Development of Artificial Intelligence in the Automotive Field

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Artificial Intelligence has had its own development throughout the course of the years, evolving from early minimalistic algorithms to deep learning methods and neural networks. It has, however, faced critique, low points and had failed to be recognized as an industry worth investing in. Looking at what it has become today, the Artificial Intelligence scientific domain has met a rather unique field, the Automotive Industry. Cars have, themselves, progressed from serving basic purposes to providing comfort and serving as more than a mean of transportation to the driver and the passengers. The Auto industry is blooming as companies find new intelligent software features to be added to the infotainment systems. The Artificial Intelligence field has become an inseparable asset of the Automotive industry, the two developing together and merging into a promising future.

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1 Introduction

This research study is meant to analyze the evolution of the Artificial Intelligence technologies along with the development of the Automotive field. The author has taken into consideration facts from the past years, current behavior and future predictions of the market.

The Automotive domain has evolved along the years in every possible aspect. From faster manufacturing procedure with the introduction of assembly lines in 1908's Ford, to 2013 BMW's Greer usage of robots along the assembly and supply chain in the South Carolina plant [1]. It has seen improvements in the Quality Control methods of hardware and software components, market analysis, cabin monitoring and inside environment to name a few.

The production of vehicles has grown from 56,258,892 in 1999 to 80,145,988 in 2021 [2]. The high density of motors and vehicles producers is displayed in Figure 1.

2 Connected Car

An immense importance for the Automotive Industry is placed on the driver's environment quality and safety. The Connected Car concept is meant to do so. With variable connected services over the Cloud communication it has become a central subject of interest for many automotive companies.

Projecting a Connected Car is achieved through Telematics method meant to provide data regarding GPS tracked movement or OBD (on-board diagnostics) from the car to the manufacturer.

Telematics evolved from two separate science subjects: telecommunication and informatics, used by the US Defense Department to track the movement of the country's assets and improve military communication [4]. The evolution of internet had facilitated its development along with various driving Assistance Systems.

