Using Deep Convolutional Neural Network to Avoid Vehicle Collision

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***Abstract* — A traffic collision occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree, pole or building. Traffic collisions often result in injury, death, and property damage. With the power of computers this vehicle collision can be reduced and the best possible solution is self-driving car/ autonomous car.**

We performed simulation test of self-driving car which can avoid collisions against the obstacles on track. Here, open source simulator provided by Udacity is tweaked and using deep convolutional neural network, models were trained and tested on two versions of simulators. Different outcomes were compared to build a model which effectively avoids crash.

***Index Terms*— Convolutional Neural Network (CNN), simulation, Self Driving Car**

1. INTRODUCTION

A self-driving car (sometimes called an autonomous car or driver-less car) is a vehicle that uses a combination of sensors, cameras, radar and artificial intelligence (AI) to travel between destinations without a human operator. To qualify as fully autonomous, a vehicle must be able to navigate without human intervention to a predetermined destination over roads that have not been adapted for its use.

Companies developing and/or testing autonomous cars include Audi, BMW, Ford, Google, General Motors, Tesla, Volkswagen and Volvo. Google's test involved a fleet of self-driving cars – including Toyota Prii and an Audi TT navigating over 140,000 miles of California streets and highways.

AI technologies power self-driving car systems. Developers of self-driving cars use vast amounts of data from image recognition systems, along with machine learning and neural networks, to build systems that can drive autonomously. The neural networks identify patterns in the data, which is fed to the machine learning algorithms. That data includes images from cameras on self-driving cars from which the neural network learns to identify as traffic lights, trees, curbs, pedestrians, street signs and other parts of any given driving environment.

Autonomous Driving has been said to be the next big disruptive innovation which is in phase of development. Considered as being predominantly technology driven, it is supposed to have massive social impact in all kinds of fields.

2. LITERATURE SURVEY

2.1. Background

According to Marlon G. Boarnet [1], a specialist in transportation and urban growth at the University of Southern California Approximately every two generations, we rebuild the transportation infrastructure in our cities in ways that shape the vitality of neighborhoods; the settlement patterns in our cities and countryside; and our economy, society and culture and as many believe, autonomous driving cars are this new big change everyone is talking about. Leading not only to high impact environmental benefits such as the improvement of fuel economy [2] , through the optimization of highways [2], the reduction of required cars to only 15% of the current amount needed [1], and platoon driving that would save to 20-30% fuel consume [3], but also leading to societal aspects such as immense productivity gains while commuting[4], decline on the accident and death tolls considered as the eight highest death cause worldwide in 2013 [5], stress reduction [6], and the decline of parking space to up to of the current capacity [7]. It would also, according to a study by Morgan Stanley (2013) lead to an average 38 hours reduction of commuting time per individual per year as well as saving the US economy alone 1.3 trillion dollars per year, creating a shift on the possibilities and different applications, developing completely new markets, partnerships and possible business models [8]. That will change the society as we know it.

All the benefits of course, and not only to mention the Technological difficulties do not come without a certain amount of challenges, complications and necessary changes in current systems in order to work. By now several States in the US have passed laws permitting autonomous cars testing on their roads [9]. The National Highway Traffic Safety Administration in the United States (2013) provides an official self-driving car classification dividing into No-Automation (Level 0), Function-specific Automation (Level 1), Combined Function Automation (Level 2), Limited Self-Driving Automation (Level 3) and Full Self-Driving Automation (Level 4). Europeans have also started modifying the Vienna Convention on Road Traffic and the Geneva Convention on Road Traffic [10] in order to be able to adapt this new technology, but legal issues and doubt still arise as one of the main concerns of discussion. Some of the main issues surrounding the autonomous driving field found throughout the literature and the web are; test and standard set for critical event control, how to deal with the requirement for a driver, ownership and maintenance [11], civil and criminal liability, corporate manslaughter [12], insurance, data protection and privacy issues [13].

