

# Contradictions in assessing human morals and the ethical design of autonomous vehicles

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**Abstract**—Autonomous vehicles (AVs) promise to bring many benefits to society, such as safety, an increase of accessibility and life quality, among others. Unlike humans, they do not get tired and, supposedly, do not fail. However, there might be cases where, due to limit visibility, occlusions or even a sensor failure, the system might not be capable to detect one or more obstacles along the vehicle's path early enough to avoid a crash. Although these situations might be rare if one considers a single vehicle, if predictions are correct, these AVs are to be adopted in large quantities in the near future, making even rare situations more commonplace. AVs will have to deal with these forced-choice situations in the best possible way. This paper presents a review of the ethical discussion regarding the matter of AVs and an analysis of a questionnaire implemented by the authors. Our results show evidence for several types of contradictory choices made by the subjects, which suggest the moral choices do not necessarily follow strict logical reasoning.

## I. INTRODUCTION

The technology contained in an AVs promises to bring many social and economic benefits like reduction of traffic accidents, increase of the life quality, reduction of costs [1] and increase the accessibility of low-income families and people with locomotion difficulties [2].

Based on the adoption of previous vehicle technologies, it can be estimated that in 2050 AVs will represent 90% of vehicle sales, 50% of vehicle fleet and 65% of all vehicle travels [3].

Ideally, sensors combined with computational power have the ability to drive safely, committing neither traffic violations nor errors. They are always vigilant and never get tired [4]. However, there might be cases where the vehicle will face a scenario where it will be forced to make a decision between two or more possible bad outcomes, such as deciding whether to run over a group of kids or hit a wall, exposing its passengers to a certain amount of danger in order to protect the life of other road users from an equal or even bigger risk [5]. Forced decisions like that, will have to be programmed in sophisticated algorithms that will be mostly based on ethical assumptions [6].

The Moral Machine from MIT is a survey where the user was invited to choose between the option she or he judged as the least awful of two bad outcomes. In the situations, the

vehicle is in a two way street with walls on the sides leaving only two options: keep going or swerve to the adjacent lane. The car is either empty or occupied with one or more persons or animals, and in front of the vehicle, there can be a wall or a group of people crossing the crosswalk. The group of people change in each instance and may have different social classes, genders, stereotypes, and ages. In the end, it is presented to the user which of the characters she or he saved/sacrificed the most, as well as a summary of the principles presented by her or him compared to the average of the other users [7].

In the results from the survey [8], the authors found out that the strongest preferences on a global scale were to save more lives, spare humans over animals and to spare the younger. In a demographic level, they analyzed the influence of cultural, economic and social aspects among the user's preferences.

In [9] the authors proposed an algorithm to search an ideal safest trajectory for a fully AV based on the user preferences and data analysis. The designed data analysis occurs using real crash data to foresee future accidents and traffic jams. The user preferences, such as shortest time, shortest distance, fuel economy, are ranked and converted into profiles, with the condition that safety always overrides all preferences.

In this work, we simulate the situation where a user is supposed to customize an AV based on his or her own moral values. In order to do that, we use an online questionnaire to assess peoples moral judgments in several pairs of forced-choice scenarios. We use the Analytic Hierarchy Process to estimate a weighted value vector representing their preferences. Additionally, we ask a few multiple choice and free-form questions. The contestants are mainly from Brazil, with some participants from Europe and Asia. In the results, we highlight several contradictory answers, which are likely to become difficult obstacles for future attempts in customizing AV moral decision making according to user preferences. It is divided as follows: Section II reviews some of the ethics aspects involving the issue. Section III presents the questionnaire used and the procedures utilized to analyze it. Section IV shows some results and arguments obtained from the data and Section V concludes.

## II. ETHICS AND AUTONOMOUS DRIVING

An ethical dilemma differs from an engineering problem. While the former is an idealized state that does not have an ideal solution, in the latter the problem is stated in practical terms and it is through the pragmatic implementation of

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models or prototypes that it is possible to differentiate a good from a bad solution [10].

Human beings face ethical dilemmas all the time. To solve them, there are many socially accepted ethical practices, but, in the end, it is the individual who has to choose the action to be taken. For the technological systems that have to face these dilemmas, the difference is that these decisions often must be built-in. Even for systems that can learn ethical rules, it is not clear that they become autonomous moral agents, and, therefore, the programmer of such a system would still be responsible for its behavior [11]. The author in [11] believes that for an artificial system to be considered as a moral agent it would still need to show other elements such as consciousness, the ability to feel pain or to fear death, reflexive deliberation and evaluation of its ethical system and moral judgment, among other things.

The algorithm implemented in an AV is typically designed in such a way to need a cost function to assign, and calculate, the expected cost of several possible options, selecting the one with the lowest value - which can potentially determine who lives and who dies [12]. For the author in [12], optimizing the outcome of a collision means choosing the course of actions that most likely lead to the minimum amount of damages, even when it means choosing between two evils as, for instance, run over an 80-year-old elderly woman or an 8-year-old young girl, however unlikely such event might be.

Even if such situations never happen, AVs programming should include rules defining what should be done and this must be done before these vehicles become a global commodity [13].

Hypothetical situations about ethical dilemmas are commonly debated. An example is the trolley problem, initially proposed by Thomson [14], which is currently much referenced in discussions of ethical principles in AVs [15], [16].

The adapted version of the problem is the following: an AV travels through a road. A group of people suddenly appears in front of the vehicle which, due to its speed, cannot fully break before hitting the group. If the car does not change its trajectory, the group will be killed. The car can swerve and run over a pedestrian on the sidewalk. If the pedestrian is replaced by a wall, the collision would kill all the vehicle occupants.

All possible decisions regarding the problem are morally questionable, which is why it is common to analyze such a scenario with an ethical doctrine like consequentialism or deontology [10].

According to Menon and Alexander [17], the consequentialist approach to the problem would seek to reduce the overall damage by minimizing the number of people injured. In this case, it is possible that the best solution would be self-sacrifice. A decision that could be taken by a driver if he or she were to consider it the most ethical option. But one thing is to come to this decision voluntarily. Another different thing is if a machine comes to this decision without previous knowledge of the user that self-sacrifice could be an option. Noble attitude if volunteer, but criminal otherwise [12].

The deontological approach, on the other hand, would consider whether there are rules governing the acceptance of changing the trajectory, completely disregarding the risk offered to any of the individuals involved. For Goodall [5], a deontologist could argue that the autonomous vehicle has the duty to act, in an accident situation, as if the penalty for injuring its passengers were comparable to the penalty for injuring anyone else in danger (i. e. not giving any privilege to passengers in spite of strangers).

#### A. Personalized algorithm

Gogoll and Miller [18] criticized and rejected the option of letting the user choose the ethical settings of the vehicle. According to them, this would result in the prisoner's dilemma in traffic, because if a considerable number of people decide to use strategies that maximize their self-preservation, the most likely result would be an increase in the number of general losses. Applin [19], on the other hand, thinks that people might want their vehicles to reflect their ethics as if they would be driving themselves. The author also argues that AVs with a single ethical setting defined by default would not offer the flexibility needed to accommodate the human agency, once that people's ethical principles may vary from culture to culture.

Rachels [20] calls it naive to suppose that our ethical ideas could be shared by all people for all time. He affirms that since the time of Herodotus, enlightened observers were used to the idea that the conceptions of right and wrong differ from culture to culture.

The idea that cultural differences might be related to differences in moral judgment has also been presented in [21]. This idea is based on the study conducted with British and Chinese participants where they were presented with situations similar to the trolley problem. As a result, the authors found out that the Chinese participants were less inclined to sacrifice one person to save 5 others, and were even less inclined to consider such actions as correct.

In another study [22], Faulhaber *et al.* tried to establish a structure for the ethical decision-making that could serve as a base for a model to be implemented in the vehicles. To do that, the authors made use of virtual reality to present variations of the trolley problem to human participants, where the avatar's quantity and ages were variables. In the comparison by age (children, adult, elderly) the younger were saved at the expense of the older. As a general result, it was concluded that most of the participants would act in a utilitarian way, saving as many avatars as possible, with little influence from other variables (people in the sidewalk, the height of the avatars, self-sacrifice).

By moving from human drivers to AVs, we move the intelligence for the decision making from conditions of extreme stress to a much calmer and quieter environment. By doing so, the ethical standards expected by the public might increase, such that it is expected that an engineer developing an autonomous vehicle makes sure that it will react in a morally acceptable way, no matter how a human driver would react in the same situation [17].

Gerdes and Thornton [16], on the other hand, believe that, in the rare cases where a collision may really be unavoidable, society might accept suboptimum results, as long as the AVs clearly possess a respect for the human life above other priorities. On the contrary, our questionnaire shows evidence, that some people might prefer saving animals over humans. Goodall [23] adds that the solution does not need to be ideal, as the vehicle will have to quickly decide with incomplete information, in situations mostly not considered, but that such solution must be thoughtful and defensible.

Gerdes and Thornton [16] adapt the three laws of Asimov (deontology) for the AVs, replacing the concept of hurt by colliding:

- 1) An AV must not collide against a pedestrian or cyclist;
- 2) An AV must not collide against another vehicle except when it conflicts with the first rule;
- 3) An AV must not collide against any other obstacle except when it conflicts with the first and second rule.

For the authors, these laws could be implemented with the current levels of sensors and perception capability that exist in vehicles, considering only that the obstacles, sometimes, can be wrongly classified. Menon and Alexander [17] state that while implementing rules is conceptually simpler than having the autonomous vehicle perform calculations to minimize risk (consequentialism), deontology ethics requires the formulation of rules for every situation the vehicle might face.

### B. Liability

By defining a single type of algorithm for the AV, we would consider that there is only a type of response for different situations. For humans, however, there is no such thing as one mindset for all people. Nevertheless, one question stays open: consider that the manufacturer allows the user to customize or choose between different moral algorithms. In such scenarios, who is to blame if an accident occurs?

Davis *et al.* [24] consider that the programmer might be considered morally and legally responsible for all the possible outcomes that might result from the actions of the AV, in case they could have foreseen these outcomes (in a way that they could have been prevented or avoided). For them, the decision-making must be done by qualified and well-informed people and that great care must be taken when giving orders to a robot, just as it is when giving orders to humans.

For Sio [25], pedestrians and cyclists (regardless of how negligent they might be), that, if not by the actions taken by an AV, would not be involved in an accident, must not be seen as targets, even if by doing so, more lives would be saved. The justification for this is that the vehicle manufactures have responsibilities regarding pedestrian and cyclists for taking the risk of producing a dangerous machine capable of killing, as well as respecting their basic rights as human beings.

For Goodall [15], it is too much to ask a third party to tolerate a great deal of damage in order to assist a stranger, but not to demand that any effort be made seems to be against society's preferences. He also asks if it should be allowed

to a vehicle, without its owner's permission, to intentionally collide at low speed and with low risks if such actions would protect a pedestrian.

Sparrow and Howard [26] consider that, once AVs become provenly safer than vehicles with human drivers, it will be unethical for a human to take control of an AV, as it would represent a risk to third parties. For them, the human driver would be the equivalent of a "drunk robot" and that probably in the future it might be illegal for a human to drive.

For Goodall [23], manufactures and software developers, in case of an accident, will have to defend the actions taken by the AV in unimaginable ways, much different from what currently happens to human drivers. For him, questions like "Why?" will become valid, as in "Why did not the vehicle swerve from the person that suddenly appeared in front of it?"

Lin [27] considers that in cases where it will be necessary to choose who the victim will be, vehicle manufactures could still be found guilty for allowing the user to make that choice, discriminating by doing so, a specific category of vehicle or people. He believes that even being the user who has defined the ethical settings, the accident victims will still be able to sue the manufacturer for having created the algorithm that made them a target and for allowing the user to make them predictably victims in certain scenarios. The author still complements that if the responsibility moves to the user, by valuing more their life over others, it would mean targeting someone, and this premeditation is the difference between manslaughter and premeditated murder.

Millar [28] considers the question of who should decide in the case of accidents as important as the question of how to act in such situations. The author compares such decision-making with what is currently universally accepted in the medical assistance, where it is usually left to the person to whom the question has direct moral implications to decide which outcome is preferable. Regarding AV, he believes that although the manufactures can produce the AV, it does not grant them the authority to impose a moral decision for all users.

So far, the questions presented here do not have a universal answer. They need to be analyzed and discussed so that when needed they can be safely applied.

## III. QUESTIONNAIRE

Decision-making is frequent in human life. In order to make a decision, it is necessary to know the problem, the need and the purpose of the decision, the decision criteria, its sub-criteria, the stakeholders, the affected group and the possible courses of action [29].

To assist in some of these cases there are the Multi-Criteria Decision Making (MCDM) methods, which are procedures that evaluate real-world situations based on several qualitative/quantitative criteria in an uncertain/certain/risk environment to find the choice/strategy/action most suitable among the possible alternatives [30].

The Analytic Hierarchy Process (AHP), developed by Professor Thomas Saaty in the 1970s, is a measurement

theory based on pairwise comparisons and relies on user judgment to produce priority scales. The comparisons are made using absolute judgment scales to represent how much more one element dominates the other relative to a given attribute [29].

The questionnaire that we designed and applied is composed of two main parts. The first part consists of general questions designed to identify the participant's profile, followed by questions regarding the acceptance of the AVs and who would be responsible in the cases of accident. After this initial stage, in the second part, the participant is presented with 34 objective questions, based on the hierarchy shown in Fig. 1, where, for each of them, he or she must indicate his or her preferences in a hypothetical situation of forced choice. These hypothetical forced-choice situations simulate potential traffic accidents, and the participants' preferences will serve as tuning parameters for a decision-making algorithm for an AV in a future work.

Applying the AHP to the answers from the pairwise comparisons, we obtain the preferences of the user. The difference in our approach, when compared with the usual application of the method, is that we do not ultimately wish to choose among multiple alternatives, being the scale priorities our final result.

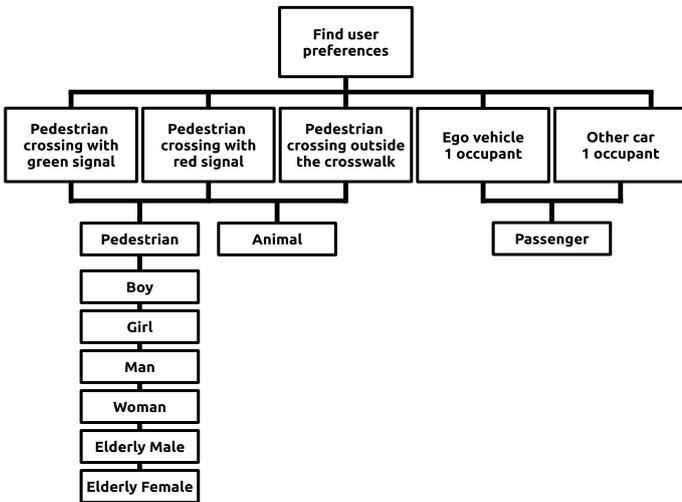


Fig. 1. Structure of the pairwise comparisons

The reader can refer to [31] for a more detailed explanation of the method and the style of questionnaire applied.

#### IV. DATA ANALYSIS AND DISCUSSION

The original AHP includes a method for consistency check based on the eigenvalues of the comparison matrix. It was when we attempted to apply this consistency check method to our collected data that we started to realize how much contradiction could be found in the answers. Trying to make sense of these contradictions gave us some interesting insights into the nature of the human moral decision-making process.

When asked if the participants would like to have an AV, about 80% answered yes. From these, about 60% changed

their answer if the AV was allowed to sacrifice their lives when it would result in a bigger utility. This agrees with the results from Bonnenfon, Shariff and Rahwan [13], where they realized that, although people tend to agree that the best solution, aiming to maximize the overall utility, would be the use of utilitarian AVs, these same people would like their vehicles to protect them at all cost.

The participants were asked how many people would need to be saved in order for them to consider sacrificing themselves. The result is present in Table I, where the cases are the following:

- Case I - considering all the participants;
- Case II - considering only the participants who would like to have an AV;
- Case III - considering only the participants who would like to have an AV even if it was allowed to sacrifice their life if it would mean saving more lives.

TABLE I  
HOW MANY PEOPLE WOULD NEED TO BE SAVED TO THE PARTICIPANT CONSIDER SACRIFICE HIS OR HER LIFE.

	Case I	Case II	Case III
1 person	14.1%	13.9%	22.1%
2 people	13.6%	14.5%	22.1%
3 people	11.7%	9.7%	11.8%
5 people	8.3%	7.9%	8.8%
More than 5 people	13.6%	13.9%	10.3%
I would always choose to save myself	38.8%	40.0%	25.0%

It is interesting to notice, that in Case III, 25% of the participants said they would always choose to save themselves, even though they answered that they would be fine with owning an AV that could sacrifice their lives for the greater good. Here it seems the participants were inclined to accept a more noble stance as long as they were not pressed to make that choice themselves.

In respect to personalizing the AVs settings, 68% would like to have this possibility, while 27.7% would like the vehicle to have standard factory settings. The remaining 4.4% would prefer a solution in the middle, where the user could choose among a few configurations that would always prioritize safety.

Regarding who should be responsible in case of an accident if the user was allowed to personalize the settings according to his or her own moral and ethical principles the answers we obtained are divided as follows:

- 52.9% of the participants said the liability for the accident should be shared between manufacturer and user;
- 21.8% said it should be only of the user;
- 25.2% said the manufacturer should be the only responsible.

#### A. Pairwise comparisons

Regarding the pairwise comparisons, some conclusions obtained from the data are:

- 18.5% would prefer to save the animal in comparison with the pedestrians and passengers;
- 31.0% would prefer to save the younger (boy or girl) with respect to the other categories of the pedestrians;
- 3.5% would prefer to save the older (elderly male or female) with respect to other categories of the pedestrians;
- 5.5% gave a bigger preference to gender (male or female);
- 70.5% gave a bigger preference to saving the pedestrian who is in his or her rights (crossing with green signal) in comparison with the other options (crossing with red signal or crossing outside the crosswalk);
- 22% gave a bigger preference to the pedestrians over the vehicles disregarding the location of the pedestrian on the road;
- 9.5% gave a bigger preference to the ego vehicle (to his or her life).

This last item is contradictory when compared with Table I. On a direct question, the number of participants who would always save their own life is at least twice as big in comparison with the percentage obtained with the pairwise comparison.

For better visualization and interpretation of the data, we applied the Principal Component Analysis to reduce the number of dimensions and created clusters with a Gaussian Mixture Model. After experimenting with a different number of clusters, we settled with 5 clusters. Fig. 2 presents the clusters with respect to the first and second principal components. Table II contains the normalized means of each cluster with respect to all the dimensions. For this analysis, the weights of each component are not distributed according to Fig. 1, but are normalized between their own categories (thicker division line).

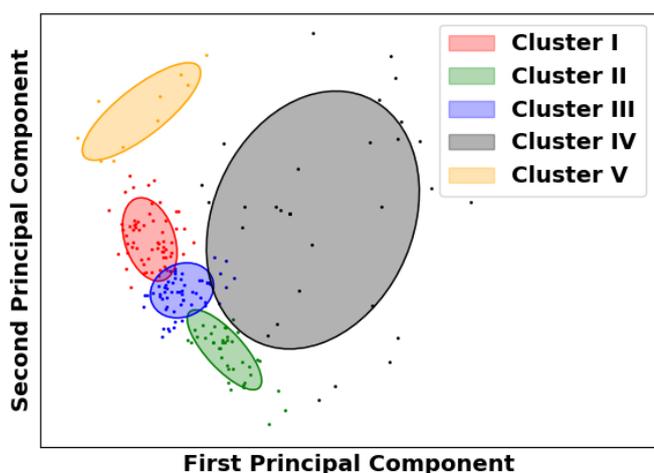


Fig. 2. Clusters

From Table II we can infer the majors' characteristics of each cluster:

- Cluster I: Passengers are prioritized, followed by pedestrians and animals with the minimum percentage possible. In the middle part, penalizes the pedestrians who

do not obey the law. The biggest value belongs to the pedestrian crossing with the green signal. Gives preference to the younger.