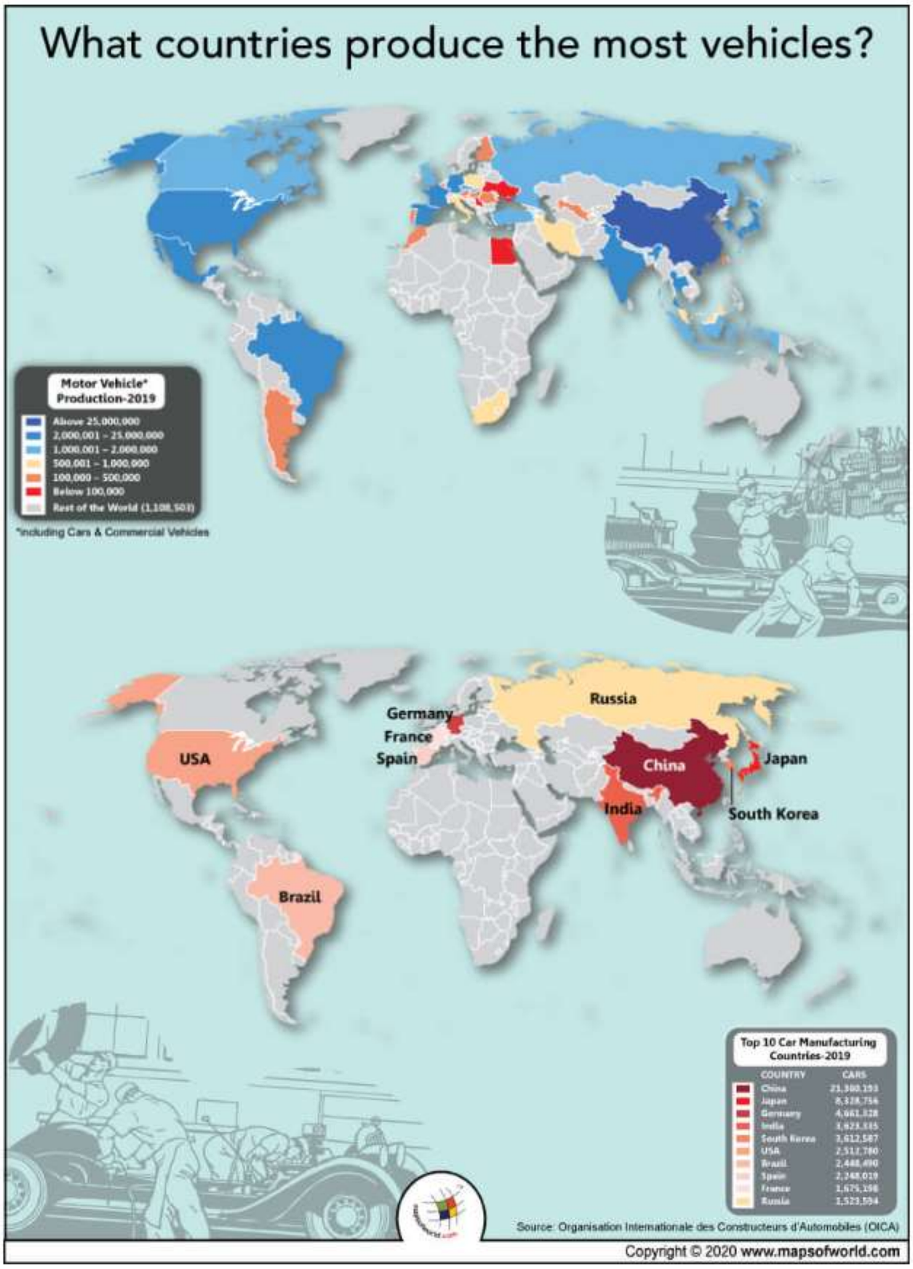

Fig. 1. World map with top motor vehicles production and car manufacturing countries [3]

In Figure 2 can be observed how data is collected from the car through On-Board Diagnostics (OBD) systems which can detected various problems with the electronic parts of the vehicle and even monitor driver behavior. This plays a major role in the collection of data as companies are able to organize their own large datasets and train different models of Artificial Intelligence [5].

