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Study on a Deterrent against Deer Collisions in Railway Operation Environment

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Abstract

This paper introduces a study on the efficacy of a bird deterrent, the “Marine Saponin”, to deer in a real railway operation environment. This deterrent has been developed for years but has not yet been tested in the transportation aspect. A field experiment was conducted using railway vehicles in normal commercial operation on a line in an area with high deer population. Front view videos from the vehicles involved in the experiment were recorded. An original dataset for object recognition model for identification of deer in the videos was constructed mainly using recorded scenes of officially reported deer collisions. With this model, deer that were encountered by the railway vehicles were recognized and categorized. Although the efficacy of “Marine Saponin” was not scientifically verified due to small sample size, it was regarded as a highly potential method. The behavior patterns of deer spotted but not involved in accidents were first obtained by computer vision in this study and contributed to statistical significance tests.

Keywords: railway operation safety, animal collision accident, optical deterrent, deer vision, deer behavior, real railway operation environment, computer vision.

1 Introduction

The animal problem is a major threat to railway operations in Japan. The most severe problem is the collision between railway vehicles and animals, and the most involved species in Japan is the deer (*Cervus nippon*, sika deer). In fiscal year 2022, among the 3,625 cases of train delay over 30 minutes happened in Japan due to external causes, 1,393 cases (38.4%) were caused by animals, which once again breaks the past records [1]. Besides, much more cases causing less than 30-min delays are happening every day. For example, on the 114km lines operated by WILLER TRAINS Inc., record-breaking 591 cases of animal collision accidents have happened in fiscal year 2022 [2].

As countermeasures, many methods for preventing deer from entering railway lines have been developed and developing. Take the lines operated by WILLER TRAINS for example again: the major applied deterrents are fences, traps and acoustic device (experimental) [2]. Acoustic devices mainly include generators of high-frequency sound [3], warning sound of deer [4] and sound of natural enemies of deer [4]. However, out of the 114km of lines, only approximately 3.3km are equipped with deer deterrents [2,5], and cannot be regarded effective enough.

Another deterrent worth mentioning is the optic solution. Experiments using visible light strobe [6] and laser [7] have been conducted in the past, but the results were not satisfactory. Reasons reported include adaptivity and eager for food [6], but one of the more fundamental reasons is believed to be on the vision of deer. Jacob et al. [8] have studied the structure of a deer's eye, and found that deer have different waveband sensitivity from humans. For example, the deer is more sensitive to lights with shorter wavelength [8]. The light emitting device used in the study about visible light strobe was "a very intense aircraft strobe" [6] commonly generating red, green and white lights that does not falls into deer's sensitive waveband, and therefore was not effective.

In view of the spectral sensitivity of deer, a compound named "Marine Saponin" extracted from the starfish has come into researchers' eyes. This compound has photoluminescent effect that generates lights within deer's sensitive waveband when exposed to near-ultraviolet rays [9]. In addition, the absorbed and generated lights are both out of humans' sensitive waveband, which means the application of such compound will not have visual influences on humans (Figure 1). This compound has been commercialised in Japan as a product to repel crows and some other birds [9], because the targeted birds are very sensitive to and wary of the lights generated by it. Yamanta et al. [9] has verified that this compound also has warning effects in a static environment to deer which have similar colour sensitivity with crows. However, the study also found a limitation that it does not have effects on young deer.

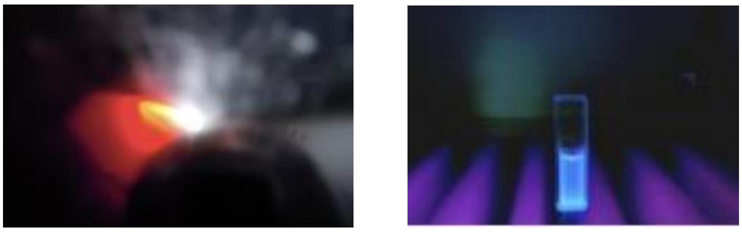

Figure 1: Images of highly concentrated marine saponin solution under ultra-violet irradiation, taken by (a) a special camera that shows lights out of visible range in

visible lights simulating the vision of a deer, and (b) a normal camera simulating the vision of human [10].

