Analytical Foundations of Pixel-Based Video Displacement Estimation

by

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Submitted to the Department of Electrical Engineering
and Computer Science on August 31, 1988 in partial fulfillment of the
requirements for the Degree of Doctor of Philosophy

Abstract:

Reliability and accuracy in displacement estimation from general video sequences is sought. Reliability is studied as the problem of getting correct displacement estimates under ideal circumstances (i.e., zero noise and zero scene evolution); accuracy is studied as the deterioration of estimates from introduction of non-ideal factors (i.e., noise). Based on these studies, analytical descriptions of phenomena underlying displacement estimation are offered.

Because of the focus on general sequences, only pixel-based algorithms are considered. More specifically, an architecture encompassing distinct modules for image filtering, local displacement estimation, and displacement field smoothing is employed. The architecture serves as a platform for iterative displacement estimation, and use of a spatio-temporal local estimator permits various aspects of system design and performance to be treated analytically. The work should be of interest to design engineers due to its attention to systems integration and to its use of familiar building blocks.

The reliability study concentrates on convergence properties of local displacement estimation. A novel frequency domain argument is used to intuitively account for rapid convergence (3 or 4 iterations for displacements of up to 10 pixels), and to establish guidelines for required low-pass filtering. The accuracy study applied to local estimation leads to a means for translating image brightness noise statistics into local displacement estimation error statistics. This is significant because knowledge of the latter is required as an input to the design of velocity field smoothing filters. As lesser local estimation result is also obtained, holding that block size, up to a maximum size, does not materially affect accuracy with this architecture.

Displacement field smoothing accuracy is advanced relative to prior works in three ways: 1) a stochastic formulation is used to permit incorporation of local displacement error statistics; 2) existing approaches are generalized to accept local displacement estimates computed from image blocks, not pixels; and 3) duality between variational and stochastic smoothing formulations is used to enforce that smoothing not cross foreground-to-background contours if the location of such contours is known.

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