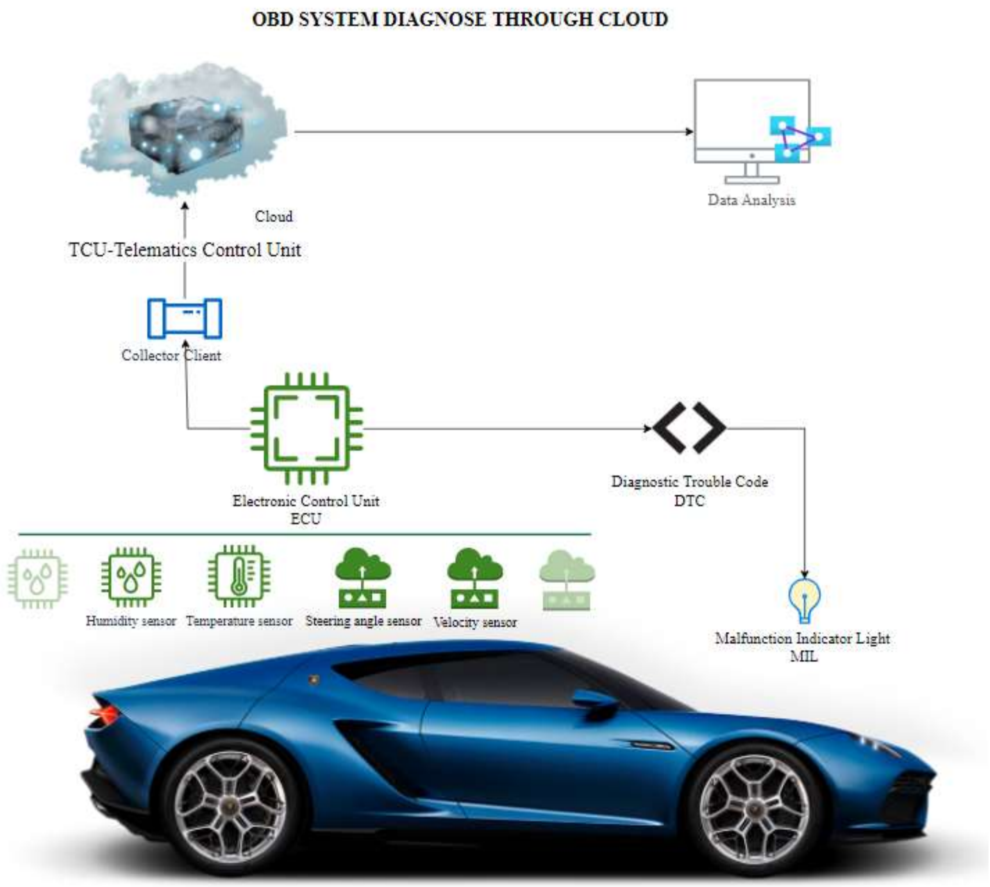

Fig. 2. Process of infotainment analysis

An OBD System acts like a collector of data. Its components, such as the Electronic Control Unit or ECU gathers the data that comes from various sensors placed in the car, indicating Humidity, Temperature, Velocity or Steering Wheel information [6]. The ECU then transmits a Diagnostic Trouble Code, known as DTC, that the end user is able to see on the display as a Malfunction Indicator Light (MIL) [7].

Through a Collector Client the data reaches the Cloud via an internet connection established on the Telematics Control Unit (TCU), Cockpit Domain Controller (CDC), or Central Gateway (CGW).

This is how, a company such as Otonomo has developed a data services platform which provides data from vehicles around the world, located in Europe, Asia, Canada and the United States, with no less than 18 million passenger and commercial vehicles [8]. This gives companies the opportunity to study and analyze impressive amounts of data that can consist as training models for different AI algorithms to be implemented into the vehicles.

Today, the usage of Artificial Intelligence is a new asset to the Telematics' existing platform [4] which allows vehicle manufacturers to go further in their data collection and analysis. Cabin monitoring specifically concentrates on monitoring driver's behavior with the scope of enhancing cabin's environment and improving safety of passenger by avoiding collision while keeping the driver alert. There is a great emphasis on using Artificial Intelligence algorithms to improve human's driving experience. A simple addition of a board camera unleashes multiple possibilities of monitoring behavioral patterns of the driver through facial recognition. Here, Cognitive Load, Cognitive Distraction and Drowsiness Prediction are some of the aspects that automotive companies are covering now.

3 Drowsiness prediction

Drowsiness is the underlaying problem of a 2017 estimation of 91,000 crashes only in the USA, according to The National Highway Traffic Safety Administration [9].

This has forced companies to focus on finding solutions on maintaining drivers' focus while driving and has pushed the industry to investing into intelligent solutions that define the states of a driver: attentive, distracted and even asleep. Drowsiness prediction is based on multiple face detection components and calculations that can determine a driver's state by analyzing and processing facial measurements data.

The process starts with an on-board camera that is monitoring the driver's face and is able to classify the driver's state based on face recognition and applied algorithms.

What is taken into consideration while analyzing the user's face is the EAR, Eye Aspect Ratio, a formula based on the ratio between the length of different points on the eye width and the eye height as described in Figure 3. The visual representation of the focus points for the eyes can be seen in Figure 4.

$$EAR = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

||p2-p6|| means the distance between points p2 and p6

Fig. 3. EAR formula [10]

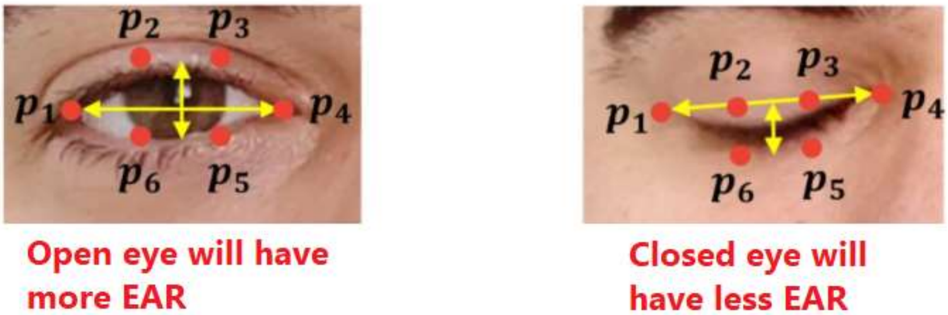

Fig. 4. Visual representation of EAR [10]

Smaller the ratio, the more likely is the driver to experience drowsiness, thus, to close their eyes. Other information, such as head position, yawning, lane deviation, lost control of the steering wheel, energy features of the human body, like heartbeat rate, can contribute to a better determination of the driver's state [11].