To test the efficacy of "Marine-Saponin" on preventing railway animal collision accidents, an experiment was conducted with the following targets. The available duration of the experiment was very short. Therefore, the criterion is set as the difference in behavior patterns of deer observed in addition to the commonly used numbers of accidents happened.

1. Verification of the efficacy of a novel deer deterrent: marine saponin.
2. Development of a method to obtain behavioural patterns of deer observed but not hit.
3. Analysis of the behavioural patterns of deer obtained in Target 2.

2 Methods

2.1 Experimental Setup

The experiment was carried out on Miyazu Line operated by WILLER TRAINS Inc. during regular service time for 22 days, from July 10th to July 31st in 2023. Four rolling stocks were used in this study, in which two were equipped with tapes containing marine saponin as the experimental group, and the remaining two were not and served as the control group. Figure 2 shows a rolling stock in the experiment group in regular service leaving from a station.

Figure 2: A rolling stock in regular service equipped with 5 pieces of "marine saponin" containing tape, shown in red frames. Photographed by the author.

These four vehicles were equipped with small video cameras on both ends in the cab areas serving as drive recorders. The cameras were held by vacuum suction cups, and anti-theft wires were installed for a security purpose. Accessory sockets at 24VDC were added to the vehicles as the power source for the cameras. Figure 3 shows the installation of a video camera. To lower the influence of the reflection from the cabin on the front glass, the back LED of the cameras were turned off, and custom covers made with black plastic corrugated cardboard were installed (Figure 4).

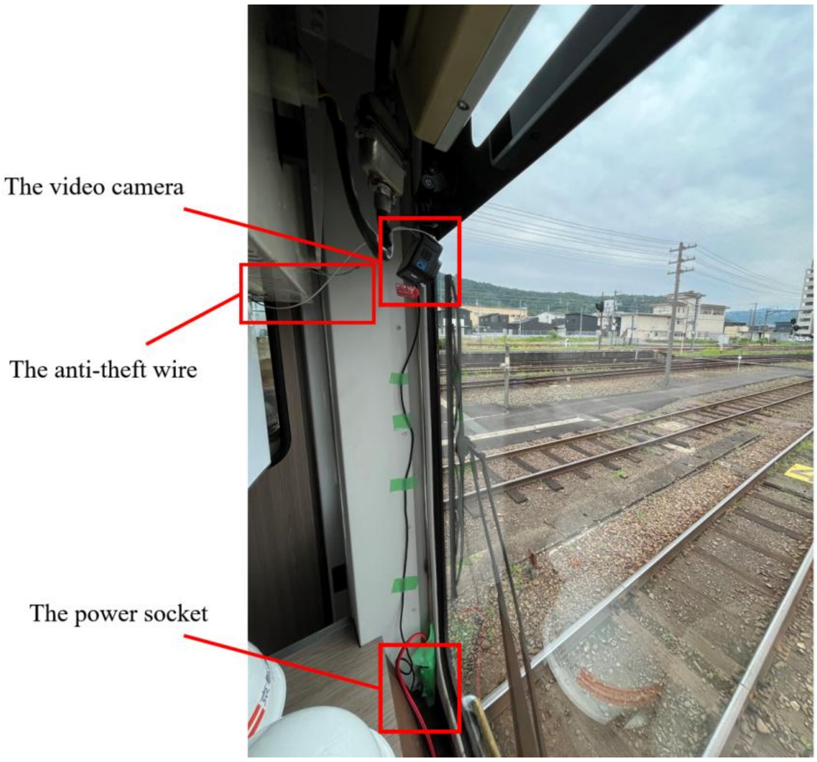

Figure 3: The camera installation. Photographed by the author.

