Composite Super-Resolution

COMP 4102 Project Report

Garrick Wong
101052553
Carleton University
4-17-2021

Abstract

This project seeks to develop a prototype program to demonstrate composite super-resolution imaging. A composite super-resolution image is a higher resolution image created from merging multiple lower resolution images of the same object, which reduces image noise and makes the overall image clearer. This project will attempt to apply theories derived by Sina Farsiu and his associates to develop this prototype program.

Introduction

This project seeks to implement various ideas from Farsiu's work in super-resolution. The primary paper the project will make use of is "Fast and Robust Multiframe Super-Resolution", written by Sina Farsiu, M. Dirk Robinson, Michael Elad, and Peyman Milanfar. This paper proposes what the authors believe to be a "computationally inexpensive method is robust to errors in motion and blur estimation" [1]. Their experimentation with implementing this new method appeared to produce favorable results, and the complexity of their algorithm leads me to believe it is a candidate sufficient for this project, as it cannot simply be reproduced using a few OpenCV functions.

Background

"Fast and Robust Multiframe Super-Resolution" was the primary work utilized and cited for this project. In this paper, the authors describe two of the approaches previously explored for super-resolution, a frequency domain approach, and a spatial domain approach. Both approaches were found to have drawbacks, with the frequency domain approach being sensitive to model errors and the spatial domain approaches either being too computationally expensive or lacking in other ways [1]. Thus, the authors have proposed a method that makes use of an L_1 norm minimalization estimator and a regularization function they have called "bilateral TV" based on the total variation regularization method and the bilateral filter technique [1]. These two functions are important aspects of the super-resolution algorithm, as the estimator is used to fuse the data from the low-resolution images for an estimate of the super-resolution image, while the regularization function is needed to modify the data to resolve the under- and over-determined cases found due to super-resolution being an ill-posed problem [1]. All of this is necessary to understand how to make use of the super-resolution algorithm in the prototype program.

Approach

For this project, the attempted approach was to create a prototype program utilizing the algorithm developed by Farsiu, Robinson, Elad and Milanfar. Based on their theory, the program would utilize the following equation:

$$
\underline{\widehat{X}}_{n+1} = \underline{\widehat{X}}_n - \beta\Big\{ \sum_{k=1}^{N} F_k^T H_k^T D_k^T sign(D_k H_k F_k \underline{\widehat{X}}_n - \underline{Y}_k)
$$
$$
+\lambda \underbrace{\sum_{l=-P}^{P} \sum_{m=0}^{P}}_{l+m\geq 0} \alpha^{|m|+|l|}[I - S_y^{-m} S_x^{-l}] sign(\underline{\widehat{X}}_n - S_x^l S_y^m \underline{\widehat{X}}_n)\Big\} \qquad \textbf{(22)}
$$

Figure 1: Algorithm derived by Farsiu et al. [1]

In this equation, Farsiu et al. state that the value of β is the step size in the direction of the gradient, F, H, D, S, and their transposes correspond to direct image operators, and S_y^{-m} and S_x^{-l} denote the transposes of S_y^m and S_x^l. Farsiu et al. derived this algorithm from the L_2 estimator and the bilateral total variation method they had previously specified. However, since the estimator will likely take a significant amount of time to implement, the estimator will be simplified to a mean estimation of the images instead. This will likely make the program less robust as Farsiu et al. state when they compare the various estimators [1], but should be less difficult to implement, as it is an averaging of the multiple images together. The regularization function will be added after the estimator is implemented.

Result

Unfortunately, the result of the project was ultimately a failure. The prototype program does not have the regularization function implemented and the estimator does not provide the expected output. The program itself would likely be completed with more time, however that would also likely enable the opportunity to create Farsiu's original estimator. The failure can be attributed to inadequate time allocated to the project, partially due to the need to split focus amongst other courses and projects that were concurrently in progress. Current results of the program are presented in figures 2 and 3. The likely reason for the current output is from errors in the attempted implementation of the mean estimator, and a lack of a regularization function to improve the output.

