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DECLARATION OF THESIS

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LIST OF ABBREVIATIONS

BGR	Blue, Green, Red
CBIR	Content-based Image Retrieval
DFD	Displace Frame Difference
DM	Derivative Model
HSV	Hue, Saturation, Value
LAB	Luminance, A, B
LBP	Local Binary Patterns
LDD	Linear Dependence and Vector Model
NCC	Normalize Cross Correlation
PTZ	Pan-Tilt-Zoom
RANSAC	Random Sample Consensus
SCD	Statistical Change Detection
SM	Shading Model
SURF	Speeded up Robust Features
WCD	Wronskian Change Detector
VLSI	Very-large-scale Integration
WM	Wronskian Model

Penganggaran Pergerakan Kamera dan Pengestrakan Objek Menggunakan Berbilang Bingkai Berturur-turut untuk Kamera Pan-Tilt-Zoom

ABSTRAK

Kajian ini membentangkan kaedah baru untuk mengestrak objek bergerak menggunakan kamera Pan-Tilt-Zoom (PTZ). Sistem yang menggunakan kamera bergerak menghadapi beberapa masalah, termasuk ketidakselarian antara bingkai semasa dan rujukan, kehadiran objek yang tidak diingini (hantu), perubahan pencahayaan, bayang-bayang dan orang ramai. Kajian ini membina satu algoritma yang dapat mengelakkan masalah ketidakselarian gambar-gambar, menghapuskan hantu dan objek-objek yang tidak diperlukan. Algorithma ini terdiri daripada enam langkah, iaitu menganggar pergerakan kamera, mengestrak objek, membuang hantu, mengesan dan menghalus bayang-bayang dan membuang titik-titik. Kajian ini mencadangkan untuk mengaggar pergerakan kamera sebanyak dua kali, iaitu antara tiga turutan bingkai. Titik-titik utama bagi setiap gambar dikesan menggunakan pengesan "SURF", iaitu Mencepatkan Ciri-ciri yang Teguh. Kemudian menghasilkan matriks homografi. Homografi ini mempunyai infomasi pusingan dan terjemahan satu gambar ke satu gambar yang lain. Ia digunakan untuk meledingkan bingkai-bingkai sebelumnya merujuk bingkai semasa. Dalam pengestrakan objek, bingkai semasa dibandingkan dengan kedua-dua bingkai sebelumnya menggunakan pengesan perubahan Wronskian (WCD). Ia menghasilkan hantu, iaitu objek yang bergerak dalam bingkai-bingkai sebelumnya. Kajian ini telah membina penghapus hantu, di mana dua imej output daripada proses pengestrakan objek dibandingkan piksel demi piksel. Kemudian, kaedah yang tersedia ada untuk menghapus bayang-bayang, Penyelaras Korelasi Bersilang (NCC) digunakan untuk menghalus imej output. Sesetengah piksel mungkin salah diklasifikasikan sebagai bayang-bayang. Oleh itu, penghalusan pengesanan bayang-bayang dilakukan supaya bayang-bayang sebenar dihapuskan dan bayang-bayang yang salah diklasifikasikan dikembalikan kepada entiti latar belakang. Bagi menghapus titik-titik yang tidak diperlukan, satu penapis 3x3 dihasilkan. Ia digunakan untuk menapis imej output di mana piksel tengah akan mencari piksel putih. Bilangan piksel putih dalam seluruh penapis ini akan dibandingkan dengan ambang. Akhirnya, pengendali morfologi digunakan untuk menghapus lebihan titik yang tidak diperlukan. Algoritma ini telah diuji menggunakan tujuh set data iaitu latar belakang berbelang, objek bergerak perlahan, penyamaran objek, objek kecil, banyak objek bergerak, objek bergerak menghala ke kamera dan bayang-bayang. Algoritma ini berjaya mengestrak objek bergerak, menghapus hantu, bayang-bayang dan titik-titik yang tidak diperlukan dan mengesan perubahan cahaya. Berdasarkan pengiraan secara manual dan pemerhatian, sistem ini mempunyai ketepatan yang paling tinggi iaitu 95.13%, diikuti teknik satu kali WCD 93.99%, Penolakan Latar Belakang 93.42%, Nisbah Pencahayaan 92.92%, Histogram Warna-Tepu-Nilai (HSV) 91.85% dan Histogram Skala Kelabu 91.47%.

Camera Motion Estimation and Object Extraction using Multiple Consecutive Frames with Ghost and Noise Removal for Pan-Tilt-Zoom Camera

ABSTRACT

This research presents a new algorithm for extracting moving objects using Pan-Tilt-Zoom (PTZ) camera. Previously, system that uses moving camera faces some problems, including misalignment between current and template frames, appearance of unwanted objects (ghost), illumination changes, shadow and crowd. This research developed an algorithm to avoid misalignment images, remove ghost and noises. The proposed algorithm consists of six steps, which are camera motion estimation, object extraction, removing ghost, detecting shadow, refining shadow and noises elimination. This research proposed to apply camera motion estimation twice, which is between three consecutive frames. Keypoints of each image are detected using Speed-up Robust Features (SURF) detector, then produces homography matrix. The homography contains rotation and translation of one image from another image. It is used to warp previous frames with respect to the current frame. In object extraction, current frame is compared to both compensated previous frame 1 and compensated previous frame 2 using Wronskian Change Detector (WCD). Detecting changes using multiple frames produces ghost, which is actually moving objects in previous frames. Then, this research has developed a ghost removal technique, in which two output images of object extraction are compared each other, pixel by pixel. Then the existing method of shadow removal, Normalized Cross-Correlation (NCC) technique is applied to refine the output image. Some pixels may be misclassified as shadow pixels. Therefore, refinement of shadow detection is done so that the actual shadow is removed, while the false detected shadows are returned to be background entities. To remove other noises, a 3x3 noise filter has been created. The filter is used to scan the output image where the centre of the 3x3 window will look for white pixel. Number of white pixel in the whole window (filter) will be compared to the threshold. Finally, morphological operator is used to remove undesirable foreground pixels. The developed algorithm had been tested on seven image conditions; striped background, objects move slowly, camouflage object, small moving object, multiple moving objects, objects move towards the camera and shadow. The developed algorithm has successfully extracted moving object, removed ghost, removed shadow, noises and detected illumination changes. Based on the manual calculation and visual observations, this system has the highest average accuracy which is 95.13%, followed by single WCD 93.99%, Background Subtraction 93.42%, Luminance Ratio 92.92%, HSV Histogram 91.85% and Greyscale Histogram 91.47%.

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, surveillance system gaining significant impact for both military and civilian purposes as the concerns of people about safety and security increases. Also, it has attracted interest from military agencies and law enforcement. Extraction of moving object plays an important role in surveillance system. These extraction techniques must be accurate, robust and has less false detection under the influence of several factors, such as background scene that changes frequently, illumination variation from both artificial and natural lighting and also occlusion. The technique is useful for counting people or vehicles entering an entrance and for monitoring purposes.

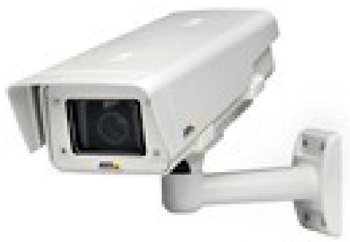

Figure 1.1: Static Camera (*Axis Fixed Network Camera*, 2013)

Previously, stationary camera was commonly used in surveillance system. An example of static camera is shown in Fig. 1.1. Extraction of moving objects is easier by using static camera, since the scene is static and skips the background estimation steps.

It only needs single background image for template matching purpose. For tracking or monitoring large area, security system needs more than one static camera to cover a large area, hence it needs a pass over technique between cameras.

Nowadays, security system has been improved. The usage of single moving camera is simpler than multiple static cameras and the cost is lower. One of the moving cameras is a Pan-Tilt-Zoom (PTZ) camera, which is widely used currently. Refer Fig. 1.2.

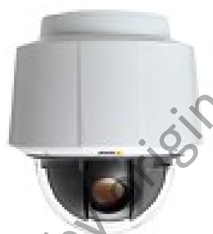

Figure 1.2: PTZ camera (*Axis PTZ Camera*, 2013)

It stays at a static platform, yet it can rotate by itself since it is capable of remote directional and zooming control. The advantages of using a PTZ camera are that it can monitor and track moving objects in one area using only one camera. This intelligent camera is able to cover up to 360 degrees of pan, more than 100 degrees of tilt and zoom in on specific details. This type of camera is used in this research.

1.2 Statement of the Problem

In previous research, a number of problems in extracting moving objects were found. First problem is the technique for background estimation which is applicable to the usage of Pan-Tilt-Zoom (PTZ) camera needs further improvement. Most of the previous methods used static camera and the estimated background is easy to be obtained, when compared to using moving camera (Kawanishi, 2012). False estimation may cause misalignment image between current and reference images for moving camera. Refer Section 2.2 for existing method of background modelling for both static and moving camera.

