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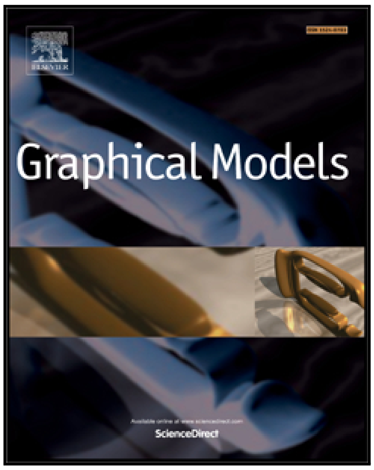

Accurate and Reliable Extraction of Surfaces from Image Data using a multi-dimensional Uncertainty Model

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Accurate and Reliable Extraction of Surfaces from Image Data using a multi-dimensional Uncertainty Model

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Abstract

Surface extraction is an important step in the image processing pipeline to estimate the size and shape of an object. Unfortunately, state of the art surface extraction algorithms form a straight forward extraction based on a pre-defined value that can lead to surfaces, that are not accurate. Furthermore, most isosurface extraction algorithms lack the ability to communicate uncertainty originating from the image data. This can lead to a rejection of such algorithms in many applications. To solve this problem, we propose a methodology to extract and optimize surfaces from image data based on a defined uncertainty model. To identify optimal parameters, the presented method defines a parameter space that is evaluated and rates each extraction run based on the remaining surface uncertainty. The resulting surfaces can be explored intuitively in an interactive framework. We applied our methodology to a variety of datasets to demonstrate the quality of the resulting surfaces.

Keywords: Surface Extraction, Uncertainty Visualization, Parameter Space Exploration

1. Introduction

Surface extraction is an important task in the image processing pipeline. The goal is to transform selected pixels of the input image into a surface, representing the boundary of the object visible in the image [1]. These surfaces are used in different applications, for example to analyze the size, position and shape of tumors in the human body [2].

The extraction of surfaces was subject of many prominent algorithms during the last decades (see Section 2). Unfortunately, surface extraction methods are not widely spread in many applications. A major problem with these algorithms is the lack of uncertainty quantification and communication [3]. Real world datasets can be highly affected by uncertainty, meaning that domain scientists cannot determine the objects captured in the image data with absolute certainty. When exposing these experts with a surface extraction, they tend to reject them as they cannot rate the reliability and accuracy of the extraction algorithm's output. In addition to that, surface extraction algorithms work on a globally selected isovalue, determining the resulting surface. This assumption is wrong in many cases as the actual surface can alter slightly around the predefined isovalue [4].

In order to solve the mentioned problems, the goal is to design a surface extraction algorithm, that outputs a reliable and accurate surface. Therefore, this paper presents a novel surface extraction methodology, that is able to quantify the uncertainty of each image pixel as a multi-dimensional vector. This uncertainty space is utilized to optimize an initially extracted surfaces such that the remaining surface uncertainty becomes minimal. Therefore, the presented method evaluates a high-dimensional parameter space, performs multiple surfaces optimizations and rates the resulting surfaces to present the best results and its corresponding parameters to the user. Finally, the user can inspect the best results in an interactive system through comparing different surfaces with each other as well as identifying uncertain areas in selected surfaces (see Section 4).

Therefore, this paper contributes:

- An optimization approach for surfaces based on an high-dimensional uncertainty model
- A quantification of surface uncertainty (global and local)
- An intuitive visualization to explore and compare surfaces

To show the effectiveness of our approach, we tested our methodology by reconstructing surfaces from predefined objects and compared our results to a state of the art marching cubes algorithm outputs. In addition to that, the algorithm was applied to a variety of real world datasets and it can be shown, that the overall error can be minimized (see Section 5). At last, the paper will be concluded and future directions are given in Section 7.

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