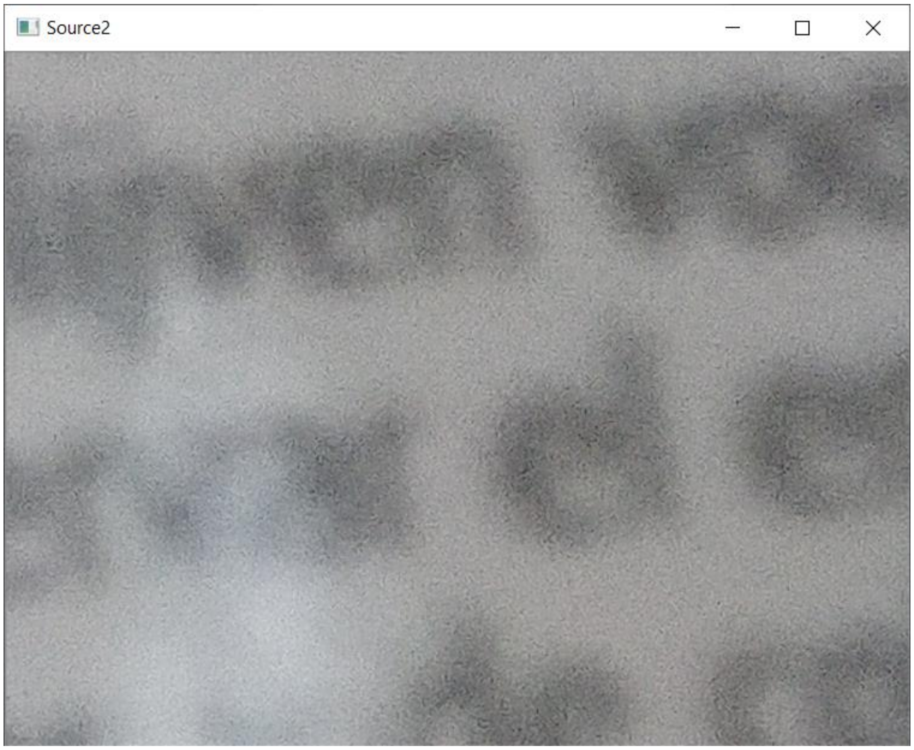

Figure 2: One of the source images

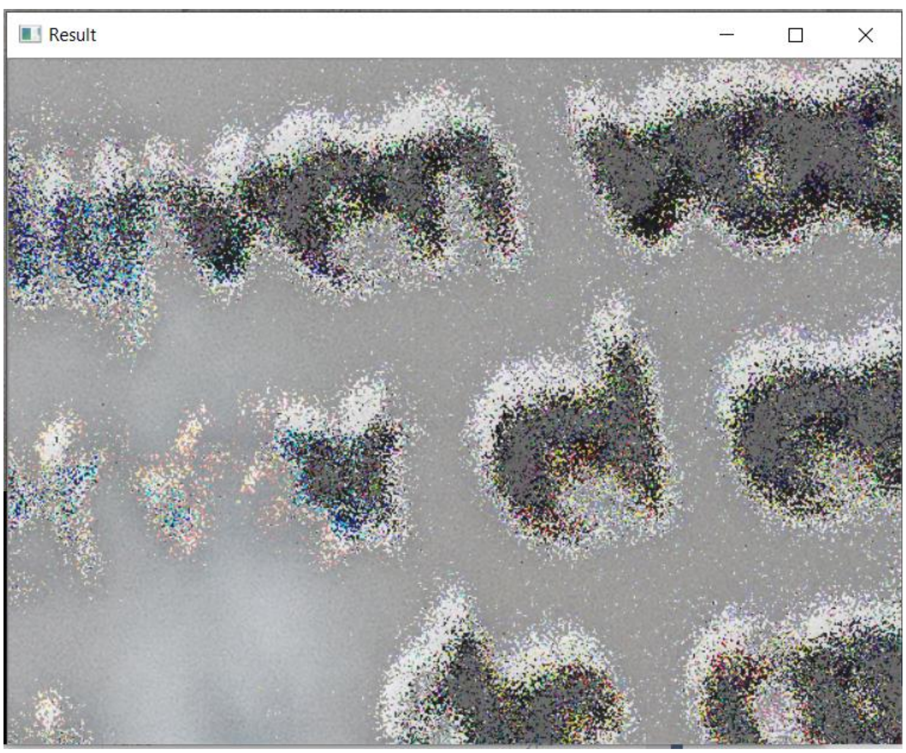

Figure 3: Output image of prototype

GitHub Page

https://github.com/GarrickWong/COMP4102Project

References

[1] S. Farsiu, M. Dirk Robinson, Michael Elad and Peyman Milanfar, "Fast and Robust Multiframe Super Resolution", *IEEE Transactions on Image Processing*, vol. 13, October 2004