Scintillation mitigation for long range surveillance video

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INTRODUCTION

Atmospheric turbulence is a naturally occurring phenomenon that can severely degrade the quality of long range surveillance video footage. Major effects include image blurring, image warping and temporal wavering of objects in the scene (refer to **Figure 1**). Mitigating these effects, while preserving motion not caused by turbulence, can increase the effectiveness of a camera system designed for long range surveillance.

The parallel processing performance, high memory bandwidth and programmability of modern Graphics Processing Units (GPUs) make them ideal platforms for implementing the image processing algorithms required for this task.

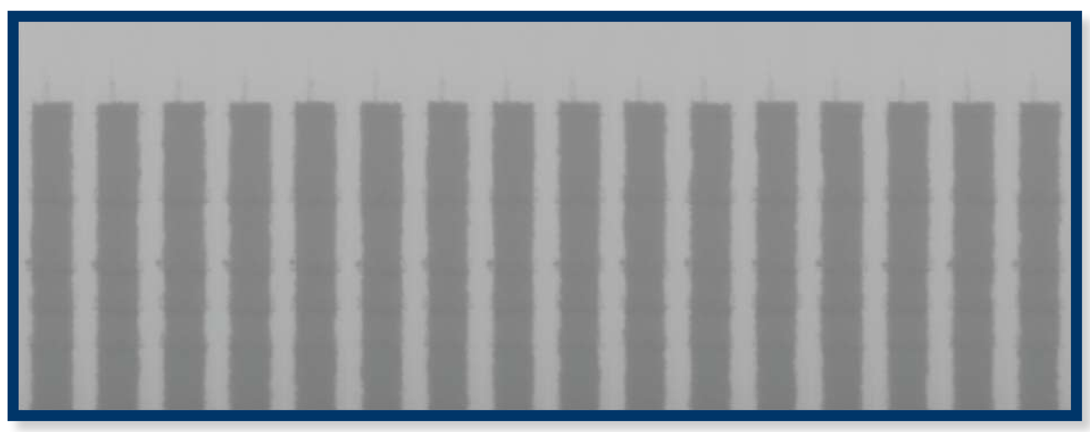

Figure 1: A montage of parts of 16 consecutive video frames captured (40ms apart) by a long range surveillance camera showing the dynamic influence of scintillation on the objects in the images.

RELATED WORK

Mitigation of scintillation effects has been studied in the areas of astronomy (Li and Simske, 2009) and long range surveillance (Robinson, 2009; Li, Smith and Mersereau, 2006; Li and Simske, 2009; Frakes, Monaco and Smith, 2001).

Image pyramid processing algorithms (Adelson, Anderson, Bergen, Burt and Ogden, 1984; Strengert, Kraus and Ertl, 2006) naturally lend themselves to GPU implementations and can be used for interpolation (Marroquim, Kraus and Cavalcanti, 2007).

DE-BLURRING ALGORITHM

We implemented the de-blurring algorithm as described in Robinson (2009). Blur in the image can be modelled as an Optical Transfer Function (OTF) and one such model has been created by Hufnagel and Stanley (Robinson, 2009; Li *et al.*, 2006; Li and Simske, 2009). Once the OTF has been computed or estimated, it can be used in a Wiener restoration filter. **Figure 2** shows what can be achieved by such a filter.

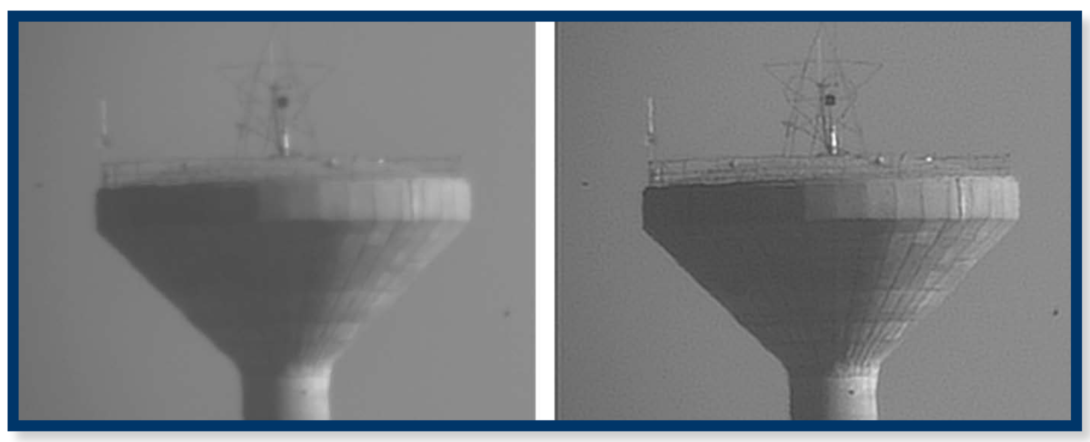

Figure 2: De-blur results: The left image shows an unprocessed incoming video frame and the right image shows the image after the application of the Wiener restoration filter.

