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Intelligent Security Surveillance System for Communities in Areas Adjacent to Abandoned or Vacant Lots with Image Processing Technology

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ABSTRACT- This work presents the development and testing of an intelligent security surveillance system capable of automatically detecting people and flames, with an alert system sending notifications via Telegram Bot. The objective is to increase the efficiency of security in the communities by testing under various environmental conditions at detection ranges from 5 to 30 meters during daylight, low light, and night times, including testing gaits such as slow walking and running. Next, the system was tested in the Rung Sawang Village 1 community, Bang Khen District, Bangkok, which has an area adjacent to a large abandoned or vacant lot. The test results showed that the system was able to detect people in daylight with a maximum similarity percentage of 98.45% at a distance of 5 meters and could detect at a distance of as far as 30 meters in cases involving slow walking. Running was detectable at a distance of 20 meters. During low light hours, the system's efficiency was reduced to 72.31% similarity at a distance of 5 meters with the closest slow walking detectability at 20 meters, while running was detectable within 15 meters. As for flame detection, the system was found to only work at night due to sunlight interference during the day. Candle flames were detectable at distances of 10 meters, and piles of paper were detectable at distances of 25 meters with a similarity percentage of 78.95% at a distance of 5 meters. Next, the notification system *via* Telegram Bot was tested, yielding average notification speeds ranging from 6.53 to 7.19 seconds. When the system was tested in actual use by measuring user satisfaction among 30 people, it was found that the image resolution from the camera was 4.27 points, followed by the motion detection system at 4.27 points and the suitability of the installation site at 4.13 out of 5 points.

Keywords: Automatic Detection, Surveillance System, Community Safety, Image Processing.

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1. INTRODUCTION

Bangkok has a total area of 1,568.7 square kilo meters or 980,437.5 rai [1]. The administration was divided into 50 districts [2] with the governor of Bangkok holding the highest administrative position [3]. When inspecting the Bangkok area, it was found that there are more than 11,600 rai of abandoned or vacant lots with the potential to cause safety issues. Statistics from the Royal Thai Police Headquarters in 2024 found burglary and trespassing crimes in Bangkok to have increased by 8.5% over the past three years, particularly in areas adjacent to abandoned or vacant lots. And in 2023, the Department of Disaster Prevention and Mitigation stated that 22% of all fires in Bangkok started in abandoned or vacant lots. Furthermore, case studies abroad have developed interesting intelligent surveillance systems such as Singapore and the Smart Nation Sensor Platform project, which was equipped with intelligent surveillance cameras and AI video analysis systems that have reduced the crime rate by 42%, [4] Japan's development of the AI-Enhanced Urban Safety Network that detects the start of a fire 7 minutes earlier than the traditional system, and [5] South Korea's Safe City Seoul project by Kim & Park that uses thermal imaging with AI, thereby reducing the crime rate by 37%.

The application of technology as an intelligent surveillance system consists of image analysis [6] capable of precisely distinguishing suspicious behaviour at as high as 91.3%. Xavier, K. L. B. L., & Nanayakkara, V. K. introduced heat and smoke sensors to help detect fires in the early stages 4-8 minutes faster than previous systems. [7] Automated alarm technology also reduces emergency response time by up to 47%. Therefore, the development of an intelligent surveillance system that uses Big Data Analytics to predict risk areas was important. Thus, Bokolo, A. J. advised that community participation in the design and monitoring of the use of these systems [8] was a key factor in successful performance, taking into account the balance between public safety and privacy.

For this reason, researchers developed an effective security surveillance system capable of detecting trespassing and notifications of fire risks in a timely manner. The project aims

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to improve the quality of life and safety of people in communities, particularly those adjacent to abandoned or vacant lots, with three objectives:
1. To develop a surveillance and security system to prevent trespassing in community areas by using image processing technology;
2. To design and develop a system for detecting fires potentially spreading from vacant or abandoned lots to communities to minimize potential risks;
3. To create a real-time emergency notification system through Telegram Bot API and use renewable energy with solar panels (PV panels) as the power supply for the system.

The system developed by the researchers can detect people and flames at the same time, which will create safety for residents in communities. The researchers visited the community studied and found that the community has an area adjacent to a large vacant lot, as shown in *figure 1.*

Figure 1. Rungsawang Village 1 Community Area

2. LITERATURE REVIEW

The development of an Intelligent security surveillance system for communities adjacent to abandoned or vacant lots with image processing technology consisted mainly of the following components: (1) object detection (2) solar energy and (3) the Internet of Things.

2.1. Object Detection

It is an image processing technique that aims to identify the location and type of object appearing in an image or video. Redmon, J. et al., proposed object detection in the form of square frame drawing [9] in which the basic principles for image processing consist of feature extraction, positioning, and object classification. Modern object detection involves using the processes of deep neural networks, which involves the following basic equations used for image analysis:

1. The equation for predicting a square frame surrounding an object was determined by coordinates (*x, y, w, h*) (*x, y, w, h*) (*x, y, w, h*), where *x*, *y* are the coordinates of the upper left corner of the frame, w was the width of the frame, and h was the height of the frame. The most popular image processing model was the YOLO (You Only Look Once) model, which was used to predict the coordinates of a square frame [11], as shown in *equations (1)-(4)*.

$$bx = \sigma(tx) + Cx \quad (1)$$

$$by = \sigma(ty) + Cy \quad (2)$$

$$bw = pw^{etw} \quad (3)$$

$$bh = ph^{eth} \quad (4)$$

In this model, *bx, by, bw, bh* are the prediction values of square frames; σ was the Sigmoid function; *tx, ty, tw, th* are the values obtained from the model's learning; *cx, cy* are the coordinates of the cells in the table, and *pw, ph* are the sizes of the anchor boxes.