Secondly is the difficulty in extracting moving object using a moving camera, as compared to static camera. The common technique, background subtraction, is a technique which uses background image with no moving objects in it, as a template (Kawanishi, 2012). The possibility of having false detection is minute. However, by using a moving camera, it is difficult to have a static background image for each position of the camera.

Thirdly is the detection of false object, in which the background object starts to move away. It is called as 'ghost' (Yin, Makris & Velastin, 2008). Ghost is a moving object in previous frame that appears in the output image when the object extraction using frame differencing technique between current and previous frame is applied.

Fourth problem is illumination effects, which is shadow. It is formed when an object is either partially or completely blocked by light. Shadow appears in both indoor and outdoor scene (Xu, Liu, Li, Liu, & Tang, 2005). It is considered as non-moving objects. It is usually falsely detected as moving object, and produces undesirable consequences like connecting multiple objects and making it as a single object (Jacques, Jung, & Musse, 2005).

Fifth problem is the presence of other noises that cannot be eliminated by morphological operation, since the morphological operation only removes small noises. On the other hand, the erosion technique is not only remove noises but also reducing all remaining objects (Khvedchenia, 2011). In this case, another noise filter which remove noise without damaging object's blob, need to be created.

1.3 Hypotheses

In the beginning of this study, the problem statements have been clearly listed and understood. In term of techniques, modification in background estimation technique is needed. By using a static camera, it only needs either two consecutive frames or one background image to estimate a background. By using a moving camera, the usage of Speeded up Robust Features (SURF) detector in background estimation enables the background image to be updated. Frame differencing technique between multiple consecutive frames will helps in removing ghost, which occur after the process of object extraction. Then, an image filters will be created to remove ghost and to avoid any object misclassification. Also, the usage of an existing method of shadow removal will avoid any false detection. Finally, a noise filter will be created to refine an output image.

1.4 Objective of the Study

The purposes of this study are as follows :

i. To extract objects of interest from images consist of moving objects captured using a PTZ camera.
ii. To remove unwanted object (ghost) that occur as a result of frame differencing process.
iii. To remove dual objects (shadow) existed in the image and to filter the image.
iv. To validate the effectiveness of the algorithm proposed.

Several dataset have been taken in the office of MIMOS Bhd which is located at Technology Park Malaysia, Kuala Lumpur. The dataset consist of various conditions, which are:

i. Moving objects on striped background.
ii. Slow motion objects.
iii. Camouflage moving object.
iv. Small moving object.
v. Multiple moving objects.
vi. Objects move towards the camera.
vii. Moving object with its shadow.

1.5 Research Contributions

This study has introduced the usage of multiple consecutive frames in background estimation so that the system suits with PTZ camera. This allows the background constantly updated, hence improves the alignment between current image and template.

This research has used an existing method of object extraction, which is Wronskian Change Detector (WCD) (Aguilar-Ponce, Tessier, Baker, Emmela, Das, Tecpanecatl-Xihuitl, et al., 2005). But, this will cause the presence of unwanted objects, called 'ghost'. The proposed system has used the technique of WCD by twice, so that the ghost can be eliminated at the next step.

In the proposed system, two image filters have been created. One is for removing ghost and another one is to refine the final output. In most system, ghost is ignored because the capture rate is very fast. The ghost is not obviously visible. The ghost removal is very useful when the capture rate is low or the object moves too fast. Another image filter is used to remove small noises, including noised that formed by misalignment images. These two proposed filters are successfully avoid any object misclassification.

In addition, this study used an existing method of shadow identification (Jacques, Jung and Musse, 2005) so that shadow is not detected as moving object. This technique is used to complete the detection of moving object for both indoor and outdoor scene.

1.6 Thesis Outline

Chapter one introduces a system that using the extraction of moving object and what the source that people use in this system. This chapter includes the research issues. Also, this chapter elaborates the purposes of the research and the dataset that used.

Chapter two discusses the previous research works related to this study and analyzes the gap of knowledge. This chapter is used to find the best method among a number of existing methods to be a basic technique in this research, and helps in creating new algorithm.

Chapter three elaborates on research design that starts with overall workflow, offline system, development of new algorithm and online system. It includes the purposes of dataset captured, how threshold values are selected and the technique of measuring the system performance.

Chapter four discusses on the results of a number of existing techniques and the results of each step in the proposed algorithm.

Chapter five summarize the steps in proposed algorithm, applications of this technique, contributions of the proposed algorithm, difficulty in using PTZ camera as compared to static camera and suggestions on future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 discusses some relevant previous researches according to their techniques and methods. The objectives are to analyze existing methods in order to find the best technique according to the problem statement, to test the best existing technique using new dataset with various situations and to determine the gap of knowledge. This chapter is organized as following steps in moving object detection. It starts with background modelling, discussed in Section 2.2. Section 2.3 elaborates various techniques for object extraction, where each will be discussed in subsection 2.3.1 until 2.3.8. Section 2.4 discusses the ghost removal technique. Next, shadow removal techniques are discussed in Section 2.5 and final step, other noises removal techniques is elaborated in Section 2.6. For each section, techniques and its advantages and disadvantages are summarized in a table. Finally, summary of all related works is stated in Section 2.7.

2.2 Background Modelling

Background modelling is the first step in moving object extraction. It needs to estimate a background image so that the foreground objects can be extracted from the image. Bad background estimation leads to noises appearance, hence causes false detection. Using static camera, an estimated background image can be obtained by capturing an image at the same position as current image but the image contains only background objects (without moving objects), then processing it to remove any variation within them (Kawanishi, 2012).

Monteiro, Marcos, Ribeiro and Batista (2008) estimate a background using median background estimation. It starts with capturing multiple background images and storing its camera positions. Then the background is estimated by taking the median of these multiple frames.

Some authors generate panaromic background images by mapping all single background frames (Sugaya & Kanatani, 2004). It begins with extracting and tracking feature points through the sequence and select the trajectories of camera points by exploiting geometric constraints based on the Affine model and use Kanade-Lucas-Tomasi algorithm. The frame-by-frame image mapping is necessary for estimating camera motion. It based on intensity-based optical flow or feature point matching using robust estimation techniques like Random Sample Consensus (RANSAC), for avoiding moving object regions (Araki, 2000 ; Irani, 1995 ; Sawhney & Ayer, 1996).

Mixture models are a type of density model which comprise a number of component functions, usually Gaussian. These component functions are combined to provide a multimodal density. They can be employed to model the colours of an object in order to perform tasks such as real-time colour-based tracking and segmentation.

These tasks may be made more robust by generating a mixture model corresponding to background colours in addition to a foreground model, and employing Bayes' theorem to perform pixel classification (Raja & Gong, 1999).

Stauffer and Grimson (1999) model each pixel as a mixture of Gaussians and using an on-line approximation to update the model. Each pixel is classified based on whether the Gaussian distribution which represents it most effectively is considered part of the background model.

Elgammal, Harwood and Davis (2000) proposed a novel non-parametric background model. The model estimates the probability of observing pixel intensity values based on a sample of intensity values for each pixel, using Kernel Estimator. Density estimation using a Normal kernel function is a generalization of the Gaussian mixture model, where each single sample of the N samples is considered to be a Gaussian distribution by itself. Then the density function can be estimated more accurately and depending only on recent information from the sequence. This also enables the model to quickly “forget" about the past and concentrate more on recent observation.

Table 2.1 shows comparison between several techniques of background modelling.

Table 2.1: Comparison between several techniques of background estimation.

Technique	Advantages	Disadvantages
Capture background image	- The template is 100% aligned to the current frame. - It can use background subtraction technique.	- It only applicable for static camera. - Background image is not updated.
Time-averaged background	- The simplest technique.	- It requires a training period absent of moving objects. - The motion of background objects after the training period and foreground objects motionless during the training period would be considered as permanent moving objects. - It cannot cope with gradual illumination changes.
Kalman filter	- It can cope well with the illumination changes	- It cannot handle the problem of objects being introduced or removed from the scene.
Median Background Estimation	- It can use the simplest technique in object extraction, which is background subtraction. - It can use a PTZ camera as image source.	- It needs to find the corresponding background image for each current frame in object extraction. - It only applicable for PTZ camera.
Panaromic Background	- It can use a PTZ camera as image source.	- Background is not updated.
Gaussian mixture model	- It reduces the effect of small repetitive motions; moving vegetation like trees and bushes. - The system is stable, real-time outdoor tracker which reliably deals with lighting changes, repetitive motions from clutter, and long-term scene changes. - It can work in a rainy and snowy day. - It copes with slowly-varying lighting conditions.	- It has slow learning at the beginning (for busy environment). - It cannot distinguish between moving shadows and moving objects
Non-parametric background model using Kernel Estimator	- It can handle situations where the background of the scene is cluttered and not completely static but contains small motions such as tree branches and bushes.	- It has high computational complexity