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Reliability of parking assistants depending on the material of detected obstacles

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Abstract. Today's modern vehicles are equipped with a range of assistance systems to enhance road safety. The standard equipment of most cars are parking assistants. It turns out that not always sensors can reliably detect the obstacle on the travel path of the vehicle. The aim of the paper is to determine the reliability of the parking sensors depending on the material of the obstacle detected. The original parking assistants of Škoda Rapid, Škoda Octavia II, and Škoda Superb have been tested in laboratory conditions using obstacles made of various materials (glass, mirror, plastic, metal, cardboard ...) located at distance of 100 cm from the vehicle. Distance values of the original sets of parking assistants were measured during the measurement from on-board diagnostic vehicle using diagnostic kit VAG-COM. The real distance was checked using a calibrated gauge. The results of the research show, that original sets of parking assistants achieve significantly more accurate results with a wider coverage of the space being scanned. Material composition of obstacles has a great influence on the reliability of parking systems. Not every material can respond properly to parking sensors.

Key words: parking sensors, assistance systems, reliability, materials.

INTRODUCTION

Assistance technologies in the automotive industry are becoming an integral part of mass-produced cars. The main reason for this is to increase the driving comfort and safety of car traffic. In particular, the second motive - safety - is an important incentive for the development of vehicle driver assistance systems. Minor accidents are most often due to driver inattention and during difficult parking situations. These types of accidents usually occur at relatively low driving speeds, but despite this, minor injuries to the crew can occur, such as whiplash injuries. However, pedestrians are much more at risk and, unfortunately, most are children who may not be registered by a parking driver due to their low body height. Although the damage and severity are usually low, these accidents represent a significant proportion of all road complications.

Different systems - laser, radar and others - can be used for assisted parking. However, sensors based on ultrasonic (US) waves are most commonly used Kidd & McCartt, 2016. The reason is their relative reliability, low cost and technical robustness.

The rear parking sensor system works by automatically switching on when the reverse gear is engaged, thus guarding the space behind them. The active part of the device sends a US signal that bounces off the obstacle and travels back to the sensor receiving area, which evaluates the quality and latency of the response. The result is returned as the distance of the car from the obstacle.

The quality and intensity of the received signal - US echo - is significantly influenced by the distance the US wave must travel from emitter to sensor. This part of the detection system is very well tested by the manufacturer, and its calibration is reliable and accurate. Virtually the only possible artificial intervention that may interfere with the result is the mechanical contamination of the sensor itself. Depending on the quality level of the system, the measuring apparatus can be equipped with back-up control systems for correct operation. The second component of the system is the reflection point for US, hence the obstacle itself. In this case, the reliability of the measurement cannot by its very nature be ensured by standard conditions, as this element is subject to changes depending on the operation of the motor vehicle (Filatov & Serykh, 2016). The detection system should therefore be primarily designed to capture as many types or qualitative variations of surfaces as possible that serve as a reflective surface for US. It can be assumed that surfaces that are homogeneous, smooth and reflect US well will be detected well. The problem, however, is obstacles whose surface is differently porous or otherwise inhomogeneous. At such a moment the US signal can pass through the obstacle, be reflected in different directions, or it can be absorbed. No signal response is returned to the target detector, which the system incorrectly evaluates as an absence of an obstacle and an accident may occur (Mazzae et al., 2008).

For this reason, it is important to also pay attention to parking sensors in terms of their reliability depending on the material of the relevant obstacle. Nowadays, these systems are assembled in most vehicles in the basic equipment, and it is therefore appropriate to verify their reliability for detection of obstacles from different types of material.

This issue can be resolved, for example, by changing the measurement method principle used to detect obstacles, such as automatic emergency braking systems that operate with radar technology in combination with a laser. However, it should be borne in mind that ultrasonic parking sensors are most often used in transport, even for parking assistants. For this reason, it is necessary to know their reliability.

