A Fast Area-Based Stereo Matching Algorithm

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Abstract

This paper presents an area-based stereo algorithm suitable to real time applications. The core of the algorithm relies on the uniqueness constraint and on a matching process that allows for rejecting previous matches as soon as more reliable ones are found. The proposed approach is compared with the left-right consistency constraint, being the latter the basic method for detecting unreliable matches in many area-based stereo algorithms. The algorithm has been carefully optimised to obtain a very fast implementation on a Personal Computer. This paper describes the computational optimisation strategy, which is based on a very effective incremental calculation scheme. Finally, we provide experimental results obtained on stereo pairs with ground-truth as well as computation-time measurements; we compare these data with those obtained using a well-know, fast, area-based algorithm relying on the left-right consistency constraint.

1 Introduction

Dense depth measurements are required in applications such as teleconferencing, robot navigation and control, exploration and modelling of unstructured environments, virtual reality. According to a recent taxonomy [17], stereo algorithms that generate dense depth measurements can be roughly divided into two classes, namely *global* and *local* algorithms. *Global* algorithms, e.g. [14], rely on iterative schemes that carry out disparity assignments on the basis of the minimisation of a global cost function. These algorithms yield accurate and dense disparity measurements but exhibit a very high computational cost that renders them unsuited to real-time applications. *Local* algorithms, e.g. [6, 8, 13, 15], also referred to as area-based algorithms, calculate the disparity at each pixel on the basis of the photometric properties of the neighbouring pixels. Compared to *global* algorithms, *local* algorithms yield significantly less accurate disparity maps but, nowadays, thanks to both research and technology advances, can run fast enough to be deployed in many real-time applications. Numerous examples of dense stereo applications which require real-time performance can be found at the web sites [2, 3].

As far as local matching algorithms are concerned, and considering the more common case of a binocular stereo imaging system, a widely adopted method [8, 15, 6] aimed at detecting unreliable matches, such for example those due to occlusions or photometric distortions, is the so called *left-right consistency constraint* [9], also referred to as *bidirectional matching* or *left-right check*. The method can be described as follows. Initially, for each point of the left image find the best match into the right image. Then, reverse the role of the two images and for each point of the right image find the best match into the left image. Finally, keep only those matches that turn out to be coherent when matching left-to-right (direct matching phase) and right-to-left (reverse matching phase). It is worth observing that in both phases the match associated with each pixel is established independently of those found at neighbouring pixels, since the other matching phase will highlight ambiguous matches. The *left-right check* has proven to be particularly effective in detecting and discarding the erroneous matches necessarily yield by area-based algorithms in presence of occlusions [7, 15, 6]. However, this approach is characterised by a significant computational cost. In fact, it requires two matching phases (direct and reverse) and, although some authors have proposed calculation schemes aimed at reducing the impact of the left-right check on the overall stereo execution time [6], in most implementations this implies doubling the computational complexity of the matching process.

This paper presents a fast *local* algorithm which enables real-time dense stereo applications on a standard Personal Computer. The algorithm is based on a matching core that detects unreliable matches during the direct matching phase and therefore does not require a reverse matching phase.