2. IoU accuracy measurement was Intersection over Union (IoU) in the form of an important metric used to measure the accuracy of object detection [11], as shown in *eq. (5)*.

$$IoU = \frac{|A \cap B|}{A \cup B} \quad (5)$$

A and *B* are the areas of the predicted and actual frames, respectively. The main object detection models are:
1. R-CNN (Region-based Convolutional Neural Networks) [12] uses deep learning object detection methods, which are continuously developed into Fast R-CNN and Faster R-CNN;
2. The YOLO model [13] uses the concept of "you only look once" to predict both square frames and distinguish the types of objects at the same time, which offers high speed and was suitable for real time use;
3. SSD (Single Shot MultiBox Detector) [14] employs principles similar to YOLO but predicts with multi-level feature maps to increase the detectability of objects in various sizes and
4. Transformer group models based on transformers such as DETR (DEtection TRansformer) [15] use a new method that does not require anchor boxes or post-processing, which yields good results and a simpler structure. Based on the above capabilities, object detection models can also be applied to flame detection, using the flame's unique characteristics of color, brightness, motion, and uncertain shape in addition to distinguishing objects from the background by converting the color space to HSV or YCbCr to classify flames.

2.2. Solar Cell Energy

It is an important renewable energy source today that was constantly evolving in terms of both efficiency and economic value. Razykov, T. M. et al. described the main components of photovoltaic (solar cell) systems [16] as follows:
1. PV (solar) panels that convert solar energy into electricity;

2. Inverters, which are devices that convert the DC electricity (DC) from the Solar panels into AC electricity for use in homes or buildings. Deline, C. et al. conducted a study comparing the performance of various types of inverters and found that microinverters [17] have the advantage of minimizing the effects of partial shading better than any other type of inverter;

3. Energy storage systems: also known as batteries, energy storage systems are an important part that helps store electricity produced during the day for use at night or when sunlight was insufficient. In designing solar cell systems, it was necessary to calculate the total energy requirement, the size of the solar

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panels and the battery capacity to be sufficient for use, which can be calculated with the following equations: [18].

i. Calculation of total energy requirements, which can be calculated as shown in *eq. (6)*,

$$E_{total} = \sum P_i \; x \; t_i \tag{6}$$

where E_{total} was the total energy required per day (W_h/day), P_i was the power of each device. (W), qnd t_i was the operating time of each device per day (hours).

ii. Calculation of PV Panel size, which can be calculated as shown in *eq. (7)*,

$$P_{panel} = E_{total}/(P_{SH} \; x \; \eta_{system}) \tag{7}$$

where P_panel was the required power of the solar panels (Wp), P_SH was the peak sun hours, usually about 4-5 hours in Thailand, and η_system was the overall system efficiency (about 0.7-0.8).

iii. Calculation of battery capacity, which can be calculated as shown in *eq. (8)*,

$$C_{battey} = (E_{total} \; x \; D)/\;(DOD \; x \; \eta_{battery} \; x \; V_{system}) \tag{8}$$

where C_battey was the battery capacity (Ah), D was the number of power reserve days (days), DOD is the depth of discharge (approximately 0.5-0.8), η_battery was the battery efficiency (approximately 0.85-0.95) and V_systemis the system voltage (V).

2.3. The Internet of Things (IoT)

IOT network has developed rapidly, particularly with the application of notification systems through various messaging platforms such as Telegram Bot API, LINE Messaging API, Google Chat Webhooks, etc., which provide real-time notifications to users [19]. IoT connects and exchanges data with other devices and systems over the Internet. Pavithra, D., & Balakrishnan, R. proposed combining the IoT with alarm systems to facilitate inspection and responses to various events in a timely manner. [20] Al-Masri, E. et al. proposed that architecture using MQTT (Message Queuing Telemetry Transport) [21], which was the communication protocol for linking the IoT with alarm systems via Telegram API, can send real time alerts when specified events are detected in advance. Vanitha, V., et al. developed an IoT system for home security surveillance using Telegram Bot to alert users when intrusions are detected. [22] The system was capable of immediately sending messages and images from a closed-circuit camera to users [23] Singh, A., & Kumar, S. proposed an IoT sensor-based air quality monitoring and control system in conjunction with Telegram Bot API, which not only alerts when the air quality falls below a certain threshold, but also allows users to control air purifiers through commands in Telegram. Kumar, V. et al. identified major issues with message transmission reliability in environments with unstable internet connections. [24] Therefore, Thabassum, S., & Tharannum, N. proposed repetitive mechanisms and confirmation of receipt of messages to increase system reliability. [25] In addition to the researchers mentioned above, studies and practical applications have also been developed. such as a remote health examination system using IoT devices to check the vital signs of patients and send alerts *via* Telegram Bot [26] and a smart agriculture system that uses IoT sensors to measure soil moisture, temperature, and other factors [27] by sending alerts via Telegram Bot when plants need water or when the environment was not suitable [28] and to predict equipment failures before they actually occur [29] by the technique of machine learning.

Figure 2. Internet of Things (IoT)

3. DESIGN AND DEVELOPMENT OF INTELLIGENT SECURITY SURVEILLANCE SYSTEMS FOR COMMUNITIES

A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis. Do not add extensive basic definitions or well-known theories, instead highlight theoretical background and its specific usages in view of your work only.

3.1. Structural Design and System

Components of an Intelligent Community Security Surveillance System Using YOLOv8-Based Image Processing in Python for Early Trespass and flame Risk Detection with Solar Power Supply and Real-Time Notifications *via* Telegram Bot API. The structure and components of the system are as shown in *figure 3*. The design of the control cabinet was small and easy to move.

The system consists of: 1. size 50W solar panels; 2. webcam; 3. servo motor; 4. solar charger; 5. Raspberry Pi 4 with display; 6. Stepdown DC to DC; 7. WiFi Module Block and 8. 12V 100Ah battery.

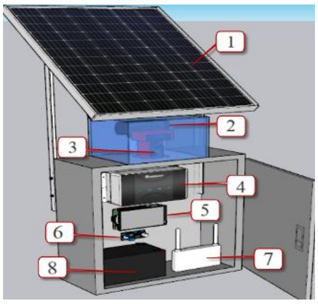

Figure 3. System structure and components

Table 1. Estimated power consumption of devices

Accessories	Current consumption (mA)	Voltage (V)	Electrical power (W)	Duration of use (hours)
Raspberry Pi 4 with display	600	5.0	3.0	24
Servo motor	250	5.0	1.25	12
Webcam	250	5.0	1.25	12
Wi-Fi Module	100	3.3	0.33	24
Total	1,450	-	7.08	

According to *table 1*, the power consumption of the equipment in the system was 7.08 watts, which can be used to calculate the need for power with *eq. (9)*, the size of the solar panels with *eq. (10)* and the battery capacity sufficiency for use with *eq. (11)*, which will make it possible to select suitable equipment for use. The value used for the design of the energy system can be calculated. The power system design allows for functioning when there was no sunlight for 2 days or 48 hours.

From *eq. (6)–(8)*, the total daily energy demand can be calculated as

$$E_{total} = (3\text{ W} \times 24\text{ h}) + (1.25\text{ W} \times 12\text{ h}) + (1.25\text{ W} \times 12\text{ h}) + (1\text{ W} \times 24\text{ h}) = 126\text{ Wh/day} \quad (9)$$

Based on the computed value of E_{total}, the required size of the PV panel can be calculated from *eq. (7)*:

$$P_{panel} = \frac{126\text{ Wh}}{5\text{ h}\times 0.7} = 36\text{ Wp} \approx 40\text{ Wp} \quad (10)$$

Applying a safety factor of 1.25 gives a required panel size of approximately 50 Wp.

Furthermore, using the total daily energy demand from *eq. (1)*, if 4 days of energy autonomy are required, the battery capacity for a 12 V system can be calculated from *eq. (8)*:

$$C_{battery} = \frac{126\text{ Wh}\times 4}{0.5\times 0.9\times 12\text{ V}} = 93.33\text{ Ah.} \approx 100\text{ Ah} \quad (11)$$

3.2. The intelligent security surveillance system

for communities adjacent to abandoned or vacant lots with image processing technology consists of 5 main device components: 1. Raspberry Pi board; 2. solar panels (50 W.); 3. webcam; 4. 12V 100Ah batteries and 5. wi-Fi box, as shown in *figure 4*.

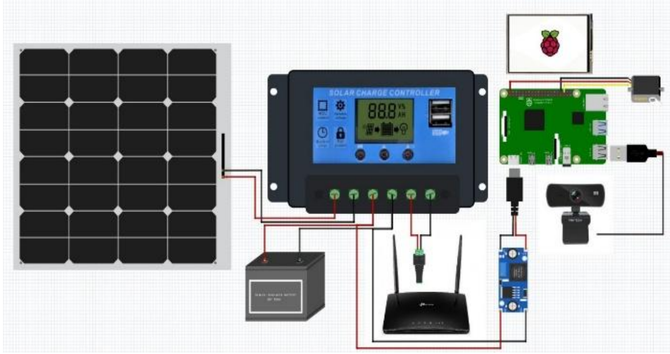

Figure 4. Circuit and device connections

Figure 3 shows a small solar system consisting of solar panels on the left that convert sunlight into DC electricity sent to the battery charge controller, which controls the safe charging of the lithium-ion battery and prevents overcharging. Then the controller supplies power for the Raspberry Pi board with a monitor displaying the results with Raspberry symbols and was linked with a Wi-Fi router and the webcam for processing the detection of people or flames to send an alert *via* the Telegram Bot API application with the equipment linked as shown in *table 2*.