MATERIALS AND METHODS

The research was carried out in the laboratory of the Department of Vehicles and Ground Transport, Faculty of Engineering, Czech University of Life Sciences Prague. Testing took place under the following laboratory conditions: 21 °C, 49% humidity and 493 lx light intensity. Three vehicles from VW group were selected for testing:

- Škoda Superb combi (model year 2018)
- Škoda Rapid (model year 2016)
- Škoda Octavia combi (model year 2004).

The distances of the individual obstacles were detected using the OBD of the VAG-COM Diagnostic System, where the immediate distance values of the obstacles from individual sensors were read by means of serial communication with the control unit of the parking system. The actual obstacle distance was determined via a calibrated distance gauge.

Test distance of the obstacle from the vehicle of 100 cm was determined for measurement repeatability and accuracy.

The choice of material was adapted to the physical properties of US waves so that obstacles from good, moderate and minimally reflective materials are represented, and which are realistic in normal operation.

- Sheet metal (without corrosion), thickness 2 mm, manufacturer unknown
- OSB, thickness 18 mm; Egger Holzwerkstoffe Wismar GmbH & Co. KG Am Haffeld 1 23970, Wismar Deutschland
- MDF laminated particleboard (mdf), white, smooth (also laminate board); Kronospan CR, spol. s.r.o, Company ID No. 62417690 Registered office: Jihlava, Na Hranici 6
- Carton - plain smooth packaging paper cardboard
- Polystyrene - extruded polystyrene Isover EPS 100; (Divize ISOVER, Saint-Gobain Construction Products CZ a.s., Prague)
- Straight foam rubber, smooth, thickness 30 mm, manufacturer unknown
- Glass wool - Basalt wool Isover N (Divize ISOVER, Saint-Gobain Construction Products CZ a.s., Prague) (https://www.isover.cz/produkty/isover-n)
- Mirror
- Wire glass, thickness 6 mm, size ok wire mesh 10 x 10 mm
- Transparent glass thickness 3 mm, smooth
- Glass with thin wire mesh (thin wire) – window size 2 x 2 mm, wire strength 2 mm
- Glass with thick wire mesh (thick wire) – window size 30 x 30 mm; wire strength 3 mm
- Facade fabric, window size 4 x 4 mm, Vertex R 117, fibre thickness 2 mm; Saint-Gobain Construction Products CZ, Prague

The test materials were always 100 x 100 cm in size. Individual tests were performed cyclically using them. These tests were repeated 10 times for each sensor. The measurements were carried out on rear parking sensors. The test surface was placed at a constant distance from the vehicle and the distance detected by the parking assist control unit was checked against the real distance determined by the certified length gauge.

The statistical method ANOVA and Tukey's HSD test were used for statistical evaluation.

RESULTS AND DISCUSSION

As expected, problems occurred with some of the test materials in that the sensors were not able to detect them. These materials are summarized in Table 1.

Table 1. Undetected materials

Materials	Superb	Rapid	Octavia
mirror	+	-	-
straight foam rubber	+	+	+
glass wool	+	+	+

+ means undetected materials; - means detected materials.

These materials probably cause poor reflection of ultrasonic waves. In this case these materials was used as an obstacle in form of standing solid object but some materials can be used as a clothing material. Especially glass wool can have a similar properties as many winter clothing materials. There is a possibility that it could lead to bad detect a moving person in winter clothes.

Fig. 1 show the average detected distance of individual obstacles measured on the Škoda Superb at distances of 100 cm. Parking sensors showed lower distance values than the real obstacle distance. The parking sensors had different results depending on the obstacle. The worst values were achieved by the obstacle of glass with thick wire mesh, where the sensor has detected an obstacle with a wider variance of distance and close to the nominal value of 100 cm.

