Advancements and challenges in Autonomous Vehicles: Accelerating or braking based on Image processing

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Jon-Eder Alday Vitorica

Student ID: x23230525

School of Computing

National College of Ireland

Supervisor: Victor del Rosal

National College of Ireland

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School of Computing

Student Name:	Jon-Eder Alday Vitorica		
Student ID:	X23230525		
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Advancements and challenges in Autonomous Vehicles: Accelerating or braking based on Image processing

Jon-Eder Alday Vitorica
X23230525

Abstract

To achieve a correct decision process in autonomous vehicles and increase their safety, one of the main processes involved is the decision the vehicle must make between accelerating and braking. Deciding this will involve information the sensors retrieve from the environment and processing it using precise computing systems. However, the vehicle must incorporate trained data that involves different situations in which the vehicle must decide. The trained data must be precise and must be tested before being applied in autonomous vehicles, making sure it is precise and reliable. In this study, the investigation focuses on the effectiveness of image processing techniques, in this case, Support Vector Machine (SVM), to make the appropriate decision to accelerate or brake.

1 Introduction

The advancement of the vehicles has kept their focus on improving the driving experience and making it safer so that in case of an accident the passengers of the vehicle do not suffer any harm. These advancements have been more specific depending on the different brands. In the case of autonomous vehicles, the analysis shows that these kinds of vehicles would improve safety in terms of preventing accidents caused by human causes. These new advancements prove that they could be beneficial for the actual way of driving and the lifestyle of the population worldwide.

This is produced by the large amount of technology that is used in these new vehicles, which involves processing many different images to be able to give precise solutions to different situations, supported by fast processing using online servers that can keep track of every move the autonomous vehicle must make. Not only do autonomous vehicles base the decisions that must be taken with the cameras incorporated in the vehicle, but also, they also use the traffic cameras and other cameras that are available in public streets.

One of the most important decisions that autonomous vehicles need to make is whether the car needs to accelerate or brake. In order to take this decision, the software being used in the processing of the actions the car does must have been trained correctly by using millions of images that show different situations, as well as being able to process new situations and incorporate the data. There are many factors that can interfere with this decision, such as other cars, signals, or people, and therefore the car must be able to identify the different situations.

The main focus of the study will be to perform an SVM analysis and analyse the results obtained. The key research question that will be addressed in this study will be: How effectively can image processing techniques, in this particular case SVM, determine if the autonomous vehicle must perform the action of braking or accelerating in real-time situations?

2 Related Work

Autonomous vehicles have become a reality in the past years in different areas, not only in day-to-day driving but also in agricultural functions, transport of materials, and others. However, it is hard to make it a usual thing since it faces different problems that are hard to overcome. This involves things such as the liability an autonomous vehicle has in terms of an accident, who is responsible for the accident, the driver, or the company that produced the car. However, it has been proven that 94% of accidents are attributable to human causes, and this could be improved by introducing self-driven cars (G. Minond , 2023).

The self-driving vehicle can not only improve the day-to-day life of the drivers, but it can also help in certain fields, such as the transport of materials and agriculture. These are tasks that must be performed with high accuracy, which can be hard for the operators of the machinery and can cause mistakes such as following the correct patterns. Since agriculture has turned into a less interesting and profitable activity to perform, it is getting abandoned in the first world countries. These new technologies could make it more attractive to perform this kind of task since it will make it comfortable, easier, and increase productivity (Bai, et al., 2023).

Image processing is the main point in autonomous vehicles, which is involved in all the functions to be able to make the car suit every kind of situation in order to be able to drive correctly with the other human-driven cars. It counts on many systems that make it able to "watch" around the vehicle, so it is able to understand the surroundings. The system used in autonomous vehicles is the Advanced Driver Assistance System, which involves systems that are able to have adaptative cruise control, automatic braking, lane-keeping systems, blind spot assistance, lane departure warning systems, and lane detection systems (Zakaria, et al., 2023).

