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# Image segmentation incorporating double-mask via graph cuts☆

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ABSTRACT

This paper described a novel strategy to apply double-masking in image segmentation based on graph cuts. We provided a reasonable method for imposing seed information automatically at object regions where image labels are difficult to determine during complex underwater scene segmentation. *Cr* component pre-segmentation based on Mahalanobis distance played a role in *YCrCb* space. The pre-segmentation region was used as object mask for the graph model of the original image in *Cr* pre-segment binary image. The minimum-enclosing rectangle of the object mask could reduce the calculative area in graph model and the bounding box-provided graph model of the original image with the background mask. Our approach was easily realized and did not require specialized hardware, prior knowledge of underwater conditions, or scene structure. Experimental results demonstrated the robustness and accuracy of the performance of our proposed method.



## 1. Introduction

Many segmentation methods aim to separate an image into meaningful objects using low features such as intensity, color, edge, and texture. However, the complex scene remains the primary constraining factor in image segmentation. Underwater imaging is especially challenging because of the physical properties of such environments. In contrast with common images, underwater image segmentation continues to be a challenging work in image processing and computer vision. Several problems in underwater images include limited range visibility, noise, occlusion, low contrast, non-uniform light, blurring, and diminished color. Traditional general-purpose segmentation methods often fail under these conditions. Therefore, underwater image segmentation is considered to be a classic computer vision problem.

In recent years, studies on interactive image segmentation have attracted significant attention. The ultimate goal is to extract an object with as few user interactions as possible. The use of graph cuts has been considered to be an effective image segmentation method that incorporates prior knowledge [1]. The popular method that we use in this study is based on graph cuts [2]. This method minimizes an energy function composed of a data term (computed using color likelihoods of foreground and background) and a boundary term (modulated with the contrast in the image). The study by D.M. Greig, et al. [3] is the first to combine graph cuts with the problem. Their study proposed the creation of a graph according to MAP-MRF energy function, and the construction of a one-to-one correspondence between MRF configurations and graph

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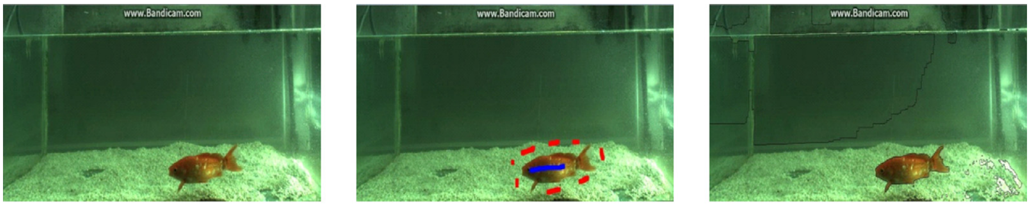

(a) (b) (c)

**Fig. 1.** (a) Original image; (b) image with some constraints, in which blue represents object and red represents background based on user input; (c) generated image segmentation using graph cuts.

cuts. Therefore, the configuration with minimum energy can be found by the min-cut of the graph. Min-cut can be calculated by max-flow algorithm using Ford and Fulkerson's theory [4]. Unfortunately, because of the relatively slow operation speed and application restriction, Greig *et al.*'s work did not obtain deserved recognition at the time. Graph cuts received increased attention in the vision domain after the development of Y. Boykov, et al. [5]. Since then, varied methods based on graph cuts have been developed and these approaches have used widely in medical images, video, and natural image segmentation. This method requires the establishment of an energy function that will reach a minimal value when the image is segmented as an expected result. For graph cut segmentation, the energy function is constructed based on regional and boundary information, and can achieve a globally optimal result [6].

However, segmenting a target in the complex underwater scene can be difficult when the graph cuts approach is used alone. Fig. 1(a) shows an original image. In Fig. 1(b), the user constrains some pixels to be object and background using the mouse. Fig. 1(c) shows the segmentation by graph cuts generating some contours. Many unnecessary contours appeared in the result shown in Fig. 1(c), and even some reasonable constraints in Fig. 1(b) are set. These figures show that removing interference from the scene will be necessary.

Several researchers developed various algorithms that address this project, and these algorithms can be categorized into three approaches: pixel-, contours-, and shape-based. T. Saitoh's [7] mathematical morphology method and K. S. Tan *et al.*'s [8] ideas on clustering were applied in pixel-based segmentation. The contour-based segmentation included geometrical [9] or statistical active shape model and active contour algorithms [10]. L. Massoptier and S. Casciaro developed a graph-cut method initialized by an adaptive threshold [11]. Shape prior-based graph-cut algorithms have also been considerably investigated. These algorithms incorporate the shape information of the object into the energy function to improve segmentation result [12–15]. The energy of the prior shape was combined into the energy function. For shape prior-based graph cuts, establishing the shape template was highly important. Many potential segmented objects can be adopted as the training set to build the shape template. However, the process of capturing the training set results in additional burdens in image processing and a shape model is not easy to define. Thus, a shape model is the direction of our future work.

In this study, we propose to impose object and background prior constraints by double-masking from pre-segmentation and applying prior information in graph cuts. The rest of the paper is organized as follows. In Section 2, the background for the graph cuts based on the energy function and our segmentation strategy incorporating double-mask in graph cuts are presented. In Section 3, we first describe our experimental platform and data and then show the segmentation results and experimental analysis. Some comparison methods are also provided. The conclusion and future works are shown in Section 4.

With the increasing interest in exploiting aquarium fish and the demand for aquaculture development, increasing attention has focused on acquiring and comprehending exact information of underwater scenes. In this study, the method can be applied widely in the appreciation of aquarium fish and posture recognition in aquaculture.

## 2. Methodology

### 2.1. Graph cuts

Many segmentation problems can be formulated in terms of energy minimization, which could be handled in the maximum flow problem in graphs. Therefore, graph cut segmentation achieved an optimal solution by minimizing an energy function via the max-flow/min-cut algorithm.

An undirected graph can be denoted as $G = \langle V, E \rangle$ where $V$ is a set of vertices and $E$ is a graph edge that connects every two neighbor vertices. The vertex $V$ includes neighborhood nodes that correspond to the pixels and two terminal nodes that consist of $s$ (source) and $t$ (sink). This type of graph is also called $s$-$t$ graph, where in the image, the $s$ node usually represents the object and the $t$ node denotes the background. In this type of graph, two types of edges exist, n-links and t-links. In the graph, each edge is assigned a non-negative weight denoted as $w_e$, which is also named "cost." A cut is a subset of edges $E$ that can be denoted as C and expressed as $C \subset E$. The cost of cut $|C|$ is the sum of the weights on edges $C$, which is expressed as follows.

$$|C| = \sum_{e \in C} w_e \tag{1}$$

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