Table 2. Circuit connections

Accessories	Connection port	Connecting devices
Raspberry Pi4	USB type C 5V	Stepdown
Stepdown	DC+, DC- Cabel	Battery 12V 100Ah
Camera	USB on Raspberry Pi	Raspberry Pi4
Servo Motor	GPIO16	Raspberry Pi4
Solar Cell 12V 50W	DC+, DC- Cabel	Solar Charger
Battery 12V 100Ah	DC+, DC- Cabel	Solar Charger
Router Wi-Fi 2.4 GHz	USB Output 5V	Solar Charger

3.3. Workflow for the system

The design of the workflow chart for the intelligent security surveillance system for communities adjacent to abandoned or vacant lots with image processing technology showing the working process of the system for detecting persons and flames with alerts was as shown in *figure 5*.

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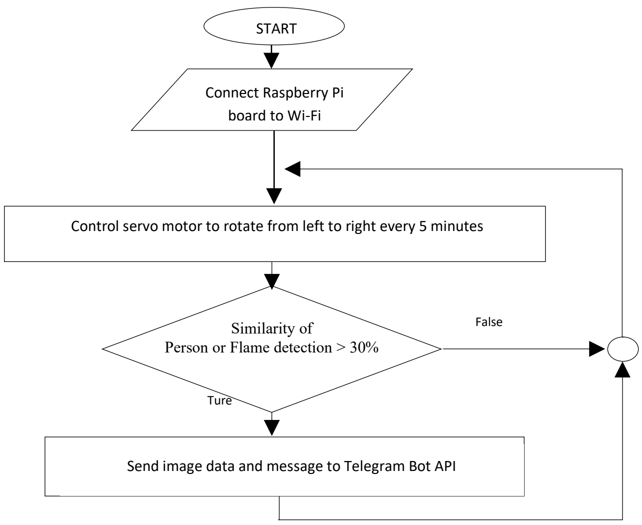

Figure 5. System operation flowchart

Figure 5 The workflow chart of the intelligent security surveillance system for communities adjacent to abandoned or vacant lots with image processing technology, which will be processed through a Raspberry Pi board, which will be connected to the Internet. When the similarity score for either a person or a flame in the image exceeds 30%, an alert is generated and sent via the Telegram Bot API. When the similarity score for either a person or a flame exceeds 30%, the system generates an alert and transmits it via the Telegram Bot API. The servo motor continuously sweeps the camera's field of view from left to right, pausing every 5 seconds at each position to capture a frame at 320 × 240 pixels. Each captured image is analyzed by the detection algorithm, and if the similarity score is above the preset threshold, the event is recorded and the image is sent with an alert message to the user through the Telegram Bot API for real-time notification.

4. SYSTEM TESTING

4.1. Person and Flame Detection Testing

(1) Testing the system's Person detection accuracy involved testing to determine the effectiveness of person detection to determine the similarity and detection time, as shown in *table 3*.

Table 3. Person Detection Test Results

Period	Movement gestures	Person detection similarity (Percent) at distance (Metes)						
		5	10	15	20	25	27	30
08.00-17.00 น. Daytime	Walk slowly	98.45	96.23	95.17	78.46	63.24	50.75	42.15
	run	92.15	89.75	75.85	50.23	-	-	-
17.00-19.00น. Low light	Walk slowly	72.31	63.14	56.23	45.12	-	-	-
	run	60.43	54.83	40.51	-	-	-	-

Table 3 shows the results of the human detection testing based on the characteristics of movement at 5 to 30 meters. At 8:00 am-5:00 pm (daytime), walking was detected at distances as far as 30 meters and at 20 meters for running. The similarity value ranged from 50.23 to 98.45%. Between 5:00 and 7:00 pm (low light), walking could be detected from as far as 20 meters away and 15 meters for running. The similarity value ranges from 40.51 to 45.12% was as shown in *figure 6*.

Figure 6. Similarity of person vs Distance

(2) Flame detection accuracy testing involved determining the effectiveness of flame detection to determine the similarity and detection time, as shown in *table 4*.

Table 4. Flame detection test results

Period	Types of Flames	Flame detection similarity (Percent) at distance (Metes)						
		5	10	15	20	25	27	30
08.00-17.00u. Daytime	Candle	-	-	-	-	-	-	-
	Pile of Paper	-	-	-	-	-	-	-
19.00-21.00u. Dark	Candle	47.83	30.12	-	-	-	-	-
	Pile of Paper	78.95	66.92	51.15	32.41	30.05	-	-

Table 4 shows the results of the flame detection testing according to the type of flame, which was tested at distances of 5 to 30 meters. From 8:00 am to 5:00 pm, no measurements could be taken, because sunlight made it impossible for the camera to catch flames. From 5:00 to 7:00 pm (low light), candles could be detected at 10 meters and piles of paper could be measured at 25 meters. The similarity value ranged between 30.05% and 78.95% was as shown in *figure 7*.

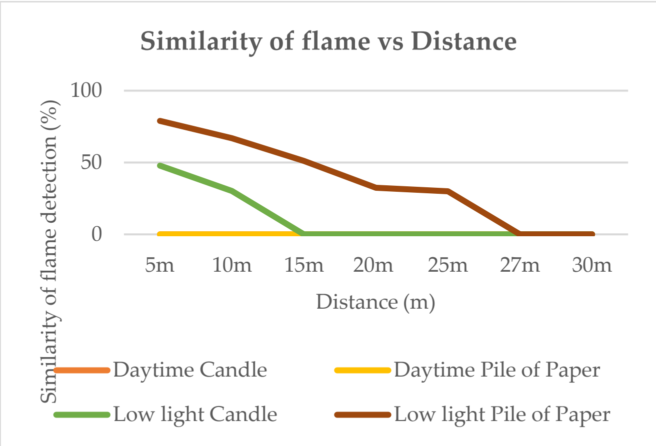

Figure 7. Similarity of flame vs Distance

(3) Human detection testing in a standing position was conducted at various test points at distances from 3 to 30 meters from the camera along. The y axis (meters) by testing from 08:00 am to 5:00 pm (daytime), as shown in *table 5*.

Table 5. Person Detection Test Results

Distance from camera along y-axis (Meters)	Similarity of people detected by the camera (%)						
	Distance to the right of the camera (Meters)			center point	Distance to the right of the camera (Meters)		
	6m	4m	2m	0	2m	4m	6m
3	-	-	96.34	99.15	97.34	-	-
5	-	87.76	95.76	98.33	96.99	90.22	-
7	-	75.45	93.44	97.43	94.73	91.00	-
9	79.45	70.87	94.35	95.63	95.86	89.70	83.25
11	67.53	67.99	92.76	94.88	93.22	78.55	76.34
13	54.77	62.35	89.81	90.78	90.44	69.86	72.00
15	49.82	60.22	85.94	86.18	87.54	65.32	57.89
17	40.44	58.80	82.43	83.54	86.62	62.63	53.77
19	35.61	52.43	73.23	78.55	79.79	57.51	50.75
21	35.82	50.39	71.72	72.11	75.55	53.87	47.91
23	34.36	45.66	64.82	66.88	69.43	49.63	42.83
25	30.49	40.78	60.98	62.19	64.94	43.44	40.22
27	-	39.89	52.54	51.23	59.44	44.75	38.44
30	-	-	42.22	43.65	46.78	35.76	30.05
31	-	-	-	-	-	-	-

In *table 5*, axial camera distance detection of people along the *y* axis (meters) from 3 meters to 31 meters, it was found that the system was capable of detecting persons at a distance of no more than 30 meters in open areas and by measuring from the left to right edges at a distance of 6 meters from the center on each side, which could be measured in degrees ranging from -45 to 45 degrees, as shown in *figure 8*. The similarity values ranged from 30.05 to 99.15%

Figure 8. Detect people during the day

(4) In flame classification testing under different light conditions, comparisons were made between no light interference and light interference in the test area at different test points at distances of 3 to 19 meters from the camera along the *y* axis (meters) by testing at 7:00 pm to 12:00 am (nighttime), as shown in *table 6* and *table 7*.

Table 6. Light discrimination test results in the absence of light interference

Distance from camera along *y*-axis (Meters)	Similarity of people detected by the camera (%)						
	Distance to the right of the camera (Meters)			Center Point	Distance to the right of the camera (Meters)		
	6m	4m	2m	0	2m	4m	6m
3	-	-	64.15	80.34	65.44	-	-
5	-	62.61	61.62	76.54	62.89	63.33	-
7	-	57.77	62.43	72.91	63.71	56.76	-
9	49.23	53.80	59.65	65.73	60.45	52.92	50.77
11	47.56	50.55	56.81	63.31	57.62	51.87	49.81
13	44.96	47.86	50.31	60.53	52.90	46.88	45.49
15	39.69	43.31	42.37	52.69	43.43	42.44	40.50
17	33.70	36.64	37.74	45.72	38.80	37.30	32.22
19	31.62	33.50	34.65	34.63	34.71	32.57	30.76
20	-	-	-	-	-	-	-

In *table 6*, light classification testing without light interference was conducted, which can be drawn as a graph showing the similarity values by displaying the images in the form of a radar graph, as shown in *figure 9*.

