as follows: (1) Extract the major factors for determining AVs collision, and (2) based on extracted factors, draw the expected AVs traffic accident scenarios. The aim is to utilize traffic accidents data of AVs and machine learning methodology for the extraction of AVs traffic accident scenarios. The contribution is that (1) scenarios can be derived by using AVs accident data containing direct accidents, (2) as not human driving vehicles (HVs) data but real AVs accident data, empower actually AVs safety, (3) identify main decision factors through machine learning, and (4) be able to relieve dependence on the knowledge of experts which was deemed a blind spot.

This paper is organized as follows: In Sect. 2, we present collecting and preprocessing AVs accident data. Section 3 summarizes the method of using machine learning and describes the process of extraction to major decision factors. Based on this, we derive fundamental AVs accident scenarios in Sect. 4. Finally, Sect. 5 concludes the paper.

2 Data Collecting and Preprocessing

In this section, we collect and preprocess the AVs traffic accident data.

2.1 Collecting AVs Accident Data

Currently, more than 13 production companies, including Waymo, GM, and Drive AI, are participating in the demonstration of autonomous driving in California, the USA. However, as the information about these test runs is confidential to the manufacturer, the manufacturer does not disclose data containing the driving information on its own. Although there is a limit to the collection of operating information data, the Department of Motor Vehicles (DMV) in California is releasing data on the 'traffic accident' situation that occurred in AVs [21]. The report shows AVs manufacturers, accident times, vehicle driving conditions (move and stop), autonomous driving modes, road users (pedestrians, etc.), weather, lighting, road conditions, information that can be inferred from the accident, etc.

Accordingly, we collected data on AVs accidents released by the State of California. They have data from 2014, but the data they are currently disclosing is data from 2019 onward. So, we contacted DMV and shared data for 2014–2018. As a result of checking the data, about 300 data existed, and the report format was changed around April 2018.

2.2 Preprocessing AVs Accident Data

We collected the accident history information provided by DMV and dataized what it regards will affect the accident situation. As previously described, the format of the report changed from 2018, so there was a limit to dataizing all data. As a result, data has been utilized since April 2018, with accounting for a total of 219 cases.

The data determined by the critical variables was referred to in Kang et al. [10]. First of all, we extracted accidents that occurred in autonomous driving mode through 'Mode' variable. The data corrected consists of 'Time,' 'AV injury,' 'Weather,' 'Lighting,' 'Roadway surface (Rs),' 'Roadway conditions (Rc),' 'Vehicle 1,2-Movement Preceding Collision (MPC),' 'Vehicle 1,2-Type of Collision (TC),' and 'Other associated factors (Other)' as shown in Table 1. Among them, the extra variables such as MPC 1–1 and 2–1 were two marked values in raw data, which were determined to be variables that affect the accident situation by reviewing the 'Accident Details' section. Consequently, we finally obtained 138 data consisting of 15 variables.

Table 1 AVs traffic accidents of features

Feature	Description
Mode	The driving mode of AVs including autonomous and conventional mode
Time	The time when AVs accident occurred
AV injury	The degree of injury to AVs in the accident including Minor, Major, MOD, etc.
Weather	The weather at the time of the accident
Lighting	The illumination of the surrounding environment at the time of the accident
Roadway surface (Rs)	The type of road surface at the time of the accident
Roadway condition (Rc)	The condition of the road surface at the time of the accident
Movement preceding collision (MPC) of vehicle 1	Vehicle 1 movement before the accident
Movement preceding collision (MPC) of vehicle 1–1	Vehicle 1 (additional) movement before the accident
Movement preceding collision (MPC) of vehicle 2	Vehicle 2 movement before the accident
Movement preceding collision (MPC) of vehicle 2–1	Vehicle 2 (additional) movement before the accident
Type of collision (TC) of vehicle 1	Type of collision that caused the accident
Type of collision (TC) of vehicle 1–1	
Type of collision (TC) of vehicle 2	
Type of collision (TC) of vehicle 2–1	
Other associated factors (other)	Other factors that may be associated with

3 Learning Method and Result

In this section, we extract important factors from AVs accidents by utilizing machine learning methodology for the purpose of the study.

