A generalized matching concept for area-based reconstruction of planetary

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Sub-pixel image correlation by means of area-based least-squares adjustment is a well proven technique that generally allows obtaining high density coverage with conjugate points using automated mapping procedures. Its main limitation has been attributed to the requirement of operating on small image windows of fixed size, which would set an obvious limit to the ability to map local variations of stereo disparity. Diverse feature-based matching operators, as well as interoperable techniques for measuring disparity manually have been proposed as a remedy to add more detailed disparity information.
This line of reasoning in our view is misleading in two important aspects. First, a certain "area-based" component is involved in any method for point transfer due to the simple fact that each method operates on discrete, two-dimensional images. Second, and more important, resolution is not strictly limited by the finite size of the operator window in itself, but, more specifically, by the ability of the matching process to take into account spatial variations of the disparity field inside of the matching area. As a standard, this is addressed by estimating the parameters of an affine transform (a six-parameter two-dimensional linear transfer function that establishes the relationship between the pixel coordinates of each pair of stereo images) during least-squares adjustment. In cases where the affine transform provides a good fit to the actual disparity pattern (e.g. for arbitrarily inclined planar terrain patches) and where its parameters can be derived accurately (depending on geometric and radiometric image and scene properties, such as geometric calibration of the sensor, noise, directional reflectance), conjugate sub-pixel positions can be obtained not only for a single point in each matching area, but rather for the transformed image patches as a whole. In short, the resolution of disparity variations depends primarily on the ability to model these variations.
We suggest that the high quality of digital stereo data available today allows us to extend this concept for the analysis of more complex relief elements based on higher degree transform functions, at the same scale of window dimensions typically used in conventional affine-transform matching. Such functions should ideally be hierarchically organized, which allows selective application in areas of different relief complexity; moreover, they should preferably use small numbers of free parameters and possess efficient algorithmic implementations. We investigate the use of 2D polynomial functions because they appear to provide a reasonable match to the geometric complexity of planetary surfaces, they include the well-known case of affine-transform image matching, and they require moderate computational cost.
Our experiments, which use stereo images of Mars Express HRSC, LRO-LROC and Messenger MDIS demonstrate that a visible increase of resolved surface detail can be achieved, as compared to affine-transform matching. For some of our test datasets the DTM grid spacing could be reduced by a factor of 2-3 when adopting the same requirements concerning point density and point accuracy in relation to the grid spacing. Although there is a systematic increase of both the sub-pixel matching error and the 3D intersection error with the number of model parameters (i.e. the polynomial degree of the applied transfer function), we find that the average 3D point error can be kept in the same range as for affine transform matching or even improve on the order of up to 30% when the model degree is allowed to vary adaptively. In this case, a concurrent

improvement in the average accuracy of lower degree matches is observed because these are less regularly degraded by unresolved disparity variations.