DE-WARPING ALGORITHM

Our algorithm to mitigate the warping effects of scintillation contains four steps, namely:

1. Find a sparse set of matching regions in a range of consecutive images.
2. Average the pixel offsets over the range of input images.
3. Convert the sparse set of matches into a match for every pixel (dense set).
4. Move each input pixel by the calculated offset.

Region matching

The region matching algorithm tries to find, for every pixel in the current image, a matching pixel in the previous 15 input video images. Only pixels with some local detail are considered, because de-warping of uniform regions would not be noticed by the user and uniform regions are difficult to match.

Next, for every pixel that passed the local detail test, a window in each of the 15 previous video frames is considered and the best match (using the sum of squared differences) in each frame is recorded.

Offset averaging

The 15 offset maps are combined to form a single offset image by averaging. By requiring matches in a large number of earlier frames, larger movements that are not caused by scintillation can be excluded from the de-warping.

Sparse to dense offset interpolation

Our approach converts the sparse offset map into a dense map by means of interpolation using an image pyramid (Adelson *et al.*, 1984; Strengert *et al.*, 2006; Marroquim et al., 2007) approach.

The processing is split into an analysis and synthesis phase (also called a push and pull phase). During the analysis, up to four valid input offsets are combined (by averaging valid values) into a single output value.

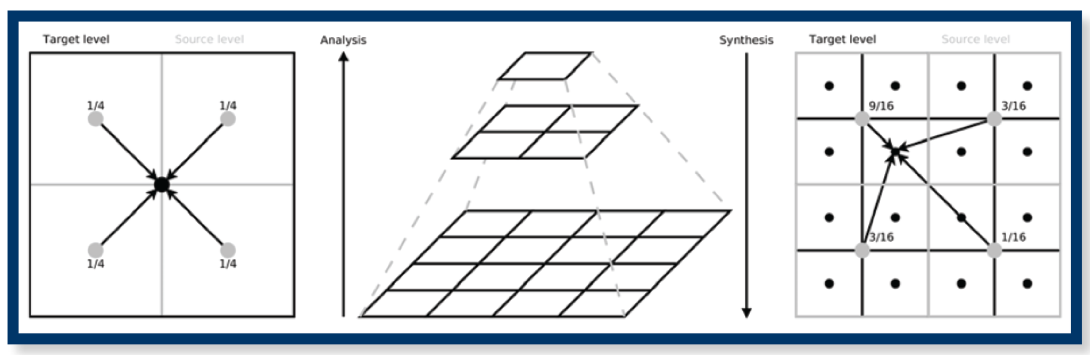

Figure 3: The analysis and synthesis phases in an image pyramid interpolation approach.

The synthesis phase now generates missing values at finer resolutions using the calculated values present in the coarser resolutions. From **Figure 3** it can be seen that an output pixel's value is determined from four input pixels. The contributions by the neighbours are weighted according to increasing distance, as in Catmull-Clark subdivision (Marroquim et al., 2007).

Image de-warping

We now have a dense map that contains the x- and y-offsets by which every input pixel should be adjusted. We interpret the map to mean that a given output pixel should be fetched from the negative offset location in the input image. Even though it is an approximation, it provides quite pleasing results.

Results

Figure 4 shows the processed version of the input images in **Figure 1**. **Figure 5** shows an input image, the de-warped version as well as the calculated sparse offset maps.

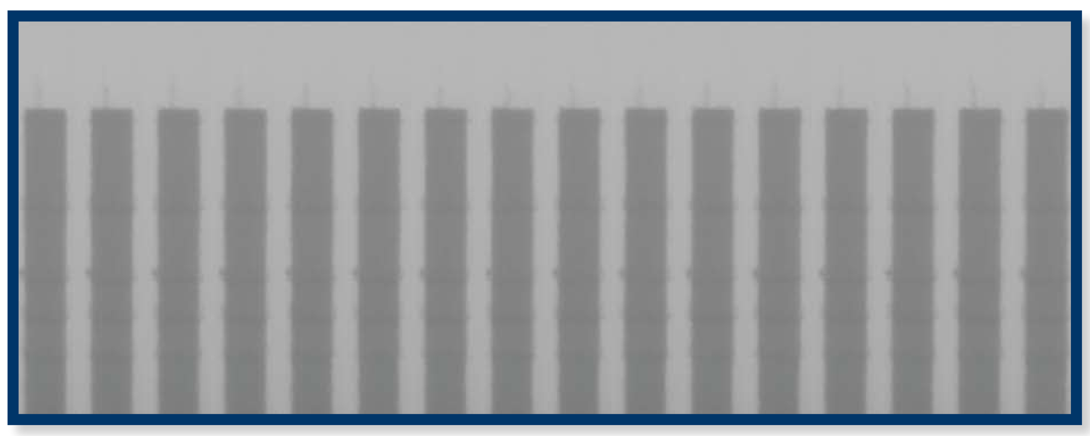

Figure 4: A montage of parts of 16 consecutive video frames captured by a long range surveillance camera after de-warping has been applied

CONCLUSION AND FUTURE WORK

The specific algorithm implementations form part of an experimental demonstrator. The GPU implementations are approaching real-time execution speeds on monochrome megapixel sized images captured at 20Hz.

Future work could include the estimation of de-blurring parameters, more detailed experimentation at all stages of the de-warping algorithm and use of the de-warped images in a super resolution algorithm.

ENDNOTE

Financial support for this work and for the collaboration with universities and students was provided by the Armscor LEDGER programme.

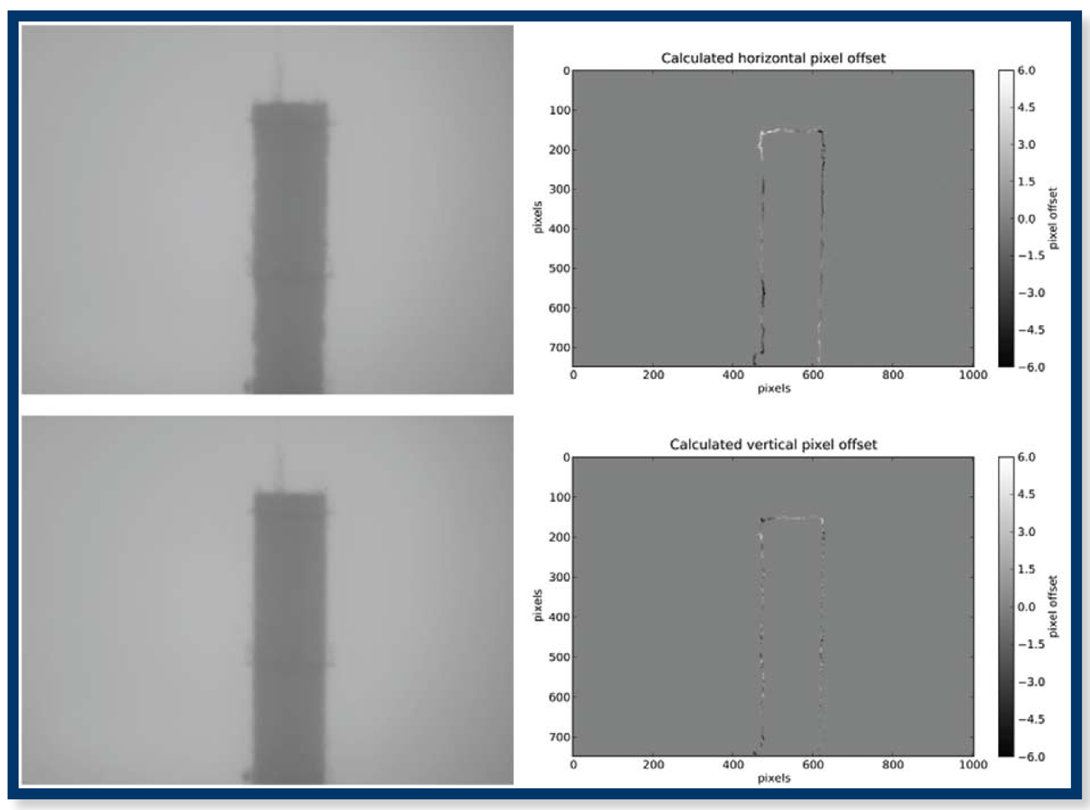

Figure 5: De-warping: The raw input image is shown at the top-left; the bottom-left shows the de-warped version of the input; the top-right represents the calculated horizontal pixel offsets and the bottom-right the calculated vertical offsets.

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