Further, a Python based face recognition algorithm has been created to determine and classify given data into two classes: "drowsy" and "not drowsy".

The Dlib toolkit was used with Python programming language to determine face landmarks and calculate distances between the points of interest as seen in Figure 5 and the eye aspect ratio. The Dlib toolkit was trained on a dataset of images, part of "iBUG 300-W dataset" [12] , which contains a total of 600 photos, 300 indoor and 300 outdoor, exposed to different expressions, face types and illumination conditions.

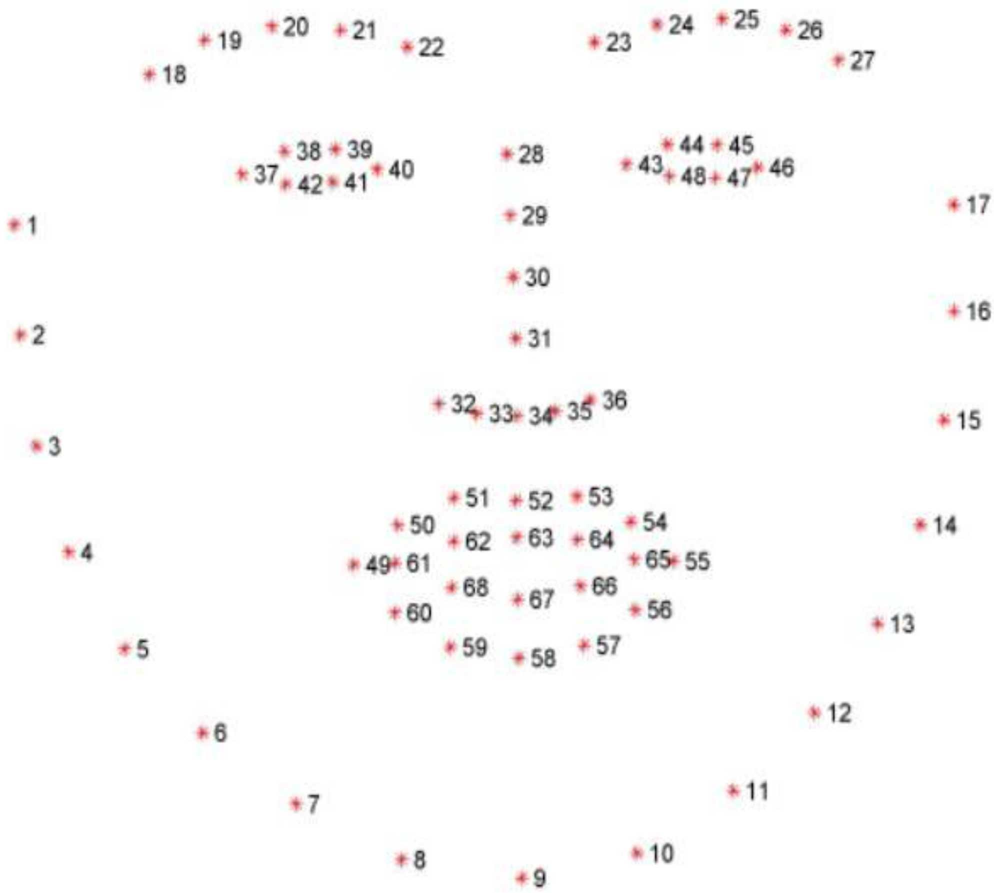

Fig. 5. The sixty-eight points of interest [12]

In addition, the OpenCV library has been used as a tool for real-time computerized vision.

The following code source creates a capture from the video using the OpenCV library that was later processed. From the captured frame, the bounding box has been drawn in the shape of a rectangle, labeled with numbers, depending on the numbers of faces detected in the video frame.

Sixty-eight circles in the form of tuples holding information of the position x and y have been drawn using the OpenCV library, pointing to main focus areas of the face.

```
cap = cv2.VideoCapture(0);
agp = argparse.ArgumentParser()
agp.add_argument("-p", "--shape-predic-
tor", required=True, help="path to fa-
cial landmark predictor");
args = vars(agp.parse_args());
detector = dlib.get_frontal_face_detec-
tor();
predictor = dlib.shape_predic-
tor(args["shape_predictor"]);

while True:
    _, captured_frame = cap.read();

    grey = cv2.cvtColor(captured_frame,
cv2.COLOR_BGR2GRAY);
    rects = detector(grey, 1);

    for (i, rect) in enumerate(rects):
        shape = predictor(grey, rect);
        shape =
main.shape_to_numpy(shape)
        (x, y, width, height) =
main.rectangle_to_bounding_box(rect);
        cv2.rectangle(captured_frame,
(x, y), (x + width, y + height), (127,
255, 212), 2)
        cv2.putText(captured_frame, "No.
#{}".format(i + 1), (x - 10, y - 10),
cv2.FONT_HERSHEY_SIMPLEX, 0.5, (127,
255, 212),
                    2)
        j = 0;
        for (x, y) in shape:
            cv2.circle(captured_frame,
(x, y), 1, (127, 255, 212), -1)
            cv2.putText(captured_frame,
str(j), (x, y), cv2.FONT_HERSHEY_SIM-
PLEX, 0.3, (127, 255, 212), 0)
            j = j + 1;
```

The result of the above code will show the following output:

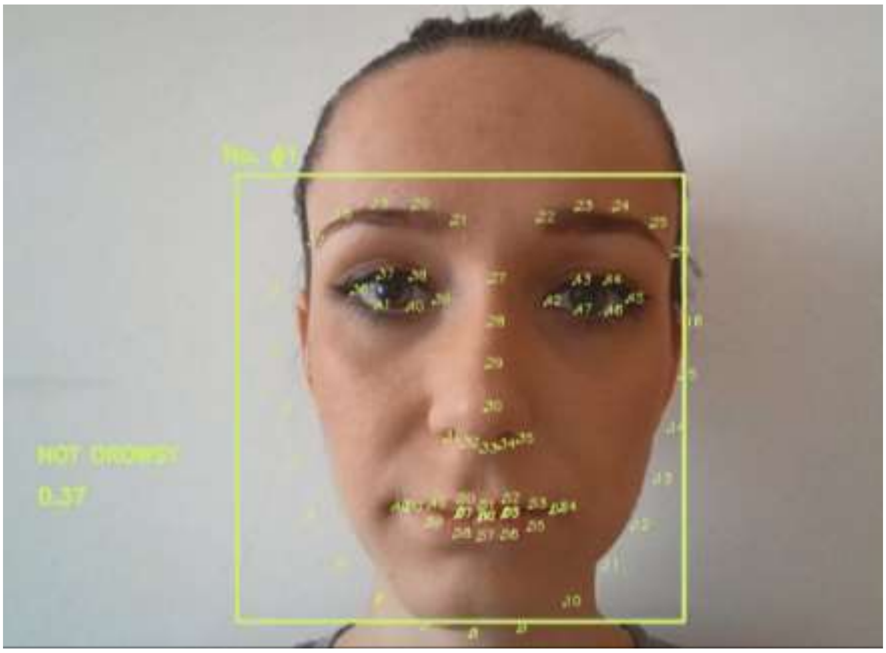

Fig. 6. Face recognition and drawing the sixty-eight points

The Euclidean formula for distance has been applied to find out the needed distance to determine the EAR of left and right eye, and then the general EAR, as it can be observed in the following lines of the source code.

```
def eye_aspect_ratio(face):
    # left eye
    distance36_39 = distance.euclid-
ean(face[36], face[39]);
    distance37_41 = distance.euclid-
ean(face[37], face[41]);
    distance38_40 = distance.euclid-
ean(face[38], face[40]);
    # right eye
    distance42_45 = distance.euclid-
ean(face[42], face[45]);
    distance43_47 = distance.euclid-
ean(face[43], face[47]);
    distance44_46 = distance.euclid-
ean(face[44], face[46]);
    EAR_left = (distance37_41 + dis-
tance38_40) / (2 * distance36_39);
    EAR_right = (distance43_47 + dis-
tance44_46) / (2 * distance42_45);
    EAR = (EAR_left + EAR_right) / 2;
    print(EAR_left)
    print(EAR_right)

    return EAR;
```