Having a closer look at the history of Autonomous Driving, as explained in the IEEE Spectrum [1] in Figure 1 it can be observed that the technological development and main milestones of the autonomous driving field started already a few decades ago. Leading to a vast analysis of some semi-autonomous features, development of present technologies and understanding on the future problematic while focusing in the near future in the connected car.

Fig 1 : Sixty five years of automotive baby steps

One of the main concerns for all semi-autonomous features in the literature is that humans are poor monitors of automation [14] meaning that driving performance declines as automation increases, leading to big safety concerns while being out of the loop in case of necessary reaction [15], situation that is imminent until the technology is fully automated. Moreover John Leonard [16], a MIT professor, reasons that current technology relies on very accurate prior maps and that keeping maps up to date shouldn't be underestimated, while his colleague Bryan Reimer, a research scientist in MITs Age Lab, argues that the most inhibiting factors related to Autonomous driving will be factors related to the human experience. Despite the fact that most experiments of full automation with future users have been done in driving simulators [3] recent studies also point that motion sickness is also higher in self-driving cars. [17] And that passengers that do not drive, experience discomfort at lower acceleration rates than car drivers do [4], not to mention the fear of technology failure [18]. Further worries derive from the social impact such as the massive job loss [19] as well as the change of social structures as insurance companies, the health industry [20] and public transport systems [7].

2.2 Recent Advancement in Self Driving Car

Several companies demonstrated interest in developing self-driving cars, and/or investing in technology to support and profit from them. Enterprises range from manufacturing cars and creating hardware for sensing and computing, to developing software for assisted and autonomous driving, entertainment, and in-car advertisement.

We provide an overview of companies doing research and development in self-driving cars. The list is not presented in any specific order, since we aim at making it as impartial and complete as possible. The information was acquired by inspecting company's websites and news published in other media.

Torc was one of the pioneers in developing cars with self-driving capabilities. The company was founded in 2005. In 2007, it joined Virginia Techs team to participate in the 2007 DARPA Urban Challenge with their autonomous car Odin [BAC08], which reached third place in the competition. The technology used in the competition was improved since then and it was successfully applied in a variety of commercial ground vehicles, from large mining trucks to military vehicles [TOR18]. Google's self-driving car project began in 2009 and was formerly led by Sebastian Thrun, who also led the Stanford University's team with their car Stanley [THR07], winner of the 2005 DARPA Grand Challenge. In 2016, Google's self-driving car project became an in-dependent company called Waymo [WAY18]. The company is a subsidiary of the holding Alphabet Inc., which is also Google's parent company. Waymo's self-driving car uses a sensor set composed of LIDARs to create a detailed map of the world around the car, RADARs to detect distant objects and their velocities, and high resolution cameras to acquire visual information, such as whether a traffic signal is red or green [WAY18b].

Baidu, one of the giant technology companies in China, is developing an open source self-driving car project with codename Apollo [APO18]. The source code for the project is available in GitHub [APOL18]. It contains modules for perception (detection and tracking of moving obstacles, and detection and recognition of traffic lights), HD map and localization, planning, and control, among others. Several companies are partners of Baidu in the Apollo project, such as TomTom, Velodyne, Bosch, Intel, Daimler, Ford, Nvidia, and Microsoft. One of the Apollo projects goals is to create a centralized place for original equipment manufacturers (OEMs), startups, suppliers, and research organizations to share and integrate their data and resources. Besides Baidu, Udacity, an educational organization founded by Sebastian Thrun and others, is also developing an open source self-driving car, which is available for free in GitHub [UDA18].

Uber is a ride-hailing service and, in 2015, they partnered with the Carnegie Mellon University to develop self-driving cars [UBE15]. A motivation for Uber's project is to replace associated drivers by autonomous software [UBE18]. Lyft is a company that provides ride sharing and on-demand driving services. Like Uber, Lyft is doing research and development in self-driving cars [LYF18]. The company aims at developing cars with level 5 of autonomy.

Aptiv is one of Lyft's partners. Aptiv was created in a split of Delphi Automotive, a company owned by General Motors. Aptivs objective is to build cars with level 4 and, posteri-orly, level 5 of autonomy [APT18]. Besides other products, the company sells short-range communication modules for vehicle-to-vehicle information exchange. Aptiv recently acquired two relevant self-driving companies, Movimento and nuTonomy.