Figure 4: The black plastic corrugated cardboard cover. Photographed by the author.

The cameras were set to work under an experimental firmware to enable additional controlling functions. For a longer video recording time, the recording was set to be at 1080p, 30fps. The duration of video recording of about 130 hours using a 128GB storage card.

To reduce the efforts of controlling the cameras, they were set to turn on and start recording when power supply is detected *i.e.*, the engine of vehicle is powered on, and stop recording and turn off when removal of power supply is detected *i.e.*, the vehicle is powered off. Under such settings, the only thing to do after installation is to change the storage cards once a week, provided that the maximum operation time of a vehicle is approximately 15 hours per day assuming no errors occurred. Therefore, the train crews and field staffs were not given additional jobs, and the train service were operated regularly.

2.2 Video Data Analysis

Front-viewing videos of regular train services were extracted from manually selected "valid videos" which contained clear front-viewing parts. "Invalid videos" include those recorded only in the depot, facing backward and facing to a linked rolling stock in multiple-unit control mode. The processed videos were put into machine learning based object recognition on a computer. The goal of this procedure is to reduce the time needed for finding deer in the recorded videos.

The main tool used is YOLOv8, the latest version of an open source "object detection and image segmentation model" based on deep learning originally developed by J. Redmon et al. [11]. The dataset was originally built for this study because no datasets can perform reasonably in this study as discussed before. The original dataset contains 80 images from recorded scenes in this experiment, as well as photos taken by the author that containing deer. Besides "Deer", another four labels were set because during initial detections, it was found out that these objects were easily recognized as "Deer". Figure 5 shows a labelling of "Deer" in a scene right before a collision accident. The number of training epochs is 100, the batch size is 18, and the image size is 640. Due to the specificity of the model, the accuracy was set low, and is not provided quantitatively in this paper.

Figure 5: The labelled "Deer" in an image for training in the dataset.

3 Results

3.1 Official Animal Collision Data

During the 22-day of experiment, 23 cases of animal collision were recorded in document. 4 of them were recorded as videos, and Figure 6 shows one of them. This means that more than one case of animal collision happened every day, and this is the data only involving the 4 vehicles used in the experiment, serving 4 out of 14 arrangements of daily services in total. The data is divided into 3 weeks based on the following reasons:

1) The operation arrangement of rolling stocks on Miyazu Line rotates on a 7-days base, which means all rolling stocks would theoretically have a identical running distance per 7 days if no disruptions were present.
2) Although the duration is 22 days, there was one day (July 13th) when many services were cancelled during nighttime due to heavy rain. Also provided that all recorded collisions during the experiment happened during nighttime, for convenience in comparisons, this day was collapsed and the first week is set to have 8 days from July 10th to July 17th.

Figure 6: The front viewing scene from a rolling stock right before a case of animal collision.

The number of collision cases are presented in Table 1, following by the graph in Figure 7 showing the trend. On one hand, the experimental group collided with decreasing number of animals during the experiment viewed by week. On the other hand, the duration of this experiment (22 days) is too short for a study involving wild animals, thus may not be a scientifically referable result.

	No. of collision cases		
Week	1 (July 10th-18th)	2 (July 19th-25th)	3 (July 26th-31st)
Control group	4	4	5
Experimental group	6	3*	1

*: Including one case of boar collision. All other collisions were with deer.

Table 1: Number of collisions with animal during the experiment

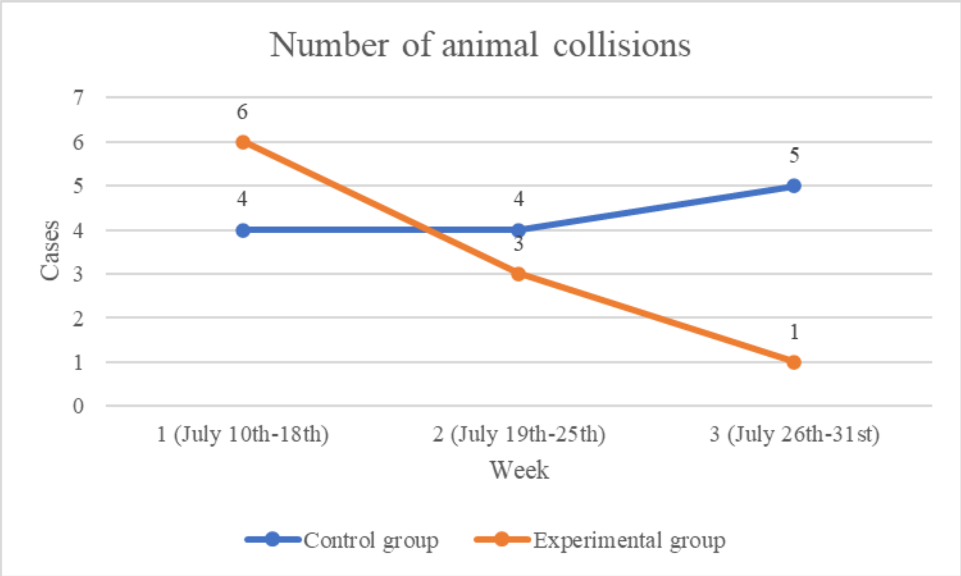

Figure 7: Number of collisions with animal during the experiment.

Seen from the data, all collisions involved by the 4 rolling stocks used during the experiment happened during nighttime. Therefore, the results in the next section were obtained from videos recorded during nighttime.

3.2 Object Recognition

59 independent cases of encountering with totally 82 deer were recognized. An independent case is from the first deer appears in the sight of the camera to the last deer disappears from the sight of the camera. For example, if there is only one deer, it will be counted as one case containing one deer. Figure 8 shows the rate of deer encountering during nighttime. Among 11 days when videos recorded during nighttime exist, on 10 (90.9%) of them at least one deer was observed. Among all observed deer, there were 4 (4.88%) of them finally hit by the rolling stocks, while 78 (95.1%) of them were not involved in a collision accident, which indicates that there are as much as 20 times more deer spotted along the railway line during time that videos were recorded. This is a result that has never been noticed before.

These cases include 41 cases containing 53 deer for the experiment group, and 19 cases containing 29 deer for the control group (Table 2). It is worth noting that the number of encountering cases can be assumed to be randomly distributed [12], therefore, it is meaningless to compare the encountering numbers between control and experiment groups.

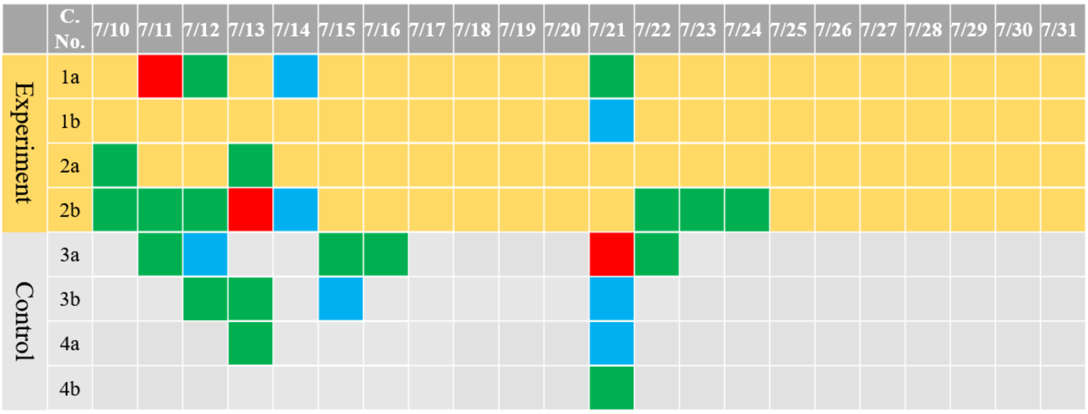

Figure 8: Days and vehicles with video recording during nighttime and deer recognized.

: days with videos recorded, : days with videos of collision scenes recorded,
: days with videos of deer encountering on 10 out of 11 days (90.9%)

Group	Experimental group	Control group
Length of videos	23h53m07s	19h48m22s
Cases	41	19
Deer	53	29

Table 2 Numbers of deer encountering and deer individuals

Also, in Figure 8, the largest problem occurred during the experiment can be seen: missing of videos. As introduced before, to use functions beyond stock features which is critical in this experiment, the firmware with experimental functions compatibility was employed. Stability of such extended functions are not granted by the manufacturer of the camera. It worked well during testing, but the instabilities may have caused some problems during actual experiment with a much longer duration. Another reason may be the bad connections within the power supply unit that is not a stock equipment of the vehicles, which happened several times during setup.

3.3 Behaviors of Deer

The behaviors of deer observed in this experiment were categorized mainly according to whether a deer was walking or running, and whether it crossed the railway line. Since in the former study [9] it was observed that the deterrent tested did not have repelling effect to young deer, young deer having a body length apparently shorter than the track gauge (1,067mm) were omitted in the summarizing Table 3. The schematic for categories is shown in Figure 9. Figure 10 shows an example of a deer about to run across the tracks.

Behaviors	Experiment group		Control group		Total	
Leaving	4	12.1%	2	10.5%	6	11.5%
Walking crossing	1	3.0%	3	15.8%	4	7.7%
Fleeing	6	18.2%	5	26.3%	11	21.2%
Running crossing	17	51.5%	8	42.1%	25	48.1%
No movement	5	15.2%	1	5.3%	6	11.5%
Complex moving	0	0.0%	0	0.0%	0	0.0%
Total	33	100.0%	19	100.0%	52	100.0%

* There was no "No movement" happened between tracks *i.e.*, is dangerous.

Table 3 Categorizing of behaviors of detected deer except young deer

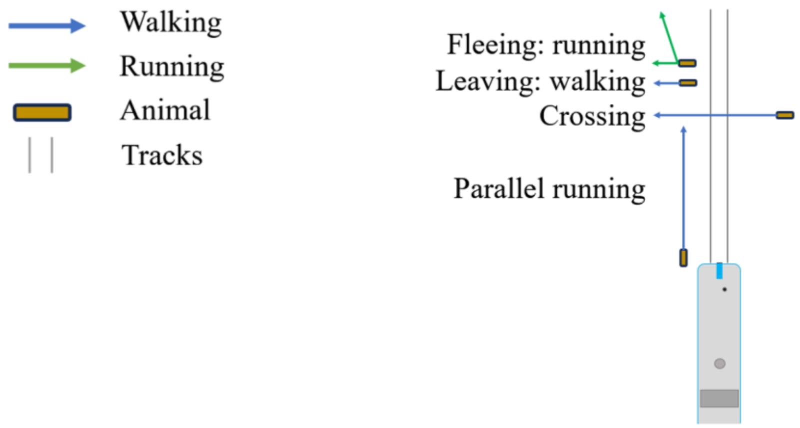

Figure 9: Categories of observed deer behaviors in this experiment.

