Improving Autonomous Vehicles Safety Driven by Critical Scenario Simulation

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Abstract. Autonomous vehicles (AV) aim to reduce accidents and improve fuel efficiency by leveraging powerful algorithms based on Artificial Intelligence (AI) and Machine Learning (ML). AVs sense the environment, understand the current situation, identify possible safety issues, and plan suitable trajectories without human intervention. Since AVs share the roads with human drivers, they must be able to deal with humans' unpredictable and sometimes erroneous behavior; for instance, AVs must avoid accidents or, whenever this is not possible, mitigate their criticality. Unfortunately, current prototypes are far from reaching these goals and have already caused accidents and fatalities, highlighting the need for better development and testing methodologies. The EU Flexcrash project aims at addressing this need by (1) studying how AVs can handle (simulated) past crash scenarios, (2) predicting relevant future mixed-traffic critical scenarios, and (3) using this knowledge to optimize the design of novel (mechanical) mechanisms to improve AV safety. This paper summarizes the proposed methodology for reconstructing real-world car crashes as critical scenario simulations and ongoing work on mixed-traffic scenario identification.

Keywords: Scenario-bases testing, mixed-traffic scenarios, critical scenarios synthesis

1 INTRODUCTION

Autonomous driving is expected to improve our society by reducing pollution and increasing safety in transportation. However, we are not there yet, as current prototypes struggle to drive alongside humans and have already caused several accidents.

Contrary to operational field tests, which run AV prototypes on the road, scenario-based testing uses computer simulations to challenge the AVs; consequently, scenario-based testing is more efficient and effective, less dangerous, and it is widely adopted for testing autonomous vehicles in nominal conditions (e.g., regular traffic) and in critical ones (e.g., collision or near collision scenarios). However, generating valid and realistic scenarios is an open challenge, as the number of potential driving scenarios is infinite, and manually setting up the simulations that implement them is time-consuming and error-prone.

One possibility for generating relevant scenarios is to replicate real-life situations into driving simulations, a practice that is also known as scenario synthesis. As previous studies showed [1],[2],[3],[4], simulating safety-critical scenarios like car accidents is paramount for testing AVs because those scenarios challenge the AVs in situations that are difficult to observe in real life [5].

Critical scenario simulation enables developers to assess how AVs could avoid crashes or mitigate their criticality, but accurate data (i.e., collected by sensors) documenting real-world crashes is not generally available. Thus, researchers proposed synthesizing critical scenarios from alternative data sources, including police reports [1][3] and dash cam videos [2]. These approaches are promising but suffer from the low accuracy of the data; thus, they can generate simulations that match the original accidents only partially. Additionally, since the available data documenting accidents limits the critical scenario coverage achievable by those approaches, better mechanisms are needed to discover additional critical scenarios involving human drivers and autonomous vehicles.

As briefly discussed in the remainder of this paper, the EU Flexcrash project [6] aims to address those problems by improving existing scenario synthesis methods (Section 2) and developing a Web platform that enables studying live interactions in (simulated) mixed-traffic scenarios (Section 3).

2 THE FLEXCRASH METHODOLOGY FOR RECONSTRUCTING REAL-WORLD ACCIDENTS

To identify future critical scenarios and understand how AVs could deal with them, Flexcrash assumes that hypothetical AVs will always respect traffic regulations, thus actively causing no accidents. Consequently, in future mixed-traffic scenarios, only human misbehavior or distraction would cause critical situations and accidents.

Under this assumption, Flexcrash focuses on challenging AVs against human errors and proposes the following four-step methodology: (1) Identify critical car accidents from existing accident databases that would have required not trivial evasive maneuvers to be avoided; for instance, accidents at intersections involving traffic moving in opposite directions are generally complex scenarios that result in severe injuries and fatalities. (2) Analyze the selected accidents to identify which of the involved vehicles caused them and under which conditions the accidents could have been avoided or mitigated. (3) Recreate the selected accidents as simulations in which preprogrammed vehicles replay the faulty behaviors under different conditions while driving agents drive the other vehicles. Finally, (4) study how and under which execution conditions the driving agents can avoid the impacts or mitigate their severity.

Flexcrash will rely on domain experts for the first two steps, whereas for the other two steps, it will build on existing techniques that synthesize simulations of real-world accidents from crash narratives using natural language processing [1] and accident sketches using image analysis [2]. Since these techniques work on very different inputs and provide complementary information about documented accidents, Flexcrash will suitably combine them to cope with each other's limitations. Finally, Flexcrash will leverage metaheuristics algorithms to explore each simulation's parameter space and efficiently find the relevant boundary conditions [7].

3 A PLATFORM FOR STUDYING LIVE INTERACTIONS IN SIMULATED MIXED-TRAFFIC SCENARIOS

Studying the live interactions of humans and autonomous vehicles in simulated mixed-traffic scenarios requires having them participate in the same simulations concurrently. Doing so is challenging because we must involve many human drivers, find a simulation paradigm suitable for humans and artificial intelligences, and protect the participants' identities and intellectual properties.

Flexcrash addresses those challenges by developing an online platform that relies on standard and scalable Web technologies, follows the online multi-players gaming paradigm, and uses an established framework for scenario-based testing [8]. In a nutshell, Flexcrash provides a Web platform and a set of Rest APIs to enable the remote participation of humans and AIs in driving scenarios exposed as turn-based strategy games. The central ideas are (1) abstracting the driving simulations to their essence (i.e., trajectory planning) to reduce the cognitive load on humans and promote engagement and (2) using logical time (i.e., the turns) instead of real-time to simplify the management of the simulations, avoid the need to have humans and AIs constantly attached to the platform, and improve the overall scalability of the systems.

According to Flexcrash design, humans and AIs taking part in mixed-traffic scenarios will be presented with compatible but possibly conflicting driving tasks (e.g., drive till the end of the road, cross the intersection), share the same simulated roads, and make the simulations progress step-wise by deciding where to drive in the next round but without knowing who is driving the other vehicles and where they will drive next.

During the simulation executions, the Flexcrash platform will record each participant's states at every turn, check for collisions, and update the scenarios' state. Next, it will publish scenarios' data openly to enable post-mortem analyses and the possibility of feeding the methodology presented in Section 2 with new critical scenarios.

4 CONCLUSIONS

Flexcrash aims to improve AVs' safety by deploying tailored safety mechanisms using its advanced production technology. To do so, having information about future critical scenarios and how AVs handle them is important to optimize the design of the safety mechanisms, for instance, by making some of their elements stiffer or harder. Our contributions to Flexcrash are a methodology to recreate real-world car accidents as simulations to study how AVs handle human unpredictable and unsafe driving and a scalable Web platform to study live interactions in mixed-traffic scenarios to identify future relevant scenarios.

5 REFERENCES

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