Bi-Layer Video Segmentation with Foreground and Background Infrared Illumination

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ABSTRACT

In this paper, we investigate two ways of employing infrared video with color video for automatic foreground-background video segmentation: foreground infrared (IR) illumination and background IR illumination. Foreground IR illumination gives an initial foreground template, which is combined with image segmentation to complete foreground segmentation. Two algorithms are explored, Graph Cut and Relaxation Labeling. The disadvantage of foreground IR illumination can be compensated by background illumination.

Keywords

Video segmentation, Graph Cut, Relaxation Labeling, Infrared Illumination

1. Introduction

Many tasks in computer vision involve foreground-background video segmentation. One of the major applications is video conferencing, where there is a need to replace the background to create the impression of a virtual meeting. While there are some excellent algorithms solving this problem, based either on stereo [1] or motion [2], they all have problems with illumination changes, with large moving objects in the background and with high computational costs. In this paper, we seek a solution to bi-layer segmentation problem by fusing infrared, color and contrast information. The challenges solved by our proposed system include real-time processing, automatic segmentation, and robustness to illumination changes and dynamic backgrounds.

We investigate two ways of employing IR information by illuminating different parts of the scene: foreground IR illumination and background IR illumination, where foreground and background are illuminated by the IR illuminator. In the foreground IR illumination, the resulting video sequences are fed into the segmentation algorithm to complete foreground segmentation. We explored two algorithms, Graph Cut and Relaxation Labeling. A technical demo is produced using the Graph Cut algorithm.

2. Foreground IR Illumination

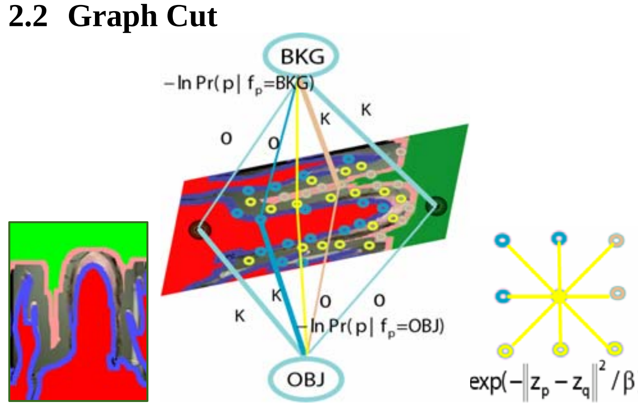
2.1 Data Acquisition

In an earlier paper [3], we have described a data acquisition unit for producing automatically synchronized IR video and color video. The same data acquisition unit is used in this paper (see [3] for more details). By lighting the foreground with the IR illuminator, the resulting IR image is bright in the region closer to IR illuminator and dark in the background. The IR image can be easily registered with the video image so that there is a pixel-by-pixel correspondence between the IR image and the color image. A binary foreground template can be obtained by thresholding the IR image, as shown in Figure 1.

(a) (b) (c)

Figure 1. (a) Original produced IR image and color image pair (b) Registered IR image (c) Foreground template

2.2 Graph Cut



(a) (b) (c)

Figure 2. (a) Pentamap (b) Graph construction with T-links (c) Graph construction with N-links

We introduced the concept of a pentamap in [3]. The pentamap partitions an image into five regions as shown in Figure 2(a). The red and blue areas result directly from the foreground template. We grow this template by a strip of width w, and predict that missing foreground parts are in this strip region, called "unknown region". The value of w can be determined from the IR configuration. Any area beyond the unknown region is predicted to belong to the background area, which is marked by pink and green regions. The blue area is a thin boundary strip extracted from the foreground template, and is used to build the foreground color model, which is a Gaussian Mixture Model (GMM) in our system. The same principle is applied to extract the pink area, which is used to build the background color model. The color models for foreground and background are derived from the blue and pink area because they are neighbor regions of the unknown area, and it is more reasonable to assume the pixels in the unknown area is color-consistent with these two regions.

A graph G is constructed from the pentamap in order to apply the Graph Cut algorithm. Since we are certain that the red and blue areas belong to the foreground and background, respectively, as determined from the IR information, they are represented as two nodes. The other nodes correspond to each pixel in blue/pink/unknown regions. T-links between each node and terminal nodes reflect the probability of a pixel belonging to the foreground/background, as shown in Figure 2 (b), determined by clustering each pixel based on foreground/background GMM. N-links shown in Figure 2(c) reflect contrast information between neighborhood pixels.

More details for this approach can be found in [3], and we attach a technical demo to this paper, produced by the Graph Cut algorithm. The processing rate is about 10 fps for an image of size 365X480.

2.3 Relaxation Labeling

We also produced competitive segmentation result using Relaxation Labeling [4]. The advantage of this method is that it is a parallel algorithm that can be implemented on a GPU.

(a) (b) (c)

Figure 3. (a) Original frame (b) Segmentation before relaxation labeling (c) Segmentation after relaxation labeling

First, for each pixel in the unknown area, we compute the probability that it belongs to the foreground using the foreground color model, GMM, as in the last Section. Thus, we have a probability map for each frame to process. Simply thresholding this probability map results in poor segmentation as shown in Figure 3 (b). With Relaxation Labeling, the probability of each pixel in unknown region is iteratively updated based on the linear neighborhood constrain. We found that 10 iterations are sufficient for segmentation; results are shown in Figure 3(c). Due to the space limitation, more details of this method can be found in our paper [5].

2.4 Discussions

There are many advantages for foreground IR illumination method. First, the IR image has many good attributes so that it can automatically initialize a pentamap, which is fed to the image segmentation algorithms with color image. With the assistance of pentamap, we can automatically obtain foreground segmentation by segmentation algorithms. Second, the IR illumination is independent of ambient light in visible spectrum, so that our segmentation result is robust to illumination changes. Third, the IR image can automatically detect a foreground template if the foreground object is within the effective distance of the IR illuminator. The effective distance acts like a plane dividing foreground and background. Any moving background objects will not affect the segmentation result if it is out of effective distance of the IR illuminator, because it still appears dark in the IR image and therefore will not change foreground color model GMM. There are, however, two cases that undesired objects will be captured as foreground in our system: 1) The object appears in front of the foreground object. 2) The object is behind the foreground object but is very close to the foreground. The latter case can be solved, in a degree, by background IR illumination method.

3. Background IR Illumination

In addition to foreground illumination, where the foreground object is illuminated by the IR source, we also investigated background illumination, where the background is illuminated by the IR source. Figure 4 shows a sample image produced with background illumination.

We found that background illumination has several advantages. First, the IR image can capture the foreground with a very sharp boundary and a strong foreground-background contrast (see Figure 4). Second, with background illumination one has more freedom regarding the positioning and orienting of the IR source (or sources). Even background objects that are close to the foreground object can be illuminated with an IR source and thus are easily classified as background objects. This reduces errors due to spurious foreground objects, which can occur with the forward method.

Figure 4. Video frame by background IR illumination

4. References

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