European Optical Society

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EOS Conference On Industrial Imaging and Machine Vision

13. - 15. June 2005
Munich, Germany

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The International Society for Optical Engineering

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A novel three stage technique for accurate disparity maps

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Summary

Stereo vision analysis deals with the extraction of 3D coordinates of a scene, using images acquired by a stereo camera setup. We propose a three stage technique for the accurate retrieval of dense disparity maps. A major advantage of this new technique is that it can be implemented straightforwardly in hardware.

Introduction

Stereo matching is one of the most complex tasks in machine vision. It refers to associating points of one image to the other. Assuming an accurately calibrated stereo setup, corresponding points reside on the same epipolar line and thus the search is reduced theoretically within a scan line. The horizontal distance of these points is the disparity. The disparity map consists of all disparity values. Having extracted the disparity map, problems such as 3D reconstruction, positioning, mobile robot navigation, obstacle avoidance, etc, can be addressed more efficiently.

In order to provide fast techniques to address this problem, area-based algorithms have been proposed. In such algorithms the search is performed over a window centered on a pixel. However, a major issue which arises, is that small windows produce very noisy results, especially for low textured areas, whereas large windows fail to produce dense disparity maps. In this paper we propose a new adaptive window search to overcome this problem. Furthermore, we generally employ small windows and filter the results using a cellular automaton approach [2]. The resulting images exhibit high accuracy and detail preservation.

Discussion

The algorithm proposed consists of three steps. First, the local variation of the image is computed for various window sizes. Second, the disparity map is evaluated using a technique similar to di Stefano's [1] for window sizes dependent on the variation results. Last, the disparity map is filtered to remove noise using a cellular automaton method. An overview of the algorithm is presented in Figure 1.

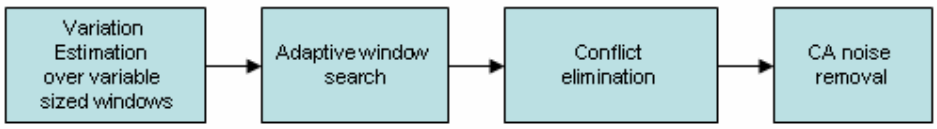

Fig 1. Proposed technique

The smallest window used for the evaluation of the disparity map is 2x2. Hence, we calculate local variation first over a window of 2x2 pixels. Points with local variation smaller than a threshold value are marked for further processing. For marked points, the local variation over a 5x5 range is computed. This is similarly compared to a second threshold.

An algorithm similar to di Stefano's [1] is used for the generation of the disparity map. The results from the previous step are used to determine the window size for each point of the image. Possible window sizes are 2x2, 5x5 and 7x7. Lower variation pixels use larger windows. However, the main portion of a typical image is processed using a 2x2 pixel window.

The use of small sized windows is essential to preserve image details and to accomplish high accuracy. However, the resulting images are extremely noisy. In order to enhance the disparity maps, with the minimum loss of 3D information, a simple cellular automaton approach is employed.

The resulting disparity maps are highly accurate. A sample image pair, as well as the produced disparity map can be seen in Figure 2. Although this technique performs poorly in software, the cellular automaton filter can be implemented straightforwardly in hardware. Such an implementation would be capable of speed demanding applications.

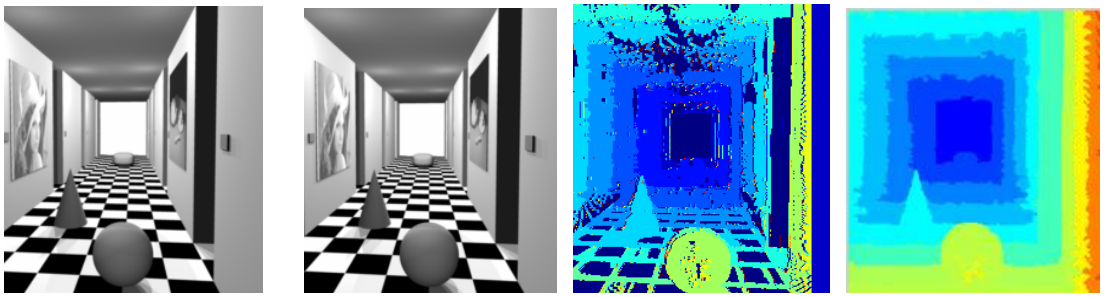

Fig 2. Left and right images. Disparity map before filtering. Resulting disparity map.

Conclusions

A three-stage algorithm addressing the stereo vision matching problem has been proposed. It employs an adaptive window constrained search as well as a cellular automaton approach to noise removal. Although computational expensive in software, it can be easily implemented in hardware. The resulting disparity maps exhibit high accuracy with minimal noise.

References

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[2] Tommaso Toffoli, and Norman Margolus, *Cellular Automata Machines: A New Environment for Modeling*. MIT Press, Cambridge, MA, 1987.