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Consequences of an Analysis Using Biblical Analogies for Automated Vehicle Control Design

Abstract.

The paper proposes an analysis of learning-based approaches for automated vehicle control systems from an ethical viewpoint. An analysis using analogies between selected biblical texts and operation concepts of learning-based approaches is performed. Thus, analogies for supervised, unsupervised, and reinforcement learning-based approaches are created. Through the analogies, the root of the automatic control design problems, i.e. forming objective functions, on a theological level is explored. The analysis leads to three consequences, which are related to the difficulty of forming control objective, the difficulty of considering human objectives in control, and the necessity of viewing systems in all their complexity. The paper proposes the application of the consequences in an illustrative route selection vehicle control example. A multi-layer control concept involving the consequences of the analysis is proposed, with which some ethical challenges of the selected control problem can be handled.

Keywords: biblical analogies, automated vehicle control, ethical challenges, machine learning

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Introduction and Motivation

The increasing complexity of automated systems leads to several challenges in the field of control theory and artificial intelligence approaches. Besides their technological aspects, the impact of innovation on daily life poses social, political, ethical, philosophical, and theological challenges alike.[2] Most of the problems are related to human–machine interactions and human resources, which are influenced by the level of automation. Autonomous driving features and intelligent transportation systems are current fields where these problems have made a significant presence.[3] For example, may an autonomous driving feature have the authority to decide on the damage of human participants in traffic scenarios with unavoidable accidents? How can the society handle the problems of employees who have lost or have to change their work due to the increasing vehicle automation level? Since the efficient use of high-level vehicle automation and the coordination of automated vehicles can require expensive infrastructure investments, do automated driving technologies increase the disparity between developed and undeveloped regions?

Due to the many challenges, in the past few years, the engineering research field has shown an increasing interest in ethical the consequences of such innovations. One of the most famous research projects is the Moral Machine at the Massachusetts Institute of Technology. In this project, decision priorities of humans in critical traffic situations, in a worldwide aspect are examined.[4] The contributions of the analysis are the determination of moral preferences, their priorities and their dependence on individual, cultural, and demographic characters. Nevertheless, the consequences can generate a psychological roadblock to automated vehicles because the requests of vehicle consumers and the maximization of the lives saved are in conflict.[5] Another relevant contribution in the field of

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[2] REED, Randall (2021): A.I. in Religion, A.I. for Religion, A.I. and Religion: Towards a Theory of Religious Studies and Artificial Intelligence. In: *Religions*. 12, 6. 1–2.

[3] MAURER, Markus – GERDES, J. Christian – LENZ, Barbara – WINNER, Hermann (2016): *Autonomous Driving: Technical, Legal and Social Aspects*. Berlin–Heidelberg, Springer. 1–7.

[4] AWAD, E. – DSOUZA, S – KIM, R. – SCHULZ, J. – HENRICH, J. – SHARIFF, A. – BONNEFON, J.-F. – RAHWAN, I. (2018): The Moral Machine Experiment. In: *Nature*. 563. 59–64.

[5] FUREY, H. – HILL, S. (2021): MIT's Moral Machine Project Is a Psychological Roadblock to Self-Driving Cars. In: *AI and Ethics*. 1, 151–155.

ethics and automated vehicle control is presented by Thornton.[6] The concept of his work is that some ethical considerations in a Model Predictive Control (MPC) structure can be built. In the MPC structure deontology, a rule-based ethical framework motivates the development of constraints on the system. Consequentialism, a cost-based ethical framework, motivates the construction of the objective function in the MPC problem. Furthermore, the motion of automated vehicles in a traffic-level context with selfish or altruistic characters can also be formulated.[7] The character of the vehicle through the setting of the automated control can be set. Another approach of the problem is imitation learning, where the goal of creating a neural network is to approximate human driving style.[8] Although it can provide an effective solution to the driving task, it poses the problem of preliminary decision on the acceptability of a human driving intervention. The decision requires an a priori rule, which can also require ethical considerations.

The previous contributions of this area point out the crucial problems of building ethical considerations in the automated control systems, which are as follows: First, it is difficult to establish appropriate ethical laws for the control system that would be acceptable for both consumers and the society and, simultaneously, that would be economically and technically reliable. Second, even if the ethical laws are selected, it can be difficult to formulate them in a mathematical way for control design. In this paper, the method of creating analogies is used for providing solutions to these problems. The analogies between selected machine learning approaches and biblical texts are created. This method is under the assumption that biblical texts can be efficient sources of ethical laws, which is confirmed

6 THORNTON, S. M. – PAN, S. – ERLIEN, S. M. – GERDES, J. C. (2017): Incorporating Ethical Considerations into Automated Vehicle Control. *IEEE Transactions on Intelligent Transportation Systems*. 18, 6. 1429–1439.

7 KESKIN, Musa Furkan – PENG, Bile – KULCSÁR, Balázs – WYMEERSCH, Henk (2020): Altruistic Control of Connected Automated Vehicles in Mixed-Autonomy Multi-Lane Highway Traffic. *IFAC-PapersOnLine*. 53, 2. 14966–14971.

8 BOJARSKI, Mariusz – DEL TESTA, Davide – DWORAKOWSKI, Daniel – FIRNER, Bernhard – FLEPP, Beat – GOYAL, Prasoon – JACKEL, Lawrence D. – MONFORT, Mathew – MULLER, Urs – ZHANG, Jiakai – ZHANG, Xin – ZHAO, Jake – ZIEBA, Karol (2016): *End to End Learning for Self-Driving Cars*. www.arxiv.org/abs/1604.07316 (last accessed on: 27/09/2021).

by the Jewish and Christian theological and philosophical traditions.[9] The contribution of the paper is an analogy-based theological analysis for selected machine learning approaches (supervised, unsupervised, and reinforcement learning), which sheds light on the root of ethical problems concerning automated vehicle control design. As a further contribution, the consequences of the analysis in an automated vehicle control problem through the proposal of a multi-layer design concept have been applied.

The novelty of the paper is exploring the connection between the fields of Christian theology and control theory, through which a solution for some ethical challenges of automated vehicles can be provided. Ethical challenges of automated vehicles mainly from the viewpoint of philosophy are examined.[10] Some theological works also deal with these challenges, especially with the trolley problem,[11] but a solution that a control engineer could adopt in practice is yet to be found, to the best of the author's knowledge.

The paper is organized as follows. Section 2 proposes the analogies for three selected learning-based approaches, which represent most of the learning features in automated control systems. The proposed analogies are used for forming some ethical aspects of the control design process. These are concluded in Section 3. In Section 4, the application of the consequences for an illustrative vehicle control design problem is proposed. Finally, the conclusions of the paper and further challenges are summarized in Section 5.

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[9] GREEN, Ronald M. (1999): Jewish and Christian Ethics: What Can We Learn from One Another? In: *The Annual of the Society of Christian Ethics*. 19. 3–18.

[10] See e.g. LIN, Patrick – ABNEY, Keith – JENKINS, Ryan (2017*): Robot Ethics 2.0: From Autonomous Cars to Artificial Intelligence*. Oxford, Oxford Scholarship Online; BONNEFON, Jean-Francois – SHARIFF, Azim – RAHWAN, Iyad (2019): The Trolley, the Bull Bar, and Why Engineers Should Care about the Ethics of Autonomous Cars. In: *Proceedings of the IEEE*. 107, 3. 502–504; WAGNER, Michael – KOOPMAN, Philip (2015): A Philosophy for Developing Trust in Self-Driving Cars. In: Meyer, G. – Beiker, S. (eds.): *Road Vehicle Automation. 2*. 163–171. Springer.

[11] E.g. ANDERSON, William H. U. (2021): *Technology and Theology*. Vernon Press. 19.

Creating Analogies for Learning-Based Approaches

In this section, the analogies for three common learning approaches are created. In the case of each approach, the idea behind the learning process is briefly introduced, and then the analogy based on biblical texts is created. The biblical texts using New Revised Standard Version (NRSV) are cited.

1.1. Analogy for Supervised Learning Methods

One of the most popular techniques of artificial intelligence is supervised learning. It has several application fields concerning automated systems, e.g. image and object recognition, prediction of processes, speech recognition. In an automated vehicle context, the most common supervised learning applications are the processing of camera frames, LiDAR clouds,[12] controlling motion, and the energy management of the vehicle.[13]

The idea behind supervised learning-based approaches is to use labelled datasets for training algorithms to classify data or to predict outcomes accurately. The training dataset includes inputs and correct outputs, which allow the model to learn over time. The algorithm measures its accuracy through the loss function, adjusting until the error

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[12] See e.g. KATO, Takeo – NINOMIYA, Yoshiki (2000): An Approach to Vehicle Recognition Using Supervised Learning. *IEICE TRANSACTIONS on Information and Systems*. 83, 7. 1475–1479; SIVARAMAN, Sayanan – TRIVEDI, Mohan Manubhai (2010): A General Active-Learning Framework for On-road Vehicle Recognition and Tracking. In: *IEEE Transactions on Intelligent Transportation Systems*. 11, 2. 267–276; TEICHMAN Alex – THRUN Sebastian (2011): Practical Object Recognition in Autonomous Driving and Beyond. In: *Advanced Robotics and Its Social Impacts*. 35–38; SERNA, Andrés – MARCOTEGUI, Beatriz (2014): Detection, Segmentation and Classification of 3D Urban Objects Using Mathematical Morphology and Supervised Learning. In: *ISPRS Journal of Photogrammetry and Remote Sensing*. 93. 243–255.

[13] PARK, Jonghyun – KIM, Youngjin (2020): Supervised-Learning-Based Optimal Thermal Management in an Electric Vehicle. In: *IEEE Access*. 8. 1290–1302; NÉMETH Balázs – HEGEDŰS Tamás – GÁSPÁR Péter (2021): Design Framework for Achieving Guarantees with Learning-Based Observers. In: *Energies*. 14, 8; NIKULIN, Vsevolod – PODUSENKO, Albert – TANEV, Ivan – SHIMOHARA, Katsunori (2019): Regression-Based Supervised Learning of Autosteering of a Road Car Featuring a Delayed Steering Response. In*: International Journal of Data Science Analitics*. 7. 149–163.

has been sufficiently minimized.[14] An example of the labelled dataset for vehicle detection is illustrated in *Figure 1*, where the result of the training is an agent (in practice, a deep neural network) that is able to classify vehicles on the actual new frames – see e.g. the yellow rectangles in *Figure 1*.

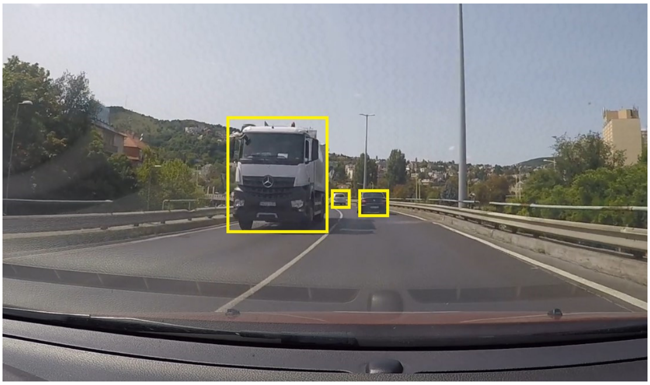

Figure 1. *Example of labelling vehicle objects*

In spite of the several successful applications of supervised learning, it has some limitations. For example, the resulted agent can be easily overfitted. Moreover, the generalization of the learning can be difficult: e.g. if the agent is able to classify vehicles, it cannot be able to classify pedestrians automatically. The problem can be handled with an increased number of categories in the labelling, but it may require a huge number of instances in the dataset. Thus, creating accurate training datasets has a fundamental role in improving the effectiveness of the agent (e.g. avoiding the problem of racial bias).[15] Consequently, supervised learning approaches are based on static rules that are achieved through the training process. In the formulation of the rules, the training dataset has an important role in that it influences the generalization capability of the resulted agent.

[14] DEMUT, H. – HAGAN, M. – BEALE, M. (1997): *Neural Network Design*. Cambridge, PWS Publishing Co.

[15] YUCER, Seyma – AKCAY, Samet – AL-MOUBAYED, Noura – BRECKON, Toby P. (2020): Exploring Racial Bias within Face Recognition via Per-Subject Adversarially-Enabled Data Augmentation. In: *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops*. June. 83–92.

The approach of supervised learning is analogous to ethics, which is based on learning and following strictly predefined rules. Although following rules is an important part of the operation of social systems, strict following can lead to conflicts sometimes. In a traffic context, a simplified problem for illustration purposes is shown in *Figure 2*. In this example, the automated vehicle for following two fundamental rules has been learned. First, lane changing is prohibited in the direction of unbroken dividing lines. Second, it is necessary to keep a safe distance from objects on the road. In the illustrated scenario, the joint following of the rules is possible, but it stops the vehicle and a traffic jam is caused until the unwanted object is not removed from the road. Although stopping the vehicle is acceptable from the aspect of the fundamental rules, it is unacceptable from the viewpoint of a global traffic perspective, i.e. ensuring the functionality of the traffic network.

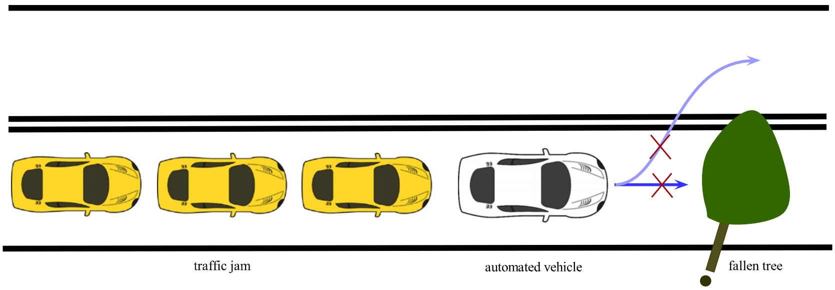

Figure 2. *Illustration of a simplified traffic scenario with conflict*

A quite similar problem of strict rule following is found in the debate of Jesus and the Pharisees in the Gospel of Luke as follows: "But woe to you Pharisees! For you tithe mint and rue and herbs of all kinds, and neglect justice and the love of God; it is these you ought to have practiced, without neglecting the others" (Luke 11:42).

Another scene of a debate is found in the Gospel of Mark: "But you say that if anyone tells father or mother, 'Whatever support you might have had from me is Corban' (that is, an offering to God) – then you no longer permit doing anything for a father or mother, thus making void the word of God through your tradition that you have handed on. And you do many things like this" (Mark 7:11–13).

The context of the debate is the validity of tradition and of the Pharisees' rules, i.e. 613 commandments that the Pharisees have discerned in the Law of Moses. The criticism from Jesus is due to neglecting the love of God, although the formal law is followed. The principle of love of God has the highest priority even if it leads to the violation of the Pharisees' rules. It is quite similar to the problem of a vehicle stopping, where the action originated from the global perspective can sometimes have priority over the action originated from the generally acceptable strict rules. Consequently, supervised learning approaches have limited validity range from an ethical viewpoint, and thus its result based on the guarantees of global performance specifications must be examined.

1.2. Analogy for Unsupervised Learning Methods

Further important types of learning-based methods are unsupervised learning approaches. In spite of supervised learning, it does not require a labelled dataset, and thus the algorithm learns by itself, without supervision. Unsupervised learning algorithms discover hidden patterns or data groupings without the need of external (e.g. human) intervention. Since its ability is to discover similarities and differences in information, its most common application areas are clustering, outlier detecting, and developing association rules.

Focusing on clustering methods, the role of the agent in unsupervised learning is to differentiate groups (clusters) in a given dataset. Nevertheless, the clustering process requires a metric with which each cluster can be characterized. A classical solution is to apply the Euler metric, i.e. computing distances within the elements of the clusters through minimizing cluster diameter, or to use the K-medoid method.[16] A conductance-based metric has been introduced in the work of Kannan,[17] and F-measure using reference clusters has been defined in the work of Radovanović.[18]

An example of the application of unsupervised learning in automated vehicle control is illustrated in *Figure 3*.[19] The presented example is related to the overtaking control

[16] MEGIDDO, Nimrod – SUPOWIT, Kenneth (1984): On the Complexity of Some Common Geometric Location Problems. In: *SIAM Journal on Computing*. 13, 1. 182–196.

[17] KANNAN, Ravi – VEMPALA, Santosh – VETTA, Adrian (2004): On Clusterings: Good, Bad and Spectral. In: *Journal of ACM*. 51, 3. 497–515.

[18] RADOVANOVIĆ, M. (2011): *High-Dimensional Data Representations and Metrics for Machine Learning and Data Mining*. Ph.D. dissertation. University of Novi Sad. 44–66.

[19] Details on the simulations and the measurements can be found in: NÉMETH B. – GÁSPÁR P. – HEGEDŰS T. (2018): Optimal Control of Overtaking Maneuver for Intelligent Vehicles. In: *Journal of Advanced Transportation*.

strategy of an automated vehicle, in which the motion of surrounding human-driven vehicles are predicted. Prediction is based on preliminary datasets on the related pairs of longitudinal acceleration (a_x) and the difference from the reference speed (e_v). The role of the clustering is to differentiate human driving characteristics. The related points, i.e. each cluster with the same colours, are illustrated.

Unsupervised learning is used not only in technological sciences but also in personal relationships and the operation of social systems. For example, in the work of Shafto and Seifert, unsupervised learning is explained in the context of education, i.e. in the relationship between teacher and student.[20] Another example is the analysis of changing fictional relationships in the context of digital era through unsupervised learning.[21] Nevertheless, a crucial problem of all unsupervised learning approaches is the definition of metrics because an inappropriate selection can lead to a higher risk of obtaining inaccurate results. Therefore, in practice, the output variables through human intervention must be validated.

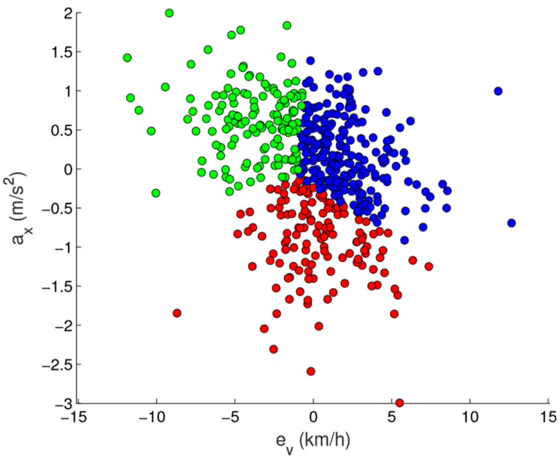

***Figure 3.** Example for the result of a clustering process*

[20] SHAFTO, M. G. – SEIFERT, C. M. (2015): Teacher and Learner: Supervised and Unsupervised Learning in Communities. In: *Behavioral and Brain Sciences*. 38, 64. 1–17.

[21] IYYER, Mohit – GUHA, Anupam – CHATURVEDI Snigdha – BOYD-GRABER, Jordan – DAUMÉ III, Hal (2016): Feuding Families and Former Friends: Unsupervised Learning for Dynamic Fictional Relationships. In: *Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*. San Diego, California, Association for Computational Linguistics. 1534–1544.

The problem of finding an a priori good metric can also be encountered in the Old Testament. In Deuteronomy, before the Hebrews entering Canaan, Moses exhorts them to walking in the way of God:

> See, I have set before you today life and prosperity, death and adversity. If you obey the commandments of the Lord your God that I am commanding you today, by loving the Lord your God, walking in his ways, and observing his commandments, decrees, and ordinances, then you shall live and become numerous, and the Lord your God will bless you in the land that you are entering to possess. (Deut 30:15–16)

In the text, the possible consequences of the ways of the Hebrews are provided, such as life and death. The consequence depends on loving the Lord, which fundamental principle (see the analogy for supervised learning) can be handled as a metric.

From the viewpoint of unsupervised learning approach, the classification of the future depends on this metric, and two consequences (clusters) are possible, namely: life and death. As opposed to supervised learning, the unsupervised learning approach is able to work directly with the fundamental principle, and thus the resulted agent can have an increased generalization potential. Nevertheless, the provided eternal principle, loving the Lord, is somewhat abstract and is difficult to formulate in particular contexts, e.g. as an objective function for automated control systems. Thus, we have come upon a trade-off between the examined supervised and unsupervised learning methods. The approach of supervised learning from an ethical viewpoint can lead to a less general solution but with an easily interpretable objective. The analysed unsupervised learning approach may contain a general eternal objective, but this generality poses challenges against the learning process.

At the end of the analysis of unsupervised learning, a short remark on the abstract characteristics of the principle of loving the Lord is added. In one of his studies, Todd G. Buchholz, the former Director of Economic Policy at the White House, proposed the advantage of the abstract characteristics. He stated that as an abstract religion with an abstract, non-material God, Judaism required the mental manipulation of ideas to a greater extent compared to religions (e.g., Babylonian or Canaanite) that worship suns, moons, or idols. This character of Judaism might also promote minds that would welcome technology, and thus Hebraic law favoured innovation and invention.[22]

1.3. Analogy for Reinforcement Learning Methods

The last selected learning-based approach for the analysis is reinforcement learning. In practice, this approach covers several methods, e.g. value-based methods, policy gradient methods, actor-critic methods, or model-based methods.[23] The core of reinforcement learning is that the agent is trained throughout episodes. During these episodes, the operation of the actual agent and the result of the operation are evaluated. It requires a predefined formulation of the objective of learning, which is the reward function. At the end of each episode, the reward is computed and the agent is improved for maximizing the reward. Thus, in reinforcement learning approach, we will not find a supervisor, but there is a feedback that informs the agent on the successfulness of the learning process.

In an automated vehicle and traffic control context, reinforcement learning has various application possibilities, e.g. traffic light control[24] or cruising on a highway.[25] An illustrative example for the learning of motion strategy in intersections can be found

[22] BUCHHOLZ, Todd G. (1988): Biblical Laws and the Economic Growth of Ancient Israel. In: *Journal of Law and Religion*. 6, 2. 389–427.

[23] See e.g. KIUMARSI, Bahare – VAMVOUDAKIS, Kyriakos G. – MODARES, Hamidreza – LEWIS, Frank L. (2018): Optimal and Autonomous Control Using Reinforcement Learning: A Survey. In: *IEEE Transactions on Neural Networks and Learning Systems*. 29, 6. 2042–2062; KIRAN, B. Ravi – SOBH, Ibrahim – TALPAERT, Victor – MANNION, Patrick – AL SALLAB, Ahmad A. – YOGAMANI, Senthil – PÉREZ, Patrick (2021): Deep Reinforcement Learning for Autonomous Driving: A Survey. In: *IEEE Transactions on Intelligent Transportation Systems*. 1–18.

[24] LIANG, Xiaoyuan – DU, Xunsheng – WANG, Guiling – HAN, Zhu (2019): A Deep Reinforcement Learning Network for Traffic Light Cycle Control. In: *IEEE Transactions on Vehicular Technology*. 68, 2. 1243–1253.

[25] ARADI Szilárd – BÉCSI Tamás – GÁSPÁR Péter (2018): Policy Gradient Based Reinforcement Learning Approach for Autonomous Highway Driving. In: *IEEE Conference on Control Technology and Applications (CCTA)*. 670–675.

in *Figure 4*,[26] where the automated vehicle (blue) must drive in an unsignalized intersection, where there are also human-driven vehicles (green, blue, yellow, red). Due to the increased variety of episodes (number of vehicles, their speed and position, direction of motion), it can be difficult to generate a labelled training dataset for supervised learning. Reinforcement learning is an appropriate method for learning the optimal motion of the automated vehicle, but it requires a large number of episodes. The reward function of the learning process can contain avoidance of collision, consumed energy, comfort of cruising, trip time, etc.

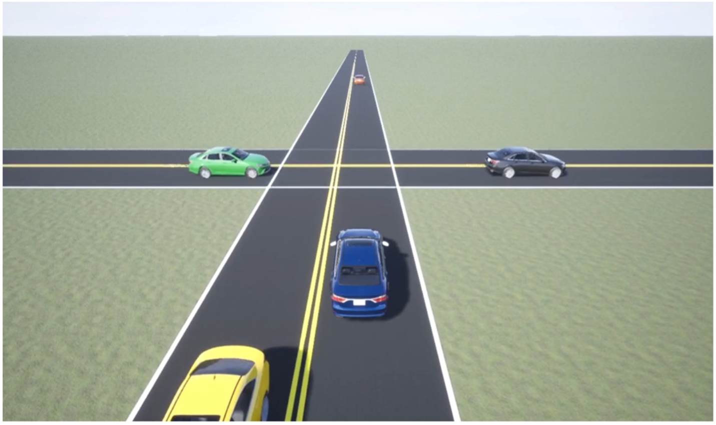

Figure 4. *Illustration of automated vehicle motion in intersection*

Although in many control tasks the formulation of the reward function can be evident, the problem of formulation becomes more difficult if ethical considerations are incorporated. First, it poses again the challenge of an acceptable metric, similarly to unsupervised learning. The reward function has to inform the agent of the successfulness of learning; but what should lead to a positive or a negative reward? For example, avoiding collision is a positive reward, but if collision cannot be avoided, which kind of action can lead to the maximization of the reward? This takes us to the problem of good and bad, similarly to the life and death in the analysis of unsupervised learning. Therefore,

[26] Details on control methodology and the simulation example can be found in: NÉMETH Balázs – GÁSPÁR Péter (2021): The Design of Performance Guaranteed Autonomous Vehicle Control for Optimal Motion in Unsignalized Intersections. *Applied Sciences*. 11, 8.

the first challenge is quite similar to the challenge of unsupervised learning. Second, a special challenge of reinforcement learning is a necessity of the episodes. Since the learning process can require a large number of episodes, some of them can lead to unacceptable results with low reward. Although, before the implementation of an agent, this must be validated through several scenarios, in a real environment context, the almost perfect operation requires lifelong learning with a constantly increasing number of episodes. In practice, the development time of a product is limited, which means that the reinforcement learning process of an agent after a limited number of episodes must be stopped, and, probably, further updates of the automatic control can be applied. The second ethical challenge is based on the limitation of episode numbers. For example, in the case of a vehicle control application, the following question can be posed: how many accidents should it take to achieve a more accurate control system?

In the rest of this section, some analogies between biblical texts and the approach of reinforcement learning are proposed. In several biblical texts, learning can be interpreted in the life of people of God. Specific examples are the prophets in the Old Testament. The role of the prophets is to interpret the actual historical context and the intentions, actions of Hebrews in the light of the principle of loving God.[27] Thus, from the viewpoint of reinforcement learning, the actor in the learning structure is the people of God, and the critic-agent is the actual prophet. In most of the prophetical texts, the ungrateful role of the prophet is to give a negative reward, which created dangerous situations for them: see e.g. the Book of Jeremiah. The learning process for achieving the goal, i.e. walking in the ways of God, contained a large number of episodes throughout the centuries. In spite of the increased number of real scenarios, the people of God was unable to achieve perfection. From a theological viewpoint, this has clearly demonstrated the necessity of redemption, which is given by Jesus Christ through his death and resurrection. The Parable of the Tenants (see Gospel of Mark 12:1–12) also illustrates this tendency.

Analogies for reinforcement learning in the stories of the New Testament can also be found. The stories of the Gospels show that becoming a disciple, an apostle of Jesus requires a learning process. Since Jesus calls the disciples to follow him, not to imitate him, reinforcement learning provides a more precise analogy instead of supervised learning for

[27] SOGGIN, Alberto J. (1987): *Introduction to the Old Testament.* Westminster, John Knox Press.

discipleship. Imitation is found in some texts of the Pauline Letters; see the analysis of Bohren.[28] Being with Jesus (and later with his Holy Spirit) in real-world scenarios provides the environment for learning to become a disciple, which can be achieved through episodes. It can be also seen in the life of Paul, e.g. in the statement of his mission: "He is an instrument whom I have chosen to bring my name before Gentiles and kings and before the people of Israel; I myself will show him how much he must suffer for the sake of my name" (Acts 9:15–16).

In this text, *I myself will show him* and *suffering* reflect a learning process, which is an own way of Paul as an apostle. The episodes, whose results are suffering and experiencing the strength of God in the mission, can be read in the Acts of Apostles and in the Pauline Letters. If we can draw a parallel between Paul's life and mission and a reinforcement learning process, which can guarantee the successfulness of the learning? Paul provides an answer to this in the Romans: "I am convinced that neither death, nor life, nor angels, nor rulers, nor things present, nor things to come, nor powers, nor height, nor depth, nor anything else in all creation, will be able to separate us from the love of God in Christ Jesus our Lord" (Romans 8:38–39).

Thus, the guarantee of convergence in the learning process is the election of grace. The root of ethical problems in automated control systems is the fact that it is impossible to formulate an election of grace, not just through a mathematical representation but also through all representations of the world. It is the secret of God, inside of his sovereignty.

Finally, a brief remark on the *Confessions of Augustine* is made concerning reinforcement learning. Through the analysis of the Confession, Sain showed that it is possible to set up control theoretical models of human will.[29] Especially in the selected texts of the Confessions, the difficulties of the decision to follow Jesus, i.e. the nature of will, are examined. The proposed analogy is based on control theory, which contains a feedback loop with the actual "value of will". From an ethical viewpoint, the role of feedback

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28 BOHREN, Rudolf (1971): *Predigtlehre*. Gütersloher Verlagshaus. 390–394

29 SAIN, Barbara K. (2008): Theology and Engineering: A Conversation in Two Languages. In: Won, C.-H. – Schrader, C. B. – Michel, A. N. (eds.) *Advances in Statistical Control, Algebraic Systems Theory, and Dynamic Systems Characteristics*. Birkhäuser. 319–330.

in this concept is close to the role of reward, i.e. to provide information on the actual human state. Thus, analogies of reinforcement learning, based on the history of people of God after the biblical times, may be formed.

Consequences of the Analogy-Based Analysis

The analogy-based theological analysis of the most relevant learning-based approaches leads to consequences for automated control systems. In this section, three consequences are highlighted that have relevance on the design of automated vehicle control systems.

1.4. Difficulty of Forming a Control Objective

The analysis of unsupervised learning and reinforcement learning approaches has led to the problem of finding an appropriate metric or a reward function, which can be difficult. The outlined analogy for unsupervised learning resulted in a choice between life and death, which can be performed through the metric of loving the Lord. Moreover, the formulation of reward in reinforcement learning has also led to a selection problem involving positive reward.

The first consequence of the analogy-based analysis is that in complex real-world scenarios it is difficult to form an appropriate control objective, leading to an ethical operation of the automatic control. On the level of biblical texts and theological thought, the problem of good and bad comes up, which is out of scope for control engineering science. Furthermore, from a biblical viewpoint, the absolute knowing of good and bad is in the authority of God, because good is his own characteristic – e.g. Jesus states: "No one is good but God alone" (Mark 10:18b). Nevertheless, man has limited knowledge on good and bad, which roots in the sin of Adam and Eve – see "the Lord God said, 'See, the man has become like one of us, knowing good and evil'" (Gen 3:22). Asking God to achieve this limited knowledge is also found in the Prayer of Solomon: "Give your servant therefore an understanding mind to govern your people, able to discern between good and evil; for who can govern this your great people?" (1 King 3:9).

The relevance of this text on control problems is based on the purpose of this prayer, i.e. governance with wisdom, which is in parallel with the control with good objectives. Finally, Apostle Paul reflects also on the problem of good and bad: “I can will what is right, but I cannot do it. For I do not do the good I want, but the evil I do not want is what I do” (Romans 7:18–19). This text reflects the discrepancy between having knowledge about what is good and acting in a good way.

The proposed biblical texts confirm the consequence of the analysis that in complex real-world scenarios it is impossible, or at least extremely difficult, to form such objectives for automatic control systems that would meet the specifications of biblical ethics. Nevertheless, in simplified real-world scenarios, these objectives can be formed. For example, in case of a reinforcement learning approach to a cruise control system in signalized intersections, the reward can be formed. In this case, a positive reward is given if the vehicle stopped at the red light and a negative reward if it did not stop. As a counterexample, the classification of good and bad instances to achieve an appropriate decision tree for lateral vehicle control systems is not trivial.[30] If the formulation of acceptable objectives for simplified vehicle control tasks is not an easy problem, then the formulation of a technically, economically, and ethically acceptable control objective in complex multi-vehicle scenarios with human participants can be extremely difficult.

1.5. Difficulty of Considering Human Objectives in Control

The second consequence of the analysis provides a deeper insight into the problem of designing automatic control systems. It is based on the previous consequence, i.e. the difficulty of forming control objective. From a biblical viewpoint, “the whole world lies under the power of the evil one” (1 John 5:19), which statement is rooted in original sin. Therefore, this corruption is valid for the entire human being (i.e. body, thinking, intentions, etc.), nobody is free from it (Romans 5:12), and thus it appears in the control objectives formed by humans.

[30] See e.g. FÉNYES Dániel – NÉMETH Balázs – GÁSPÁR Péter (2021): Design of LPV Control for Autonomous Vehicles Using the Contributions of Big Data Analysis. In: *International Journal of Control.* 1–12.

The problem of sin leads to two consequences for the objectives of control systems. First, the objective of imitating human decisions or human acts can have a limited validity range through an automatic control. It is closely related to the examined problem of supervised learning approaches. In case of simplified scenarios, e.g. recognizing vehicles on a camera frame, humans can provide appropriate objectives such as labelling vehicles on a frame; but imitation learning approaches in automated driving control (e.g. steering) have their own limitations. They can be adopted under normal driving scenarios, but in extreme manoeuvring human intervention is generally unacceptable. However, in complex real-world scenarios involving accidents and dangerous traffic situations, the decisions and actions of humans might not be used as samples for learning. Thus, the imitation of human acts and decisions can have serious limitations in an automatic vehicle control system. Second, the corruption of the human mind has imprints on the formulation of the control objectives. Since all of the control objectives are formed by humans, corruption emerges in all control systems. Thus, from a biblical ethical viewpoint, it is impossible for humans to formulate an absolute good objective. Augustine puts this as *non posse non peccare*, i.e. 'not able not to sin'. The only way out of this status is the redemption by Jesus Christ, which can confer the individuals of the people of God the status of *posse non peccare*, i.e. 'able not to sin'. Martin Luther argues that in this status humans are *simul iustus et peccator*, i.e. 'simultaneously righteous and sinners'. John Calvin formulates the problem in a slightly different manner, i.e. from the viewpoint of the Fall: "For although there is still some residue of intelligence and judgement as well as will, we cannot call a mind sound and entire which is both weak and immersed in darkness."[31]

This is followed by the Second Helvetic Confession, Chapter IX, stating: "…in external things both the regenerate and the unregenerate enjoy free will. For man has in common with other living creatures (to which he is not inferior) this nature to will some things and not to will others. Thus he is able to speak or to keep silent, to go out of his house or to remain at home, etc. However, even here God's power is always to be observed…"[32]

[31] See the analysis of: BONEVAC, Daniel (2021): John Calvin's Multiplicity Thesis. In: *Religions.* 12, 6.

[32] COCHRANE, Arthur C. (ed.). (2003): *Reformed Confessions of the Sixteenth Century*. Westminster, John Knox Press.

Thus, humans have a highly limited capability for setting appropriate control objectives in an ethical sense.

What follows the second consequence, i.e. the difficulty of considering human objectives in control? The answer is embarrassment and release at the same time: in the automation process, the fact of imperfection must be taken into account. All automation purposes suffer under the corruption due to sin, and thus imperfection is imprinted in the entire automation process from a biblical ethical viewpoint. Nevertheless, it releases control engineers from the pressure of designing a perfect automated system. Designers must strive for fault-tolerant, economical, and enhanced systems. Automated vehicles must be as safe as possible, in which control designers have a certain responsibility, but absolutely fault-free solutions cannot be achieved, independently from the selection of control objectives.

1.6. Viewing Systems in All Their Complexity

The third consequence of the analysis is related to the previous one, i.e. handling ethical considerations in control design requires viewing systems in all their complexity. Since original sin – from a biblical-ethical viewpoint – has an impact on all systems, this impact coming only from their subsystems can be excluded through control design. In the case of vehicle control systems, human life can be made easier through automation. For example, there are at least 2.2 billion people living with vision impairment or blindness – see the report of the World Health Organization.[33] Vision impairment has a significant influence on driving safety, which safety level can be improved through automated driving functionality with camera- and LiDAR-based vision systems. Moreover, fully autonomous driving provides equality in transportation for blind and non-blind people. On this level of transportation system, i.e. on the vehicle automation level, the imperfection of human body can be done away with. Nevertheless, it might pose two challenges on higher transportation levels. First, it induces an increased transportation demand with increased environmental impact and load on the roads, which requests an improved traffic control management. Second, high-level automation poses the challenge of

[33] World Health Organization (2019): *World Report on Vision*. Technical report. www.who.int/publications/i/item/9789241516570 (last accessed on: 27/09/2021).

decision making in dangerous situations by control systems, as has been analysed previously. Although the problem is handled within a subsystem, i.e. on the vehicle control level, it has not been solved regarding the whole system, i.e. on the global transportation level.

The ethical challenges posed by automation cannot be handled only on individual and moral levels, as they reflect a global level of the complex system. From a theological viewpoint, automation is in connection not only with individual and moral sin but also with structural sin. Therefore, a design of automated control systems requires the consideration of the system in all of its complexity. Unfortunately, this can be difficult in practice because reduced-order models are used in the design process of automated control systems. Moreover, for handling ethical problems in control engineering, it is recommended to have, besides expertise in technological fields, a proper knowledge in social, psychological, philosophical, theological, etc. studies. Consequently, the complex socio-technical transportation system during the control design process of automated vehicles must be incorporated.

Application of the Findings in a Vehicle Control Problem

Finally, in this section, the achieved results of the analysis in a vehicle control problem are applied. In the application example, the automated vehicle has to select its route in a dangerous situation.[34] The route selection poses an ethical problem because all scenarios result in accidents. Accident outcomes are different in their nature and severity, which poses the following ethical questions: Is there a good selection? If yes, how can it be determined?

Before presenting the application, some remarks on the selected ethical problem must be made. Although the popular culture of artificial intelligence is well aware of the selected ethical problem of automated vehicles and several papers deal with it, it has some unrealistic characteristics from an engineering viewpoint.[35] First, in the case of automated vehicles, it is supposed that if there is a critical fault in the vehicle (e.g. actuator or sensor),

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[34] Several examples for each dangerous situation can be found in: AWAD 2018, 59–64.

[35] See also: DAVNALL, Rebecca (2020): The Car's Choice: Illusions of Agency in the Self-Driving Car Trolley Problem. In: *Artificial Intelligence. Reflections in Philosophy, Theology – The Social Sciences*. Brill. 189–202.

it cannot be started, or it operates with reduced functionality. Thus, due to the advanced fault detection algorithms and fault-tolerant control system, the risk of a fatal accident is significantly reduced.[36] Second, the goal of the automated vehicle control is to avoid the possibility of critical manoeuvring, i.e. the motion of the vehicle must be kept far from critical vehicle dynamic situations.[37] Consequently, the risk of an accident caused by an automated vehicle (e.g. through an actuator fault) is very low, but not zero. The design of automated vehicle control poses further relevant ethical problems such as their applications in military context[38] or their impact on the labour market.[39] Moreover, automation increases alienation between humans and their tools,[40] induced data privacy problems,[41] and, finally, the automated vehicles may increase social inequality.[42] Although automated vehicles induce a whole range of ethics-related challenges, the selected problem illustrates well

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36 Rajamani, R. – Howell, A. S. – Chen, Chieh – Hedrick, J. K. – Tomizuka, M. (2001): A Complete Fault Diagnostic System for Automated Vehicles Operating in a Platoon. In: *IEEE Transactions on Control Systems Technology*. 9, 4. 553–564; Fang, Yukun – Min, Haigen – Wang, Wuqi – Xu, Zhigang – Zhao, Xiangmo (2020): A Fault Detection and Diagnosis System for Autonomous Vehicles Based on Hybrid Approaches. In: *IEEE Sensors Journal*. 20, 16. 9359–9371; Boukhari, Mohamed Riad – Chaibet, Ahmed – Boukhnifer, Moussa – Glaser, Sébastien (2018): Proprioceptive Sensors' Fault Tolerant Control Strategy for an Autonomous Vehicle. In: *Sensors*. 18, 6.

37 Németh 2018; Fényes 2021, 1–12.

38 Johansson, Linda (2018): Ethical Aspects of Military Maritime and Aerial Autonomous Systems. *Journal of Military Ethics*. 17, 2–3. 140–155.

39 Nikitas, Alexandros – Vitel, Alexandra-Elena – Cotet, Corneliu (2021): Autonomous Vehicles and Employment: An Urban Futures Revolution or Catastrophe? In: *Cities*. 114. 103203.

40 Coeckelbergh, M. (2015): The Tragedy of the Master: Automation, Vulnerability, and Distance. In: *Ethics and Information Technology*. 17. 219–229.

41 Costantini, Federico – Thomopoulos, Nikolas – Steibe, Fabro – Curl, Angela – Lugano, Giuseppe – Kováčiková, Tatiana (2020): Autonomous Vehicles in a GDPR Era: An International Comparison. In: Milakis, Dimitris – Thomopoulos, Nikolas – van Wee, Bert (eds.): *Policy Implications of Autonomous Vehicles*. Vol. 5. 191–213 (series: Advances in Transport Policy and Planning [series ed.: Van Wee, Bert]). Academic Press.

42 Bissell, David – Birtchnel, Thomas – Elliott, Anthony – Hsu, Eric L. (2020): Autonomous automobilities: The Social Impacts of Driverless Vehicles. *Current Sociology*. 68, 1. 116–134.

the possible contributions of the proposed analogy-based analysis in an engineering context. Furthermore, the selection of the ethical problem driven by my personal interest as a researcher in the field of vehicle control is also well grounded.

The core of the decision problem is the formulation of the objective in the automated vehicle control design. In critical situations, the automated system must take a decision, and thus it is requested to find an algorithm that results in a good decision. Nevertheless, the formulation of a control objective resulting in a good automated decision is problematic – see the results of the analogy-based analysis in Section 3, suggesting that neither an optimal control nor an imitation of human behaviour can result in absolute good decision. Therefore, in critical fatal situations, adopting a random decision might be a way to go, which is a random selection of the vehicle route in the case of automated vehicles.

Some biblical thoughts confirm the legitimacy of resorting to randomness. The practice of using Urim and Thummim is a special way to ask the will of God. Although there are lots of open discussions in this field,[43] using Urim and Thummim presumes randomness, as one of the conventional forms of decision – see e.g. Numbers 4:27 or Ezra 2:63. Moreover, choosing Matthias as an apostle also reflects the old tradition: "And they cast lots for them, and the lot fell on Matthias" – see Acts 1:26. In spite of the random outcome of lot, it can be acknowledged as a decision of God, as in: "The lot is cast into the lap, but the decision is the Lord's alone." – see Proverbs 16:33. It is a common interpretation of random events, and it has become part of the Christian tradition as well. Since randomness is under the governance of God, it can be included under the topic of His providence.[44] The legitimacy of randomness in theological contexts is also underlined by the works of Bradley.[45] Although randomness in popular discourse seems to be analogous

[43] See e.g. VAN DAME, Cornelis (1997): *The Urim and Thummim: A Means of Revelation in Ancient Israel.* Eisenbrauns; HOUTMAN, C. (1990): The Urim and Thummim: A New Suggestion. In: *Vetus Testamentum.* 40, 2. 229–232.

[44] RUSSELL, Robert John – MORITZ, Joshua M. (eds.). (2019): *God's Providence and Randomness in Nature: Scientific and Theological Perspectives.* Templeton Press.

[45] BRADLEY, James (2012): Randomness and God's Nature. In: *Perspectives on Science and Christian Faith.* 64, 2. 75–89; BRADLEY, James (2016): Random Numbers and God's Nature. In: Giberson, Karl W. (ed.): *Abraham's Dice: Chance and Providence in the Monotheistic Traditions.* Oxford, Oxford University Press.

to unpredictability, irregularity, and unsystematic thought, it can be formed as part of the nature of God. This statement is based on the omniscience of God and on creation, and it presupposes the viewpoint of Christian Platonism.

In summary, interpreting random decision as a way to respect the decision of God, under the faith in His providence, especially in critical situations, is close to the Christian thought. In the rest of this paper, the concept of a multi-level automated vehicle control structure is introduced, which involves random decisions. The concept of the control structure contains the following layers:

1. The first layer is in relation with the conventional control strategies of automated vehicles. In normal traffic scenarios, without critical or dangerous situations, the vehicle is driven through control systems with well-defined objectives. In case of a route selection problem, the objective of the control contains the avoidance of collision, the eco-driving motion, and the minimization of the travelling time.[46]
2. The second layer is related to control strategies when an accident is unavoidable, but an accident scenario without fatal injury can be attained.[47] This falls into the topic of crash protection, e.g. for passengers, cyclists, pedestrians, etc.[48] In this case, it is necessary to select the route for the automated vehicle, which results in the smallest expected injury for the participants.
3. The third layer handles the traffic scenarios that are unavoidable without a fatal accident. In this case, the scenarios, i.e. route selection through objectives, are not examined but a random scenario (route) is selected. Random selection is generated by an algorithm on the vehicle, which poses some mathematical challenges.[49]

A random algorithmic process of machines cannot be equal to the will of God, but it is recommended to view the scenario in its context – see e.g. an illustrative scenario in *Figure 5*. In the scenario, the automated vehicle is driven along a road section with

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46 See e.g. NÉMETH 2018; THORNTON 2017, 1429–1439.

47 REZAPOUR, Mahdi – MOOMEN, Milhan – KSAIBATI, Khaled (2019): Ordered Logistic Models of Influencing Factors on Crash Injury Severity of Single- and Multiple-Vehicle Downgrade Crashes: A Case Study in Wyoming. In: *Journal of Safety Research*. 68. 107–118.

48 ITO, Daisuke – YOKOI, Yusuke – MIZUNO, Koji (2015): Crash Pulse Optimization for Occupant Protection at Various Impact Velocities. In: *Traffic Injury Prevention*. 16, 3. 260–267.

49 BRADLEY 2016, 59–83.

bottleneck due to a concrete Jersey barrier. There is also an inattentive pedestrian in the traffic situation, who crosses the road when the vehicle is within stopping distance. The traffic scenario can have two outcomes, namely: either the pedestrian or the passenger of the vehicle gets injured. Both scenarios result in fatal accident and the automated vehicle must decide on its route. In the context of the scenario, the probability of each event can be calculated with the help of a product of more probability values. It can be defined a probability value E_1, which describes that an automated vehicle on a given road segment is driven. E_2 is a further probability value, which characterizes the chance that the pedestrian is also on the given road segment. The probability value of the pedestrian's inattention is E_3. The probability value of the fault that the automated vehicle control system does not recognize the intention of the pedestrian in advance is E_4. And, finally, E_5 probability value characterizes the decision of the algorithm. Therefore, at least five probability values are defined of which four components are real-world random events. Considering that the components are independent from each other, the total probability value is $E = E_1 \cdot E_2 \cdot E_3 \cdot E_4 \cdot E_5$. This means that component E_5 does not modify significantly the natural random character of the traffic scenario.

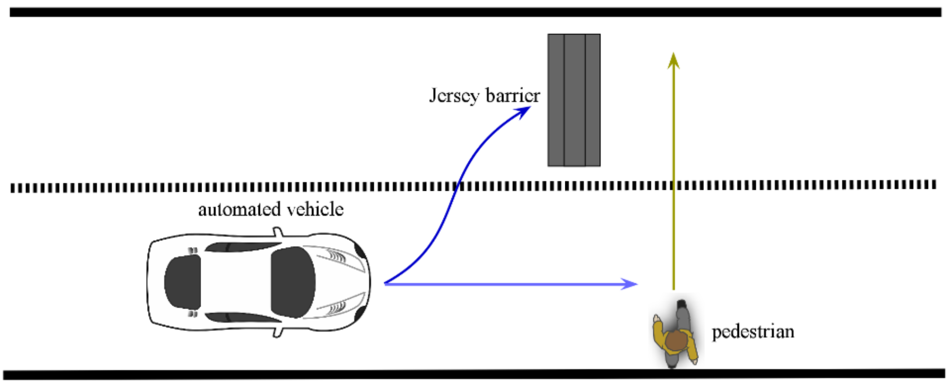

Figure 5. *Illustration of a critical traffic scenario*

Note that the previous ethical problem can be approached from a responsibility point of view. Nevertheless, in the previous example, all participants of the fatal accident can have responsibility. The pedestrian has responsibility for not paying attention. Responsibility for the inaccurate recognition of the pedestrian's intention is an open problem. It can be resulted from design problems, so in this case the producer has responsibility. But the owner (i.e. the passenger) of the vehicle can also have responsibility if e.g. the service periods of the vehicle are ignored. Therefore, the evaluation of the responsibility cannot lead to a better route selection algorithm.

Conclusions

The present paper proposed an analysis of some ethical challenges of automated vehicle control systems, based on biblical analogies. The analysis focused on the objective of the control design. Three learning-based methods have been examined, with which most of the learning-based automated vehicle control methods can be covered: supervised learning, unsupervised learning, and reinforcement learning. It has been stated that biblical analogies for all these approaches can be created. The analogies considered have led to three consequences that are related to the difficulty of forming a control objective, the difficulty of considering human objectives in control, and the necessity of viewing systems in all their complexity.

Finally, an application of the findings concerning the outlined vehicle control problem has been proposed. In the example given, a multi-layer control concept for handling critical situations has been recommended, which uses random selection in one of its layers. An open problem – and thus a further challenge of the research – is to find a detection method with which the seriousness of the actual vehicle dynamic and traffic scenario can be evaluated. Particularly crucial is the reconfiguration of control strategies between the second and the third layer. It is also a challenge for the research to find random generation algorithms whose results are close to the characteristics of a natural random event. Furthermore, a fundamental role of the research from an ethical viewpoint is to design enhanced control algorithms with the help of which critical situations can be prevented. It is necessary to strive for keeping the operation of the control in the first layer of the structure during the motion of the vehicle. At the same time, it is also necessary to be aware of the proposed theological consequence that this goal might not be achieved in the entire lifespan of the vehicle.

References:

ANDERSON, William H. U. (2021): *Technology and Theology*. Vernon Press.

ARADI Szilárd – BÉCSI Tamás – GÁSPÁR Péter (2018): Policy Gradient Based Reinforcement Learning Approach for Autonomous Highway Driving. In: *IEEE Conference on Control Technology and Applications (CCTA)*. 670–675.

AWAD, E. – DSOUZA, S – KIM, R. – SCHULZ, J. – HENRICH, J. – SHARIFF, A. – BONNEFON, J-F. – RAHWAN, I. (2018): The Moral Machine Experiment. In: *Nature*. 563, 59–64.

BISSELL, David – BIRTCHNEL, Thomas – ELLIOTT, Anthony – HSU, Eric L. (2020): Autonomous automobilities: The Social Impacts of Driverless Vehicles. *Current Sociology*. 68, 1. 116–134.

BOHREN, Rudolf (⁶1971): *Predigtlehre*. Gütersloher Verlagshaus.

BOJARSKI, Mariusz – DEL TESTA, Davide – DWORAKOWSKI, Daniel – FIRNER, Bernhard – FLEPP, Beat – GOYAL, Prasoon – JACKEL, Lawrence D. – MONFORT, Mathew – MULLER, Urs – ZHANG, Jiakai – ZHANG, Xin – ZHAO, Jake – ZIEBA, Karol (2016): *End to End Learning for Self-Driving Cars*. www.arxiv.org/abs/1604.07316 (last accessed on: 27/09/2021).

BONEVAC, Daniel (2021): John Calvin's Multiplicity Thesis. In: *Religions*. 12, 6.

BONNEFON, Jean-Francois – SHARIFF, Azim – RAHWAN, Iyad (2019): The Trolley, the Bull Bar, and Why Engineers Should Care about the Ethics of Autonomous Cars. *Proceedings of the IEEE*. 107, 3. 502–504.

BOUKHARI, Mohamed Riad – CHAIBET, Ahmed – BOUKHNIFER, Moussa – GLASER, Sébastien (2018): Proprioceptive Sensors' Fault Tolerant Control Strategy for an Autonomous Vehicle. In: *Sensors*. 18, 6.

BRADLEY, James (2012): Randomness and God's nature. In: *Perspectives on Science and Christian Faith*. 64, 2. 75–89.

(2016): Random Numbers and God's Nature. In: Giberson, Karl W. (ed.): *Abraham's Dice: Chance and Providence in the Monotheistic Traditions*. Oxford, Oxford University Press.

BUCHHOLZ, Todd G. (1988): Biblical Laws and the Economic Growth of Ancient Israel. In: *Journal of Law and Religion*. 6, 2. 389–427.

COCHRANE, Arthur C. (ed.). (²2003): *Reformed Confessions of the Sixteenth Century*. Westminster, John Knox Press.

COECKELBERGH, M. (2015): The Tragedy of the Master: Automation, Vulnerability, and Distance. In: *Ethics and Information Technology*. 17. 219–229.

COSTANTINI, Federico – THOMOPOULOS, Nikolas – STEIBE, Fabro – CURL, Angela – LUGANO, Giuseppe – KOVÁČIKOVÁ, Tatiana (2020): Autonomous Vehicles in a GDPR Era: An International Comparison. In: Milakis, Dimitris – Thomopoulos, Nikolas – van Wee, Bert (eds.): *Policy Implications of Autonomous Vehicles*. Vol. 5. 191–213 (series: *Advances in Transport Policy and Planning* [series ed.: Van Wee, Bert]). Academic Press.

DAVNALL, Rebecca (2020): The Car's Choice: Illusions of Agency in the Self-Driving Car Trolley Problem. In: *Artificial Intelligence. Reflections in Philosophy, Theology – The Social Sciences*. Brill. 189–202.

DEMUT, H. – HAGAN, M. – BEALE, M. (1997): *Neural Network Design*. Cambridge, PWS Publishing Co.

FANG, Yukun – MIN, Haigen – WANG, Wuqi – XU, Zhigang – ZHAO, Xiangmo (2020): A Fault Detection and Diagnosis System for Autonomous Vehicles Based on Hybrid Approaches. In: *IEEE Sensors Journal.* 20, 16. 9359–9371.

FÉNYES Dániel – NÉMETH Balázs – GÁSPÁR Péter (2021): Design of LPV Control for Autonomous Vehicles Using the Contributions of Big Data Analysis. In: *International Journal of Control.* 1–12.

FUREY, H. – HILL, S. (2021): MIT's Moral Machine Project Is a Psychological Roadblock to Self-Driving Cars. In: *AI and Ethics*. 1. 151–155.

GREEN, Ronald M. (1999): Jewish and Christian Ethics: What Can We Learn from One Another? In: *The Annual of the Society of Christian Ethics*. 19. 3–18.

HOUTMAN, C. (1990): The Urim and Thummim: A New Suggestion. *Vetus Testamentum*. 40, 2. 229–232.

ITO, Daisuke – YOKOI, Yusuke – MIZUNO, Koji (2015): Crash Pulse Optimization for Occupant Protection at Various Impact Velocities. In: *Traffic Injury Prevention*. 16, 3. 260–267.

IYYER, Mohit – GUHA, Anupam – CHATURVEDI Snigdha – BOYD-GRABER, Jordan – DAUMÉ III, Hal (2016): Feuding Families and Former Friends: Unsupervised Learning for Dynamic Fictional Relationships. In: *Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*. San Diego, California, Association for Computational Linguistics. 1534–1544.

JOHANSSON, Linda (2018): Ethical Aspects of Military Maritime and Aerial Autonomous Systems. *Journal of Military Ethics*. 17, 2–3. 140–155.

KANNAN, Ravi – VEMPALA, Santosh – VETTA, Adrian (2004): On Clusterings: Good, Bad and Spectral. In: *Journal of ACM*. 51, 3. 497–515.

KATO, Takeo – NINOMIYA, Yoshiki (2000): An Approach to Vehicle Recognition Using Supervised Learning. *IEICE TRANSACTIONS on Information and Systems*. 83, 7. 1475–1479.

KESKIN, Musa Furkan – PENG, Bile – KULCSÁR, Balázs – WYMEERSCH, Henk (2020): Altruistic Control of Connected Automated Vehicles in Mixed-Autonomy Multi-Lane Highway Traffic. *IFAC-PapersOnLine*. 53, 2. 14966–14971.

KIRAN, B. Ravi – SOBH, Ibrahim – TALPAERT, Victor – MANNION, Patrick – AL SALLAB, Ahmad A. – YOGAMANI, Senthil – PÉREZ, Patrick (2021): Deep Reinforcement Learning for Autonomous Driving: A Survey. In: *IEEE Transactions on Intelligent Transportation Systems*. 1–18.

KIUMARSI, Bahare – VAMVOUDAKIS, Kyriakos G. – MODARES, Hamidreza – LEWIS, Frank L. (2018): Optimal and Autonomous Control Using Reinforcement Learning: A Survey. In: *IEEE Transactions on Neural Networks and Learning Systems*. 29, 6. 2042–2062.

LIANG, Xiaoyuan – DU, Xunsheng – WANG, Guiling – HAN, Zhu (2019): A Deep Reinforcement Learning Network for Traffic Light Cycle Control. In: *IEEE Transactions on Vehicular Technology*. 68, 2. 1243–1253.

LIN, Patrick – ABNEY, Keith – JENKINS, Ryan (2017): *Robot Ethics 2.0: From Autonomous Cars to Artificial Intelligence*. Oxford, Oxford Scholarship Online.

MAURER, Markus – GERDES, J. Christian – LENZ, Barbara – WINNER, Hermann (2016): *Autonomous Driving: Technical, Legal and Social Aspects*. Berlin–Heidelberg, Springer.

MEGIDDO, Nimrod – SUPOWIT, Kenneth (1984): On the Complexity of Some Common Geometric Location Problems. In: *SIAM Journal on Computing*. 13, 1. 182–196.

NÉMETH Balázs – GÁSPÁR Péter – HEGEDŰS Tamás (2018): Optimal Control of Overtaking Maneuver for Intelligent Vehicles. In: *Journal of Advanced Transportation*.

NÉMETH Balázs – GÁSPÁR Péter (2021): The Design of Performance Guaranteed Autonomous Vehicle Control for Optimal Motion in Unsignalized Intersections. *Applied Sciences*. 11, 8.

NÉMETH Balázs – HEGEDŰS Tamás – GÁSPÁR Péter (2021): Design Framework for Achieving Guarantees with Learning-Based Observers. In: *Energies*. 14, 8.

NIKITAS, Alexandros – VITEL, Alexandra-Elena – COTET, Corneliu (2021): Autonomous Vehicles and Employment: An Urban Futures Revolution or Catastrophe? In: *Cities*. 114. 103203.

NIKULIN, Vsevolod – PODUSENKO, Albert – TANEV, Ivan – SHIMOHARA, Katsunori (2019): Regression-Based Supervised Learning of Autosteering of a Road Car Featuring a Delayed Steering Response. In: *International Journal of Data Science Analitics*. 7. 149–163.

PARK, Jonghyun – KIM, Youngjin (2020): Supervised-Learning-Based Optimal Thermal Management in an Electric Vehicle. In: *IEEE Access*. 8. 1290–1302.

RADOVANOVIĆ, M. (2011): *High-Dimensional Data Representations and Metrics for Machine Learning and Data Mining*. Ph.D. dissertation. University of Novi Sad.

RAJAMANI, R. – HOWELL, A. S. – CHEN, Chieh – HEDRICK, J. K. – TOMIZUKA, M. (2001): A Complete Fault Diagnostic System for Automated Vehicles Operating in a Platoon. In: *IEEE Transactions on Control Systems Technology*. 9, 4. 553–564.

REED, Randall (2021): A.I. in Religion, A.I. for Religion, A.I. and Religion: Towards a Theory of Religious Studies and Artificial Intelligence. In: *Religions*. 12, 6.

REZAPOUR, Mahdi – MOOMEN, Milhan – KSAIBATI, Khaled (2019): Ordered Logistic Models of Influencing Factors on Crash Injury Severity of Single- and Multiple-Vehicle Downgrade Crashes: A Case Study in Wyoming. In: *Journal of Safety Research*. 68. 107–118.

RUSSELL, Robert John – MORITZ, Joshua M. (eds.). (2019): *God's Providence and Randomness in Nature: Scientific and Theological Perspectives*. Templeton Press.

SAIN, Barbara K. (2008): Theology and Engineering: A Conversation in Two Languages. In: Won, C.-H. – Schrader, C. B. – Michel, A. N. (eds.) *Advances in Statistical Control, Algebraic Systems Theory, and Dynamic Systems Characteristics*. Birkhäuser. 319–330.

SERNA, Andrés – MARCOTEGUI, Beatriz (2014): Detection, Segmentation and Classification of 3D Urban Objects Using Mathematical Morphology and Supervised Learning. In: *ISPRS Journal of Photogrammetry and Remote Sensing*. 93. 243–255.

SHAFTO, M. G. – SEIFERT, C. M. (2015): Teacher and Learner: Supervised and Unsupervised Learning in Communities. In: *Behavioral and Brain Sciences*. 38, 64. 1–17.

SIVARAMAN, Sayanan – TRIVEDI, Mohan Manubhai (2010): A general active-learning framework for on-road vehicle recognition and tracking. *IEEE Transactions on Intelligent Transportation Systems*, 11.2, 267–276.

SOGGIN, Alberto J. ([3]1987): *Introduction to the Old Testament*. Westminster, John Knox Press.

TEICHMAN Alex – THRUN Sebastian (2011): Practical Object Recognition in Autonomous Driving and Beyond. In: *Advanced Robotics and Its Social Impacts*. 35–38.

THORNTON, S. M. – PAN, S. – ERLIEN, S. M. – GERDES, J. C. (2017): Incorporating Ethical Considerations into Automated Vehicle Control. *IEEE Transactions on Intelligent Transportation Systems*. 18, 6. 1429–1439.

VAN DAME, Cornelis (1997): *The Urim and Thummim: A Means of Revelation in Ancient Israel*. Eisenbrauns.

WAGNER, Michael – KOOPMAN, Philip (2015): A Philosophy for Developing Trust in Self-Driving Cars. In: Meyer, G. – Beiker, S. (eds.): *Road Vehicle Automation 2*. 163–171. Springer.

WORLD HEALTH ORGANIZATION (2019): *World Report on Vision*. Technical report. www.who.int/publications/i/item/9789241516570 (last accessed on: 27/09/2021).

YUCER, Seyma – AKCAY, Samet – AL-MOUBAYED, Noura – BRECKON, Toby P. (2020): Exploring Racial Bias within Face Recognition via Per-Subject Adversarially-Enabled Data Augmentation. In: *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops*. June.