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A collision avoidance scheme for autonomous vehicles inspired by human social norms☆

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ABSTRACT

This paper introduces the novel idea of using human social norms and human emotions to improve the collision avoidance of Autonomous Vehicles (AVs). Until now, the literature has been concerned with theoretical debates regarding ethical issues connected to AVs, while no practical steps have yet been undertaken. This paper introduces the concept of an artificial society of AVs with different personalities and with social norms coded into their autopilot so that they act like well-behaved drivers. For proof of concept, the standard agent modelling tool Netlogo is utilized to simulate the artificial society of AVs. Furthermore, comparisons are made with random walk-based non-social-based collision avoidance techniques. Extensive testing has been carried out using the behaviour space tool to determine the performance of the proposed approach regarding the number of collisions. A comparative study undertaken with a random walk method indicates that the proposed approach provides a better option for tailoring the autopilots of future AVs, while also promising to be more socially acceptable and trustworthy regarding safe road travel.

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1. Introduction

Autonomous Road Vehicles (ARVs) are considered better than human-driven vehicles about road safety and traffic management. According to the study by Riaz and Niazi [1,2], Autonomous Vehicles (AVs) are considered helpful in decreasing the number of road accidents as compared to human-driven vehicles. According to Mersky and Samaras [3], the issue of traffic jams can be resolved by replacing human drivers with fully connected autonomous cars. Also, Mersky and Samaras [3] illustrate that AVs are very helpful in decreasing road pollution and in protecting the environment. By these benefits, it is conceivable that legal authorities will delegate the task of driving to AVs by issuing driving licenses to them. However, to perform the complex task of driving, there is a need for a mechanism which supports autonomous vehicles – a robot which would obey both the road rules and the social rules that are practised by well-behaved drivers.

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The role of ethics and social norms is considered to be important in making robots social, well-behaved and more compatible with humans. According to Malle [4], robots can serve as competent social agents by integrating moral norms. Rakotonirainy et al. [5] prove that social norms can be utilized in designing human-compatible social AVs robots. According to Kummer et al. [6], social norms can be used in tailoring crash-free AVs robots to operate on roads wisely. From the above discussion, it is implied that social norms combined with a norm-compliance mechanism can be used to tailor the next generation of more trustworthy social AVs.

Furthermore, emotions can be used as a norm-compliance mechanism, as it has already been proven that emotions help in sustaining the social norms of human society. According to Elster [7], self-attribution emotions like shame help humans to avoid violations due to the fear of losing their social status. According to Criado [8], prospect-based emotions like fear influence humans to follow the social norms to avoid punishment from law enforcement agencies. Researchers have used emotions as a norm-compliance mechanism for artificial agents as it has been proven by Staller et al. [9] that emotions play an important role in the sustainability of social norms in human society [9]. Hence, it is implied that we can use emotions as a norm-compliance mechanism to design social norm-enabled AVs. While Gerdes and Thornton [10] propose the mathematical model of social norms for designing the control algorithms of AVs, their work still lacks the simulation or proof of concept of the proposed mathematical models.

Problem statement. The existing research is not focused on procedures that would allow AVs to configure their autopilots to make collision avoidance decisions about norm compliance using emotional motivation in the same way that human drivers can. For example, Tavani [11] suggest the use of social norms in AVs in theoretical respect for discussing a mathematical model and its implementation. Rakotonirainy et al. [5] propose a novel concept of measuring the emotional state of a driver using the HUD-UP technology and transmitting the social norms from driver to driver to modify the behaviour behind the steering of an AV. However, the concept of social norms is not integrated into the autopilot of the AV in a way that would help them to make collision avoidance decisions automatically. The major challenge for AVs is the question of how they will take decisions at the time of a crash; this issue is addressed by Kumfer and Burgess [6]. In this regard, the authors use social norms as a decision mechanism for choosing a less harmful crash among possible collision options. However, this paper does not provide a collision avoidance strategy using a social norm compliance mechanism to avoid collision situations.

Contribution. The existing research is associated with a set of contributions to building a norm-compliant collision-free artificial society of AV inspired by human social norms and related emotions. We aim to provide humans with reliable AVs that can delegate driving tasks regulated by legal and social norms. The main contributions of the paper are the following:

- Modeling of a social norms-inspired artificial society of AVs.
- Simulation of the social norms-compliant artificial society of AVs using NetLogo.
- The rigorous analysis regarding the number of collisions of the proposed approach in comparison with a random walk travelling strategy.

This paper is organized as follows: Section 2 illustrates the related work, while Section 3 describes the methodology. In Section 4, a description of the proposed model is provided, while Section 5 illustrates the experiments. Section 6 elaborates the results and includes a discussion, and Section 7 provides a conclusion and points to future directions in research.

2. Related work

The literature review is divided into three main categories. The first category addresses the literature supporting the role of ethics in robots and the related theoretical debate. The second category contains the literature that supports the role of using theoretical concepts of ethics or norms in the design of AVs. The third category deals with state-of-the-art literature concerning the social norms in autonomous vehicles based on a simulation approach.

According to Voort et al. [12] computers are becoming more autonomous every day and capable of making decisions on their own. Intelligent computer systems can get information from a human, analyze it, take decisions and store that information or provide it to third parties. However, there is a need to monitor the moral values of computer decisions. Researchers [12] have suggested that there is a need to add ethics to technology, as it lags behind in this respect. Malle [4] points out that from 1995 to 2015 few efforts have been made concerning the implementation of ethics in robots. Past studies have considered whether a robot could be a moral agent or not. Also, researchers [4] have found that a robot could be treated as a living thing that can take actions based on its own decisions, and it can decide what is right and what is wrong together with humans.

According to Etzioni and Etzioni [13], the latest smart machines like AVs are becoming smarter due to the incorporation of Artificial Intelligence (AI) algorithms. Furthermore, these AVs are becoming more and more autonomous in the sense that they are now taking decisions using these AI algorithms. Etzioni and Etzioni [13] suggest that since these AVs' basic purpose is to serve humans, there is a need to equip them with ethical and social rules so that the autonomous devices can take decisions on their own that will not harm passengers and other road commuters [7]. According to Gerdes and Thornton [10], it is the responsibility of researchers and programmers to devise ethics-enabled control algorithms for AVs that can make them more acceptable for human society. The authors argue that the incorporation of ethics in the society in which AVs operate will help courts to determine the level of responsibility of an AV in the case of an accident [10]. In this regard, they have proposed a mathematical model of ethical frameworks to incorporate into the control algorithms of autonomous

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