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Use of thermal imaging camera for wild animal detection along roads

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Abstract: Vehicle collisions with wild animals are a common problem on roads, having a significant impact on road safety and wildlife populations. Collisions with wild animals are one of the most frequent road accidents. According to police statistics, there were nearly 16 000 road accidents caused by collisions with animals in the Czech Republic in 2019. Collisions with deer are the most common. There are several technologies and measures that can help reduce the risk of a vehicle colliding with a wild animal. One of the technologies used is a night vision system based on infrared spectrum sensing. This technology is slowly becoming part of the equipment of, in particular, premium car brands dueto its high cost. This paper tested a low-cost solution using a commercially available thermal imaging camera and found a substantial reduction in the time to detect wild animals along the road, namely in the order of seconds.

Keywords: night vision; active vehicle safety; systems for preventing traffic accidents; traffic accident

Cars are currently the most widely used means of transport. This fact is one of the main reasons why a great emphasis has been placed on active and passive safety. It is already a matter of course that every car company implements active and passive safety systems in their cars and that their development is constantly improving (Markovnina et al. 2021; Sierra Muñoz et al. 2024).

The progress of humankind requires constant improvements in transport accessibility, which often entails unwittingly interrupting the natural migration routes of wild animals and their possible collision with the driver. An increasing emphasis is being placed on environmental ecology and the protection of wild animals, as well as on driver safety. Natural corridors for wild animals are being replaced by artificial ones, roads are fenced or lined with odour repellents, vegetation is removed from the immediate vicinity of roads and drivers are warned of the danger of the presence of wild animals by warning signs (Ward et al. 2015; Zellmer et al. 2022).

Despite these measures, however, collisions between vehicles and wild animals occur more and more frequently. As can be seen in Figure 1, the number of accidents involving forest animals has increased several-fold from 1993 to 2018, and, since 2010, the number of these accidents has increased (BESIP 2019; Valerio et al. 2021).

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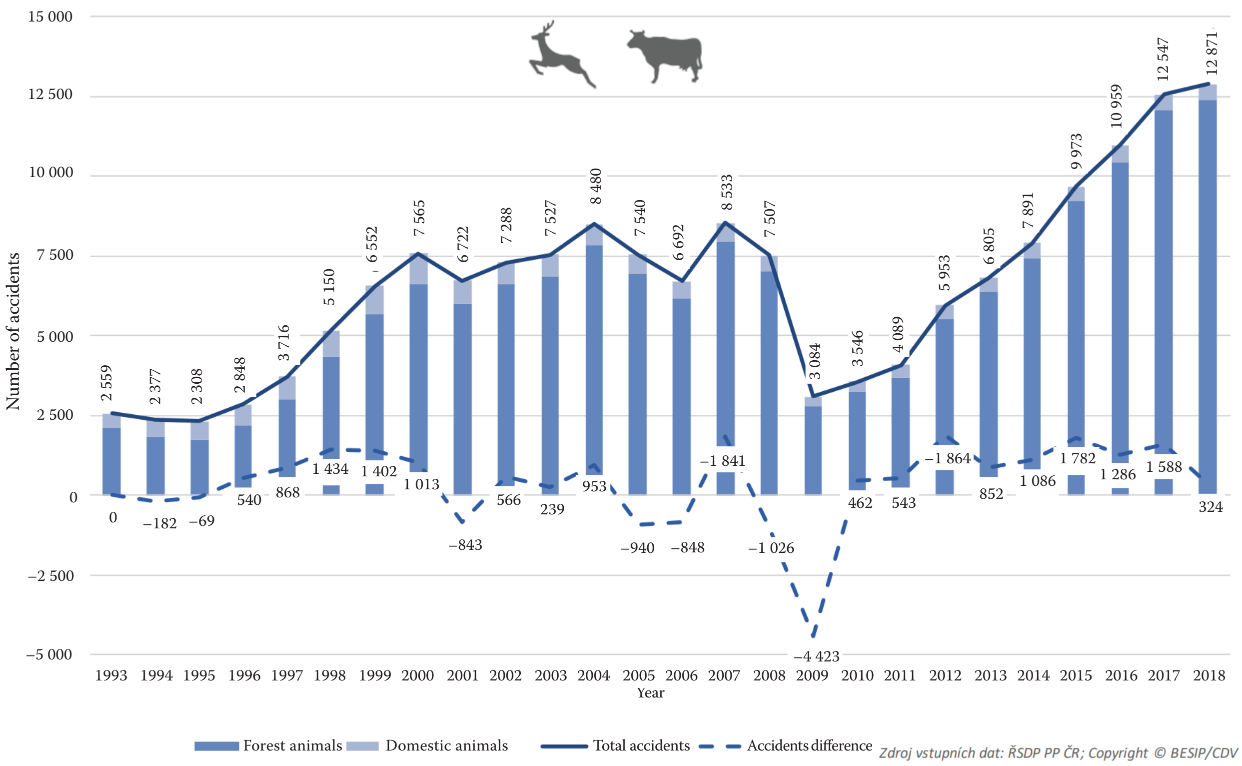

