3D Reconstruction by a Combined Structure Tensor and Hough Transform Light-Field Approach

Authors: Alessandro Vianello\textsuperscript{1,2}, Giulio Manfredi\textsuperscript{1}, Bernd Jähne\textsuperscript{1}

Affiliations:
\textsuperscript{1} Heidelberg Collaboratory for Image Processing (HCI) at IWR, Heidelberg University, Germany
\textsuperscript{2} Robert Bosch GmbH, Robert Bosch Campus 1, Renningen, Germany

In recent years, techniques based on light-field analysis have been widely developed. Specifically, a 4D light-field can be expressed as a collection of pinhole views from several view points parallel to a common image plane. In this simplified case of a camera moving linearly in front of a scene (or just a linear camera array), every captured scene point corresponds to a linear trace in a so-called Epipolar Image Plane (EPI), where the slope of the trajectory determines the scene point’s distance to the cameras.

In literature, Wanner and Goldlücke \cite{ref1} used the structure tensor to estimate the slope of each pixel in the EPI, obtaining a coarse depth map which is then refined by means of a global optimization. More recently, Kim et al. \cite{ref2} proposed a method which computes reliable depth estimates around the object boundaries (i.e., in the scene’s high textured areas) by testing all the possible disparity hypothesis and choosing the one that leads to the best color constancy along the EPI-line. Afterwards, the sparse depth map is refined with a fine-to-coarse approach, by iteratively downsampling the EPI and repeating the procedure. Unfortunately, all these methods are either extremely time consuming or give coarse results. The Hough Transform (HT) is an elegant method for estimating parametrized line segments in an image. This approach can locate regular curves like straight lines, circles, parabolas, ellipses, etc. The advantages of the HT are that it is relatively robust against noise, and also unaffected by occlusions in the image. Moreover, HT is tolerant to gaps in the edges. The main drawback of Hough transform methods is the high computational effort. In the line detection case, for each point in the image, the algorithm must compute the line’s parameters and increment each point in the Hough space through which the line passes. Nevertheless, the HT treats each point independently; this means that the algorithm can be parallelized and run in realtime applications. Another way to minimize the amount of computation needed to detect lines, is by exploiting the information given by the structure tensor (ST). In fact, the ST gives an estimation of the local orientation in the EPI image. This orientation can be used to initialize the search in the Hough space. A Hough Transform based approach seems ideal to treat linear light-fields. The HT can be considered a semi-global method; in fact, differently from the structure tensor, which provides a local evaluation of the EPI-line’s slope by only using a portion of the line, in the HT all the points lying on the line contribute to increase the value of the accumulation matrix location corresponding to the real line. Moreover, this approach is robust against occlusions and noise, a very important feature for 3D reconstruction. The proposed approach combines the ST and the HT to detect a set of lines in an EPI. The results show that the HT-based approach by far outperforms the simple structure tensor in terms of reconstruction of statistical uncertainty and robustness against systematic errors, due to its semi-global nature. Moreover the proposed approach gives better results also around depth discontinuities, where sharp edges are correctly reconstructed.

References: