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Optimised Implementation of Dense Stereo Correspondence for Resource Limited Hardware

[1,2]Deepambika Vadekkettathu Anirudhan and [3,4]Malangai Abdul Rahiman

[1]*Department of ECE, Karpagam Academy of Higher Education, Coimbatore, Tamilnadu, India*
[2]*Department of ECE, LBS Institute of Technology for Women, Trivandrum, Kerala, India*
[3]*Karpagam Academy of Higher Education, Coimbatore, Tamilnadu, India*
[4]*Pro-Vice Chancellor, APJ Abdul Kalam Technological University, Trivandrum, Kerala, India*

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Corresponding Author:
Deepambika V.A.
Department of ECE, LBS Institute of Technology for Women, Trivandrum, Kerala, India
Email: deepambika.va@gmail.com

Abstract: Computer stereo vision is a passive sensing technique that helps to recover 3D information of an environment from 2D images. The stereo correspondence is a challenging task that finds out matching pixels between the stereo image pair based on Lambertian criteria and its result is a disparity space image. The depth of the objects from the camera can be calculated from this disparity value by using the principle of triangulation. For the vision guided robot navigation, the requirement of stereo matching algorithms on low power dedicated hardware that can achieve a high frame rate is unambiguous. A new, highly optimized implementation of correlation based, Sum of Absolute Differences correspondences algorithm on a low cost resource limited FPGA is presented here. This System-on-Programmable-Chip architecture based system achieved a higher frame rate of 50 fps with 64 disparity levels without using a microprocessor. On performance evaluation, the disparity map shows a maximum error of 0.308% only. This reconfigurable parallel processing, high speed architecture of the algorithm implementation takes only 43% of available resources of low density Altera Cyclone II. This hardware implementation of stereo vision system outperforms in terms of accuracy, speed and resource utilization of all the other existing stereo systems of its similar kind. Also, it offers a better trade-off between run-time speed and accuracy and is found suitable for most of the range finding real-time applications.

Keywords: Stereo Vision, Stereo Correspondence, SAD, FPGA, SoPC

Introduction

The primary intention of robotic vision is to enable robots to cope with its surroundings in order to perform various tasks like navigation in unknown cluttered environments, moving object tracking and pick and place applications Ude (2010). Among the various sensory modalities, the most dominant one is vision. But even the latest intelligent vision system that exists in computer vision is still far away from cognitive capabilities of the human visual system and the computer stereo vision tries to mimic human vision.

The stereo vision system is an inexpensive passive sensing technique that allows to obtain precise 3D information of the surroundings from 2D images and there is no interference with other sensing devices if multiple sensors are working in the same environment. Based on the Lambertian criteria, the stereo correspondence algorithm detects conjugate pair of pixels between the input stereo images and the result is a disparity space image. The depth of the objects from the camera is inversely proportional to this disparity values. The main categories of stereo correspondence algorithms are local and global methods Scharstein *et al*. (2001). The correspondence steps start with the matching cost computation, cost aggregation, disparity computation and finally the disparity refinement. Local stereo matching can be of feature based and area based methods that will result in sparse and dense disparity maps respectively. In the area based, also known as correlation based or window based local approach, a window of required size centered at a pixel of interest from one input image is used to search in the other image for similar intensity levels. This similarity check is done