These kinds of vehicles have shown that their performance is correct when the weather conditions are optimal for their driving. When adverse weather conditions are found, their performance can be affected, such as when there is fog, rain, or snow. This is due to their sensors malfunctioning when this kind of condition occurs. The possible malfunctioning from the sensors has been tried to resolve by adding large amounts of data of raining images to process this situation more easily. The other method that was used to reduce this kind of malfunctioning was to use images in which the rain had been removed to make it easier to process by using a method called deraining (Jiang, et al., 2023).

Thanks to the introduction of the 5G, the process of data can be quicker and more effective, so that the processes of the autonomous vehicle can be handled faster and with a higher accuracy. It can also use video surveillance systems to get more accurate information on the traffic status and be able to get the best route possible. However, the amount of data these vehicles need to process is in large quantities, and in order to get a more efficient process of the information, the idea of transferring this information to an external cloud has become more popular. However, this process can be difficult to handle since a large amount of data can make it difficult to handle real-time information and reliable data handling. Therefore, it will be needed to get cloud computing with high latency that counts with powerful computing services, storage, and communication capacity (Chen, et al., 2023).

Artificial intelligence is directly involved in the development of autonomous vehicles, applying different techniques that affect the outcome of the performance of these vehicles. One of the main points involved in their performance is the data being used to train the vehicles to be able to detect the different artifacts that could affect driving. Certain things, such as other vehicles, traffic, signals, or even the lines on the road, affect the performance and the decisions that these vehicles must make. The decisions taken by the vehicles are applied by using sensors all around them to detect these potential threats and then processed based on the data they are previously trained on. These can be images used to train the model on which the cars are based.

One of the most important decisions that autonomous vehicles must make is whether to accelerate or brake, depending on the situation they encounter. In a previous study performed by Fu*, Li, Richard Yu, H. Luan, & Zhang* it was shown that rare-end collisions are mainly caused by human action since they might not be able to brake completely or do not effectively brake. However, in autonomous vehicles, the decision to brake is performed effectively due to the fast response provided by the technologies implemented.

The decision-making process of an autonomous vehicle on whether to brake or accelerate can be influenced by different factors, such as road conditions or weather conditions. Driving in different environments can affect the decisions these vehicles make, and in order to avoid this, the correct decision is to collect information in these kinds of situations and analyse it (Reschka, Rüdiger Böhmer, Saust, Lichte, & Maurer, 2012).

3 Research Methodology

The methodologies that have been used in terms of analysing the performance of image processing in autonomous vehicles are normally CNN, and in order to obtain new answers, we will apply a different method and obtain different conclusions to assess the performance of these vehicles. The methodology that could be interesting to apply could be either SVM or Random Forest, which will allow us to check the results that we can obtain. The final decision to perform an SVM analysis is motivated by the fact the research is looking for a two-factor analysis between accelerating or braking, and therefore this kind of study is ideal for the research.

To get to the final study that was performed, several steps were needed. In the first instance, the data that was going to be used to perform the study was obtained from a company that is already developing autonomous vehicles. This was to be able to perform the study with the best accuracy possible and closer to situations that happen in an autonomous vehicle. Although several platforms were used to attempt analysing these images obtained, the dataset was too big, and the computer or the program wasn't able to process it, when loading it from the drive. Another problem encountered was that when the file was downloaded to upload from the local disc, it appeared as a tar file, and the program wouldn't process correctly this kind of file.

Therefore, since the first option didn't perform the analysis needed, another dataset was introduced, and the code was programmed to be able to process jpg files. This dataset was obtained from Kaggle, and it is based on a self-driving car in India (P V, 2019). The study will be performed using an SVM analysis that will be based on a dataset of images of vehicles in different situations in which the car must accelerate or brake.

