Automatic Foreground Propagation in Image Sequences for 3D Reconstruction

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Abstract. In this paper we introduce a novel method for automatic propagation of foreground objects in image sequences. Our method is based on a combination of the mean-shift operator with the well known intelligent scissors technique. It is effective due to the fact that the images are captured with high overlap, resulting in highly redundant scene information. The algorithm requires an initial segmentation of one image of the sequence as an input. In each consecutive image the segmentation of the previous image is taken as an initialization and the propagation procedure proceeds along four major steps. Each step refines the segmentation of the foreground object and the algorithm converges until all images of the sequence are processed. We demonstrate the effectiveness of our approach on several datasets.

1 Introduction

Efficient and interactive foreground/background separation of images have become a fundamental part of many applications in computer vision and 3D reconstruction [10]. Obviously manual segmentation is a tedious and time consuming process, especially when applied on a large number of images, as usual needed for a dense 3D reconstruction of complex objects. Therefore many segmentation algorithms have been developed recently [1,7].

This paper addresses the problem of automatic propagation of a foreground object in a complex environment for 3D reconstruction, whose background can not be removed in a simple way. The key idea of our approach is to take advantage of the high overlap of the images. Essentially we utilize redundant scene information to automate the segmentation procedure and propagate an initial segmentation through the image sequence. The goal of our approach is to achieve a fast, automatic and robust foreground segmentation. Moreover, our method minimizes the expenditure of time to achieve an accurate foreground segmentation. Its power can be derived from the fact that labelled image sequences simplify the correspondence problem dramatically and therefore, dense 3D reconstruction results of complex objects can be clearly improved.

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The main methods to accomplish the propagation procedure are the well known mean-shift technique and the intelligent scissors approach. Intelligent scissors, introduced by Mortenson and Barrett [7], also known as Live Wire or Magnetic Lasso, allows the user to define a precise contour with minimized human interaction, by roughly tracing the objects contour with the mouse. A user selects interactively optimal contour segments by immediately displaying the minimum cost path between the so called current seed point and the previous one, where the current seed point is represented as the position of the mouse cursor. The optimal path is computed via dynammic programming by applying Dijkstra's graph search algorithm [4] to find the optimal spanning tree. The second related technique is mean-shift analysis, which was originally invented by Fukunaga and Hostetler [5] and recently successfully applied to image segmentation and tracking by Comaniciu and Meer [2,3]. The mean-shift analysis approach is essentially defined as a gradient ascent search for maxima in a density function defined over a high dimensional feature space. The feature space include a combination of the spatial coordinates and all its associated attributes that are considered during the analysis. The main advantage of the mean-shift approach is based on the fact that it considers geometric coordinates and the associated attributes together at the same time.

The remainder of the paper is composed as follows. After a brief overview of our method we discuss the novel parts of the automatic foreground propagation algorithm in section 2. Experimental results and concluding remarks are presented in section 3 and 4.

2 The Automatic Foreground Propagation Algorithm

Our method is a multistage approach to separate a foreground object, for example a statue, from the background in all images of an image sequence. The algorithm requires as input an initial segmentation of one image, which can be obtained by utilizing intelligent scissors [7], GrabCut [9] or other interactive segmentation techniques. In this paper we focus on the propagation of this initial segmentation through all images of the sequence. The propagation task itself is mainly based on a region based matching algorithm. Therefore we segment the image into a certain number of regions. All these regions are classified into three different sets (foreground, background and uncertain regions), illustrated in Figure 2. The final contour can be extracted from these three sets. For dividing the image into regions we employ a mean-shift image segmentation proposed by Comaniciu and Meer [3].

Additionally, to improve the robustness of the propagation procedure, our algorithm requires the relative orientation of the images to be known. The orientation is determined based on methods described by Horn [6], and Nister [8] and provides both, an accurate orientation and a set of corresponding points.

The workflow of our proposed approach can be roughly seen as the composition of the following consecutive subtasks: