Data-driven machine learning and optimization pipelines for real-world applications

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CHAPTER 2

Automated Damage Assessment

2.1 Objectives

Industrial applications suffer wear. For example, in assembly lines parts are often exchanged at an early stage to avoid fatal failures and longer downtime's, even when the parts are not roughly worn out. Exchanging such parts later would be beneficial due to longer part operation times and lower material costs. The objective is to exchange parts very shortly before the critical condition of the part is reached. Assembly lines are often equipped with sensors which record conditions. Based on machine learning techniques and the data recorded by the latter sensors, predictive models can be created to estimate failures more precisely without sophisticated process monitoring systems. Using such predictive models for failure detection is called predictive maintenance. Predictive maintenance can not only be realized in assembly lines but also in, e.g., passenger cars, trucks, construction machinery or any other kind of devices or machines which have useful data.

Though, some applications suffer other kinds of losses which are often caused by the human interaction due to incorrect handling or undesirable incidents like vehicle accidents. Such cases often require experts to inspect the damage, evaluate the damaged parts and carry out the repair. Depending on the damage and the machine this can be a time-consuming procedure. Using predictive models for such incidents would allow estimating the loss and the damaged parts directly after a vehicle accident. This estimation would decrease the time needed for the repair, because damaged parts can be ordered and painted even before the car arrives at a workshop. Furthermore, the owner of the vehicle would receive a very transparent overview of the required repair, as well as the precise time needed for the repair.

Figure 2.1: A vision of a customer journey of a low speed crash settlement.

The feasibility study to estimate the damaged parts caused by a vehicle crash is carried out in the automated damage assessment project. This project focuses on low speed crashes with a maximum change in velocity of approximately 16 km/h (RCAR, 2018). Low speed crashes usually do not cause injuries to the occupants and are considered as the most occurring accidents. Though, such events are stressful for occupants and usually associated with longer settlement times. An automatic assessment would primarily support the customer shortly after the accident and secondly improve the whole damage settlement.

Figure 2.1 illustrates a vision of an ideal customer journey of a low speed crash settlement.

The journey is separated in four phases:

1. Driving,
2. Detection,
3. Supporting and
4. Repair.

The vision is arranged in a circle for clockwise reading and the starting point is called driving. The driving represents the main purpose of using a car. In the unlikely and unfortunate case of a low speed accident the car is able to detect such an event (phase 2). This detection is based on machine learning techniques (de Silva et al., 2017). A message is shown on the HMI (Human-Machine Interface) in the car with the request to call the accident call center, which supports (phase 3) the customer in all aspects, i.e. calming down, calling the ambulance and police if necessary, helping to proceed in the correct way and finally take over the whole settlement with, e.g., insurance companies and workshops.

Shortly after the customer has granted the request a connection to the accident call center is established. Furthermore, a small data package is transferred to a back-end system which is used by the machine learning assessment model to estimate the damaged parts (de Silva et al., 2017; Koch et al., 2019). This estimated assessment information is provided to the customer which allows the customer to settle the whole accident shortly after the crash via call or app. In the last phase of Figure 2.1, the repair, the car is picked up and delivered to the workshop, repaired and brought back to the customer. In all steps, the customer can access the current car status.

One objective of this project is to increase the time the car is available for driving, i.e. the time of workshop visits should be shortened. Furthermore, this automated assessment should provide a convenient and transparent way to settle such accidents.

Amongst many other things, within this dissertation, we evaluate time series classification methods to assess the damages caused by low speed crashes. Furthermore, along this service development, we have evolved a method to run such data-driven projects in the industry.

2.2 Data

The damage assessment project is targeted to use only vehicle on-board data which is available in all modern passenger cars, i.e., no additional sensor is needed for this purpose. Nowadays, not all cars are equipped with sophisticated camera systems, radar and so on. However, nearly all cars have some sensors, e.g. acceleration sensors for airbag deployment. This project focuses primarily on such sensor systems which are available in most of the vehicles, because it is very likely that an assessment model based on those data can already deliver precise results. And equally important, the number of cars equipped with serial sensors is much higher than cars equipped with more sophisticated sensors. Therefore, using only serial sensor data allows to equip as many cars as possible with such a service. Furthermore, it keeps the data packages to a minimum which is important to limit needed resources like bandwidth, memory and so on. Obviously, for cars with a sophisticated sensors equipment additional data can be used if needed and for new car designs additional sensor could be added.

Figure 2.2: The vehicle coordinate system. (Original photo from `BMW Group Technical Qualification Media`)

To develop such an assessment model, sensor data from crash events, as well as its damages are needed. Within this work first data was generated in a tedious manual process. In the following our crash test setting is described: 12 similar cars were used and crashed in a driving-car-to-standing-car configuration in 50 different combinations. Each of those cars was equipped with recording devices to track the sensor data while the accident had happened. Due to the 50 different combinations, our final data set contains 100 cases: 50 from standing vehicles and

50 from driving vehicles. Each case contains the tracked sensor data of the crash events. We have built our assessment models with the following sensor data:

- Acceleration X,
- Acceleration Y,
- Yaw rate,
- Resulting velocity.

Figure 2.2 shows the vehicle coordinate system. It indicates that X describes the longitudinal direction and Y the lateral direction. The used sensors are located close to the vehicle center of gravity.

After each crash combination both cars were partially disassembled to investigate the damage in detail. A low speed crash usually does not cause any damage on structural parts. Therefore, this damage investigation only requires removing the outer, mounted parts. Some representative damaged parts of low speed front crashes are shown in Figure 2.3.

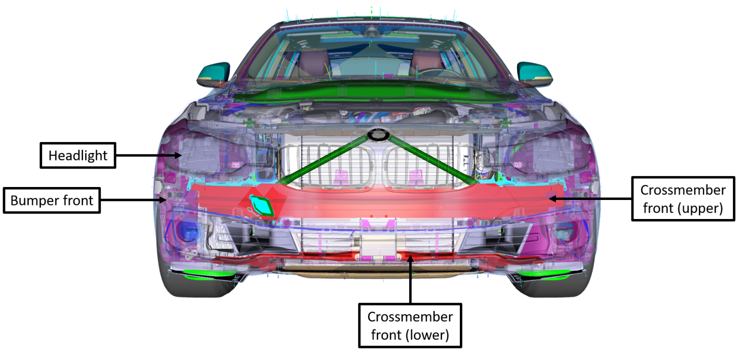

Figure 2.3: Exemplary damaged parts of a low speed crash.