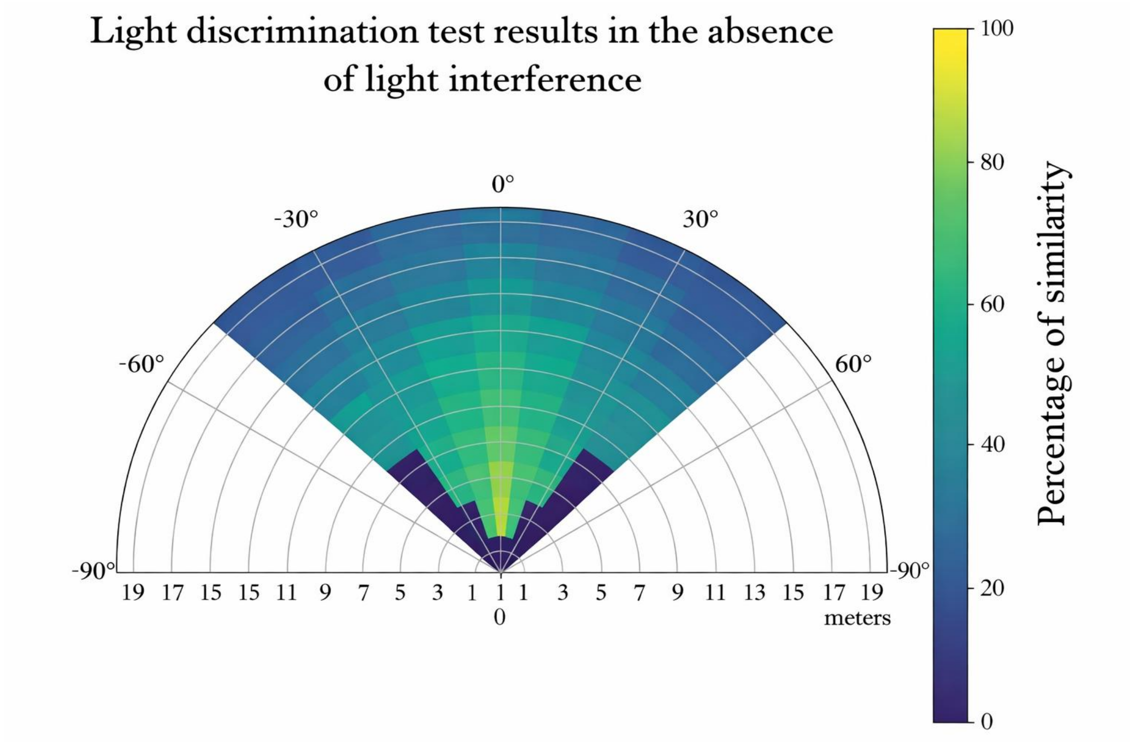

Figure 9. No light disturbance

The light classification testing with light interference on the left side of the camera was conducted in *table 7*, which can be drawn as a similarity measurement graph, with the images displayed in the form of a radar graph, as shown in *figure 10*. According to the findings, human detection by the system could not exceed 19 meters in open areas with measurement from the left and ride edges at distances of 6 meters from the center on each side, which can be measured in degrees ranging from -45 to 45 degrees, with similarity values from 30.76 to 80.34%.

Table 7. Light discrimination test results when there is light interference on the left side of the camera

Distance from camera along y-axis (Meters)	Similarity of people detected by the camera (%)						
	Distance to the right of the camera (Meters)			center point	Distance to the right of the camera (Meters)		
	6m	4m	2m	0	2m	4m	6m
3	-	-	50.32	73.11	62.16	-	-
5	-	48.57	48.64	68.04	60.83	62.09	-
7	-	47.61	46.77	65.94	59.75	55.82	-
9	42.13	46.69	45.81	60.85	58.77	53.46	48.14
11	40.76	42.75	42.63	57.71	56.82	52.93	47.64
13	35.53	38.27	40.84	54.36	53.48	47.82	44.77
15	31.55	36.24	40.67	47.45	42.34	46.15	38.82
17	-	31.19	33.99	41.02	36.59	38.13	34.67
19	-	-	-	-	33.50	31.42	33.92
20	-	-	-	-	-	-	-

