Ain Shams University
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Enhancement of motion estimation under varying illumination in videos

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Sarah Abdelwahab Ali Elsharkawy

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ABSTRACT

The estimation of optical flow plays a key-role in several computer vision problems, including motion detection and segmentation, frame interpolation, three-dimensional scene reconstruction, robot navigation, video shot detection, mosaicking and video compression. In this work we propose a new algorithm for computing a dense optical flow field between two or more images of a video sequence, which tackles the inherent problems of conventional optical flow algorithms. These conventional optical flow algorithms usually show a bad performance in regions of low texture with single orientation, near motion boundaries as well as under illumination changes. We try to overcome these problems by combining different constancy assumptions such as the brightness constancy assumption, the gradient constancy assumption, and the smoothness constraint in an innovative model. These constancy assumptions were deeply studied and the advantages and disadvantages of each of them were clearly stated. These constancy assumptions are integrated together using different weight values that differentiate the importance of each assumption over the other. Also, to overcome the problems resulting from illumination changes, we used photometric invariant constancy assumption instead of the mostly used brightness constancy assumption. These photometric invariants provided our proposed approach with robustness under illumination differences such as shadows and shadings.

In this thesis, most of the techniques existing in literature were studied and implemented. Some of them were merged together and tested in order to figure out the effect of combining certain constancy assumptions together on the estimation of optical flow. Finally, we proposed a new approach based on our studying of the strengths and weaknesses of these techniques. The proposed approach was tested on different image sequence having different kinds of motion such as translation, rotation, or dilation. All the test sequences used are benchmarked and their ground truth values are known. The proposed approach was also tested under illumination variations and noise by applying a Gaussian additive illumination and a Gaussian noise with different standard deviations to the sequences.

The main conclusion of this thesis is that the photometric invariants are very important in overcoming illumination changes, the smoothness constraint enables the approach to produce flow fields with 100% density, the gradient constancy assumption is very useful in case of image sequences containing translation motion only, and the brightness constancy assumption produces accurate flow fields but only in case of no illumination changes. All this facts were taken into consideration when formulating the proposed approach. Finally, the proposed approach produced accurate results with the lowest average angular errors when compared to other approaches from literature. It also proved its robustness under illumination changes and noise and it produced flow fields with 100% density.

1. Introduction

1.1 Motivation and Problem Statement

Motion estimation is an important part of any video processing system. In this thesis, we are only concerned with the estimation of 2D motion. Motion estimation itself has a wide range of applications, including video compression, video sampling rate conversion, video filtering, etc. Depending on the intended applications for the resulting 2D motion vectors, motion estimation methods could be very different.

All the motion estimation algorithms are based on temporal changes in image intensities (more generally color). In fact, the observed 2D motions based on intensity changes may not be the same as the actual 2D motions. To be more precise, the velocity of observed or apparent 2D motion vectors is referred to as optical flow. Optical flow can be caused not only by object motions, but also camera movements or illumination condition changes.

Optical flow or optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer (an eye or a camera) and the scene. The estimation of the two-dimensional velocity field between two images of a video sequence is one of the oldest and most active research topics in computer vision. One of the first important studies on the computation of optical flow was published by Horn and Schunk [5] in the year 1981. According to their work, we define optical flow as follows.

> *The optical flow is a velocity field in the image, which transforms one image into the next image in a sequence. As such it is not uniquely determined; the motion field, on the other hand, is a purely geometric concept, without any ambiguity - it is the projection into the image of three-dimensional motion vectors [6].*

The human eye perceives motion by identifying corresponding points at different times. The correspondence is usually determined by assuming that the color or brightness of a point does not change after the motion. It is interesting to note that the observed 2D motion can be different from the actual projected 2D motion under certain circumstances. Figure 1.1 illustrates two special cases. In the first example, a sphere with a uniform flat surface is rotating under a constant ambient light. Because every point on the sphere reflects the same color, the eye cannot observe any change in the color pattern of the imaged sphere and thus considers the sphere as being stationary. In the second example, the sphere is stationary, but is illuminated by a point light source that is rotating around the sphere. The motion of the light source causes the movement of the reflecting light spot on the sphere, which in turn can make the eye believe the sphere, is rotating. The observed or apparent 2D motion is referred to as optical flow in computer vision literature. The above examples reveal that the optical flow may not be the same as the true 2D motion. When only image color information is available, the best one can hope to estimate accurately is the optical flow. However, in the remaining part of this thesis, we will use the term 2D motion or simply motion to describe optical flow. The readers should bear in mind that sometimes it may be different from the true 2D motion.

Apart from the above mentioned problem, algorithms which try to compute the optical flow are based on further assumptions, which are sometimes not met in real scenes. One of these assumptions is that the optical flow varies smoothly which means that the flow fields of the whole image frame is homogenous. Another assumption is that no specular reflections or occlusions occur in the scene where the term Occlusion refers to the action of one object hiding another object. The motion of the hidden object is of course incomputable.

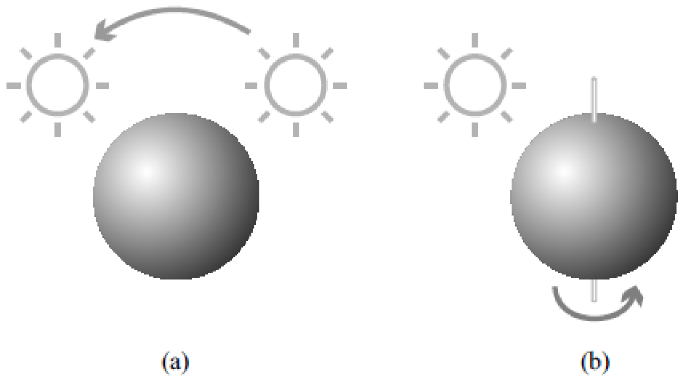

Figure 1.1: (a) A fixed sphere illuminated by a moving source generates non-zero optical flow, since the shading changes. (b) For a rotating sphere under constant illumination no optical flow can be determined. [28]

The conventional optical flow techniques face many problems during the estimation of the flow fields. First of all, most of the conventional optical flow algorithms suffer from their incapability to determine the correct velocity field in regions of homogeneous color as well as in regions of texture with only a single orientation. In addition, the estimated velocities near motion discontinuities tend to be unreliable, since algorithms ignore the fact that occlusions (pixels that are only visible in one image) are present. Also, one of the major problems is that conventional optical flow algorithms is that they assume that the brightness (grey-level) of a point in the scene does not change over time however; this is never the case in real-life scenes where different illumination changes may occur.

1.2. Contribution

Although many years have passed since Horn and Schunk published their well known work on the calculation of optical flow [5] and a lot of research has been devoted to this topic, the task of determining the correct velocity field between two images remains challenging due to several reasons.

In this work the major problem we are going to study is the incapability of conventional optical flow algorithms to face the illumination variations