3.1 Random Forest

Random forests [22] are a combination of tree predictors such that each tree depends on the values of a random vector sampled independently and with the same distribution for all trees in the forest. The generalization error for forests converges a.s. to a limit as the number of trees in the forest becomes large. The generalization error of a forest of tree classifiers depends on the strength of the individual trees in the forest and the correlation between them. In other words, while some trees of random forests have the probability of overfitting, it will be prevented by generating numerous trees.

Therefore, we utilize random forest technique that minimizes overfitting among the important variable extraction techniques to extract the main factors determining AVs traffic accidents. Among random forest importance variable extraction techniques, we deploy the 'Drop Columns Importance' method, which derives importance based on learning accuracy differences when learned except for certain variables.

3.2 Extraction of AVs Collision Factor Importance

Prior to applying the random forests, we discovered the following facts from the confirmation of refined data: (1) AVs did not crash with the object (e.g., pedestrian, etc.) in the autonomous driving mode, and (2) in a collision situation, the collision was caused by neighboring vehicles (HVs), not AVs. Therefore, we derived the feature importance of the variables by setting the dependent variable to 'AV injury' (see Table 2).

As a result of extraction (see Fig. 1), MPC2 and MPC1 were found to be the most important variables, with 24% and 22%, respectively. This is the movement of vehicles in pre-collision, and the movement of HVs (MPC1) is more important than AVs (MPC2). This is because AVs do not cause accidents, and most of the HVs around them are considered to cause accidents. Furthermore, the MPC itself is deemed to be due to the interaction between vehicles on the road. It is widely used as a vehicle safety indicator and is considered to have been derived as an important variable as it is related to time-to-collision (TTC) [23, 24], which means the time remaining immediately before the collision with the other vehicle. Next, 'Time' and 'Lighting' variables were ranked 3rd and 5th, which is deemed to be because the degree of injury in AVs operation varies depending on environmental conditions (day and night, lighting). This is related to be 'street's low-light at night' environmental conditions like Uber pedestrian fatal collision in 2018 [25]. Finally, the variables

Table 2 Learning environment of AVs traffic accidents

Feature	Class	Variable
AV injury	Output layer	0–4
Time	Input layer	0–3
Weather		0–7
Lighting		0–5
Roadway surface (Rs)		0–4
Roadway condition (Rc)		0–7
Movement preceding collision (MPC)		0–19
Type of collision (TC)		0–8
Other associated factors (other)		0–12

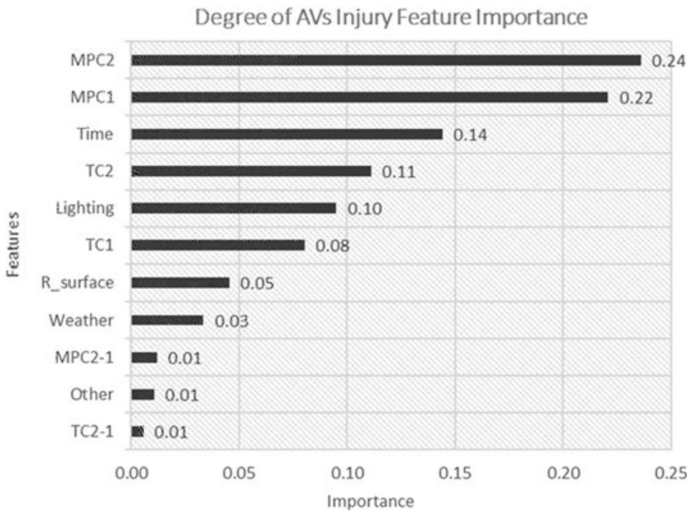


Fig. 1 Factor for determining AVs collision

for 'Type of Collision (TC)' ranked 4th and 6th, respectively. This is considered that the variables can have various effects depending on the seating position of the occupants in the vehicle. In this regard, studies of seating position in the HVs have been conducted [26–28], and many studies have carried out in the AVs sector too [29–33].

4 AVs Traffic Accident Scenarios

In this section, we derive a scenario for AVs accidents based on the factors previously extracted.

4.1 Scenario Combinations Based on Collision Situations

Scenarios are derived based on the most important factors, Movement Preceding Collision 1 and 2, as previously identified data. Among them, there will be a variety of movement preceding collisions, but we have selected five types of movement in a highway environment with relatively few objects, such as signal light and pedestrians (Table 3). In addition, AVs are carried out on the assumption that they do not cause injury to nearby vehicles (Sect. 3.2), and since the mixed situations between AVs and HVs are expected even after commercialization, the neighboring vehicles are set as HVs.