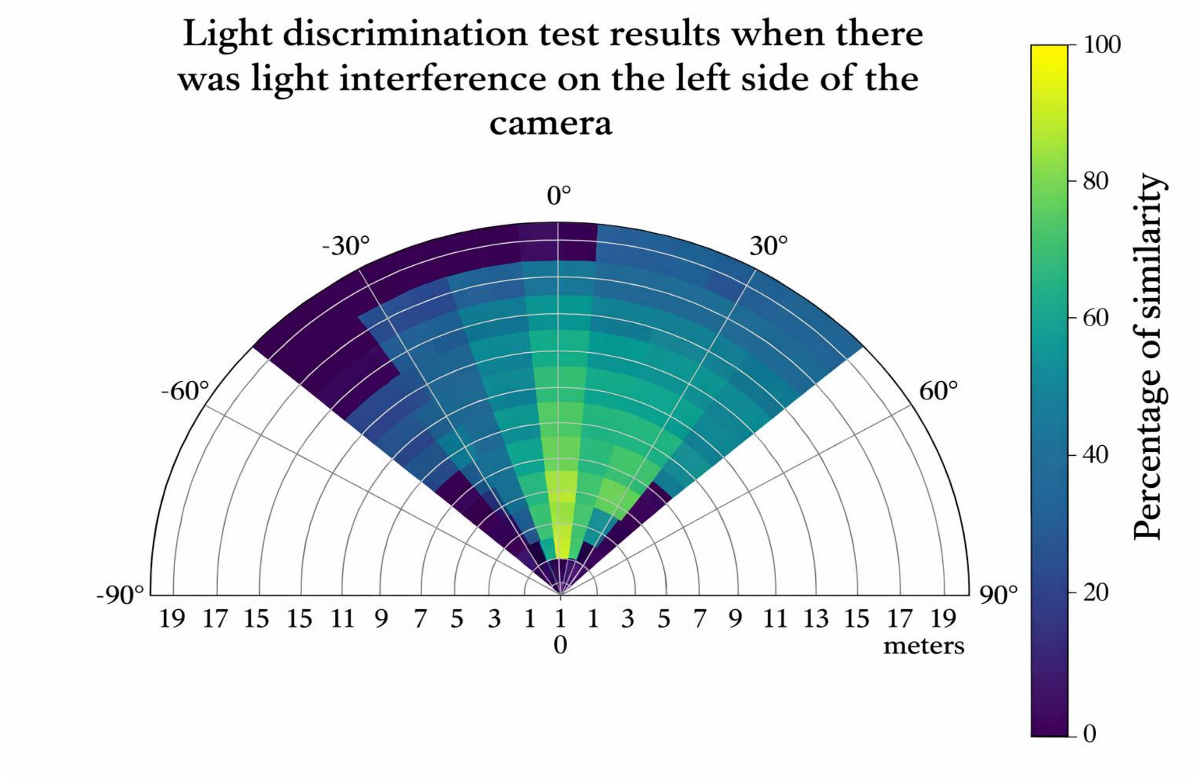

Figure 10. light interference

4.2. Notification System Testing

Testing the functioning of Telegram Bot API in sending alerts involved determining the effectiveness of human detection and flames at various distances to find the similarity and duration of notification via the Telegram Bot API application, as shown in *table 8*.

Table 8. Telegram Bot API Notification Usage Test Results

Test list	Distance of person/flame to camera (Meters)	Average similarity (Percent)	Average time to notification (Seconds)
Person detection Daytime	5	99.69	6.78
	10	92.37	6.61
	15	53.64	6.53
Flame detection Nighttime	5	76.15	6.93
	10	62.76	7.19
	15	51.48	6.54

In *table 8*, notification testing, it can be seen that human detection during the day at various distances resulted in alerts sent *via* Telegram Bot API from 6.53 to 6.78 seconds. As for the detection of flames at night at various distances, alerts are sent via Telegram Bot API from 6.54 to 7.19 seconds.

4.3. Testing the System

In testing the application of the system in the field at the Rung Sawang Village 1 community, Ramintra Road. Anusawari Subdistrict, Bang Khen District, Bangkok, the system was installed at a total of 2 points and system performance was tested, as shown in *figure 11*.

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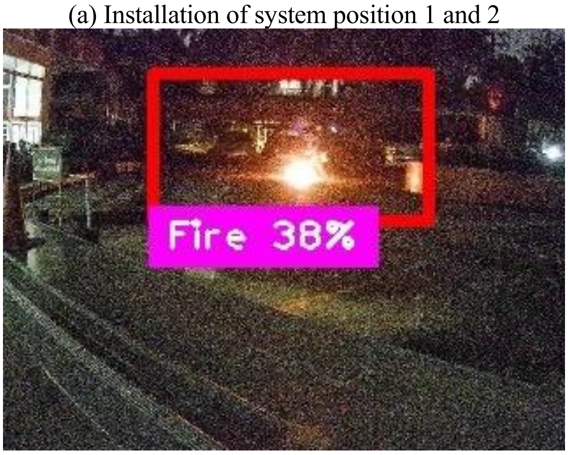
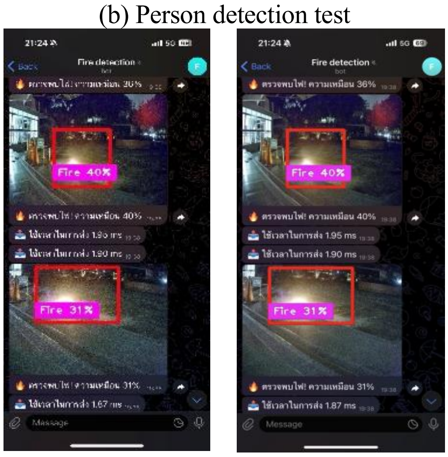
(a) Installation of system position 1 and 2

(b) Person detection test



(c) Flame detection test



(d) Notifications via Telegram Bot API application

Figure 11. Installation and testing in real-world locations

Table 9. Flame detection (nighttime)

Distance **(Meters)**	TP (True positives)	FN (False negatives)	FP (False positives)	TN (True negatives)	FPR (False Positive Rate)	FNR (False Negative Rate)	Accuracy
5	96	4	8	192	4	4	96.00
10	90	10	12	188	6	10	92.67
15	76	24	18	182	9	24	86.00
20	60	40	25	175	12.5	40	78.33

Table 10. Flame detection (daytime)

Distance (Meters)	**TP (True positives)**	**FN (False negatives)**	**FP (False positives)**	**TN (True negatives)**	**FPR (False Positive Rate)**	**FNR (False Negative Rate)**	**Accuracy**
5	98	2	5	195	2.5	2	97.67
10	95	5	10	190	5	5	95.00
15	88	12	18	182	9	12	90.00
20	78	22	28	172	14	22	83.33

Detection performance decreased as distance increased for both tasks. In nighttime as shown in *table 9*. The flame detection, accuracy dropped from 96.0% at 5 m to 78.33% at 20 m, mainly due to a sharp rise in false negatives (FNR: 4% to 40%) with a moderate increase in false positives (FPR: 4% to 12.5%). Similarly, daytime as shown in *table 10*. The person detection accuracy declined from 97.67% at 5 m to 83.33% at 20 m, with FNR increasing from 2% to 22% and FPR from 2.5% to 14%, indicating that missed detections become the dominant error at longer distances.