Figure 1. Evolution of the number of accidents involving forest and domestic animals in the Czech Republic (BESIP 2019)

In 2019, a record 15 983 accidents involving forest or domestic animals were registered in the Czech Republic (Figure 2). These accidents most often happen on class II roads. In 2018, 3 people lost their lives as a result of these accidents, 19 others were seriously injured and 150 others had minor injuries. There are, of course, many cases where a collision with wild animals occurs, but the incident is not reported; this data is then not included in these statistics (BESIP 2019; BESIP 2023).

Figure 3 shows a map of the frequency of the struck wild animals in the territory of the Czech Republic. There are various wildlife detection technologies, from simple sensors (environmental and atmospheric sensors, optical sensors, infrared sensors, thermal sensors, multispectral and hyperspectral sensors, lidar, radar, acoustic sensors, and more) to fixed and portable devices (optical cameras, thermal imaging, passive acoustics, active sonar, and more) (Lev et al. 2017; Shapoval et al. 2018; Lahoz-Monfort & Magrath 2021).

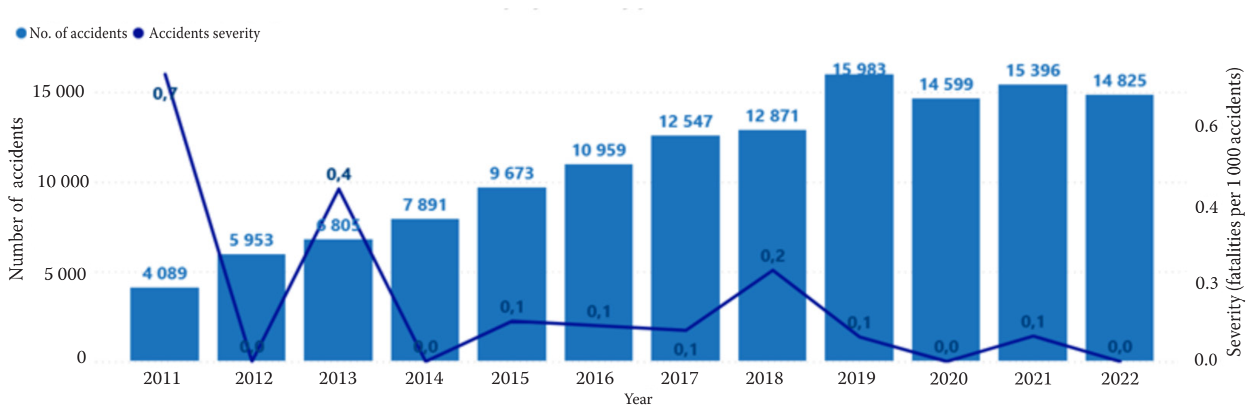

Figure 2. Trend in accidents and accident severity (BESIP 2023)

