DEVELOPMENT OF ANOMALY DETECTION USING VISION SYSTEM

AHMAD HAFIY BIN HARIZAN

BACHELOR OF MECHATRONICS ENGINEERING
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AHMAD HAFIY BIN HARIZAN

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DECLARATION

I declare that this thesis entitled “Design and Development of Anomaly Detection Using Vision System” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : AHMAD HAFIY BIN HARIZAN

Date :

APPROVAL

I hereby declare that I have checked this report entitled "Design and Development of Anomaly Detection Using Vision System" and in my opinion, this thesis complies the partial fulfillment for awarding the award of the degree of Bachelor Of Mechatronics Engineering With Honours.

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

As crime rate greatly increases over the years along with technological advances on vision systems, surveillance systems are being installed in almost every possible location such as banks, offices, and residential areas. With continuous recording of videos, humans are facing difficulty to monitor them manually for the detection of anomalous activity. In attention to this problem, the proposed work designs a semi-supervised anomaly detection technique in stationary backgrounds to reduce the need of human intervention in detecting anomalies. Segmentation, detection of objects and noise removal in foreground are the main phases of the proposed work. Identification of important target features such as centroid and the bounding box assists in object detection and localization of objects in frames. The performance evaluation of the simulation results based on localization error and rate of accuracy validated that the proposed work could deal with various anomaly activity in a static background scene and successfully detect anomaly without much human intervention.

ABSTRAK

Kadar jenayah kian meningkat seiring dengan kemajuan teknologi pada sistem penglihatan, sistem pengawasan dipasang di hampir setiap lokasi yang mempunyai kebarangkalian jenayah yang tinggi seperti bank, pejabat, dan kawasan kediaman. Dengan rakaman video berterusan, manusia menghadapi kesukaran untuk memantau mereka secara manual untuk mengesan aktiviti anomali. Dalam perhatian terhadap masalah ini, kerja yang dicadangkan ini merangka teknik pengesanan anomali pengawasan separa dalam latar belakang pegun untuk mengurangkan keperluan intervensi manusia dalam mengesan anomali. Segmentasi, pengesanan objek dan penyingkiran hingar di latar depan adalah fasa utama kerja yang dicadangkan. Pengenalpastian ciri sasaran penting seperti centroid dan kotak pengikat membantu dalam pengesanan objek dan penyetempatan objek dalam bingkai. Penilaian prestasi keputusan simulasi telah membuktikan bahawa kerja yang dicadangkan dapat menangani berbagai aktivitas anomali dalam adegan latar belakang statik dan berjaya mengesan anomali tanpa banyak intervensi manusia.

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LIST OF SYMBOLS AND ABBREVIATIONS

m	-	Meter
cm	-	Centimeter
MM	-	Mathematical Morphology
GMM	-	Gaussian Mixture Model
FD	-	Frame Differencing
FP	-	False Positive
FN	-	False Negative
TP	-	True Positive
TN	-	True Negative

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CHAPTER 1

INTRODUCTION

1.1 Background

Over the past decade, the rapid growth and exceptional improvements in real-time video analytics is evident. The detection and localization of an anomaly is the primary goal of video analytics in pursuit of recognizing suspicious activities and potential threats by means of fewer or zero human intervention. Anomaly detection using vision system is a prominent research area that includes the identification and classification of human activities into ordinary (normal), irregular (anomalous) activities. The primary task is to locate uncommon events in videos using a manual, semi-automatic or fully automatic recognition system.

Anomaly detection systems can be generally categorized into two main groups: unsupervised anomaly detection which implies a fully automatic recognition system and supervised anomaly detection for manual or semi-automatic system. The goal of this project is to design and develop a semi-automatic system which involves less human intervention compared to manual systems where real-time monitoring by humans is required. On the other hand, automatic and intelligent anomaly detection systems with machine learning capabilities does not require human intervention in decision making.