4.4. Performance Evaluation

The performance of the intelligent security surveillance system was evaluated by 30 users. The evaluation of the intelligent security surveillance system was divided into two main parts: the operation of the system and the sense of security occurring after the installation of the system. The results are as shown in *table 11*.

Table 11. Evaluation results from real users

Evaluation topics	Average score	Standard division (SD.)	Rating level
Accurate motion detection system	4.17	0.83	Very Good
Speed of alerting to unusual events	3.93	0.87	Fair – Needs minor improvements
Clarity of camera images	4.27	0.74	Very Good
Ability to alert to people and flame	3.9	0.76	Fair – Needs minor improvements
Ease of use of the system	3.87	0.86	Fair – Interface can be improved
System stability	3.9	0.84	Needs improvements (system may crash/lag)
Suitability of the installation site	4.13	0.90	Very Good
Improved sense of security after installation	3.63	1.25	System testing and deployment time required
Reduced concerns about crime	3.70	1.09	System testing and deployment time required
Reliability of the system to prevent serious incidents	3.97	1.25	System testing and deployment time required
Desirability of system expansion to other high-risk areas	3.70	1.17	Additional risk factors should be considered

In table 11, the system performance was evaluated in a table containing the mean and standard deviation scores among 30 people, the item with the highest score was the clarity of the image from the camera at 4.27 points, followed by the accuracy of the motion detection system at 4.17 points and the rating for suitability of the installation sites was 4.13 points. All 3 items must be very good. Meanwhile, the item with the lowest score was a greater sense of security after installing the system at 3.63 points. In most cases, the system needs to improve in terms of notifications through the application, ease of using the system, reliability of the system in helping to prevent serious incidents, the speed of notification of unusual events and the need to expand the system to other risk areas due to the scores between 3.63 and 3.97 points, which are classified as satisfactory to requiring minor improvements.

5. DISCUSSION ON TEST RESULTS

According to the results on detection testing in *table 3*, it was found that the system performance efficiency differed in line the time and movement characteristics. During the day, the system detected slow walking well with a similarity value of 98.45% at a distance of 5 meters and could also work up to 30 meters with a similarity value of 42.15%. However, running could only be detected at 20 meters with a similarity value of 50.23%, because the rapid movement made the image blurred. In low light, the efficiency was greatly reduced, with slow walking only detectable at 20 meters with a similarity value of 45.12% and running detectable at 15 meters with a similarity value of 40.51%, which shows that natural light has significant impact on system performance.

In the flame detection testing shown in *table 4*, the system was unable to detect flames during daylight at all, because sunlight interferes with the camera's capture. At night, the system detected candle light at as far as 10 meters away with 30.12% similarity and piles of paper at 25 meters with 30.05% similarity, because piles of paper emit more heat and light.

In the human detection testing shown in *table 5*. Detection efficiency was on a line perpendicular to the camera with a similarity of 99.15% within a range of 3 meters. Efficiency was reduced when moved from the perpendicular line. The testing of the alert system via Telegram Bot API shown in *table 8* shows an acceptable response time with human detection at 6.53-6.78 seconds and flame detection at 6.54-7.19 seconds.

Field testing was conducted at the Rung Sawang Village 1 community, as shown in *figure 11*. In real system testing, the system was installed at two points to cover risk areas and show the system was able to function in a real environment. The results of the evaluation by 30 users in *table 11*. reflected key views with the highest scoring areas being image clarity at 4.27 points, the motion detection system at 4.17 points, and suitability of installation sites at 4.13 points, indicating satisfaction for technical quality. The lower scoring areas concerned feelings and perception, such as a sense of safety at

3.63 points and concern about crimes at 3.70 points, which was normal for new technologies that need time to build confidence.

6. CONCLUSIONS

In real application in the community, the Intelligent security surveillance system displayed satisfactory effectiveness in detecting individuals during daytime with accuracy up to 98.45% at close range while covering a detection area with a width up to 30 meters and a fan-like view from -45o to +45o degrees. In terms of flame detection, the system functions only at night due to the limitations of natural light. However, the system displays good effectiveness in distinguishing flames of various sizes, particularly piles of paper, which the system was able to detect at a range of up to 25 meters. The system offers speedy and reliable alerts *via* Telegram Bot API with a time of 6-7 seconds, enabling the system to give timely alerts about unusual events. After real use in the community, the system was found to have good acceptance, particularly for image clarity and detection accuracy. Nevertheless, there remain areas for improvement such as notification speed, ease of use, and confidence in the system's effectiveness. In the daytime, sunlight is very bright, so the camera automatically adjusts the image and the flame no longer looks clear. The flame can blend with the background, so the system misses it. To detect flame in daytime, use an extra sensor such as a thermal/IR or UV flame sensor. The developed system's main limitations are human detection at night and flame detection during the day, which may lead to the development of detection algorithms for better function in low light conditions, improvements to user interfaces for ease of use, and increased system stability to reduce crashes or delays. These would make this system suitable for use in communities requiring increased safety, particularly in areas at risk of trespassing or flame, and effectively enable the system to have expanded use in other risk areas.

Conflicts of Interest: The authors declare no conflict of interest.

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