Least-squares Optimal Interpolation for Direct Image Super-resolution

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In Loving Memory

Of

Alexander Gilman

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At Rest

Think of me as one at rest,
for me you should not weep
I have no pain no troubled thoughts
for I am just asleep
The living thinking me that was,
is now forever still
And life goes on without me now,
as time forever will.

If your heart is heavy now
because I've gone away
Dwell not long upon it friend
For none of us can stay
Those of you who liked me,
I sincerely thank you all
And those of you who loved me,
I thank you most of all.

And in my fleeting lifespan,
as time went rushing by
I found some time to hesitate,
to laugh, to love, to cry
Matters it now if time began
If time will ever cease?
I was here, I used it all,
and now I am at peace.

Abstract

Image super-resolution aims to produce a higher resolution representation of a scene from an ensemble of low-resolution images that may be warped, aliased, blurred and degraded by noise. There are a variety of methods for performing super-resolution described in the literature, and in general they consist of three major steps: image registration, fusion and deblurring. This thesis proposes a novel method of performing the first two of these steps.

The ultimate aim of image super-resolution is to produce a higher-quality image that is visually clearer, sharper and contains more detail than the individual input images. Machine algorithms can not assess images qualitatively and typically use a quantitative error criterion, often least-squares. This thesis aims to optimise least-squares directly using a fast method, in particular one that can be implemented using linear filters; hence, a closed-form solution is required.

The concepts of optimal interpolation and resampling are derived and demonstrated in practice. Optimal filters optimised on one image are shown to perform near-optimally on other images, suggesting that common image features, such as step-edges, can be used to optimise a near-optimal filter without requiring the knowledge of the ground-truth output. This leads to the construction of a pulse model, which is used to derive filters for resampling non-uniformly sampled images that result from the fusion of registered input images. An experimental comparison shows that a 10^{th} order pulse model-based filter outperforms a number of methods common in the literature.

The use of optimal interpolation for image registration linearises an otherwise non-linear problem, resulting in a direct solution. Experimental analysis is used to show that optimal interpolation-based registration outperforms a number of existing methods, both iterative and direct, at a range of noise levels and for both heavily aliased images and images with a limited degree of aliasing. The proposed method offers flexibility in terms of the size of the region of support, offering a good trade-off in terms of computational complexity and accuracy of registration. Together, optimal interpolation-based registration and fusion are shown to perform fast, direct and effective super-resolution.

Author’s Publications

A. Gilman, D. G. Bailey, and S. Marsland, “Image Models for Image Super-resolution,” in Proceedings of IEEE International Symposium on Electronic Design, Test and Applications, Hong Kong, 2008, pp. 55-60.

A. Gilman, and D. G. Bailey, “Noise Characteristics of Higher Order Predictive Interpolation for Sub-Pixel Registration,” in Proceedings of IEEE Symposium on Signal Processing and Information Technology, Cairo, Egypt, 2007, pp. 269-274.

D. G. Bailey, and **A. Gilman**, “Bias of Higher Order Predictive Interpolation for Sub-pixel Registration,” in International Conference on Information, Communications and Signal Processing, Singapore, 2007.

A. Gilman, and D. G. Bailey, “Near optimal non-uniform interpolation for image super-resolution from multiple images,” in Proceedings of the Image and Vision Computing New Zealand, Great Barrier Island, New Zealand, 2006.

D. G. Bailey, **A. Gilman**, and R. Browne, “Bias characteristics of bilinear interpolation based registration,” in Proceedings of IEEE TENCON, Melbourne, Australia, 2005.

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