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*To my loving parents, Manolo y Fina, for walking with me in the life way, helping me to face up difficulties and magnifying my happiness. Everything I have with both of you is worth it*

Ester

*To Azucena, for her unconditional love and understanding*

Angel

# Preface

Our knowledge of the surrounding world is obtained by our senses of perception. Among them, vision is undoubtedly the most important for the information it can provide. In artificial systems, this discipline, known as Computer Vision, mainly tries to identify physical objects and scenes from captured images to be able to make useful decisions. For that, the processing and analysis of images, video sequences, views from multiple cameras or multi-dimensional data like a medical scanner, are carried out.

In this context, motion plays a main role since it provides a stimulus for detecting objects in movement within the observed scene. Moreover, motion allows obtaining other characteristics such as, for instance, object's shape, speed or trajectory, which are meaningful for detection and recognition. Nevertheless, the motion observable in a visual input could be due to different factors: movement of the imaged objects (targets and/or vacillating background elements), movement of the observer, motion of the light sources or a combination of (some of) them. Therefore, image analysis for motion detection will be conditional upon the considered factors. In particular, in this manuscript, we have focused on motion detection from images captured by perspective and fisheye still cameras. Note that, as cameras are still, egomotion will not be considered, although all the other factors can occur at any time.

With that assumption, we propose a complete sensor-independent visual system which provides a robust target motion detection. So, first, the way sensors obtain images of the world, in terms of resolution distribution and pixel neighbourhood, is studied. In that way, a proper spatial analysis of motion can be carried out. Then, a novel background maintenance approach for robust target motion detection is implemented. On this matter, two different situations will be considered: (1) a fixed camera observing a constant background where interest objects are moving; and, (2) a still camera observing interest objects in movement within a dynamic background. The reason for this distinction lies on developing, from the first analysis, a surveillance mechanism which removes the constraint of observing a scene free of foreground elements during several seconds when a reliable initial background model is obtained, since that situation cannot be guaranteed when a robotic system works in an unknown environment. Furthermore, on the way to achieve an ideal background maintenance system, other canonical problems are addressed such that the proposed approach successfully deals with (gradual and global) changes in illumination, the distinction between foreground and background elements in terms of motion and motionless, and non-uniform vacillating backgrounds, to name some.

The methods proposed in this book provide important advances with respect to state-of-the-art computer vision approaches to motion detection. Our algorithms allow a good environment adaptation of the system as it properly deals with most of the vision problems when dynamic, non-structured environments are considered. All these contributions are validated with an extensive set of experiments and applications using different testbeds of real environments with real and/or virtual targets.

Castellón de la Plana, Spain, June 2012

Ester Martínez-Martín
Angel P. del Pobil

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# Contents

# Chapter 1
# Introduction

**Abstract** One of the most challenging issues in computer vision is *image segmentation*. The reason lies on the information it can provide about the elements in the scene from the automatic image division based on pixel similarities. Therefore, what makes a pixel interesting depends on the object's features to be considered. Thus, due to segmentation of countless applications, a wide range of solutions have been proposed and tested by the scientific community during the previous years. However, considering motion as a primary cue for target detection, background subtraction (BS) methods are commonly used. In this chapter, we overview the method in general terms as well as its different variants with the aim to analyze the problems remaining to be solved.

**Keywords** Machine vision · Computer vision · Image segmentation · Background subtraction · Motion detection · Robot vision · Dynamic environments · Visual surveillance

## 1.1 Background Subtraction Overview

Motion detection is the core of multiple automated visual applications by providing a stimulus to detect objects of interest in the field of view of the sensor. Such detection is usually carried out by using background subtraction (BS) methods, especially for applications relying on a fixed camera. Basically, the idea behind this kind of techniques is to first build a background model from a sequence of images in order to find the interest objects from the difference between that background estimation and the current frame.

Therefore, the accuracy of the segmentation process depends on how well the background is modeled. In addition, the problem gets more complex when real-life scenarios are considered. Actually, natural scenes are usually composed of several dynamic entities. For that, the estimated model should properly describe the scene

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background which can change due to the presence of moving objects (e.g. swaying vegetation, fluctuating water, flickering monitors, ascending escalators, etc.), because of camera oscillations, due to changes in illumination (gradual or sudden) or in the background geometry such as parked cars, and so on.

With the aim to deal with those challenges, numerous methods have been proposed to date. These methods can be classified following the model used for the background representation as follows:

- *Basic background modeling*. the average [1], the median [2] or the histogram analysis over time [3].
- *Statistical background modeling*. the single Gaussian [4], the Mixture of Gaussians [5] or the Kernel Density Estimation (KDE) [6].
- *Background estimation*. Wiener filter [7], Kalman filter [8] or Tchebychev filter [9].

However, despite the wide research done in this area, there are still some problems that have not been addressed by most BS algorithms. Among them, we can find the quick illumination changes, the proper update of the background model when a background object is relocated, the initialization of the background estimation when moving objects are present in the scenes, or the shadows. Here, we propose a novel BS technique which is robust and generic enough to handle the complexities of most natural dynamic scenes. On this matter, two different situations have been considered: (1) a fixed camera observes a constant background where interest objects are moving; and, (2) a still camera observes interest objects moving in a dynamic background. The reason for this distinction lies on developing, from the first analysis, a surveillance mechanism that removes the constraint of observing a scene free of foreground elements during several seconds when a reliable initial background model is obtained, since that situation cannot be guaranteed when a system works in real-life scenarios. Furthermore, on the way to achieve an ideal motion detection process, other canonical problems are addressed such that the proposed approach successfully deals with (gradual and global) changes in illumination, distinction between foreground and background elements in terms of motion and motionless, and non-uniform vacillating backgrounds, to name some.

As the validation of the system with an extensive set of experiments and applications using different testbeds of real environments with real and/or virtual targets will show, the proposed motion detection algorithm allows a good environment adaptation of the system by properly dealing with most of the vision problems when dynamic, non-structured environments are considered.

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