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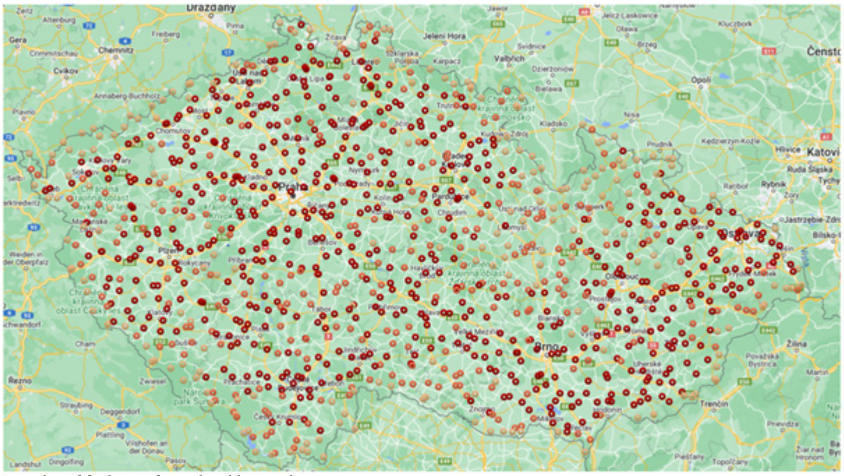

Numberof findings of struck wild animals
- > 100
- 51–100
- 1–50

Figure 3. Number of the struck wild animals (Transport Research Centre 2024)

Thermal cameras can be used for the automated detection and recognition of wildlife. A study by Christiansen et al. (2014) demonstrated the use of thermal imaging for detecting animals in agricultural fields, which can be adapted for roadside detection. The study utilised a dynamic threshold to detect hot objects and a k-nearest-neighbour (kNN) classifier for animal recognition, achieving high accuracy. Infrared thermography (IRT) is a non-invasive method that captures temperature distribution patterns on the surface of objects. Cilulko et al. (2013) highlighted the use of IRT in various wildlife studies, including the detection of animal habitats and the population estimation. This method's non-intrusive nature makes it suitable for monitoring wildlife along roads without causing stress to the animals. The disadvantage of thermal imaging technology can be the environmental conditions, such as the weather and vegetation, that can affect the accuracy of the thermal imaging. Studies have shown that dense vegetation and extreme weather conditions can obscure thermal signatures, making detection more challenging.

Today's modern vehicles, especially the most luxurious ones, usually have, as part of their optional extras, warning systems using advanced technologies such as infrared cameras with artificial intelligence for real-time image analysis. Thermal imaging cameras have proven to be, especially when driving at night, a very useful technology that can detect wild animals along roads in a timely manner. Currently, these systems are only available as an optional extra on some vehicles and usually only on premium brands of vehicles. This additional equipment is very expensive, the price can reach up to 150 000 CZK (6 000 EUR). The use of much cheaper thermal imaging cameras as additional universal equipment could significantly reduce the number of accidents caused by vehicles colliding with wild animals or people walking along the road. (ŠKODA 2020).

The aim of this paper is to test a relatively inexpensive thermal imaging technology in a real-word environment placed in front of the vehicle for the possibility of detecting wild animals on the roadside.

The paper shows that, even with an inexpensive thermal imaging camera, wild animals can be detected far ahead of the vehicle with greater advance notice than drivers can detect by themselves.

MATERIAL AND METHODS

The experiment was based on conducting a number of test drives through a predetermined area (route) with the presence of forest animals, using a thermal imaging camera and eye-tracking glasses to monitor the driver's eye activity and camera recording of the driven route (Figure 4).

Eye-tracking Tobii Pro Glasses 3. Special eye-tracking Tobii Pro Glasses 3 (Tobii, Sweden) with four integrated eye-tracking cameras and sixteen eye illuminators built directly into the lenses were used to capture the driver's eye activity. The glasses include a gyroscope, accelerometer, microphone, magnetometer, and one wide-angle camera for imaging the environment integrated directly into the frames. The recorded videos were subsequently processed in the Tobii Pro Lab software (version 1.7.4)

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Figure 4. Experiment settings (thermal imaging camera, vehicle, eye-tracking glasses)

using analytical functions to create heat maps and gaze plots.

Thermal imaging camera. For the thermal imaging, an HIKVISION DS-2TP21B thermal imaging camera (HIKVISION, China) was used. It is a device with a temperature range of –20 °C to 550 °C and a temperature sensitivity of 40 mK. The real-time imaging frequency is 25 Hz. All the measured data are recorded on the SD card which is included in the thermal imaging camera.

Ford Ranger vehicle. A Ford Ranger vehicle, was chosen as the test vehicle, mainly due to its off-road characteristics.

Measurement location. The actual experiment was carried out in the area of the Sedlice Game Preserve (Sedlická obora, GPS 49.3617344N, 13.9890319E), a nature reserve (South Bohemia). This nature reserve (Figure 5), which covers an area of 255 hectares, is surrounded by a stone wall and is mainly used for breeding wild animals. As can be seen in Figure 5, it has the shape of a regular hexagon. The roads within it are both paved, partially paved and unpaved. The game preserve is divided by a wooden fence into two parts. In the first part, there is a population of European fallow deer, a population of Dybowski's sika deer and a smaller population of roe deer. In the second part, there is a wild boar population. There are also other small wild animals in the game preserve.

The area, therefore, provides ideal conditions for possible contact between vehicles and free-ranging wild animals, and there is no risk of contact with other road users.

Measurement methodology. At least two people (driver, co-driver) were needed for each measurement. The driver's task was to drive the test route – see Figure 6, which passed through both parts of the game preserve at a speed of approximately 35 km·h^{-1}. The measurements were focused on poor light conditions, so the measurements started at the onset of darkness until complete darkness when the tested thermal imaging camera was expected to be used more. The measurements were carried out between March 4, 2023 and March 25, 2023, in sunny weather, without rain, with an average temperature of 8 °C. A total of 60 drives were carried out.

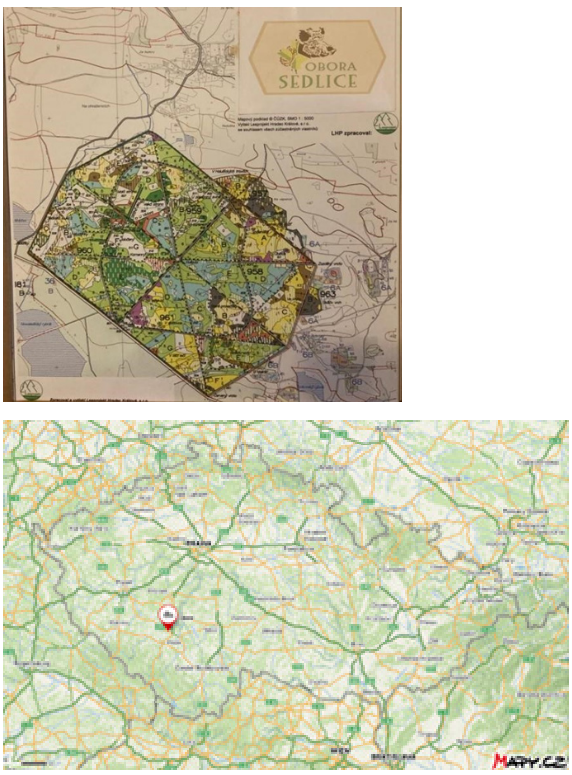

Figure 5. Sedlice Game Preserve

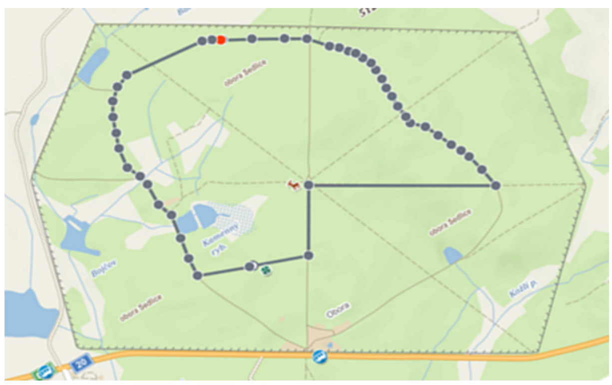

Figure 6. Test route

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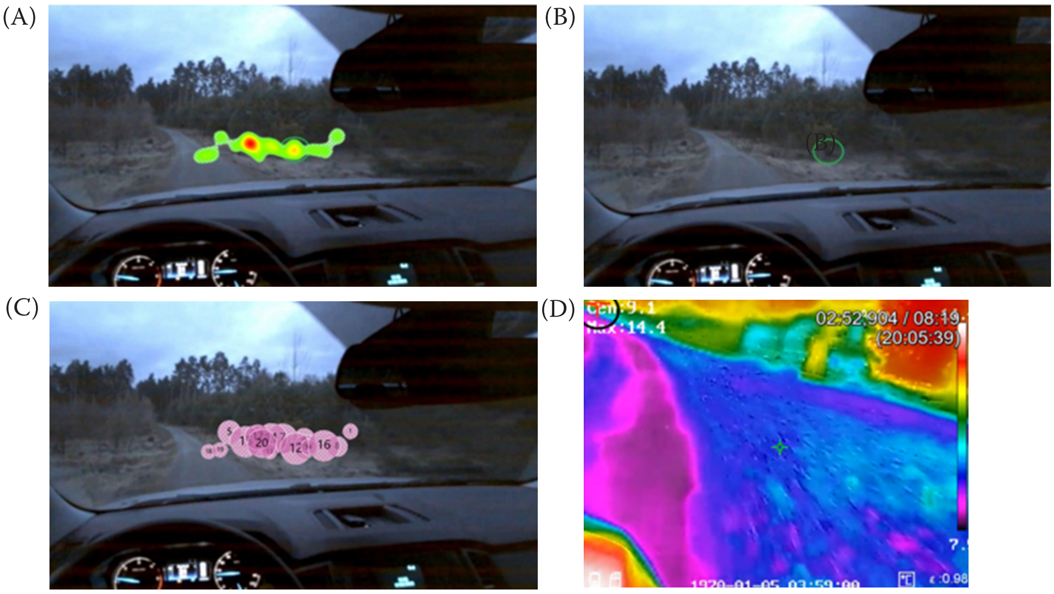

Figure 7. Driver's encounter with wild animals – dusk: (A) heat map, (B) video record, (C) gaze plot, (D) thermal image

RESULTS AND DISCUSSION

In the following part of the text, examples of the measurements from the analysis of the eye activity in different lighting conditions and a comparison of the reaction time of the driver and the thermal imaging camera will be presented.

Figure 7 shows a 15-second recording of driving at dusk, when a free-ranging wild animal was spotted running along the road. Figure 7A and C highlights the areas of eye activity at the moment of spotting the wild animal in the driver's field of view (A – heat map, C – gaze plot). According to Figure 7C, marked areas 20-12-16 are visible where the wild boar was present, and the driver was paying attention to this area. Figure 7B then shows the end of the video recording where the spotted wild animal is visible (highlighted by a red circle). Figure 7D then shows a thermal image of the area at the beginning of the recording where the area of the presence of the wild animal is again highlighted. The reaction times of the driver and the thermal imaging camera were comparable in this case.

Figure 8 shows a 10-second recording of driving at night including contact with wild animals. As can be seen in Figure 8A and B, the driver's field of view narrowed considerably during the night hours and

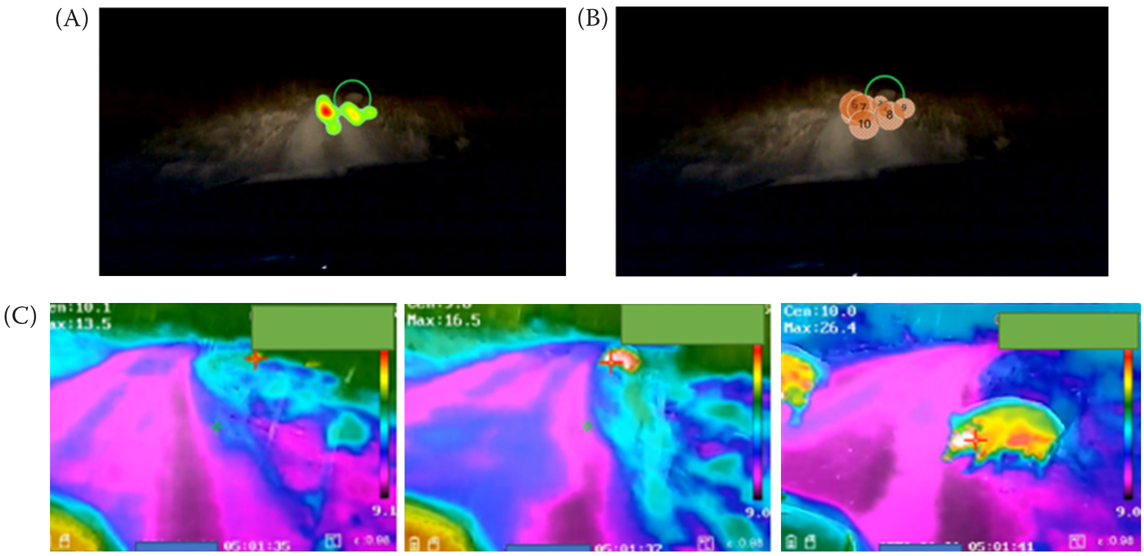

Figure 8. Driver's encounter with wild animals – night: (A) heat map, (B) gaze plot, (C) thermal image