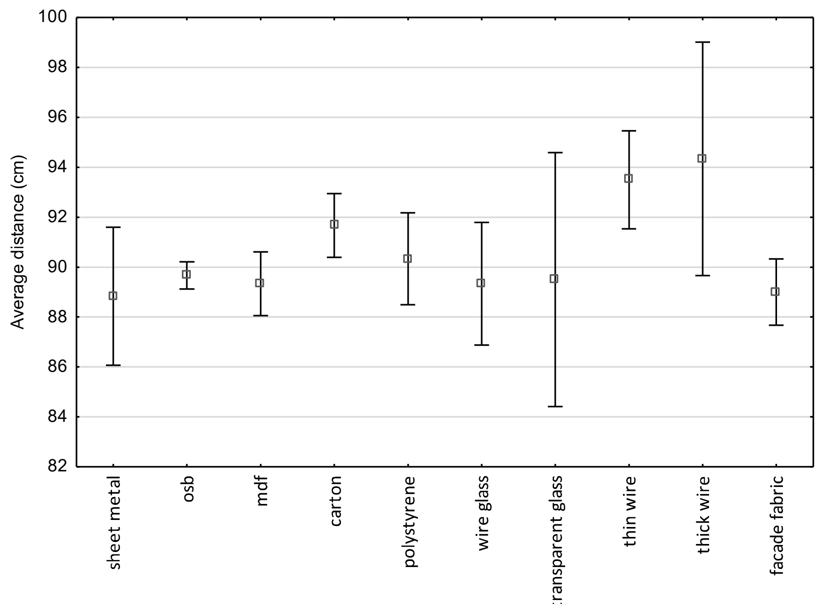

Figure 1. Measurement results for the parking sensors of the Škoda Superb vehicle at a distance of 100 cm.

Table 1 summarizes the results of distance of Skoda Superb for individual obstacles with marked out homogeneous groups calculated by Tukey's HSD test. There is evident that statistically significant difference can be seen at the obstacle of glass with thick wire mesh. Statistical analysis confirmed 2 homogeneous groups of materials with statistically significant different properties.

Fig. 2 shows the average values of distance measured on the Skoda Rapid at distances of 100 cm. The largest variance of distance were obtained at OSB obstacle. Approximately half of the obstacles

Table 1. Average distance of the obstacle and marked out homogeneous groups (*Tukey's HSD test)* on Skoda Superb

Material	Avg. distance (cm)	Homogeneous groups[1]	
sheet metal	88.83	****	
facade fabric	89.00	****	
mdf	89.33	****	
wire glass	89.33	****	
transparent glass	89.50	****	****
osb	89.67	****	****
polystyrene	90.33	****	****
carton	91.67	****	****
thin wire	93.50	****	****
thick wire	94.33		****

[1] homogeneous group symbolize the group of materials with similar properties with no statistical significant difference in measured parameter.

were detected at a distance of less than 100 cm. As a wrong detectable material can be identified the obstacle in form of wire glass, where the average detected distance exceeded the real distance by 5 cm.

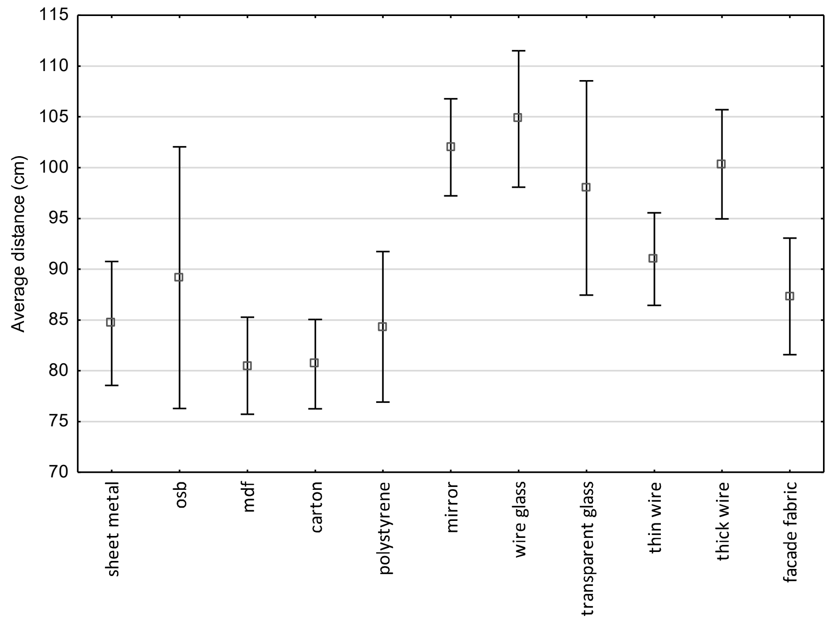

Figure 2. Measurement results for the parking sensors of the Škoda Rapid vehicle at a distance of 100 cm.

Table 2 summarizes the results of distance of Skoda Rapid for individual obstacles with marked out homogeneous groups calculated by Tukey's HSD test. There are 4 homogeneous groups of materials with statistically significant difference in dependence of detected distance.

Table 2. Average distance of the obstacle and marked out homogeneous groups (*Tukey's HSD test)* on Skoda Rapid

Material	Avg. distance (cm)	Homogeneous groups[1]			
mdf	80.50	****			
carton	80.67	****			
polystyrene	84.33	****			
sheet metal	84.67	****			
facade fabric	87.33	****	****		
osb	89.17	****	****		
thin wire	91.00	****	****	****	
transparent glass	98.00		****	****	****
thick wire	100.33		****	****	****
mirror	102.00			****	****
wire glass	104.80				****

[1] homogeneous group symbolize the group of materials with similar properties with no statistical significant difference in measured parameter.

Fig. 3 shows the average values of distance measured on the Skoda Octavia at distances of 100 cm. Compared to previously tested vehicles, in case of Skoda Octavia, obstacles were detected predominantly in distance above 100 cm. Out of measurements it is therefore evident that the detected distance may not affected only by the material of obstacles, but also by basic settings of the parking system sensitivity. The largest variance of distance were obtained at obtacle from glass with thin wire mesh.

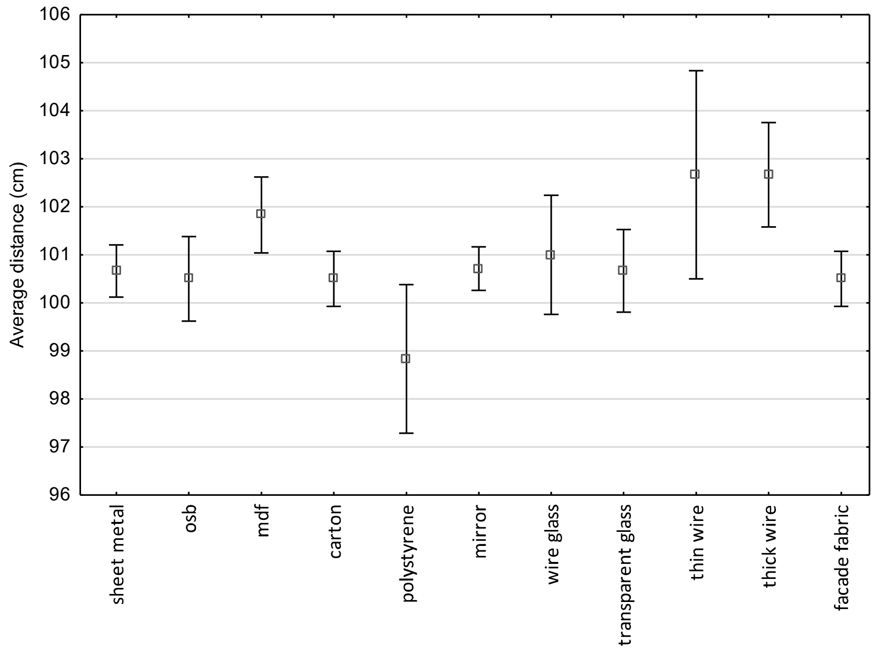

Figure 3. Measurement results for the parking sensors of the Škoda Octavia vehicle at a distance of 100 cm.

Table 3 summarizes the results of distance of Skoda Octavia for individual obstacles with marked out homogeneous groups calculated by Tukey's HSD test. There are 3 homogeneous groups of materials with statistically significant difference in dependence of detected distance.

The experiments carried out shows that the most problematic in terms of detection are materials that poorly reflects ultrasound waves. In most cases, glass-containing materials have proved problematic, while homegene materials have been detected predominantly reliably.

(Cicchino, 2019) focuses on a similar problem. Cicchino deals with the evaluation of the effects of rear

Table 3. Average distance of the obstacle and marked out homogeneous groups (*Tukey's HSD test)* on Skoda Octavia

Material	Avg. distance (cm)	Homogeneous groups[1]		
polystyrene	98.83		****	
osb	100.50	****	****	
carton	100.50	****	****	
facade fabric	100.50	****	****	
transparent glass	100.67	****	****	
sheet metal	100.67	****	****	
mirror	100.71	****	****	
wire glass	101.00	****		****
mdf	101.83	****		****
thick wire	102.67			****
thin wire	102.67			****

[1] homogeneous group symbolize the group of materials with similar properties with no statistical significant difference in measured parameter.

cameras, rear parking sensors and rear automatic braking systems during accidents. Cicchino assesses the suitability of these systems compared situations where these systems are absent. On the other hand, (Nascimento et al., 2018) deals with the improvement of the reliability of parking sensors using a Bayesian Filter, but this technology has been found to be somewhat costly.

(Mazzae et al., 2008) reported that some owners turned sensor systems off because they were not reliable. Drivers who reverse too fast may also exceed the functional capabilities of sensor systems (Llaneras et al., 2011). Finally, one study found that sensor systems had difficulty detecting pedestrians, especially moving children (Mazzae et al., 2008). Kidd et al. (2015) reported the problem of preventing a collision with an unexpected stationary or moving object in the backing path.

Lee & Chang (2014) in their article Development of A Verification Method on Ultrasonic-based Perpendicular Parking Assist System it discusses that, an accurate verification method is required to develop the parking assist system because this system has a risk of crashing into other vehicles while parking. Thus, the standard test specification and parameters of the verification method are proposed to prove the system accurately. Especially, it considers the mechanism of the parking system and risk points of sensors on the system sufficiently.

Authors (Cui et al., 2013) talk about ultrasonic array based obstacle detection in automatic parking. An ultrasonic array for automatic parking is designed and accomplished in this paper. The details of software and hardware of the system were presented in the article, and the system was validated in a refitted vehicle by automatic parking. The detection result of the ultrasonic array was contrast with that of LADAR. The system showed the advantages in the robust, economy, environments irrespective, and easy to widely application.

Another paper (Park et al, 2008) deals with parking space detection by using ultrasonic sensor. Using the multiple echo function, the accuracy of edge detection was increased. It can scan parking space more accurately in real parking environment. It was propose the diagonal sensor to get information about the side of parking space.

The results of our measurements can help to improve the system developed by the team (Hosur et al, 2016), which focused on to locate objects in the vicinity of moving and/or stationary vehicles using ultrasonic sensors. The around view system proposed here is based on distance calculation between the object and the vehicle. It is a supporting technology that assists drivers in parking and driving the vehicle more easily by giving a better understanding of the environment around vehicle. The proposed system, makes use of twelve ultrasonic sensors to cover 360 degrees of the vehicle. That means three ultrasonic sensor are used to cover one side of the vehicle with 180 degrees.