Table 3 Assumption for extracting scenarios

Environment	Driving behavior
2 lanes' expressway which has mixed between AVs and HVs	Proceeding straight (PS)
	Slowing (S)
	Passing other vehicle (POV)
	Changing lanes (CL)
	Merging (M)

Considering the MPC of AVs and the MPC of HVs, the combination of 25 scenarios (5 * 5) is derived, but considering the location and lane of AVs and HVs, a myriad of scenarios (25 * the location * the lanes) are derived. Therefore, we simulate the conditions separated by locational positions (ahead/rear) of AVs in two lanes environment. Over a hundred scenarios [25 * 2(ahead/rear) * 2(two lanes)] are generated which are presented in the order 'AVs (Ego)-HVs (Neighboring)' with each given code (movement preceding collisions are divided into PS, S, POV, CL, and M; Table 3).

4.2 AVs Ahead Situation

If AVs are forward vehicles, the surrounding vehicle, which is likely to crash, runs behind the AVs. Cases, where an accident may occur accordingly, shall be as shown in Table 4.

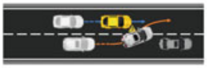
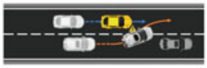
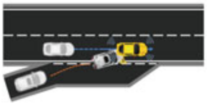
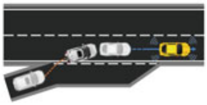
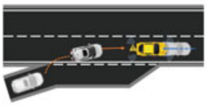
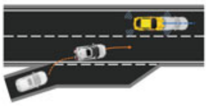
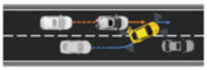
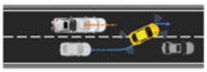
As a result of the scenario, it was found that the majority of scenarios where rear-end collisions occur depend on the behavior of the following neighborhood vehicles because the AVs are the leading vehicle. These scenarios have been found to occur a lot in passing other vehicles, changing lanes, merging situations where there is a lot of interaction between vehicles.

4.3 AVs Rear Situation

If AVs are rear vehicles, the surrounding vehicle, which is likely to crash, runs in front of the AVs. Cases, where an accident may occur accordingly, are shown in Table 5.

As a result of the scenario, since the Ego vehicle is a rear vehicle, it is expected that AVs maintain an environment where AVs do not crash according to the behavior of the preceding neighboring vehicle. Most traffic accidents occur in situations where there are some interactions such as passing other vehicles, changing lanes, and merging, and it is a frontal collision.

Table 4 Scenarios in AVs on ahead situation: it means that yellow car is the AVs, gray car is HVs, and warning sign is crash probability

Environment	Description	
	In the another lane	In the same lane
PS-PS		
PS-S		
PS-POV		
PS-CL		
PS-M		
S-PS		
S-S		
S-POV		
S-CL		
S-M		
POV-PS		
POV-S		
POV-POV		

(continued)

Table 4 (continued)

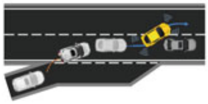
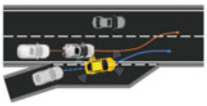
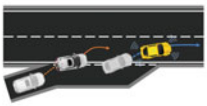
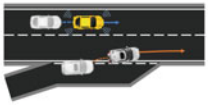
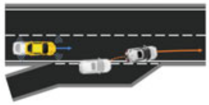
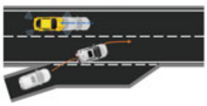
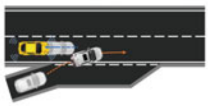
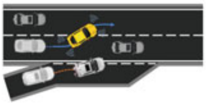
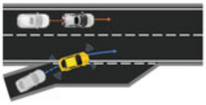
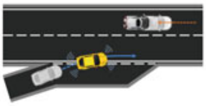
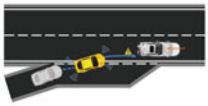
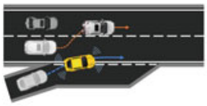
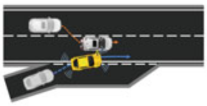
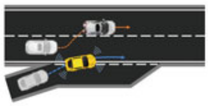
POV-CL	
POV-M	
CL-PS	
CL-S	
CL-POV	
CL-CL	
CL-M	
M-PS	
M-S	
M-POV	
M-CL	
M-M	

Table 5 Scenarios in AVs in the rear situation: it means that yellow car is the AVs, gray car is HVs, and warning sign is crash probability

