Encounters between wild animals and private cars may result in severe injuries and death. For example, in Sweden, a Nordic country, roughly 50% of all car accidents are due to situations involving wild animals. In 2005, there were 33,452 reported accidents with bears, wolves, wolverines, lynxes, moose, deer, roe deer, otters, wild boars, moufflons, or eagles, but the actual number of wildlife accidents is estimated to be substantially larger. A small proportion (3-4%) of these wildlife accidents results in injured people. In general, it is relatively harmless to collide with a wild animal in Sweden, with the exception of the Swedish moose. The latter type of collision most often results in severe injuries due to the long legs of the moose and its heavy mass.

Driver-oriented measures to decrease the number of accidents with game include the use of stationary game danger signs. However, this kind of sign has proven to be ineffective if used alone (1). This is simply because the probability of encountering game is too low for the driver to take the signal seriously, even though the probability is orders of magnitude higher in low risk areas. Other infrastructural means to prevent accidents include fences, over- and underpasses for animals, odorous substances and reflective apparatuses (1).

A motivation for this work is the rapid technical development within advanced driver assistance systems. Night vision systems have been around for some time; for example (2). The night vision systems are based on infrared technology, in which the observed temperature differences are converted into a video signal. Besides its basic use as a driver aid with the raw video showing the heat signatures displayed as a black-and-white image on a head-up display or in the instrument cluster, video processing may be employed for identification and tracking of objects. In the literature, most of the reported work in identification and tracking of objects by infrared vision is on pedestrian early warning systems (4 - 14), although a simulated software-based moose early warning system has been studied from a user point of view in (3).

The primary goal of the paper is to present the instrumentation and measurement set-up that has been developed, the moose simulator, and the design of the field tests in order to create a public database useful for the research and development of moose early warning driver-assistance systems. The main objective of a moose (or other large game) detection scheme is to alert the driver when there is a heightened risk for a collision due to the presence of a wild animal in the far field. The main contribution of the paper includes a public database with recorded typical moose-on-the-road scenarios. In our work, a commercial night driver system is patched to serve as the equipment basis for the collection of a database for the design and evaluation of big game early warning systems. The design and performance of a controllable living animal moose simulator is included as well. In Sec. 2, the technical platform and the moose...
thermal replica are described in some detail. Several typical traffic scenarios are constructed, including a vehicle and a moose, which form the basis for collection of the database during full-scale field tests. In Sec 3, the design of the field test as well as the database is described. The performance of an in-house developed early warning system is briefly illustrated in Sec 4. The conclusions are drawn in Sec 5.

2. Equipment

2.1. Night vision system

![Fig. 1 The infrared camera mounted in the front of the Audi S4 test vehicle. The size of the camera is L: 15 cm, W: 17 cm, H: 11 cm.](image)

The employed system is based on the Nightdriver system by L-3 Communications Infrared Products - a third party product suited for the Hummer H2 (2). The system consists of the actual infrared camera (as shown mounted on the test vehicle in Fig. 1) and a head unit equipped with the display for the driver, as well as a factory outlet for the composite video signal. The mounting of the camera unit in the front area of the test car is shown in Fig. 2. The camera is aligned by hand to set the view in the direction of the car. No particular calibration of its alignment is necessary. The mounting of the camera is thus similar to the mounting employed in (5), where a correct localization calibration procedure is presented. The camera video signal is transferred by wire to the head unit mounted inside in the car compartment on top of the dashboard (see Fig. 2). The head unit provides visual output by a built-in head-up display, but also by an NTSC video output signal. With reference to Figs 2-3, the video output from the Nightdriver system is fed to an external display, a digital camcorder, and the video input on the PC is fed through a video signal splitter. The Nightdriver system, video splitter, external display, and camcorder are all supplied with power by the 12-volt system of the car. It is accentuated by the fact that all of the utilized equipment consists of standard consumer electronics.

An exemplary recording from the field test is shown in Fig. 4. A second digital camcorder is placed between the front seats and provides a reference recording of the view in front of the vehicle.

![Fig. 2 Night vision equipment mounted inside the car compartment. From the top to bottom: head unit with head-up display, extra display, digital camcorder with auxiliary video input, video splitter, and CB-radio for personal communication during field tests.](image)

![Fig. 3 Block diagram of the night vision based driver assistance system utilized for the field tests. The system consists of the Nightdriver camera and head unit with head-up display (HUD), camcorder, extra display, and laptop PC. A second camcorder is used to record the reference video. In addition, GPS and maps are used for positioning and CB-radio for communication between the vehicle, the moose simulator, and the field test director.](image)
2.2. A moose thermal replica

The moose is a wild animal and cannot easily be used for controlled experiments such as the one presented in this work. A moose thermal replica may be designed and implemented by several means, for example, by water-filled barrels mounted on a stand. Here, a more pedestrian approach is employed and an Icelandic horse (that is, Equina Islandica) and its rider replaces the moose. The weight of the Swedish moose typically spans the interval 200 to 550 kilograms, whereas the height from withers to front hoof may be up to 2 meters, where the bull is 20% larger than the cow. The employed horse and carriage weighs some 340 kilograms and the height from withers to front hoof is 1.38 meters. Thus, its size and weight correspond to a tiny to mid-size moose. The moose, like the horse, has three gaits: walk, trot, and canter (although the Icelandic horse also has two more gaits: tolt and pace). It mostly moves in walk but runs in trot if it has to cover longer distances fast. The top speed of a moose in trot is 60 kilometers/hour, which it can keep up for up to 500 meters at a time. The moose canters only on rare occasions, and in these cases, only for short distances. For that reason, only walk and trot were considered for the field tests.

Some advantages of the employed moose simulator over synthetic ones include: its agility over difficult terrain, similarity with the moose in cross-country running, and the natural temperature control of the horse’s body. A field test thermal image of the simulator is shown in Fig.4.

Fig. 4. Original output of the employed night driver system showing the thermal signature of the moose simulator (Equina Islandica) and its rider during practical field tests. The distance between the camera and horse is 92 meters measured by GPS.

3. Field tests and public database

3.1. Controlled test scenarios

The recorded data originate from extensive use of the infrared imaging system at ordinary driving situations, as well as from controlled field tests. The aim of the latter experiments is to specify the scenarios for generality so that the most encountered situations are covered, for which a moose early warning system may provide additional input to the driver, resulting in an increased safety margin. Besides the recordings from the infrared camera, some reference video is recorded, GPS positioning and estimation of moving patterns are performed, and recordings are made of weather conditions and other pertinent information.

In order to simplify the directed scenarios, additional constraints are imposed. Within the view angle of the camera, no more than two heated bodies are present: the moose thermal replica and a pedestrian or stationary object. Further, moving objects are constrained to a constant speed and straight-line movements. The field tests are carried out on a road at a horizontal open piece of ground without obstacles hiding the visual view. The design of the field tests is based on observing some 20 hours of typical real-life infrared recordings from Swedish country roads and highways.

3.2. Weather conditions

The weather conditions are important for the recording of a database like the one presented here. The quality of the infrared video signal depends not only on the temperature difference between the warm objects and the surrounding, but also on surface properties of the heated body such as emissivity, reflectivity, and transmissivity. The number of reported accidents with moose obeys a periodic variation. In general, most accidents have been reported during October, but in some years, January also has a high number of reported accidents; mainly depending on the snow conditions. The large number of reported accidents during the fall coincides both with the mating season and with the increased alertness of the moose due to the number of moose hunters and berry/fungus pickers in the woods during the fall. The date of the field tests was chosen to be mid-October.