CONCLUSIONS

It is clear from the measured values that not every material is detectable by this technology, which uses ultrasonic waves to detect obstacles. Ultrasound waves are reflected from an obstacle, and if this obstacle is made from non-homogeneous material or material unable to repel ultrasound waves, this obstacle detection technology may be very unreliable. If we neglect the consequences of a minor accident in the form of damage to a vehicle or public space, this weakness may be very significant in the detection of pedestrians, especially children. Especially glass wool can have a similar properties as many winter clothing materials and therefore there is potential danger that some materials covering human body can led to poor detection of pedestrians.

The most problematic materials were foam, mirror, thin wire, glass wool and reinforcement mesh, which were not detected at all. With regard to glossy materials, there was poor reflection and distortion of the retransmission of the transmitted signal.

Out of measurements it is also evident that the detected distance may not affected only by the material of obstacles, but also by basic settings of the parking system.

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REFERENCES

Cicchino, J.B. 2019. Real-world effects of rear automatic braking and other backing assistance systems, *Journal of Safety Research* **68**, pp. 41–47.

Cui, H.H., Song, J.Z. & Liu, D.X. 2013, Ultrasonic Array Based Obstacle Detection in Automatic Parking. In: *Proceedings of 2013 Chinese Intelligent Automation Conference*, Yangzhou, China, pp.129–140.

Filatov, D.M. & Serykh, E.V. 2016. Intellegence autonomous parking control system of four-wheeled vehicle. In: *19th International Conference on Soft Computing and Measurements*, Saint Petersburg Electrotechnical University, pp. 102–107.

Hosur, P., Shettar, R.B. & Potdar, M. 2016. Environmental Awareness Around Vehicle Using Ultrasonic Sensors. In: *International Conference on Advances in Computing, Communications and Informatics*. ICACCI, Jaipur, India, pp. 1154–1159.

Kidd, D.B., Hagoski, B.K., Tucker, T.G. & Chiang, D.P. 2015, Effects of a rearview camera, parking sensor system, and the technologies combined on preventing a collision with an unexpected stationary or moving object, *Hum. Factors* **57**(4), pp. 1–26.

Kidd, D.G. & McCartt, A.T. 2016. Differences in glance behavior between drivers using a rearview camera, parking sensor system, both technologies, or no technology during low-speed parking maneuvers. *Accident Analysis & Prevention* **87**, pp. 92–101.

Lee, Y. & Chang, S. 2014. Development of a verification method on ultrasonic-based perpendicular parking assist system. In: *18th IEEE International Symposium on Consumer Electronics*, ISCE, South Korea, pp. 1–3.

Llaneras, R.E., Neurauter, M.L. & Green, C.A. 2011. Factors moderating the effectiveness of rear vision systems: what performance-shaping factors contribute to drivers' detection and response to unexpected in-path obstacles when backing. In*: SAE 2011 World Congress & Exhibition* (Paper No. 2011-01-0549), Society of Automotive Engineers, Warrendale, pp. 689–700.

Lubecke, B.O. 2016. *Doppler Radar Physiological Sensing*, 1. US: John Wiley & Sons Inc., ISBN 9781119078418.

Mazzae, E.N., Barickman, F., Baldwin, G.H.S. & Ranney, T. 2008. On-road Study of Drivers' Use of Rearview Video Systems, National Highway Traffic Safety Administration, Washington DC, pp. 1–140.

Nascimento, A.M., Cugnasca, P.S., Vismari, L.F., Junior, J.B. & De Almeida, J.R. 2018, Enhancing the Accuracy of Parking Assistant Sensors with Bayesian Filter, In: *IEEE International Conference on Vehicular Electronics and Safety*, Madrid; Spain, pp. 1–6.

Park, WJ., Kim, B.S., Seo, D.E., Kim, D.S. & Lee, K.H. 2008, Parking Space Detection Using Ultrasonic Sensor in Parking Assistance System. In: *IEEE Intelligent Vehicles Symposium*, Eindhoven, Netherlands, pp. 1039–1044.