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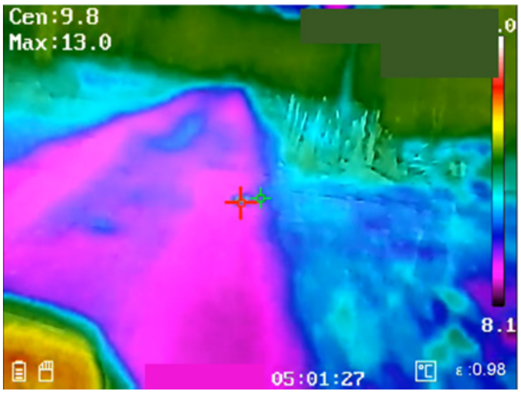

Figure 9. Mouse detection

is directed predominantly towards the centre of the driver's field of view. When a wild boar was spotted, the focus shifted slightly to the right. The thermal imaging camera detected the wild animal 2.5 seconds before the driver and subsequently detected another wild animal, while the driver only saw one wild boar at first.

Figure 9 records an interesting fact where the thermal imaging camera was able to detect a mouse crossing the road. This proves that the thermal imaging camera can also detect small creatures and bring attention to their presence.

Summary of test drives. During the experiments, 60 test drives were carried out at dusk and during night hours. From the video recordings taken, the reaction time of detecting wild animals along the road by both the driver and the thermal imaging camera was evaluated (Figures 10 and 11).

The results (Table 1) show that the average reaction time of the driver at night was 3.41 ± 0.7 s, while that of the thermal imaging camera was 1.25 ± 0.5 s, i.e., on average 2.16 ± 0.4 s shorter than in the case of the

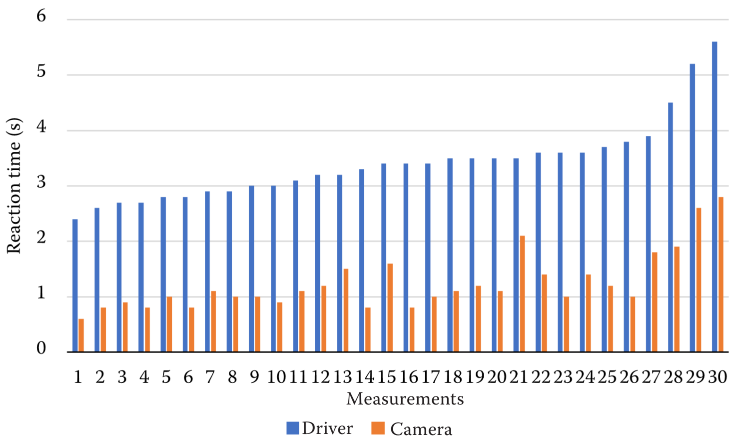

Figure 10. Reaction time at night

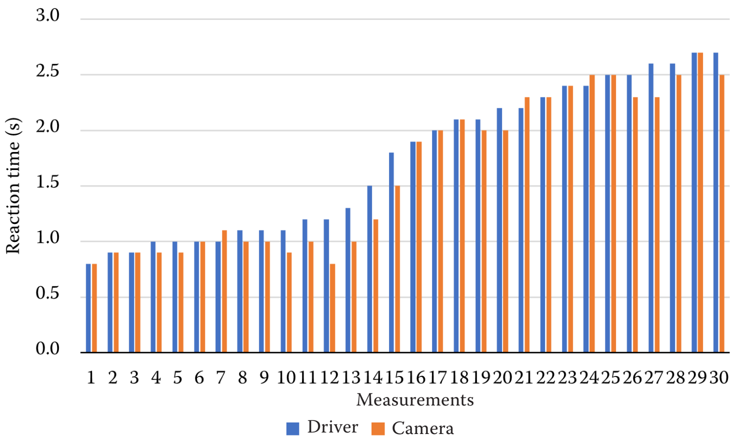

Figure 11. Reaction time at dusk

Table 1. Average values of reaction time at night and at dusk

	Night			Dusk		
	reaction time (s)		difference (s)	reaction time (s)		difference (s)
	driver	camera		driver	camera	
Average values (s)	3.41	1.25	2.16	1.74	1.33	0.41
Standard deviation (s)	0.69	0.52	0.36	0.66	0.46	0.37

