J Real-Time Image Proc (2013) 8:421–435
DOI 10.1007/s11554-011-0211-z

ORIGINAL RESEARCH PAPER

Fast implementation of dense stereo vision algorithms on a highly parallel SIMD architecture

Fouzhan Hosseini · Amir Fijany · Saeed Safari · Jean-Guy Fontaine

Received: 14 July 2010 / Accepted: 29 June 2011 / Published online: 19 July 2011
© Springer-Verlag 2011

Abstract In this paper, we present faster than real-time implementation of a class of dense stereo vision algorithms on a low-power massively parallel SIMD architecture, the CSX700. With two cores, each with 96 Processing Elements, this SIMD architecture provides a peak computation power of 96 GFLOPS while consuming only 9 Watts, making it an excellent candidate for embedded computing applications. Exploiting full features of this architecture, we have developed schemes for an efficient parallel implementation with minimum of overhead. For the sum of squared differences (SSD) algorithm and for VGA (640×480) images with disparity ranges of 16 and 32, we achieve a performance of 179 and 94 frames per second (fps), respectively. For the HDTV ($1{,}280 \times 720$) images with disparity ranges of 16 and 32, we achieve a performance of 67 and 35 fps, respectively. We have also implemented more accurate, and hence more computationally expensive variants of the SSD, and for most cases, particularly for VGA images, we have achieved faster than real-time performance. Our results clearly demonstrate that, by developing careful parallelization schemes, the CSX architecture can provide excellent performance and flexibility for various embedded vision applications.

Keywords Dense stereo vision algorithms · Parallel computation · SIMD parallel architecture

F. Hosseini (✉) · A. Fijany · J.-G. Fontaine
Italian Institute of Technology, Genova, Italy
e-mail: fouzhan.hosseini@iit.its

S. Safari
School of Electrical and Computer Engineering,
University of Tehran, Tehran, Iran

1 Introduction

Mobile robots and humanoids represent an emerging and challenging example of embedded computing applications. On the one hand, in order to achieve a large degree of autonomy and intelligent behavior, these systems require a very significant computational capability to perform a wide variety of complex tasks, some of them with real-time constraints. On the other hand, they are severely limited in terms of size, weight, and particularly power consumption of their embedded computing system since they should carry their own power supply. Moreover, since these systems need to implement a wide variety of applications, their computing systems should provide programmability of general purpose platforms. Therefore, their computing system should address three issues: computational efficiency, programmability, and adaptability [1]. Our current objective is to develop a flexible, programmable, low-power, lightweight vision supercomputing architecture for mobile robots and humanoid systems to perform various image processing tasks and, indeed, to enable new capabilities.

Various image processing computations are very common in robotic applications. A relevant class of image processing applications includes 3D modeling of environment, navigation, obstacle detection and avoidance, etc. The first step in these applications is the implementation of a stereo vision algorithm to calculate the depth information of the 3D environment. The motivation for a fast computation of the stereo vision results from the fact that it represents the first step of the overall computation in these applications.

Stereo vision has been extensively investigated and a great variety of algorithms have been developed for its computation [2]. In general, dense stereo vision methods