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COMPARISON AND ANALYSIS OF NONLINEAR LEAST SQUARES METHODS FOR VISION BASED NAVIGATION (VBN) ALGORITHMS

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Abstract. A robust scale and rotation invariant image matching algorithm is vital for the Visual Based Navigation (VBN) of aerial vehicles, where matches between an existing geo-referenced database images and the real-time captured images are used to georeference (i.e. six transformation parameters - three rotation and three translation) the real-time captured image from the UAV through the collinearity equations. The georeferencing information is then used in aiding the INS integration Kalman filter as Coordinate UPdaTe (CUPT). It is critical for the collinearity equations to use the proper optimization algorithm to ensure accurate and fast convergence for georeferencing parameters with the minimum required conjugate points necessary for convergence. Fast convergence to a global minimum will require non-linear approach to overcome the high degree of non-linearity that will exist in case of having large oblique images (i.e. large rotation angles).The main objective of this paper is investigating the estimation of the georeferencing parameters necessary for VBN of aerial vehicles in case of having large values of the rotational angles, which will lead to non-linearity of the estimation model. In this case, traditional least squares approaches will fail to estimate the georeferencing parameters, because of the expected non-linearity of the mathematical model. Five different nonlinear least squares methods are presented for estimating the transformation parameters. Four gradient based nonlinear least squares methods (Trust region, Trust region dogleg algorithm, Levenberg-Marquardt, and Quasi-Newton line search method) and one non-gradient method (Nelder-Mead simplex direct search) is employed for the six transformation parameters estimation process. The research was done on simulated data and the results showed that the Nelder-Mead method has failed because of its dependency on the objective function without any derivative information. Although, the tested gradient methods succeeded in converging to the relative optimal solution of the georeferencing parameters. In trust region methods, the number of iterations was more than Levenberg-Marquardt because of the necessity for evaluating the local minimum to ensure if it is the global one or not in each iteration step. As for the Levenberg-Marquardt method, which is considered as a modified Gauss-Newton algorithm employing the trust region approach

where a scalar is introduced to assess the choice of the magnitude and the direction of the descent. This scalar determines whether the Gauss-Newton method direction or the steepest descent method direction will be used as an adaptive approach for both linear and non-linear mathematical models and it successfully converged and achieved the relative optimum solution. These five methods results are compared explicitly to the linear traditional least-squares approach, with detailed statistical analysis of the results, with emphasis on the UAV (VBN) applications.

Conference Paper (PDF, 516 KB)

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