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Table 2. Two-sample paired *t*-test for the mean reaction time at night

	Driver	Camera
Mean	3.41	1.25
Variance	0.492655	0.277759
Observations	30	30
Pearson correlation	0.862726	
Hypothesized mean difference	0	
Difference	29	
t Stat	32.54623	
P ($T \leq t$) one-tail	1.11E-24	
t Critical one-tail	1.699127	
P ($T \leq t$) two-tail	2.21E-24	
t Critical two-tail	2.04523	

Table 3. Two-sample paired *t*-test for the mean reaction time at dusk

	Driver	Camera
Mean	1.736667	1.64
Variance	0.44792	0.474897
Observations	30	30
Pearson correlation	0.980627	
Hypothesized mean difference	0	
Difference	29	
t Stat	3.917735	
P ($T \leq t$) one-tail	0.00025	
t Critical one-tail	1.699127	
P ($T \leq t$) two-tail	0.0005	
t Critical two-tail	2.04523	

driver. This is a difference in a distance travelled of approximately 19.5 m at a vehicle speed of 35 km·h^{-1}. The statistical analysis – two-sample paired *t*-test (Table 2) shows a significant difference between the reaction time of the driver and the camera at night.

At dusk (i.e., poor light conditions), the results were not so significant, with the thermal imaging camera detecting wild animals faster by an average of 0.46 ± 0.37 s, and the worse the conditions (usually a longer reaction time), the better the results achieved by the thermal imaging camera. Nevertheless, the statistical analysis (Table 3) confirms a significant difference between the reaction time of the driver and the camera at dusk, but significantly less than in the previous case.

The results align with previous research on the use of thermal imaging for wildlife detection. Christiansen et al. (2014) highlighted the high accuracy of thermal imaging in detecting animals in agricultural fields, which can be adapted for roadside detection. Similarly, Cilulko et al. (2013) emphasised the non-intrusive nature of infrared thermography (IRT)in wildlife studies, making it suitable for monitoring wildlife along roads without causing stress to the animals. The study also noted that environmental conditions, such as dense vegetation and extreme weather, can affect the accuracy of the thermal imaging. This limitation is consistent with the findings by Lahoz-Monfort and Magrath (2021), who reported that environmental factors could obscure thermal signatures, making detection more challenging.

Nowadays, technologies such as thermal imaging and night vision are only available in vehicles as optional extras, considered luxury specialised equipment. On average, the cost of these additional technologies ranges from 100 000 to 150 000 CZK (4 000–6 000 EUR), depending on the car brand. In comparison, the developing technology of integrating thermal cameras into side mirrors is less than half the price. This method reduces the costs to tens of thousands, with a maximum of 40 000 CZK (1 600 EUR) again depending on the type of thermal camera used (Novotný & Nemrava 2021; Daňa 2022; Bhattarai & Thompson 2023; Shaw 2024).

CONCLUSION

The detection of wildlife along roads is crucial for reducing wildlife-vehicle collisions, which pose significant risks to both animals and humans. Thermal cameras have emerged as a valuable tool in this context due to their ability to detect the heat signatures of animals, even in low visibility conditions.

The study demonstrated that using a low-cost thermal imaging camera significantly improves the detection of wild animals along roads, especially in low-light conditions. The thermal imaging camera consistently detected animals 2–3 seconds faster than the driver, providing a crucial time advantage for avoiding collisions. This finding is supported by the statistical analysis, which showed a significant difference in the reaction times between the driver and the camera, particularly at night.

In order to effectively use thermal imaging cameras in cars, two thermal imaging cameras would need to be implemented. The optimal locations for placing thermal imaging cameras in the car are ei-

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ther on the sides of the front bumper or inside the A-pillars. This placement of the thermal imaging cameras would cover a sufficient angle to see potential hazards early.

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