The dataset contained 144 images in which the car is supposed to accelerate and 228 images in which it is supposed to brake. The dataset was divided into 80% for the training data and 20% for the test data. After these 5 images were used of different situations to try the model in real-life situations. The dataset had to be manually classified so that the code was able to identify the two different situations. To obtain the images, we referred to the website Kaggle to obtain a dataset with images of the roads of India.

To be able to perform the research, the methodology followed to assess the study was CRISP-DM. This method allows the researchers and companies to keep track of the process followed to perform the study. CRISP-DM is a methodology used to correctly plan, organize, and execute data mining projects. By applying this method, it can be easily tracked and assessed that it is aligned with the goals established in the project.

3.1 Business Understanding:

The first that has to be assessed is how to develop a system that is reliable and able to precisely decide when the car must break or accelerate based on image processing. Although there are multiple systems involved in this process, the study is going to focus on this topic. In order to develop a system that is able to precisely assess which action it must take, it must be accurate and have quick decision-making. Therefore, the data must be correctly processed to obtain the best results, and in order to achieve this, the development of this system must be performed by professionals.

3.2 Data Understanding:

To be able to properly create the model, it is needed to have a dataset that is able to train the model. Therefore, the data used was a dataset of autonomous vehicles on the roads of India, which had complex situations that could confuse the models. When looking deeply into the data, it is formed by 49000 images, which show different situations frame by frame of the roads of India. The images were assessed to see if they were appropriate for the study and then divided into two different files, one focused on accelerating and the other on braking, in order to prepare the labels.

3.3 Data preparation

To prepare the data for the SVM analysis, the sample data was reduced into 372 images divided between the folders accelerate and brake. These folders will then be loaded into Jupyter Notebook and get established as too different labels brake and accelerate. The images were resized to match each other and converted the colour space from BRG to RGB. After obtaining the first results, 5 sample images were introduced to retry the test and get different results. The images were normalized, and the data was split into a training set and a test set in a proportion of 80 to 20, respectively.

3.4 Modelling

The SVM model is trained with the data already cleaned and prepared for analysis as a linear SVM model. The model was performed to evaluate the accuracy by giving metrics such as precision, F1-score, recall, and display of the support of the images processed. The model tried to avoid overfitting, and since the first test may have been overfitting, a second test was performed with the samples prepared. To get a better representation of the results, the model was trained to perform a confusion matrix and ROC curve.

3.5 Evaluation

The results of the test showed that the model worked perfectly in the first test. However, this could be a clear sign of overfitting in the model, and therefore the results wouldn't be relevant for the study. When the second and third parts of the study were performed, the results showed that the model was working, although it had an error. To obtain more information, the model must be tested in a controlled environment and ensure that it is performing within the safety requirements.

3.6 Deployment

This phase of the CRISP-DM must be conducted in a further investigation since the model must be tested on a larger scale and show the precise results expected. Moreover, the model must be integrated into an autonomous vehicle to be tested in real-life situations. The model must be perfected, tested, and constantly updated, checking its performance and reliability of the model. This phase would require an investment to create or obtain an autonomous vehicle to test the model in an appropriate environment.

4 Design Specification

To be able to develop an autonomous vehicle that is ready to make use of the model that has been developed, there will be factors involved in the correct functioning of the car. The factors that need to be addressed are the following:

Model: The model is a critical point of the design of the autonomous vehicle since without it the vehicle wouldn't be able to make the correct choice in a complex situation where various factors are involved. The model must be correctly adjusted to be able to make precise and accurate decisions that make the vehicle operate. Therefore, it must be trained with accurate data and constantly updated to get the best results.

Sensors: The vehicle must incorporate a great variety of sensors that will allow it to detect possible threats on the road and adapt to adverse weather conditions. These sensors must be sophisticated and accurate in order to provide the best information possible so that the vehicle is able to react. First, the proprioceptive sensors track the dynamic system and the internal data. An example of these sensors can be encoders and location sensors, which are proprioceptive sensors. Secondly, to gather information from the environment, as it can be the distance measurement. These kinds of sensors include radio detection, light detection and range (LiDAR), and cameras.

