

# LITE: Light-based Intrusion deTection systEm Using an Optical-Camera and a Single Board Computer

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**Abstract**—This demonstration shows the working of an optical-camera-based system designed to distinguish between human and animal intrusion while rejecting clutter arising from wind-blown vegetation in an outdoor environment. The aim of the research was to use optical-camera system as a complementary sensing modality to a PIR sensor-based intrusion detection system. There are three important features to demonstrate: (a) the optical-camera based intrusion classification system using a Single Board Computer (SBC), (b) the algorithm which exploits the spatial resolution capability to help in classification, and (c) real-time demo of the visualization of features calculated and classification decisions.

## I. INTRODUCTION

An optical-camera-based intrusion classification system, LITE (Light-based Intrusion deTection systEm), is developed by our group to use it as a complementary sensing modality to a PIR sensor based intrusion classification system [1].

*a) Motivation:* A very small amplitude signal was generated by the PIR sensor during the experiments conducted in March-April 2016 in Bengaluru [2]. The reason being the ambient temperature was very close to human body temperature. This can be explained as the signal registered by a PIR sensor is function of the difference of ambient temperature and object temperature as shown in Eq. 1.

$$W = K(T_o^4 - T_{bg}^4), \quad (1)$$

where,  $K$  is a constant, and  $T_o$  and  $T_{bg}$  denote object and background temperature, respectively.

This motivated to search for a complementary sensing modality. An optical-camera was selected for the complementary sensing modality with the PIR sensor [1].

A complementary sensing modality is only required during few hours in a day-time. The optical-camera has a limitation in terms of working at the night but it is suitable for the day-time. Hence, optical camera was chosen as the complementary sensing modality. A low-complexity motion-detecting algorithms was developed which can be implemented on an SBC. An Odroid C2 (OC2) was chosen as the SBC. Only a small subclass of animals are considered here, those comparable in size and shape of a dog or a tiger.

The LITE system comprises of a C170 Logitech Camera operating at a resolution of  $(640 \times 480)$  pixels per frame, an OC2 running at 1.5GHz, and a Zolertia RE-Mote as shown in Fig. 1.

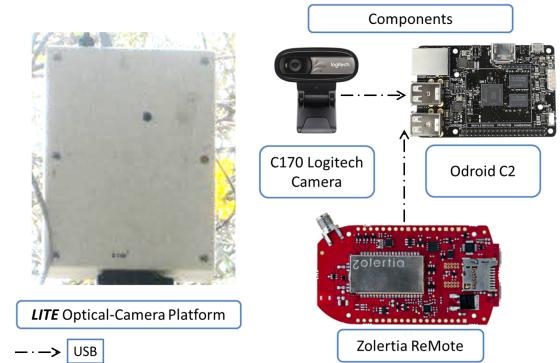


Fig. 1. The LITE and its components (C170 logitech Camera, OC2 and RE-Mote).

In our paper [1], the temporal difference between two consecutive frames and optical flow based features are used to classify intrusions while rejecting false alarms arising from clutter. Features are calculated in a manner such that spatial resolution capability can be exploited for the classification. In [3], a background-subtraction algorithm that is based on the difference of the average intensity of a selected color across two successive frames is implemented on a Raspberry Pi. We also use optical-flow based features along with background-subtraction based features. The background-subtraction based features can give more false alarm while optical-flow based features are more robust in terms of that. A feature level fusion of background-subtraction based features and optical-flow based features results in a more robust feature set.

The novelty of the work is in using an optical-camera for human-animal classification with the optical-flow based algorithm which can be implemented on an SBC.

In the later sections, we describe the hardware and software modules of the LITE, requirements for the demonstration and demonstrable system components.

## II. LITE: LIGHT-BASED INTRUSION DETECTION SYSTEM

Details related to hardware and software modules of the LITE are described below.

### A. Hardware Modules

*1) Optical Camera:* A C170 Logitech USB webcam is chosen as the camera module and captures video at a resolution

of  $(640 \times 480)$  pixels per frame.

**2) Choice of Single Board Computer:** The intrusion detection and classification algorithms were implemented on two SBCs ( a Raspberry Pi-3 and an Odroid C2). The Odroid C2 was preferred over the Raspberry Pi-3 as it was providing more frames per second which will help in better accuracy as the training is done at 25 FPS and if the captured FPS is closer to 25 FPS then it is better. The final algorithm was implemented on an Odroid C2 running Ubuntu Mate 16.04 OS, having a 1.5GHz 64-bit quad-core processor with 2GB RAM.

**3) RE-Mote:** A Zolertia RE-Mote is also the part of the system. It is used to communicate the classification decision to base station via relays. It has a CC2538 System-On-Chip for IEEE 802.15.4 RF transmission at the 2.4 GHz ISM band. The CC2538 also has an ARM Cortex-M3 running at 32 MHz with 512 KB flash and 32 KB RAM.

## B. Software Modules

### 1) Temporal-Difference-based Features:

The camera is placed at a height of 1m such that the middle of a captured frame corresponds to a height of 1m above ground level (see Fig. 2).

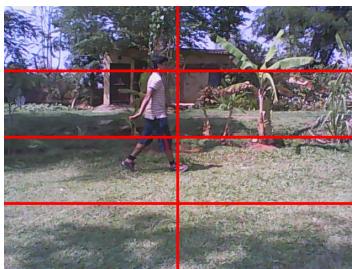


Fig. 2. Partitioning the captured frame into eight segments. A human movement contributes to a change in background in both upper and lower halves.

Fig. 3 presents a flow chart ,involving the steps used for calculating the resultant 8-dimensional feature vector arising from the temporal-difference algorithm (detailed description can be found in [1]).

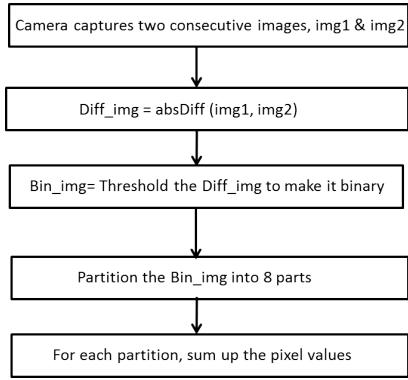


Fig. 3. Flow chart for feature extraction using temporal difference approach.

**2) The Optical-Flow-based Features:** In case of optical flow, some marker points are marked on a frame. In the next frame, these points try to find the same intensity values in their neighborhood and move at equi-potential pixels. In our

approach, marker points are hard-coded such that they provide vertical and horizontal spatial resolution (see Fig. 4).

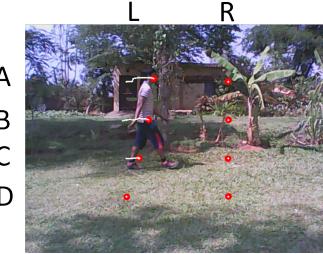


Fig. 4. 8 marker points for calculating the features using optical flow.

When a human enters the marker point position, the marker points are tracked along the human. Let's say  $(x_{LA}(t_i), y_{LA}(t_i))$  denotes the  $i^{th}$  cumulative displacement vector corresponding to the point A in the left column (see Fig. 5 ).

**Correlation Features:** Correlation function  $\rho_{AB}(\tau)$  is given by

$$\begin{aligned} \rho_{AB}(\tau) = & \sum_{i=1}^p x_{LA}(t_i)x_{RA}(t_i + \tau) + \sum_{i=1}^p y_{LA}(t_i)y_{RA}(t_i + \tau) \quad (2) \\ & + \sum_{i=1}^p x_{LB}(t_i)x_{RB}(t_i + \tau) + \sum_{i=1}^p y_{LB}(t_i)y_{RB}(t_i + \tau), \end{aligned}$$

Low correlation values for both  $\rho_{AB}(\tau)$  and  $\rho_{CD}(\tau)$  denotes no intrusion movement. High correlation values for both  $\rho_{AB}(\tau)$  and  $\rho_{CD}(\tau)$  denotes the human movement. And, low correlation value for  $\rho_{AB}(\tau)$  and high correlation value for  $\rho_{CD}(\tau)$  denotes the animal movement.

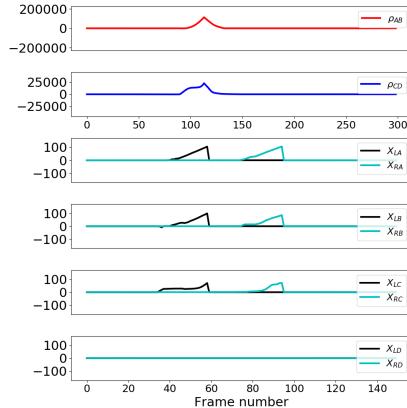


Fig. 5. The plots in this figure correspond to the intrusion shown in Fig. 4. The top two rows correspond to plots of  $\rho_{AB}(\tau)$  and  $\rho_{CD}(\tau)$  versus  $\tau$  respectively. The third row is a superimposed plot showing the values of  $x_{LA}(n)$  and  $x_{RA}(n)$  as a function of  $n$ . The last 3 plots are similar plots as third plot with A replaced by B, C, D, respectively.

**Energy Features:** The maximum energy of a displacement vector for each of the eight marker points  $\{LA, LB, LC, LD, RA, RB, RC, RD\}$  is also calculated to help in classification.

The feature vector is fed to Support Vector Machine (SVM) to classify between different classes.

## III. DEMONSTRATION REQUIREMENT

The following are the requirements for demonstration setup.

- A table, at least of 2m x 1m size and a poster board
- 230V three-pin power outlets (at least three)
- Two large displays with VGA cables
- Open lighted area of 5m x 5m would be preferred in front of the camera-system so that the audience can walk there and can visualize the features and decisions
- A setup time of at least one hour

#### IV. FEATURES OF THE DEMONSTRATION

The scope of this demonstration is to show how an optical-camera system can be used for intrusion classification and also to demonstrate the low-complexity algorithms running on an Odroid C2. The following features will be demonstrated.

##### 1) Optical-flow algorithm implemented on the Odroid C2:

Conference participants will be able to see the optical-flow algorithm running on the Odroid C2. The working of the optical flow algorithm will be demonstrated in a real-time visual form. They will also be able to see how the marker points are tracked along the human movement.

##### 2) Simple algorithm design:

Conference attendees will be able to understand the algorithm design for optical-camera based intrusion classification system. It is a simple but effective arrangement of an array of 8 marker points as shown in Fig. 4. This provides the spatial resolution capability to the camera to help in classification. Intuitively the correlation features  $\rho_{AB}(\tau)$  and  $\rho_{CD}(\tau)$  (see Fig. 5) help in classifying between intrusion and wind-blown vegetative motion as their motions are translation and oscillatory motions, respectively. The correlation features also help in classifying between human and animal based on which correlation values are high. Additionally, the energy values corresponding to the displacement vectors of the marker points are also used to distinguishing between different classes. The highlight of the research is the feature engineering. Better feature design will result in an easy to differentiate features for different classes. Feature calculation corresponding to background-subtraction will also be shown (see Fig. 6)

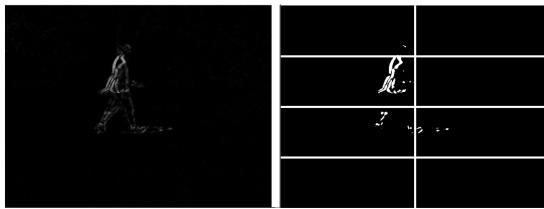


Fig. 6. The first figure shows the image after taking the absolute difference of two consecutive frames. The second figure shows the image after thresholding and having 8 partitions.

3) Real-time feature visualization: The viewers will be able to walk in front of the camera-system and observe the real-time calculations of features like correlation (as shown in Fig. 5) and energy.

4) Feature visualization for different classes: The conference participants will be able to understand the difference among the features for different classes by visualizing the features in the real-time from the already recorded videos in the database. Fig. 7 shows the displacement vectors and cross-correlation features corresponding to a dog movement from

right to left.

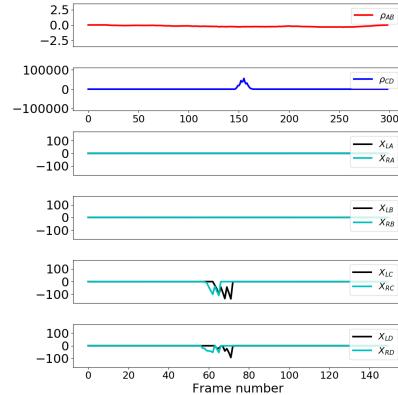


Fig. 7. The first two rows show the correlation and other rows show the displacement vector for the dog movement from right to left.

5) Real-time classification decision: The classification algorithm is implemented on the Odroid C2 and real-time classification results will be shown. Visitors will also be able to see the real-time classification for their movements.

##### 6) Transmission of decisions from LITE to border-router:

The decisions generated by the Odroid C2 will be communicated to the RE-Mote present in the LITE over UART. This decision is then communicated using IPv6 over Low power Wireless Personal Area Network (6LoWPAN), that runs on top of IEEE 802.15.4, to another Re-Mote configured as a Border Router (BR). Finally the BR connects to a computer using UART to communicate the decision over Serial Line Internet Protocol (SLIP).

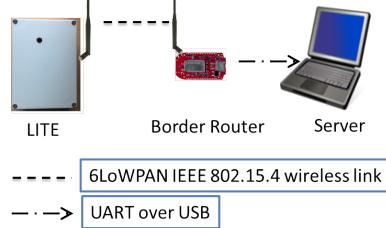


Fig. 8. Transmission of decisions from LITE to border-router using 6LoWPAN.

#### V. CONCLUSION

Some important features of the demonstration will be: (a) optical-flow algorithm implemented on the Odroid C2, (b) the algorithm exploits the spatial resolution capability to help in classification, and (c) real-time feature visualization and classification Demonstration will help the audience in understanding the optical flow and background subtraction algorithm and how to use them for intrusion classification system.

#### REFERENCES

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