Anomaly detection has practical applications in many real-life scenarios. Pimentel et al. [1] classify these scenarios in six main domains: image and video processing, medical diagnostics, electronic IT security, industrial damage detection and monitoring, text mining, and sensor networks. This project focuses on the field of image and video processing as the

other domains are beyond the scope of this work. Anomaly detection is carried out in the context of image processing and video surveillance using data collected through vision systems that monitor the behavior and activities of target objects [2]. Without the lack of ability to automatically track and analyses in real-time, a human operator had to either properly monitor an abundance of footage data in real time to detect any anomalies or events, or the footage can only be reviewed after the occurrence of an anomalous event.

Anomalous event detection can be done in two ways: firstly, by training the system with normal and anomalous events, and then utilizing prior data information to distinguish future events. Secondly, the dominant set property according to which the dominant behavior (higher occurring frequency and less attention seeking behavior) of the object is regarded as normal behavior while the less dominant behavior is recognized as unusual behavior or an anomaly. Having said that, this project focuses on the latter technique. The target for detecting anomalies is often linked to human behavior in most applications. However, it is difficult to determine what should be regarded as an anomaly when it comes to human behavior. This is because anomalies are subjective concepts defined by humans and varies according to the situation.

Since video cameras generate image data, it is natural for an automatic video surveillance system to be broken down into several image processing functional blocks such as foreground objection, motion detection and tracking, and blob analysis. The aim of this project is the design of moving object detection framework around these blocks which are implemented using Computer Vision techniques and algorithms. In order to tackle image-related issues such as variation of brightness or color information in images and changes in illumination, image processing that usually involves the segmentation of the foreground and

the extraction of features is studied. Then, target activity analysis allows preventative acts or alerts when a specific event is detected.

1.2 Motivation

Due to increased security concerns, there is now an increasing demand for automated monitoring systems in the span of the past decade. Technological advances and reduced costs have led to the accelerated deployment of both public and private surveillance cameras. The monitoring task is traditionally carried out by human operators to inspect video feeds from cameras thoroughly. It has been shown, however, that even dedicated personnel receive reduced visual attention after long periods of observation on monitoring. This prohibits their ability to detect and react to possible real-time threats [3], transforming current surveillance systems into mere recording devices used only for analyzing of footage after an event occurrence [4]. For these reasons, in the past decade, real-time event recognition and anomaly detection in using vision system has undeniably become an interesting research topic. Automatic anomaly detection algorithms can help human operators to recognize suspicious events or potential threats helping them to respond appropriately when necessary.

In this context, the recognition of human activity has been widely studied in the literature. Most approaches in this field have definitive designation of certain events and their application is therefore limited to the detection of these events, usually in controlled scenarios. An example of event detection is the infringement of prohibited areas such as ATM area break-ins after working hours. Based on market research by ATMIA and reported in the 2017 annual global fraud and security survey, the percentage of respondents reporting in ATM crime increased from 42% in 2016 to 54% in 2017 [5]. More recently, the focus has been increased on detecting anomalies without explicit modelling. However, occurrence of

events of interest in video surveillance scenarios are sparse and difficult to predict making it very difficult to train a system to cover all possible cases of anomalous events. The underlying assumption that anomalous events are characterized by their low occurrence frequency compared to normal events is common to these techniques.

1.3 Problem Statement

Traditional video surveillance systems relying on human operations are unproductive and inefficient because the number monitoring devices exceeds the monitoring capacity of human operators. Anomaly detection in many vision system frameworks requires significant human intervention making it time consuming and not scalable to high volumes of video footage [6]. In general, abnormal events seldom occur in comparison with normal activities. As a result, humans are indeed incapable to continue to analyze the ever-increasing volume of security recordings and hinder the efficiency of the security system due to fatigue and lack of observation or concentration. Subsequently, a huge portion of video is simply stored without review. With the development of anomaly detection system, management of manual labor and storage resource is less demanding as administrators can analyze specific time frames of activity occurrence.

Another challenge of the vague anomaly definition is due to the diversity of abnormal events which contributes to a high false positive decision making. In most constrained environments, abnormalities are well-defined for example the event of any movement in an ATM area after service hours is considered as anomaly. Regardless, anomaly objects in most scenarios are undefined. For example, any objects except for moving cars on a highway can be treated as anomaly. An algorithm for anomaly detection therefore encounters difficulties where it has little information to predict an event until it literally occurs. Consequently, it is

a very difficult to develop a good and accurate anomaly detector to detect unknown anomalous objects with very little information on the target of interest.

1.4 Objectives

The purpose of this research is to:

1. Design and develop a supervised anomaly detection framework on static backgrounds using vision system based on foreground detection and classifier principles.

2. Evaluate the accuracy of the proposed framework in detecting objects.

3. Analyze the performance and reliability in detecting moving objects.

1.5 Scope and Limitation

This study is based on the machine vision and image processing. The anomaly detection algorithm is done based on rule-based approach with predefined problem domain rules set as classifiers.

The proposed working system is based on interfaced program and simulation using MATLAB R2019a and V-REP PRO EDU V3.5.0 rev4. The system works with a 1280x720 X/Y resolution vision sensor with 1.00e-01m and 1.10e+01m near and far clipping planes respectively. The performance of the proposed model is evaluated based on the localization error of detected objects on static backgrounds and recognize classified activities

In particular, the surveillance system can monitor both static and moving objects in the environment and is limited to the classifying between predefined normal background and foreground. Furthermore, the evaluation of the prototype was dependent on simulated scenes in the software V-REP PRO EDU V3.5.0 rev4, which could have influenced the results that were obtained.

With anomalies being a rare occurrence, obtaining enough samples to explicitly categorize anomalous events and behavior is difficult. Another vital limitation is to develop a method that can automatically analyze the behavior of multiple moving objects in videos becomes complex especially when the objects overlaps each other. Several algorithms have been developed to track and distinguish individual targets and distinguish their action and activities in the pursuit of detecting anomaly behaviors. However, a majority of the designed algorithm are high in complexity and require an abundance of data thus is difficult to deliver successful results in a short time constraint. Another limitation entails the case when sometimes the vision of a camera in real life is not focused or blurred in the presence of smudges. Consequently, the detection of objects or foreground is hindered with no clear vision of subjects.

This analysis is expected to focus on developing the ideal foreground segmentation and anomaly detection framework using vision system to extend the ability of semi-automatic foreground detection within static backgrounds. Blob analysis which compasses the measurement, size, centroid and bounding box becomes the main parameters in this study. Based on these parameters, simulated scenes are used to study the system's performance in detecting anomalies.

CHAPTER 2

LITERATURE REVIEW

There are numerous research papers about detecting anomalies using vision system. Anomaly detection using vision system is an active research area thus plenty of previous works had been done relating this area. Past works occurred in this area can be generally classified into two categories, supervised methods where they have a training phase and unsupervised methods which they don't have such an unequivocal training phase. While several methods of detecting anomalies using vision system are highlighted in this chapter, the discussion here focuses more on pursuing supervised video event detection. This chapter firstly starts with an introduction followed by the description and related work of anomaly detection. Then, previous works and background of object segmentation methods are discussed. Finally, previous methods on noise removal and theoretical background of Mathematical Morphology is outlined before summarizing the chapter.

2.1 Anomaly Detection

Anomaly detection is described in [7] as the assignment of discovering substances in a framework that don't fit into a normal example. The term is often used as a synonym for novelty or outlier detection. As Pimentel et al. points out in [1], the term comes from different application regions, and for each of them there is no collaboratively accepted definition. In this problem class, the positive class is called "normal" while the negative class is designated as "anomaly".