Didi is a Chinese transportation service that bought Uber's rights in China. Didi's self-driving car project was announced in 2017 and, in February of 2018, they did the first successful demonstration of their technology. In the same month, company's cars started being tested in USA and China. Within a year, Didi obtained the certificate for HD mapping in China. The company is now negotiating a partnership with Renault, Nissan, and Mitsubishi to build an electric and autonomous ride-sharing service [ENG18].

Tesla was founded in 2003 and, in 2012; it started selling its first electric car, the Model S. In 2015, the company enabled the autopilot software for owners of the Model S. The software has been improved since then and its current version, the so called enhanced autopilot, is now able to match speed with traffic conditions, keep within a lane, change lanes, transition from one freeway to another, exit the freeway when the destination is near, self-park when near a parking spot, and be summoned to and from the users garage [TES18]. Tesla's current sensor set does not include LIDARs.

A Chinese company called LeEco is producing self-driving luxury sedans to compete with the Tesla Model S. The company is also backing up Faraday Future for the development of a concept car. LeEco is also partnering Aston Martin for the development of the RapidE electric car [VERG16].

Besides developing hardware for general-purpose high performance computing, NVDIA is also developing hardware and software for self-driving cars [NVI18]. Although their solutions rely mostly on artificial intelligence and deep learning, they are also capable of performing sensor fusion, localization in HD maps, and planning [NVID18].

Aurora is a new company founded by experienced engineers that worked in Google's self-driving project, Tesla, and Uber [AUR18]. The company plans to work with automakers and suppliers to develop full-stack solutions for cars with level 4 and, eventually, level 5 of autonomy. Aurora has independent partnerships with Volkswagen group (that owns Volkswagen Passenger Cars, Audi, Bentley, Skoda, and Porsche) and Hyunday [FORT18].

Zenuity is a joint venture created by Volvo Cars and Autoliv [ZEN18]. Ericsson will aid in the development of Zenuitys Connected Cloud that will use Ericsson's IoT Accelerator [ERI18]. TomTom also partnered with Zenuity and provided its HD mapping technology [TOM18]. TomToms HD maps will be used for localization, perception and path planning in Zenuity's software stack.

Daimler and Bosch are joining forces to advance the development of cars with level 4 and 5 of autonomy by the beginning of the next decade [BOS18]. The companies already have an automated valet parking in Stuttgart [DAA18] and they also have tested the so called Highway Pilot in trucks in USA and Germany [DAB18]. Besides partnering with Bosch, Daimler also merged its car sharing business, Car2Go, with BMW's ReachNow, from the same business segment, in an effort to stave off competition from other technology companies, such as Waymo and Uber [DAC18]. The new company will include business in car sharing, ride-hailing, valet parking, and electric vehicle charging.

Argo AI founders led self-driving car teams at Google and Uber [ARG18]. The company received an investment of U$ 1 billion from Ford with the goal of developing a new software platform for Fords fully autonomous vehicle (level 4) coming in 2021. They have partnerships with professors from Carnegie Mellon University and Georgia Tech [ARB18]. Renesas Autonomy develops several solutions for automated driving assistant systems (ADAS) and automated driving [REN18]. The company has a partnership with the University of Waterloo [RENE18].

Honda revealed in 2017 plans for introducing cars with level 4 of autonomy by 2025. The company intends to have vehicles with level 3 of autonomy by 2020 and it is negotiating a partnership with Waymo [HON18].

Visteon is a technology company that manufactures cockpit electronic products and connectivity solutions for several vehicle manufacturers [VIS18]. In 2018, Visteon introduced its autonomous driving platform capable of level 3 of autonomy and, potentially, higher levels. The company does not aim at producing cars and sensors, but at producing integrated solutions and software.

AImotive is using low cost components to develop a self-driving platform [AIM18]. Its solution relies strongly on computer vision, but it uses additional sensors. The company is already able to perform valet parking and navigate in highways. AImotive also developed a photo-realistic simulator for data collection and preliminary system testing, and chips for artificial intelligence-based, latency-critic, and camera centric systems.

As AImotive, AutoX is avoiding to use LIDARs in its solution. However, the company is going further than Almotive and trying to develop level 5 cars without using RADARs, ultrasonics, and differential GPSs. AutoX's approach is to create a full-stack software solution based on artificial intelligence [AUT18].

Mobileye is also seeking to develop a self-driving solution without using LIDARs, but relying mostly in a single-lensed camera (mono-camera). Mobileye is one of the leading suppliers of software for Advanced Driver Assist Systems (ADAS), with more than 25 partners among automakers. Beyond ADAS, Mobileye is also developing technology to support other key components for autonomous driving, such as perception (detection of free space, driving paths, moving objects, traffic lights, and traffic signs, among others), mapping, and control. The company partnered with BMW and Intel to develop production-ready fully autonomous vehicles, with production launch planned for 2021 [MOB18].

Ambarella also does not use LIDAR, but only RADARs and stereo cameras. The company joined the autonomous driving race in 2015 by acquiring VisLAB. Different from other companies, Ambarella does not aim at becoming a tierone supplier or selling complete autonomous-driving systems. Instead, they plan to sell chips and software to automakers, suppliers, and software developers. Ambarellas current research and development guidelines include detection of vehicles, obstacles, pedestrians, and lanes; traffic sign recognition; terrain mapping; and issues related to technology commercialization, such as system calibration, illumination, noise, temperature, and power consumption [AMB18].

Pony.ai was founded in December of 2016 and, in July of 2017, it completed its first fully autonomous driving demonstration. The company signed a strategic agreement with one of the biggest Chinese car makers, the Guangzhou Auto Group (GAC) [PON18].

Navya [NAA18] and Transdev [TRA18] are French companies that develop self-driving buses. Navya has several of their buses being tested in Europe, Asia, and Australia. Their sensor set consists of two multi-layer 360 LIDARs, six 180 mono-layer LIDARs, front and rear cameras, odometer (wheels encoder + IMU), and a GNSS RTK [NAB18]. Transdev is also already demonstrating their self-driving buses for the public [TRA18].

JD is a Chinese e-commerce company interested in building self-driving delivery vehicles [JD18]. JD's project, started in 2016, is being developed together with Idriverplus [IDR18], a Chinese self-driving car startup.

In March, 2018, Toyota announced an investment of U$ 2.8 billion in the creation of a new company called the Toyota Research Institute-Advanced Development (TRI-AD) with the goal of developing an electric and autonomous car until 2020 [TOYT18]. Besides Toyota [TOY18], other car manufacturers, such as Ford [FOR18], Volvo [VOLV18], and Mercedes-Benz [MER18], have also recently presented their plans for self-driving cars. Ford defined 2021 as a deadline for presenting a fully autonomous vehicle ready for commercial operation.

2.3 Relevance of the customer perspective

Autonomous cars are not that far away, for example Audi and Mercedes [22] have announced almost being ready from production in highly automated features. As a reflection of the daily news, we can steadily see how this technology manages to get closer to be in our everyday life, with examples of cars driving a blind man for tacos already on 2012 [22], coast to coast trips [23], an Italy to China trip [24] and 700,000 miles already travelled by Google [25]. But main automakers in the race such as Audi, BMW, Cadillac, Ford, General Motors, Jaguar, Land Rover, Lincon, Mercedes-Benz, Nissan, Tesla and Volvo, are trying to integrate it slowly to their models despite the fairly readiness of the technology. This can be interpreted as a futile attempt to keep this totally disruptive technology under control and to have overall slower customer integration, but this old model will prove to be not good enough due to the magnitude and impact of this technology [8].

According to a survey with more than 200 experts on autonomous vehicles by the IEEE (2014), the world's largest professional association for the advancement of technology, the three biggest obstacles to reach the mass adoption of driver-less cars are: legal liability, policymakers and customer acceptance, while the following three; cost, infrastructure and technology are seen as less of a problem. In the next section we can see through a literature review how the development of research has focused mainly on technology development and just begun to focus on legal liability and policymakers while research on customer acceptance has been more limited.

