Super-Resolution Algorithm with JPEG Enhancement for Compressed, Low-Resolution Images

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Overview

When low-quality cameras are the economical option for a project, such as the case of Open Orbiter's mission to develop a small satellite (CubeSat) under a cost of five-thousand, one solution to achieve high quality images is to implement a super-resolution algorithm. This process takes a sequence input of low-resolution images depicting a static scene and outputs an image of higher resolution. For this study on the image processing of a CubeSat, the low-resolution images are gray-scaled, down-sampled, compressed and from a webcam; this reflects the low bandwidth constraints of a low Earth orbiting spacecraft. This poster begins with an overview of the fundamentals, and presents the suggested software's image processing method. A comparison of the proposed method to other standard techniques and commercial software demonstrates a usefulness of this to-be-free algorithm for a simple image-taking space mission.

Index Terms- small satellites, economical, super-resolution, Bayesian method, compression, JPEG enhancement

Background

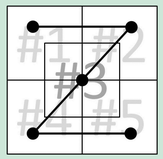

Figure 1:
Image arrangement

The approximately 20-year old study of super-resolution (SR), the production of a high quality images from one or more low-quality images, has been largely studied for aerial-related imaging, medical field imaging and much more [1]. The method used here reconstructs a high-resolution (HR) image by purposely bringing new information from low-resolution (LR) with sub-pixel shifts. An integer shift will not introduce more data as sub-pixel aliasing does [2]. The method proposed by Schultz et al works best when the images are arranged in the pattern depicted in figure 1 [3]. This estimation of the original HR image requires a separate calculation of the motion vectors [4], which is also implemented in this study.

Method

Figure 2: The GUI with ZOOM option.

A standard image set is first cropped, gray-scaled and pixel-shifted with a script that uses ImageMagick (a free image command-line editing software). The five images are loaded into the GUI (graphical user interface), which is shown in figure 2. The GUI down samples the images by 2 (Zero Order Hold method) and then (optionally) implements 6 different compression levels. Before super-resolution is applied, there is an option to apply a JPEG enhancement to the low-resolution images. The GUI develops an approximate mapping of the centroids (ideal image sets would result in centroids as in figure 1), selects a reference image (#3 in figure 3), and calls the super-resolution algorithm. The super-resolution algorithm then determines the motion vectors and up-samples the image by 2 or 4. The GUI then compares it to the original HR image by calculating the peak-signal-to-noise ratio (PSNR).

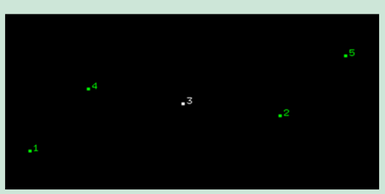

Figure 3: Centroids of pixel-shifted chiles image.

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Results

PSNR data was collected from five standard images [5] :

Comparisons made:

- Other standard interpolation methods: Zero Order Hold (ZOH), Bilinear, Bicubic and Lagrange.
- 2x or 4x up-sampling in super-resolution.
- JPEG enhancement option.

Figure 4 shows the results for one image of the test set with one compression level. Figure 5 shows the average (over all images in the test set) PSNR values vs compression level for all comparisons made.

Figure 4: From top left to right image order:
original low-resolution, super-resolution, super-resolution with JPEG enhancement, zero-order hold, lagrange, bilinear and bicubic.

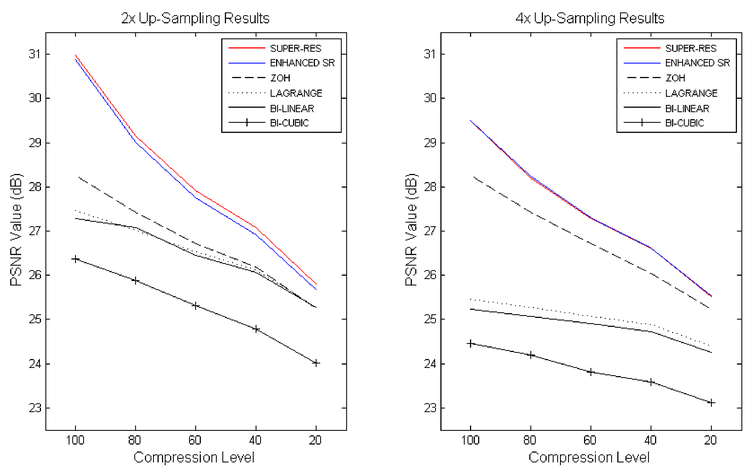

Figure 5: Average PSNR values vs compression level.

Conclusions

- At high compression rates, block-shaped artifacts appear. This is first largely noticeable at a level of 60. Though JPEG enhancement can smooth this out, the process brings artifacts and the PSNR value does drop considerably compared to without.
- Super-resolution that upsamples the low-quality image 2X had better results than 4X upsampling. This could relate to the Gibbs free oscillations [6] greater prominence in 4X upsampling.
- Super-resolution provided a better PSNR value than the other standard interpolation methods. Zero-Order Hold was second best.

Future Work

- Test PSNR validity with other ratios– ex: structural similarity (SSIM)
- Motion DSP, Ikena ISR (3.4.1304)
  - Presently: MakeAVI converted five pixel-shifted, down-sampled and compressed images into an uncompressed AVI video [8].
- Pixon Imaging
  - Presently: The Pixon method uses the fewest number of pixon kernals possible to reconstruct an image [9].

Motion DSP and Pixon result in figure 6.

Figure 6: From left to right starting with the top row:
original image, super-resolution with JPEG enhancement,
Motion DSP result and Pixon result. Compression at 20.

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