Environment	Description	
	In the another lane	In the same lane
PS-PS		
PS-S		
PS-POV		
PS-CL		
PS-M		
S-PS		
S-S		
S-POV		
S-CL		
S-M		
POV-PS		
POV-S		
POV-POV		

(continued)

Table 5 (continued)

POV-CL		
POV-M		
CL-PS		
CL-S		
CL-POV		
CL-CL		
CL-M		
M-PS		
M-S		
M-POV		
M-CL		
M-M		

4.4 Comparison with HVs Traffic Accidents

NHTSA [34] states that 'The safety benefits of automated vehicles are par-amount. Automated vehicles' potential to save lives and reduce injuries is rooted in one critical and tragic fact: 94% of serious crashes are due to human error.' Prior to the introduction of AVs, physical accident factors between HVs are speed, type of vehicles, time, violation of the law, etc. [10, 35–39]. Even in mixed situations with HVs after AVs are introduced, the majority of accident factors will be caused by HVs, so the factors that determine the accident are probably not expected to change much. However, the introduction of AVs is expected to lead to making the new accident factors. For example, a human driver was aware of AVs, but it is expected that an accident could occur because the human driver himself judged it to be a risk factor for an accident [40]. Furthermore, it is expected that the increasing market penetration rate (MPR) of AVs could lead to unavoidable accident situations between AVs. Although there is a limit to analyzing current data, it needs to be carried out in a way that increases safety by identifying and preventing it in advance through various methods.

4.5 Summary

As a result of the overall scenario elicitation, accidents will vary depending on whether AVs are at the forefront or at the rear of the surrounding vehicles. In addition, different collisions may occur in the same situation depending on the lanes of the vehicle being operated. In particular, various accidents are expected to occur in the vicinity of passing lanes and ramp sections where there are many interactions. According to the regulation that the vehicles can only change to the left lane in the POV environment, many side collisions are expected, and it is leading to serious accidents depending on the high-speed operation. In addition, for CL environments, various accidents expected than POV environments due to the free lane change situation. In the M environment, it is the only entering traffic environment on the highway, and more accidents are expected due to the interaction between the entry vehicle and the mainline vehicle. Although these would be similar to the accident situation and type of accident between HVs currently operating, we only derived scenarios consisting of accidents caused by surrounding vehicles because AVs did not cause accidents.

5 Conclusion and Future Research

While various studies are being conducted on the safety of AVs, research has recently focused on the development of active safety systems. Among them, the field of AVs scenarios that directly affect vehicle safety and testing is actively being studied. However, while countless scenarios are expected to be derived from the process of scenario-making, the tendency to rely on expert knowledge and the lack of data utilization are emerging as problems. Accordingly, the study is being conducted to extract scenarios through minimizing dependencies and utilizing real data. As part of this flow, we have derived scenarios through machine learning techniques using about 300 data obtained from real traffic accidents of AVs.

As a result of eliciting determinants of AVs accidents, the MPC of HVs was identified as the most important factor, followed by the MPC of AVs. Based on this (most importantly), we have drawn accident situation scenarios that probably occur in various ways through the extracted vehicle-to-vehicle movement variables. The scenarios were shown up where the most interactions occur and resulted in a number of collisions at the overtaking, lane changes, and merging in the expressway. Such a collision is expected to be similar to that between HVs, but it is considered that there will be a difference in the degree of accident depending on the condition that AVs did not cause accidents. This work is expected to provide practical help in establishing scenarios by deriving basic scenarios through machine learning based on AVs real-world accident data and to mitigate expert knowledge dependencies.

Machine learning and AI require a larger amount of data, but in this study, there was a limitation of the lack of data. However, since this is expected to accumulate more autonomous vehicle accident data, this research could be expected to use as basic data in the future. Similarly, we disregarded many situations as scenarios derived from the assumptions of various situations. In addition, since AVs do not interact with only one vehicle, further studies are needed later considering this. It does not mean that AVs can only prevent accidents if they are rear than the surrounding vehicles, but imply that various/basic scenarios can be established by extracting accident determinants based on accident data. In the future, we will be presenting a study to establish scenarios in the multilane expressway and in urban environments where various objects interact with each other. Furthermore, beyond the presentation of simple scenarios, predictions of where accidents will occur from the Ego vehicle's perspective will directly help improve safety, so we will conduct these studies later.

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