For all the reasons mentioned above from the IEEE Interview, the authors and experts focus on the technology in relation with human interaction [16][20], the general a priori acceptability of autonomous driving in recent and smaller studies [26], the companies approach to the technology introduction, as well as recent studies with future users concluding that trust and acceptance increases with high antrophormism in technology [27].

3. SYSTEM ANALYSIS A. EXISTING SYSTEM

3.1 EXISTING SYSTEM

Human factors in vehicle collisions include anything related to drivers and other road users that may contribute to a collision. Examples include driver behaviour, visual and auditory acuity, decision-making ability, and reaction speed. A 1985 report based on British and American crash data found driver error, intoxication and other human factors contribute wholly or partly to about 93% of crashes. Drivers distracted by mobile devices had nearly four times greater risk of crashing their cars than those who were not. Dialing a phone is the most dangerous distraction, increasing a driver's chance of crashing by 12 times, followed by reading or writing, which increased the risk by 10 times. An RAC survey of British drivers found 78% of drivers thought they were highly skilled at driving, and most thought they were better than other drivers, a result suggesting overconfidence in their abilities. Not nearly all the drivers who had in a crash, believed themselves to be at fault.

The key elements of good driving were:

- controlling a car including a good awareness of the car's size and capabilities
- reading and reacting to road conditions, weather, road signs and the environment
- alertness, reading and anticipating the behavior of other drivers

3.2 LIMITATIONS OF EXISTING SYSTEM

- Careless Driving by human.
- Distracted Driving
- Drunk Driving
- Speeding
- Reckless Driving
- Wrong Way Driving
- Unsafe Lane Changes
- Driving Under the influence of drugs
- Road rag
- Drowsy Driving

4. PROPOSED SYSTEM

Here, we are referring to an interactive simulation of the self-driving car that could eliminate all the above limitations.

We aim to design a self-driving car that could learn using convolutional neural network. These are the following steps involved.

- Recording the training data by running the simulator.
- Collecting the simulated data and store it.
- Make a deep learning model to learn from that data.
- Creating and saving a trained model.
- Executing that trained model on simulator.
- Analyze it's performance.

4.1 Data

This track was later released in the new simulator by Udacity and replaced the old mountain track. It's much more difficult than the lake side track and the old mountain track.

Used the simulator to generate training data by doing 3 to 4 rounds. Also, added several recovery scenarios to handle tricky curves and slopes.

4.2 Model Architecture Design

The design of the network is based on the NVIDIA model, which has been used by NVIDIA for the end-to-end self-driving test. As such, it is well suited for the project.

It is a deep convolution network which works well with supervised image classification / regression problems. As the NVIDIA model is well documented, I was able to focus how to adjust the training images to produce the best result with some adjustments to the model to avoid overfitting and adding non-linearity to improve the prediction.

The following adjustments to the model.

- We used Lambda layer to normalized input images to avoid saturation and make gradients work better.
- We've added an additional dropout layer to avoid over-fitting after the convolution layers.
- we've also included exponential linear unit (ELU) for activation function for every layer except for the output layer to introduce non-linearity.

In the end, the model looks like as follows:

- Image normalization
- Convolution: 5x5, filter: 24, strides: 2x2, activation: ELU
- Convolution: 5x5, filter: 36, strides: 2x2, activation: ELU
- Convolution: 5x5, filter: 48, strides: 2x2, activation: ELU
- Convolution: 3x3, filter: 64, strides: 1x1, activation: ELU
- Convolution: 3x3, filter: 64, strides: 1x1, activation: ELU
- Drop out (0.5)
- Fully connected: neurons: 100, activation: ELU
- Fully connected: neurons: 50, activation: ELU
- Fully connected: neurons: 10, activation: ELU
- Fully connected: neurons: 1 (output)

As per the NVIDIA model, the convolution layers are meant to handle feature engineering and the fully connected layer for predicting the steering angle. However, as stated in the NVIDIA document, it is not clear where to draw such a clear distinction. Overall, the model is very functional to clone the given steering behavior.

The below is a model structure output from the Keras which gives more details on the shapes and the number of parameters.

Layer (type)	Output Shape	Params	Connected to
lambda_1 (Lambda)	(None, 66, 200, 3)	0	lambda_input_1
convolution2d_1 (Convolution2D)	(None, 31, 98, 24)	1824	lambda_1
convolution2d_2 (Convolution2D)	(None, 14, 47, 36)	21636	convolution2d_1
convolution2d_3 (Convolution2D)	(None, 5, 22, 48)	43248	convolution2d_2
convolution2d_4 (Convolution2D)	(None, 3, 20, 64)	27712	convolution2d_3
convolution2d_5 (Convolution2D)	(None, 1, 18, 64)	36928	convolution2d_4
dropout_1 (Dropout)	(None, 1, 18, 64)	0	convolution2d_5
flatten_1 (Flatten)	(None, 1152)	0	dropout_1
dense_1 (Dense)	(None, 100)	115300	flatten_1
dense_2 (Dense)	(None, 50)	5050	dense_1
dense_3 (Dense)	(None, 10)	510	dense_2
dense_4 (Dense)	(None, 1)	11	dense_3
	Total params	252219	

Fig 2 : Model Summary

4.3 Data Preprocessing

Data preprocessing is a data mining technique that involves transforming raw data into an understandable format. Real-world data is often incomplete, inconsistent, and/or lacking in certain behaviors or trends, and is likely to contain many errors. Data preprocessing is a proven method of resolving such issues.

1) Image Sizing:
- The images are cropped so that the model won't be trained with the sky and the car front parts.
- The images are resized to 66x200 (3 YUV channels) as per NVIDIA model.
- The images are normalized (image data divided by 127.5 and subtracted 1.0). As stated in the Model Architecture section, this is to avoid saturation and make gradients work better).

2) Image Augmentation:
For training, the following augmentation technique along with Python generator to generate unlimited number of images is used:
- Randomly choose right, left or center images.
- For left image, steering angle is adjusted by +0.2
- For right image, steering angle is adjusted by -0.2
- Randomly flip image left/right
- Randomly translate image horizontally with steering angle adjustment (0.002 per pixel shift)
- Randomly translate image vertically
- Randomly added shadows
- Randomly altering image brightness (lighter or darker)

4.3 Training, Validation and Test

The images were splitted into train and validation set in order to measure the performance at every epoch. Testing was done using the simulator. As for training,
- Mean squared error for the loss function is used to measure how close the model predicts to the given steering angle for each image.
- Used Adam optimizer for optimization with learning rate of 1.0e-4 which is smaller than the default of 1.0e3. The default value was too big and made the validation loss stop improving too soon.
- Used ModelCheckpoint from Keras to save the model only if the validation loss is improved which is checked for every epoch.

5. EXPERIMENTAL ANALYSIS

For this experiment, we have considered udacity's self-driving car simulator[28] and self-developed simulator[29] as sim v1 and sim v2 respectively for simulation. Model is trained using deep convolutional neural network for data obtained from both simulator separately.

Fig 3: Simulator v1

Fig 4 : Simulator v2

The results of simulation are given below:

	Sim v1		Sim v2	
	Crashes	Off Track	Crashes	Off Track
Model v1	No	No	Yes	No
Model v2	No	No	No	No

Fig 5 : Model Comparison for different simulators

6. CONCLUSIONS

The model can drive the course without bumping into the side ways and crashing to the obstacles. Thus this model can be implemented in real life to make road safer.

Driver-less cars appear to be an important next step in transportation technology. They are a new all-media capsule-text to your heart's desire and its safe.

Developments in autonomous cars are continuing and the software in the car is continuing to be updated. Though it all started from a driver-less thought to radio frequency, cameras, sensors, more semi-autonomous features will come up, thus reducing the congestion, increasing the safety with faster reactions and fewer errors. People who currently reject self-driving cars would've said no to modern technology and automatic systems.

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