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ONLINE RODENT MONITORING: A NOVEL SOLUTION FOR IMPROVED PEST MANAGEMENT IN INDUSTRIAL FACILITIES

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Abstract Rodents, particularly rats and mice, are major urban pests in Japan and worldwide. When found in buildings and structures or contaminating products, especially in food facilities, they can seriously damage a brand name and a company's credibility. In Japan, rodent control is exceptionally challenging in complex facility structures such as food factories, restaurants, and urban buildings. Despite its importance, the high risk of contamination, and the ever-increasing need for food safety, rodent monitoring methods have changed very little over the last 30 years. Monitoring approaches using video data started about ten years ago. Still, they are insufficient in accuracy and time required for data checking, as they often involve using infrared sensors cameras originally designed for monitoring wild animals. In this presentation, we introduce a novel rodent-specific monitoring tool (Pest-Vision R-type). It analyses rodent movement from video images and uploads them to a web cloud for remote monitoring without needing pest management professionals to visit the site. The advantages pest control companies and factories can gain using the Pest-Vision R-type are summarized and presented, including several case studies. It also compares its detection accuracy with the presently available commercial sensor cameras.

Key words Integrated Pest Management, rodent, remote monitoring, object detection, IoT

INTRODUCTION

Rodents, particularly rats and mice, are globally recognized pests, with species such as the black rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), and house mouse (*Mus musculus*) frequently invading human dwellings. In commercial facilities and factories, rat infestations not only cause discomfort to occupants but also lead to pathogen transmission, contamination, and structural damage to products and materials (Easterbrook et al., 2007; Rivadeneira and Gouge, 2017). The rise of social media amplifies the potential reputation damage caused by reported sightings or contamination, warranting effective rat management essential. Monitoring rodent activity including detecting nesting sites or population sizes enables targeted control measures such as using traps or repellents.

Current Technologies and Challenges While various methods and tools are employed for indoor rodent monitoring, they often require a degree of skill and intuition, as will be discussed. In Japan, monitoring using glue boards is standard practice. By setting out several glue boards and finding no captured rodents upon inspection, it is concluded that no rodents are present. However, trap capture results may not always accurately reflect the rodent population. Our observations have shown that rodents sometimes jump over glue boards to avoid capture. This means that even when rodents are present, the lack of captures on glue boards may lead to inaction. Glue boards can, therefore, be considered insufficient for rigorous monitoring. Furthermore, glue boards are difficult to place in areas with high human traffic, such as floors, necessitating their placement during off-peak hours or in areas away from human activity.

Typically, rat signs such as feces, hair, footprints, and rub marks are used as clues to locate rodent movement paths and nests. Installing traps or repellents in areas with concentrated rat signs is expected to yield high effectiveness. However, locating rat signs also requires years of experience. For instance, if the droppings found are old, there could be no rodents in the vicinity. Moreover, searching for rat signs in high or narrow places is challenging. Thus, the search for rat signs is highly subjective and time-consuming.

To address these issues, some have turned to 24-hour video recordings of wide areas for more rigorous monitoring. The advantages of video-based monitoring include its ability to record rodent intrusions and behavior, even for those avoiding glue traps, as video data. Additionally, it simplifies identifying rodent entry routes by covering wide areas in buildings with large or complex structures, where signs of rats may be difficult to detect. However, a significant drawback of this method is the immense labor involved in manually reviewing the video data. Reviewing long hours of video footage can be exhausting and time-consuming, limiting its practical application to perhaps one or two days. More rigorous and efficient rodent monitoring can be achieved by automatically detecting rodents in video data.

Overview of Pest-Vision R-type "PestVision R-type" (PV-R) is an IoT camera designed to address the limitations of traditional monitoring methods. It offers a highly accurate, objective, and user-friendly solution for rodent monitoring. The palm-sized device continuously records video footage at the desired location. The software of PV-R, developed by Yokota (2016), employs a four-step process to deliver monitoring results to the users:

1. **Video Acquisition:** The camera continuously captures video footage.
2. **Video Analysis:** Background subtraction is applied to the recorded data to detect moving objects. Spatial-temporal features of the difference (e.g., area change, centroid shift) and a luminance-based metric are used to classify the detected objects as rodents or not.
3. **Bounding Box Generation:** A yellow bounding box is drawn around objects classified as rodents.
4. **Result Upload:** The corresponding video clip is uploaded to a web cloud if a rodent is detected. If no rodent is detected, a simple text data indicating "no detection" is uploaded.

Users can access these results through a web interface to analyze rodent behavior and movement patterns. This information can be used to implement targeted control measures, such as sealing entry points or placing traps and repellents in high-traffic areas. Moreover, the absence of detection data can prove rodent absence.

PV-R utilizes infrared imaging to accurately detect rodents in dark environments like attics. It provides comprehensive coverage with a wide horizontal viewing angle of 124° and a detection range of up to 15 meters (with supplemental infrared LEDs). By integrating IoT technology and a rodent detection algorithm, PV-R offers remote, objective, and standardized monitoring.

PV-R is currently being used as a monitoring tool primarily by pest control companies in Japan across various industries, including food and industrial product manufacturing, fish markets, and office buildings. Its adoption has also begun in Singapore. In Japan, it is commonly used in food processing facilities to monitor for rodents entering through shutters, in spaces connected to production areas (such as sealing), and to prevent rodent intrusion from outdoor areas.

Figure 1. Pest-Vision R-type

Traditionally, sensor cameras have been used for rodent monitoring. However, PV-R differs from sensor cameras as it does continuous recording rather than a trigger-based system activated by infrared sensors. Sensor cameras may have a delayed response to the rapid movements of rodents, potentially leading to missed detections. In contrast, PV-R continuously records video, ensuring a high probability of capturing rodent activity.

This study aims to quantitatively evaluate the rodent detection accuracy of PV-R compared to traditional trap monitoring and sensor cameras. Specifically, we will compare the detection accuracy of each method using metrics such as true positive rate and false positive rate to verify reliability of PV-R.

MATERIALS AND METHODS

The experiment was conducted at an "izakaya" (Japanese-style pub) in Osaka, Japan. Based on prior observations, two locations within the establishment where exceptionally high rodent activity was identified. Observations were conducted at Location 1 from 0830 on December 27, 2024, to 0930 on December 29, 2024. Location 1 was always dark and a narrow, confined space in the ceiling, where typically, only rodents moved. In this space, a PV-R (R) camera, a video camera (TapoC210; TP-Link Corporation Pte. Ltd., Temasek Boulevard, Singapore) (V), a sensor camera (TrophyCam; Bushnell Corporation, Kansas, United States) (S), and supplementary infrared lights (sec-irled-6b; BroadWatch, Tokyo, Japan) (IR) were installed as shown in Figure 2 (left). The infrared lights were installed to supplement the PV-R's infrared lights, as there was concern that its reach of approximately 3 meters might not be sufficient for detecting rodents in dark, distant areas. The video camera recorded 24-hour infrared footage to verify the accuracy of the PV-R and sensor cameras.

Additionally, glue boards were installed to assess the effectiveness of conventional monitoring methods, and the capture of rodents was confirmed after the experiment. To verify the detection accuracy of PV-R in situations where there is a lot of movement of people and objects, an experiment was conducted at Location 2 from 1400 on January 15, 2025, to 0900 on January 20, 2025. Location 2 was adjacent to Location 1 but was located directly above the dining area. Location 2 is a dim environment; however, during operating hours, the illumination of the seating area directly beneath it brightens the area. There are air conditioning units, beams, ducts, and other fixtures where rats freely move along these elevated structures. Similar to

Location 1, a PV-R (R) camera, a video camera (V), and supplementary infrared lights (IR) were installed, as shown in Figure 2 (right). No glue boards were installed at Location 2 because there was no stable place to install glue boards. No sensor cameras were installed. Additionally, since the wall on the far side of the sensor became dark due to the initial placement of the auxiliary LED, on January 18, we relocated the LED so that it would illuminate the far wall.

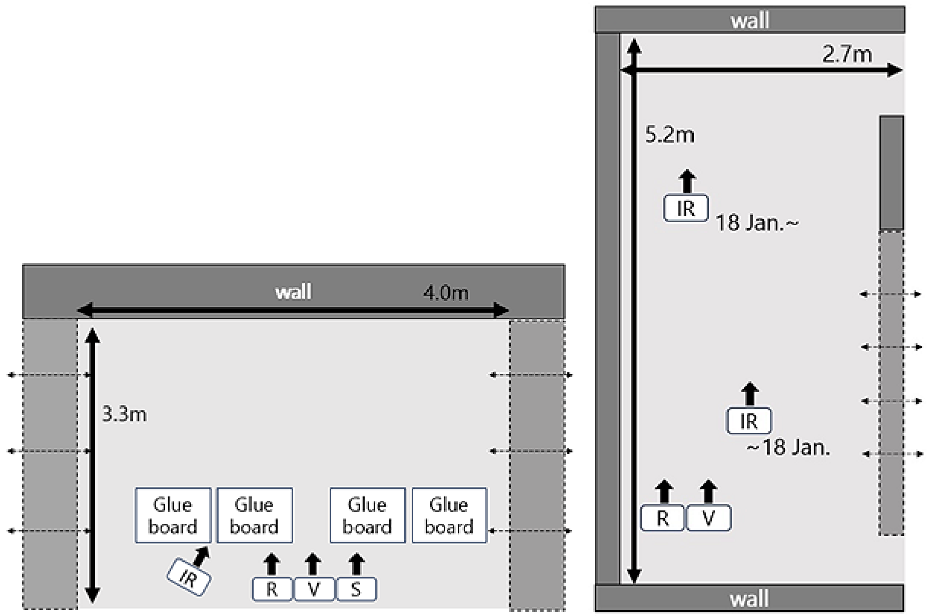

Figure 2, Overview of Locations 1 (left) and 2 (right), showing PV-R (R), video camera (V), sensor camera (S), and supplementary infra-red light (IR). Solid arrows indicate the directions of each device. Dashed walls and arrows indicate narrow gaps where rodents can come and go.

The video data was manually reviewed for both locations to identify the periods when rodents appeared. The detection records of the PV-R and sensor cameras were compared against these periods to calculate accuracy. Each instance of a rodent appearing on the video until it disappeared was defined as an "event." If a sensor detected a rodent during any portion of an event, it was considered a True Positive (TP). If a sensor failed to detect a rodent during an event, it was considered a False Negative (FN). If a sensor detected a rodent when no rodent was present on the video, it was considered a False Positive (FP). A confusion matrix was created based on these criteria (Table 1). For each location, the total number of TP, FN and FP occurrences during the observation period was used to calculate the accuracy metrics, Recall and GF1-score as follows:

$$Recall = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$F1 = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

A high recall value indicates that the sensor exhibited a high sensitivity in detecting rodents, minimizing false negatives. Conversely, a high precision value denotes a high positive predictive value, indicating a low false positive rate. Recognizing the inherent trade-off between these two metrics, which is influenced by the sensor's sensitivity, we utilized the F1-score to assess the model's overall performance. A higher F1-score implies a more optimal balance between recall and precision, suggesting a superior model.

Table 1. Confusion matrix for rodent detection

		Actual	
		Rodents	No rodent
Sensors results	Detected	**True Positive (TP)**	**False Positive (FP)**
	Not detected	**False Negative (FN)**	True Negative

RESULTS

The detection results and accuracy for both Location 1 and Location 2 are presented in Table 2. During the observation period at both locations, at least 2 rodents were observed, and both of them were identified as the black rat *R. rattus* based on morphological characteristics and behavior (Figure 3). At Location 1, a total of 33 events were recorded during the observation period. The PV-R system detected 29 events, while the sensor camera detected 2. The Recall, Precision, and F1-score for the PV-R were 0.84, 0.955, and 0.894, respectively, compared to 0.08, 1.0, and 0.148 for the sensor camera. The PV-R exhibited higher accuracy due to more True Positives and fewer False Negatives. One event was detected by the sensor camera but missed by the PV-R. Since Location 1 had no moving objects other than rats, both sensors experienced minimal False Positives. The False Positives detected by the PV-R were primarily attributed to shadow flickers and block noise during infrared imaging. Furthermore, no rats were captured on glue boards. Individuals approaching the glue board were also recorded and were observed to be concerned with their noses close to it.

At Location 2, a total of 70 events occurred during the observation period. The PV-R system achieved a recall of 0.843, a precision of 0.057, and an F1-score of 0.107. Compared to Location 1, false positives increased significantly, leading to a substantial decrease in the F1-score. These false positives were primarily attributed to factors such as fluttering posters in the dining area, human movement, flickering light reflections on beams and pipes, insect movement, and dust or smoke particles.

Table 2 Detection results and accuracy of each sensor in Locations 1 and 2

Location	Sensor	TP	FP	FN	Recall	Precision	F1-score
1	Sensor camera	2	0	31	0.061	1.000	0.114
	PV-R	29	1	4	0.879	0.967	0.921
2	PV-R	59	971	11	0.843	0.057	0.107

Figure 3, Example of PV-R detection in Location 1 (left) and Location 2 (right): the area where the PV-R was determined to be a rodent is framed.

DISCUSSION

Accuracy Evaluation of PV-R The PV-R system demonstrated more than 80% of rodent detection. However, there were some events where rodents were not detected, and no clear correlation was found between these undetected events and specific environmental conditions or rodent behaviors. Various factors, such as dark areas or the rodent's position within the camera frame, may have contributed to these missed detections. Nonetheless, the system successfully detected rodents in challenging conditions, such as low-light environments and with minimal movement, indicating its potential utility.

False positives were minimal in Location 1 but significantly increased in Location 2. This is due to the system's high sensitivity setting, which detects any potential rodent activity. This setting prioritizes minimizing false negatives, ensuring that no rodents are missed. To reduce false positives in environments like Location 2, we are exploring improvements to the system's software and utilities. For instance, a function that allows users to pause detection during specific times, such as business hours in retail settings, can help reduce noise in the detection results. Additionally, we are fine-tuning the detection algorithm's parameters to decrease false positives while maintaining high detection rates. Furthermore, we are investigating the integration of artificial intelligence (AI) to further reduce noise and improve detection accuracy.

Technological Advancements Enabled by Pest-Vision R-type Traditional monitoring methods, such as traps and manual inspections, have monitoring range, accuracy, and frequency limitations. No rodents were captured on glue boards in Location 1, which does not accurately reflect the actual rodent population. PV-R enables real-time monitoring, immediately detecting rodent activity and prompt response. This is particularly beneficial for industries such as food processing and healthcare, where strict hygiene standards are essential.

By enabling remote monitoring, PV-R reduces the time and cost associated with on-site inspections. The application of IoT technology could extend beyond rodent control. Previously, we reported a system for detecting flying insects, demonstrating the potential of IT-based solutions to revolutionize pest management (Kawatake et al. 2022). This will significantly improve food safety by leveraging IT technologies for pest management.

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