3.3. The nine test cases

The designed scenarios are summarized in Fig. 5. In total, nine scenarios were designed for the controlled experiments, from a basic scenario with a standstill vehicle and the moose thermal replica, to a turning car with a running moose and walking pedestrian in and across the view of the driver. The scenarios try to model the scenarios in which a moose early warning system should indicate
Fig. 5 Schematic design of the nine scenarios for controlled experiments with the moose thermal replica and additional heated-body obstacles. The rectangle indicates the test vehicle, the triangle indicates the moose thermal replica, and the circle and the hexagon indicate a hot object and a pedestrian, respectively. All arrows represent constant speed.

Some degree of danger. Simpler scenarios are employed as well in the application development phase, and scenarios that are more complicated can be used for general testing purposes.

Fig. 5 summarizes various designed scenarios. In scenario 1, the moose (thermal replica) is at a standstill or perpendicularly crosses with a constant speed the view of the standstill FIR-camera. This essential scenario is useful as a baseline to implement and verify different detection and tracking algorithms. In scenarios 2 and 3, some disturbances, such as thermal obstacles and pedestrians, are introduced.

In scenarios 4 and 5, the moose moves toward the vehicle, and in the latter scenario, a moving pedestrian is added. Compared to the previous scenarios, these scenarios result in gradually increasing the size of the objects in view of the FIR-camera. By tracing the changes in the baseline of object bounding boxes and the changes in their size, more detailed information such as instantaneous speed of the objects and relative distance between the objects and the test vehicle can be estimated.

In scenarios 6 and 7, background motion is introduced by driving the test vehicle at a constant speed. These tests are useful in the evaluation of motion-based detection algorithms. As they are more like a real-life situation, these background motion scenarios are also useful resources in testing the robustness in all cases.

In scenarios 8 and 9, an extra but dominating background motion speed is introduced by turning the test vehicle. These cases are useful to verify the robustness of the motion-based detection algorithm. Similar to scenarios 6 and 7, these may also be used as test resources to all algorithms.

3.4. Public database

One goal of the presented project is to build up a database with recordings suitable for education, research, and development around moose early warning systems. The database is publicly available through the project website www.ame.ee.kth.se.

Besides the sequences from the nine controlled experiments reported above, public access is allowed to a plurality of sequences from different driving scenarios, weather conditions, and time of day at a variety of geographical locations.

4. Initial experiments with a moose early warning system

In this section, the performance of the in-house developed software is illustrated briefly. The underlying video processing is beyond the scope of this presentation and is reported in detail in (15). The software, which includes features like threshold detection and continuously adaptive mean-shift tracking algorithm, is available through the website.

Despite using only pixel-wise information, threshold detection algorithm gives acceptable result in identifying target objects. As shown in Fig. 6, targets or their composing elements are highlighted and registered. The tracking algorithm evaluates the average relative speed of the target objects, which is an important factor in risk evaluation. In order to calculate the risk index, parameters such as the relative distance to target objects, position of the bounding box and the speed of target objects are used. As shown in Fig. 7, the calculated risk index of each target object is represented by the size and position of the corresponding round dot, respectively. When the risk index associated to a target exceeds a certain predefined threshold, a frequent blinking of the round dot warns the driver.

Fig. 6 Detection algorithm results: The left column shows the original FIR captured images (inverted) whereas the right column shows the parts of the target objects bounding the box.
In order to present the driver with a more comfortable and clearer view, the centric position of target objects are transformed to the distance-angular dimension space under the assumption of a flat road in front of the vision system.

Fig. 7 Exemplary human-vehicle interface of the moose early warning system. The round dots represent potential risks, where the location and size indicate the position and size of the heated body targets.

5. Conclusions

In this paper, a framework for moose early warning driver assistance systems has been presented, including publicly available baseline software and a database suitable for education, research, and development within the area. The cost for the infrared imaging equipment is high compared with the additional cost related to the implementation of an automatic moose early warning system, an add-on feature that may increase the safety margin even further. The main contribution of the work is the public database with recorded typical moose-on-the-road scenarios. The equipment used is commercial off-the-shelf products.

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