Computing systems: the vehicle must have certain computing systems to be able to process all the information that the sensors receive and make the vehicle take the correct course of action. These systems must be able to coordinate all the processes occurring in the vehicle, process images and deep learning to be able to detect objects, Tensor processing units, and specialized hardware used to accelerate and brake. The systems must be able to process information at high speed and store this information in the future. Between the computing systems, it is necessary to mark the CPU, GPU, and AI hardware accelerators.

Communication: To have the correct functioning of the autonomous vehicles, they must integrate a vehicle-to-everything communication system that allows the vehicle to locate where the vehicles, infrastructure, and pedestrians are. The connectivity of autonomous vehicles allows them to receive updates and share data in real time.

Autonomous vehicles need many different factors involved to make decisions in complicated environments and situations, such as the ones displayed before. However, other factors are involved, such as the actuators for the throttle and the brakes, high-capacity batteries to maintain all the components working, safety systems to ensure there are no undesired failures of the vehicle, and software to operate mapping and localization. These features are the ones involved in the correct functioning of the vehicle.

5 Implementation

In order to understand the magnitude of the equipment needed for the implementation of this model, it is needed to get the structure used for the model. First, the images that were going to be used in both samples of data were selected and divided into the files accelerate and brake, attempting to get rid of images that could be confusing and reducing the sample size in the program wasn't able to process the whole sample. Then the files would be introduced into a Jupiter Notebook by applying the necessary code. The aim was to achieve a correct SVM analysis of the images and obtain graphics that would show the results obtained.

The analysis was performed with Python, which is a programming language used to develop websites and software, to automate tasks, and for data analysis and visualization. Tensorflow was introduced, and data augmentation was performed to analyse the images in different positions to show the model's accuracy. After, a sample of images was used to test those same results with different images to see if they were giving back appropriate results.

However, to deploy a correct implementation for the model developed it will be necessary to perform new tests with larger amounts of data so that it is shown that the model is performing correctly. In order to do this, it will be necessary to obtain powerful computers that are able to process large amounts of images and label them to get a better outcome of the model. Regular maintenance will also be needed for both the systems used and the model itself.

Moreover, having the appropriate workers to develop an autonomous vehicle can be difficult to find. This happens since the skills needed are specific and it is a new technology for which further study and tests must be performed. Also, the coordination of all the workers involved in this kind of project must be perfect since all the components must aim to achieve the goal searched for.

In addition, the correct testing of the model would involve using an autonomous vehicle and performing tests in an environment that could be challenging for the model. However, performing this implementation in an autonomous vehicle would require large amounts of money to be able to develop or acquire them. Moreover, it would have to perform tests in real-life situations such as the ones shown in the study.

6 Evaluation

The analysis performed was an SVM analysis in which the images were introduced to the code to perform the analysis, and several experiments were performed to get reliable information for the research. The cases were analysed deeply to observe if the model is working as desired and if it is ready to be introduced in an autonomous vehicle. The SVM model will give information to the car about in which situations it is required to brake or accelerate.

6.1 Experiment / Case Study 1

After performing the first try of the SVM analysis, the results showed that the accuracy was 1.0, which shows that the model was able to classify correctly every image. Also, it showed that the precision, recall, and F1-Score were 1.0. However, not all the images on both instances were processed since we only got 75 total results. The most concerning fact is that the training data could have overfitted, and therefore it could not have given the desired results.

```
Accuracy: 1.0
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        49
           1       1.00      1.00      1.00        26

    accuracy                           1.00        75
   macro avg       1.00      1.00      1.00        75
weighted avg       1.00      1.00      1.00        75
```

Figure 1 First experiment results

After the first attempt of the analysis, we also obtain images of situations the program must identify, giving a prediction of what the car should do in each situation and then giving the real thing that it should do. As the results obtained showed the test images were obtaining the desired results.

Even though the images are blurry, it can still be seen that when a vehicle appears in the image, it correctly decides to brake, and when the road is free of vehicles, it predicts to accelerate.

6.2 Experiment / Case Study 2

Since the previous results were unclear, taking into account that the training data could be overfitting, we performed a final test to obtain clearer results. We used 5 new images for both parameters, accelerate and brake, and we obtained different results.

Figure 2 Results retrieved by first experiment

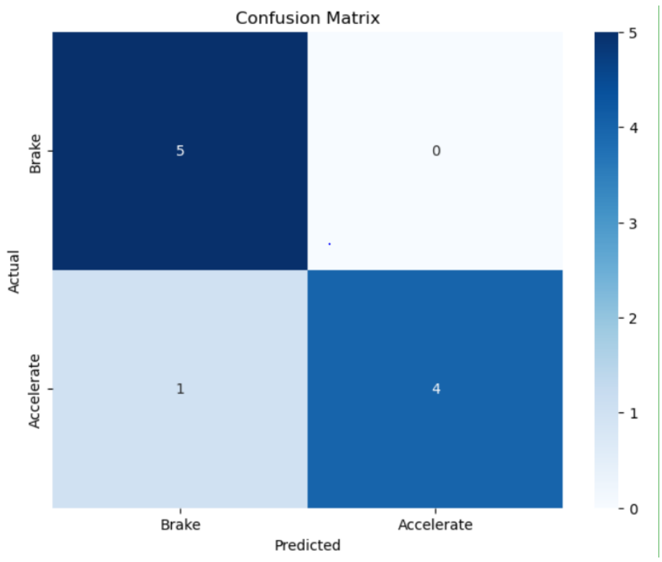

Figure 3 Confusion matrix second experiment

First, we observe the confusion matrix that shows the results obtained from performing this new test. The program managed to correctly recognize the images nine out of ten times. The study showed that we found that in five instances where the actual label was brake the model correctly predicted that it had five brake, shown as true positives. Four instances were shown as accelerate, which were accelerate, which are the true negatives. No false positives were shown, and only 1 false negative was labelled as accelerate, and the model incorrectly predicted brake.

Classification Report:

	precision	recall	f1-score	support
Brake	0.83	1.00	0.91	5
Accelerate	1.00	0.80	0.89	5
accuracy			0.90	10
macro avg	0.92	0.90	0.90	10
weighted avg	0.92	0.90	0.90	10

Figure 4 Second experiment results

Figure 5 Results retrieved by second experiment

It's been observed that the image on the left is the one confusing the model since the vehicle is in the middle and the car is unsure if it should accelerate or brake. Further investigation must be done to determine a solution for this error.

6.3 Experiment / Case Study 3

Finally, a TensorFlow was introduced to give a deeper perspective of the results and to give back a receiver operating characteristic to see a graphical representation of the performance of the SVM model. The images were altered with the image generator that allows the model to perform tests, resizing and turning the images to get a better understanding. Results obtained were the same as the first study, which shows that the model is accurate and could be applied in the future.

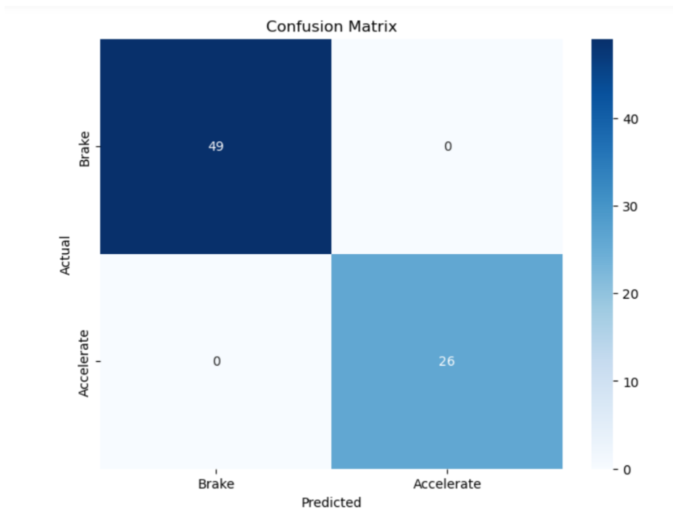

Figure 6 Confusion matrix third experiment

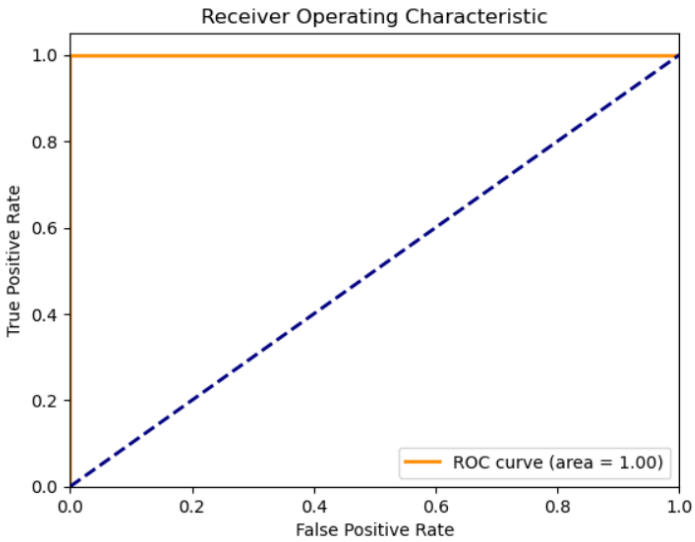

Figure 7 ROC third experiment

6.4 Discussion

The experiments show that the model is working correctly and is precise enough to be applied in an autonomous vehicle. However, the study could be overfitting since the first results showed perfect parameters. The second study was able to confirm that the model was working, although it could have some errors. The third study performed with the tensor flow and the image generator showed the accurate performance of the model.

Therefore, it is shown that the model is performing the desired task and has proven accurate enough to be used. Nevertheless, the study has been done with a small set of images, which will need to be increased in order to get a deeper understanding. Moreover, future studies must be performed in the model, such as trying different methods that will show different results.

The final step that must be performed to see if the model is correctly functioning is to introduce the model into an autonomous vehicle and perform tests in different environments and situations to see how the vehicle reacts. This will make visible the efficiency of the model and will allow us to get reliable information.

Nevertheless, based on previous research studied previously, it has been shown that to be able to achieve a fully operational autonomous vehicle, it is required to have adequate technology to perform the tests that are desired in the research. The vehicle must be able to perform different tasks in an instant and process the information to make the correct decisions.

7 Conclusion and Future Work

This research has shown the importance of the detection devices that autonomous vehicles need to operate, and which will determine the next actions the vehicle must take. The study focuses on the car having to decide whether it breaks or accelerates by using the method of SVM. Since image processing is one of the most important things in autonomous vehicles, the target was to obtain the most accurate results possible to be able to perform correctly.

After seeing the model performance, we saw that all the parameters showed a perfect score, which could mean that the model is working perfectly or that there is overfitting on the data. When the validation test done with the samples showed different results, it showed the model was working and it was showing the results properly. However, this study was difficult to put into practice since the equipment used to perform it was not used specifically for it, and therefore the sample had to be reduced.

Although the results obtained were promising, further investigation must be done, since it is needed to perform the study with a bigger sample and include a larger variety of images that can show many different scenarios so that it is better prepared. It will have to be taken into consideration that the weather conditions have a large impact on these vehicles and will also need to be included.

In conclusion, in future work, the focus should be getting a bigger sample, that will be processed with the appropriate equipment and adapt correctly to what we are looking for. Also, it will need to keep adapting to the new information that becomes available in this aspect.

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