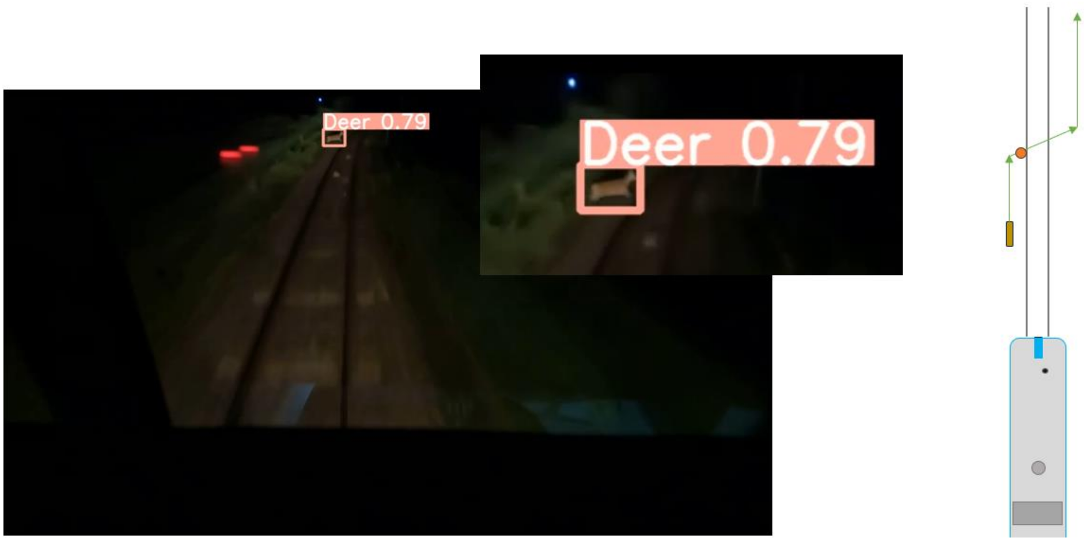

Figure 10: A deer about to run across the tracks. Recorded on July 16, 2023.

After comparing the behavior patterns in Table 3, there is apparent significant difference in only one pattern of behavior: walking crossing. This pattern indicates the disinterest of a deer to the approaching rolling stock, and therefore is also an important criterion for the efficacy of the tested deterrent. Another important criterion of the efficacy of the tested deterrent is the relative moving direction of the deer to the approaching rolling stock. The behavior of a deer that running towards the tracks or the rolling stocks when the rolling stocks were approaching were only observed in the control group.

These two criteria were summarized in Table 10, showing dangerous cases of which the ratios of numbers of cases were significantly larger in the control group than in the experiment group. The significance levels (p-values) were calculated according to Fisher's exact test, which is especially designed for tests with small sample size [13], and is equivalent to the commonly used Chi-squared test (G-test) for large sample size [14].

Criteria	Except young deer		p-values
Group	Experiment	Control	Fisher's Test
Walking across	1 (3.0%)	3 (15.8%)	0.118
Running towards trains	0 (0.0%)	4 (21.1%)	0.01

According to the significance levels of the differences between experiment and control group, the tested deterrent, marine saponin, was verified to be effective in repelling adult deer under such sample size. However, the authors themselves rejected this result because it is not scientifically convincing with such sample size in experiments involving wild animals. Therefore, this deterrent, the marine-saponin, is concluded to be a very potential deer deterrent worthing further tests.

4 Conclusions and Contributions

This study has been carried out in anticipation of the relief of animal collision problem. In detail, research on marine saponin as an optic deer deterrent, deer recognizing algorithm, and deer behavior patterns has been conducted.

Because the efficacies or cost-performance of existing animal repellent cannot be regarded enough for automatic/autonomous train operation, verification on the efficacy of marine saponin, a type of optic deterrent formerly targeted at birds, to deer was tried.

To achieve a higher and sustainable speed of data analysis, an initial model of machine learning based objective recognition was constructed. This model contributed to the success of records for behavior patterns of more than 80 deer. This model is expected to be further developed for usages in such kinds of experiments conducted in railway operation environment.

Finally, the observed behavior patterns have been categorized according to an original set of classifications for scientific significance tests for the efficacy verification. The results are not convincing enough on scientific basis due to the limitation of a small sample size but indicate an optimistic future of its application.

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