- Cluster II: The pedestrian is valued the most, followed by passengers and animals. The vehicles are penalized the most, reinforcing the idea that the pedestrians are the ones to be saved. Gives preference to the younger.
- Cluster III: Pedestrians and passengers have approximately the same priority what is not reflected in the middle section, where obeying the law plays a major role. Gives preference to the younger.
- Cluster IV: Animals have the biggest priority, followed by pedestrians and passengers. The location of the pedestrian does not matter and, as a result, the values for crossing with green or red signal as well as crossing outside the crosswalk are approximately the same. Again, gives preference to the younger.
- Cluster V: Values the passengers the most, followed by animals and pedestrians. This can also be noticed in the middle part where the ego vehicle has the biggest value. As in the Cluster I, penalizes the most pedestrian crossing with red sight or crossing outside the crosswalk. Prioritize the younger with a larger difference in comparison to the other clusters.

The participants were invited to leave comments at the end of the questionnaire, regarding his or her understanding of the matter or doubts or suggestions about the questions they had just answered. In general, they found hard to face these ethical dilemmas, which made some of them feel uncomfortable. The question regarding the number of lives that would need to be saved in order for them to consider sacrificing themselves, was the most highlighted point. Essentially many respondents wished they could have a better understanding of the situation before deciding. They wished to know things such as who were the possible victims, whose fault caused the situation (if the group broke the law or not), road conditions, et cetera.

Nevertheless, as it would be a split-second decision, if users were driving, their choice couldn't possibly be based on much detailed background regarding the victims, and the numbers from Table I would likely change.

For some people, the fact that the vehicle in some cases might put their lives in danger is a strong factor for not having one. But they do not consider the fact that most of the accidents are caused by human error and that these forced-choice situations are supposed to be rare.

## V. CONCLUSIONS

This work served as an introduction to the challenges to be faced, in our attempt to insert the moral compass of the user in the algorithm of an autonomous vehicle.

The results obtained with the questionnaire show that ethical preferences are not unanimous. Even with the technology ready and with clear regulation, the ethical settings would still play a major role in public acceptance as it depends also on knowing what the vehicle would do in extreme cases. But

TABLE II  
CLUSTER'S MEANS

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Pedestrian	0.37	0.56	0.46	0.33	0.11
Passenger	0.57	0.38	0.48	0.25	0.68
Animal	0.06	0.06	0.06	0.43	0.21
Pedestrian crossing with green signal	0.36	0.38	0.38	0.24	0.29
Pedestrian crossing with red signal	0.09	0.24	0.14	0.2	0.06
Pedestrian crossing outside the crosswalk	0.08	0.22	0.14	0.21	0.03
Ego vehicle with 1 occupant	0.27	0.08	0.18	0.18	0.39
Other car with 1 occupant	0.21	0.07	0.15	0.16	0.22
Boy	0.25	0.24	0.24	0.23	0.31
Girl	0.25	0.25	0.24	0.26	0.31
Man	0.17	0.16	0.17	0.16	0.13
Woman	0.17	0.16	0.17	0.16	0.13
Elderly Male	0.15	0.19	0.16	0.19	0.11
Elderly Female	0.14	0.16	0.14	0.18	0.1

what is acceptable or not, might not even be clear for the people who want to buy or use these vehicles.

For future work, the data obtained with this questionnaire will be applied in a scaled simulation of an autonomous vehicle where machine learning techniques will be applied in the configuration of a driving behavior matching the priorities of the user.

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