There is extensive research in computer vision and multimedia analyzing object behaviors and movements from videos. A variety of framework for anomaly detection are available including frameworks that requires no human intervention. Different researchers applied different methods and techniques to suit different applications or events. Most of the work has focused on extracting useful information including behavior patterns and situations for surveillance analysis through activity recognition and abnormal behavior detection. Some methods focus on the classification of the most common behavior patterns in each scene such as linear and radial patterns.

In a visual system, a normal example or pattern recognition is utilized to decrease and sum up the information data before sorting and classifying the information into normal or abnormal data [7]. To find defects in normal, rehashing and uniform movement of objects, an algorithm for the calculation of the anomaly detection can be implemented. A simple method in solving anomaly detection in vision system is by utilizing high speed cameras and high specifications video capturing hardware which are used in most modern visual based systems to capture frame data and then analyzing them. As stated in [7] this strategy requires costly equipment as well as a broad measure of handling power.

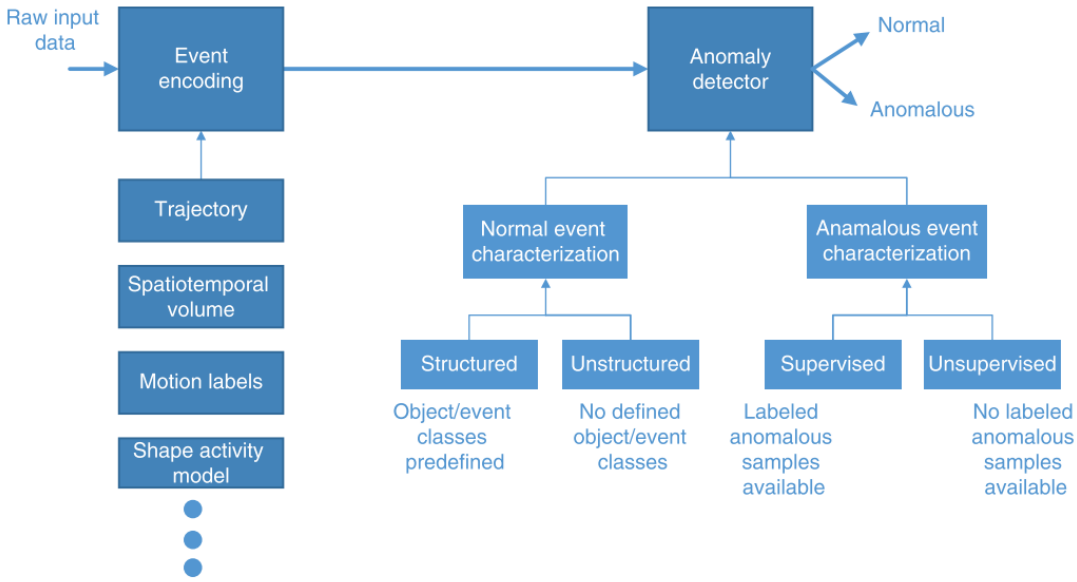

Figure 2.1 Flowchart of anomaly detection in videos [6].

2.1.1 Anomaly Detection Techniques

Unsupervised detection of anomalies refers to the scenario in which there are not enough labels of anomalous samples to precisely categorize an anomalous event class while Supervised anomaly detection refers to the setting where anomalous samples are labelled into known classes [6]. Most of the previous research into anomaly detection focuses on the understanding of behavior through manual system training. Inspired by cognitive science, previous work by Dee and Hogg [1] has demonstrated that by implementing a rule-based approach, unusual trajectories can also be identified which scales the extent of the behaviors a given target could be considered as goal-directed behavior.

A supervised learning framework that utilized the novel incremental one-class learning algorithm as key-component for modelling the distribution of normal motion trajectories occurring in a scene was proposed in [8] where the approval of an administrator is required before any behavior pattern that appears novel with respect to the model is incorporated. This algorithm is described by the control points of cubic spline curves and