Summary

Computer Vision has been recently one of the most active research areas in computer society, since it constitutes the fusion of Artificial Intelligence and Image Processing areas and aims at developing smart systems in order to recover critical information from real images. Many modern computer-machine vision and medical imaging applications, such as Super-Resolution, 3D Teleconference, Robot Navigation, Satellite Imaging and MRI-based diagnosis require the solution of the well known image registration problem.

Image registration consist in finding correspondences between two or more images, which are projections of the same (usually physical) scene. Sampling of digital images, perspective projection of the scene through pinhole camera model into the image plane and camera or scene motion are some of the factors that make the problem, in a wide sense, too difficult.

The majority of image registration algorithms recommend parametric techniques. These techniques adopt a specific parametric transformation model, which is applied to one image, thus providing an approach of the other one. The success of this approach is quantified through a similarity criterion, the optimization of which requires the optimum estimation of the parameter values. Parametric techniques register image regions or features and, based on the optimization strategy, are broadly classified into two categories; the full or exhaustive search methods and the differential or gradient based methods.

In this dissertation, the Stereo Correspondence and the general problem of Image Alignment are considered. In stereo case, the goal of correspondence is the construction of the disparity map based on the reference image. The ability of a stereo algorithm to produce a disparity map with sub-pixel accuracy as well as to provide reliable results under non uniform illumination of a scene in a real application are two necessary properties. Taking these algorithm properties into consideration, a local differential algorithm is proposed which involves a new similarity criterion, the Enhanced Correlation Coefficient (ECC). This criterion is invariant to any linear photometric distortions and results from the incorporation of a single parameter model (1D interpolation kernel) into the classical correlation coefficient, defining thus a continuous objective function. Although the objective function is non-linear in translation parameter, its maximization results in a closed form solution, saving thus much computational burden.

The proposed algorithm provides accurate results even under non-linear photometric distortions
and its performance is superior to well known conventional stereo correspondence techniques. In addition, the proposed technique seems not to suffer from pixel locking effect and outperforms even stereo techniques, dedicated to the cancellation of this effect.

Toward the image alignment problem, the maximization of a generalized version of ECC function that incorporates any 2D warp transformation is proposed. Although this function is a highly nonlinear function of the warp parameters, an efficient iterative scheme for its maximization is developed. In each iteration of the proposed scheme, an efficient approximation of the nonlinear objective function is used leading to a closed form solution of low computational complexity. Two different iterative schemes are proposed; the Forwards Additive ECC (FA-ECC) and the Inverse Compositional ECC (IC-ECC) algorithm. The variation of these schemes consist in different parameter update rules and in modifying the strategy towards the alignment. The proposed iterative schemes are compared with the corresponding schemes (FA-LK and S1C) of the leading Lucas-Kanade algorithm, through a series of experiments.

FA-ECC algorithm makes use of the known additive parameter update rule and its computational cost is similar to the one required by the most widely used FA-LK algorithm. The proposed iterative scheme exhibits increased learning ability, since it converges faster with higher probability. This superiority is retained even in presence of additive noise and photometric distortion, as well as in cases of over-modelling the geometric distortion of the images.

On the other hand, IC-ECC algorithm makes use of inverse logic by swapping the role of images. Moreover, it adopts the transformation composition update rule, thus widening the applicability of inverse logic. As a consequence of these two options, the complexity per iteration is drastically reduced and the resulting algorithm constitutes the most computationally efficient scheme than three other above mentioned algorithms. However, empirical learning curves and probability of convergence scores indicate that the proposed algorithm has a similar performance to the one exhibited by S1C. Moreover, like S1C algorithm, its learning ability seems to be sensitive to low SNR levels.

Concluding, though FA-ECC seems to be clearly more robust in real situation conditions among all the above mentioned alignment algorithms, the choice between two proposed schemes necessitates a trade-off between accuracy and speed.

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