The author has considered the minimum EAR to be 0.24, the average of the 0.339 EAR value with eyes open and 0.141 EAR value with closed eyes [13]. In the source code that follows the obtained result of the EAR is compared with the minimum value considered by the author, obtaining two possible results: “drowsy” or “not drowsy”.

```
EAR = eye_aspect_ratio(shape);

EAR = round(EAR, 2);
cv2.putText(captured_frame, str(EAR), (x
- 300, y - 10),
            cv2.FONT_HERSHEY_SIMPLEX,
0.5, (127, 255, 212), 2)
if EAR < min_EAR:
    cv2.putText(captured_frame,
"DROWSY".format(i + 1), (x - 300, y -
40),
                cv2.FONT_HERSHEY_SIM-
PLEX, 0.5, (127, 255, 212), 2);
    print("Drowsy")
else:
    cv2.putText(captured_frame, "NOT
DROWSY".format(i + 1), (x - 300, y -
40),
                cv2.FONT_HERSHEY_SIM-
PLEX, 0.5, (127, 255, 212), 2);
print(EAR)

cv2.imshow("Video detection", cap-
tured_frame);
cv2.waitKey(0);
```

The Python application result displays following outputs, depicting a Drowsy and a Not Drowsy face:

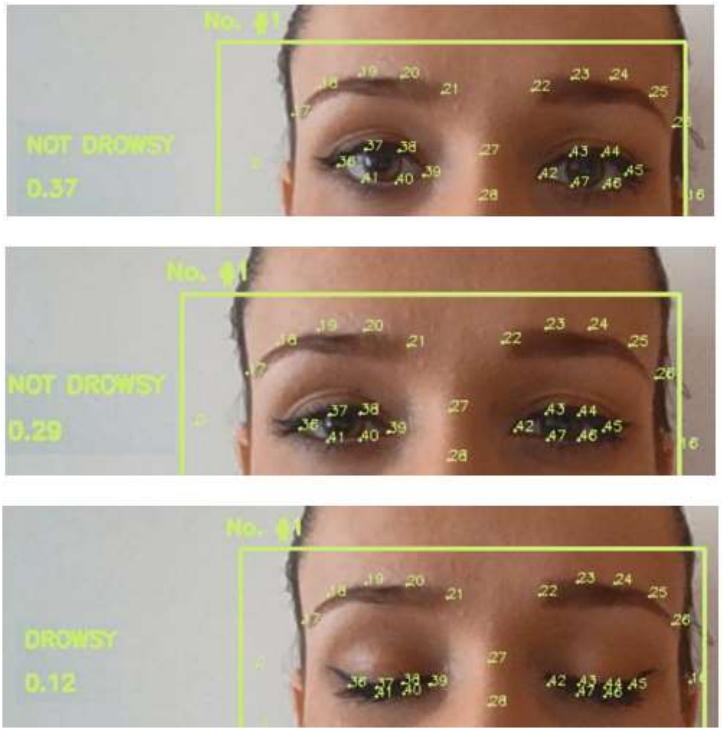

Fig. 7. Examples of multiple predictions

After the data is collected from inside the car through the OBD and transmitted via the Client through Cloud Computing services into the manufacturer's database system it is further analyzed with various algorithms of classification and prediction.

The solution comes after the analysis of these features, which first enables the algorithm to alert the driver on its state and after starts implementing different environmental changes that will most likely change the state of the driver. Changing temperature, music, or even decreasing the speed, could be solutions to changing the driver's state.

4 Conclusion

As car manufacturers have developed, they acquired large datasets that are facilitating the development of Artificial Intelligence in the Automotive Field. Moreover, the growth that both have witnessed has been a big step into merging the car systems with Artificial Intelligence features.

Further, analysis of the data from cars' systems will allow the research to correlate steering wheel degree, heartbeat rate, yawning cases, flow of car speed and traffic engage into a more detailed pattern of a driver's behavior.

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Diana GHEORGHE graduated from Bucharest University of Economic Studies, Faculty of Economics Cybernetics, Statistics and Informatics and has a Master in Databases. She works as a Full Stack Software Engineer in the Automotive field, at Harman International. The area of interest is focused on Artificial Intelligence and its development across the Automotive Industry.