Removing Moiré from Degraded Video Archives

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ABSTRACT

This paper considers the removal of moiré patterns, which may appear during film-to-video transfer using Telecine devices. A model of moiré distortion is created and studied. A new suppression algorithm using spectral analysis is presented and applied for real video sequences. This non-linear filter is based on thresholding of the magnitude of the Fourier spectrum of the image. The paper also considers the use of overlapped block processing in order to reduce the effect of ringing artefacts that could appear due to the non-stationarity of the moiré pattern.

Keywords: *Moiré patterns, Fourier analysis, Telecine devices, video restoration, overlapped processing*

1 Introduction

The moiré effect is a well known phenomenon that occurs when two or more images with periodical or quasiperiodic structures (such as dot screens, line gratings, etc.) are nonlinearly combined to create a new superposition image. Moiré patterns do not exist in any of the original images, but appear in the superposition image as result of a multiplicative superposition rule.

While this phenomenon has useful applications in several fields, such as in strain analysis or in the detection and measurement of slight deflections or deformations [1], in many areas, moiré patterns have an unwanted, adverse effect. In the digital image processing literature [2] moiré effects are often considered, in view of sampling theory, as aliasing phenomena. Sampling moiré mainly occur in the analog to digital conversion process between repetitive patterns in the original image and the device sampling lattice. Sampling moiré can be considered as a special case of superposition moiré [2].

1.1 Moiré Degradation on Film

In video archives, the moiré phenomenon is an optical effect, which can appear during the Telecine transfer due to the difference between the scanning angle of television pictures transferred to film and in the Telecine device. Figure 1 shows a block diagram outlining the elements in the production chain that may result in the formation of moiré.

Before the use of video recording machines using magnetic tape, a device called a Kinescope was used to record the pictures on the Television monitor directly onto film. The Television scan lines are observed to be transferred directly to the film and this is illustrated in the Figure 1. The spacing and geometry of the scan lines depends on the optical projection in the Kinescope as well as the geometry of the old Television monitors. Those monitors were far from flat. Thus the Television scan lines transferred to the film would probably have some kind of curvilinear distortion as well as tilt due to the raster of the Television set.

In order to convert the film recording of the Television event into a modern broadcast format, the film must now be re-scanned in the

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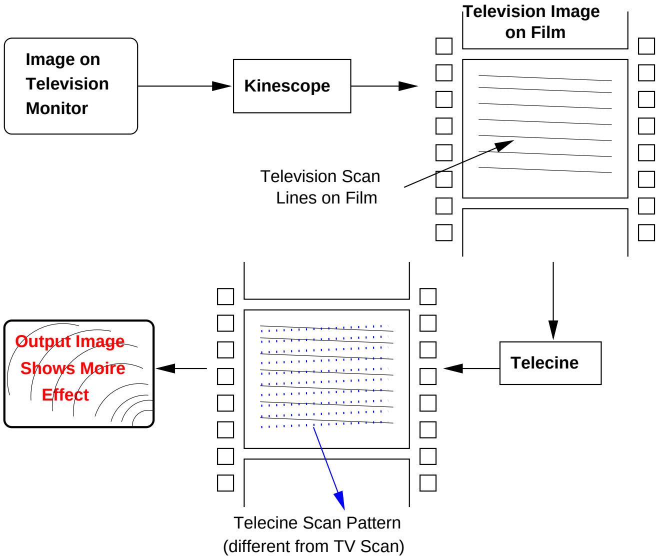

Figure 1: A block diagram of the system causing moiré degradation.

Telecine device. However, the Telecine uses a flying spot to scan the film [3] and the orientation and spacing of this scan pattern will not necessarily align with the original Television line scan. This will cause aliasing in the resulting signal, and that manifests as a periodic pattern superimposed on the resulting image. To circumvent this problem, it is necessary to “blur” or change the focus of the flying spot so that the aliasing is reduced.

Unfortunately, this is not often simple to do and the resulting image is corrupted with moiré. A frame with moiré degradation is shown in Figure 2. The moiré manifests here as periodic dark bands that become curved toward the extremities of the image. We suspect that the curved nature of the bands is as a direct result of the curved geometry of the original Television monitors.

2 A descriptive model of the archive moiré phenomena

Consider a 2-D description of moiré phenomenon. In Television monitors, the diameter of the scanning spot is less than the gap between adjacent lines. This means that there is a strip of darkness (black) between each line. First, we simulate this distance between Television scan

Figure 2: A frame degraded with moiré.

Figure 3: Example of artificially corrupted Lenna showing a convincing moiré effect.

lines by inserting strips of black between each line of the original image. Then we simulate the spread of the scanning dot in the Telecine device by applying a Gaussian filter. Finally, we resample the image vertically by interpolation between adjacent Television scan lines. The resampling period is $T_2 = \alpha T_1$, where α is close to 1. In other words, it is the ratio between the number of inserted lines and the spread of the Gaussian blur that is equivalent to the line spacing in the Telecine. T_1 is the spacing between the scan lines on the film.

Figure 3 shows Lenna artificially corrupted with moiré using $\sigma = 0.6$ (and 9×9 taps) for the Gaussian blur and $\alpha = 0.99$. In this case, only one line was inserted between each line of the original data.

In real video sequences there are two slightly different moiré patterns in odd and even Television scan lines which is the effect of Telecine device scanning dot technology. The difference between these patterns are difficult to see in stills.

3 Spectral moiré suppression

It is possible from the model and examples above to consider that the moiré degradation is the addition of a periodic pattern to the original defect-free image because of improper sampling in the Telecine device. We consider a moiré suppression algorithm based on a 2-D spectral approach. The essence of the idea is to detect peaks in the Fourier Spectrum of the degraded image and delete these peaks assuming that they represent the moiré.

The main steps are as follows

1. Protect a band of low frequencies in the image from manipulation. Assuming that the moiré is a predominantly horizontal periodic pattern, the peaks in the frequency space will appear near the vertical frequency axis. Define a range $\pm\Omega$ of vertical frequency within which the spectrum will be untouched.

2. Create a detection field $B(\omega_h, \omega_v)$ which is set to 1 at frequency components that should be removed and 0 otherwise, as follows

$$B(\omega_h, \omega_v) = \begin{cases} 1 & \text{if } (|F(\omega_h, \omega_v)| > \varepsilon\Delta) \\ & \text{and } (|\omega_v| > \Omega), \\ 0 & \text{otherwise} \end{cases}$$

   where $|F(\omega_h, \omega_v)|$ is the magnitude of the spectral component at frequency (ω_h, ω_v), $\Delta = \frac{\max|F(\omega_h,\omega_v)| - \min|F(\omega_h,\omega_v)|}{2} + \min|F(\omega_h, \omega_v)|$.

3. Replace the magnitude of each spectral component identified for removal by $B(\cdot,\cdot) = 1$, with a noise floor value. This noise floor value is the median of the magnitude of the spectral coefficients outside the protected spectral area.

4. Produce the restored image by combining the modified magnitude spectrum with the phase spectrum of the observed image.

Figure 4 shows the results of this process operating on a real degraded image frame for $\varepsilon = 0.1$, $\Delta = 94.4$ and $\Omega = 25.0$ Much of the moiré is removed.

This filter operation produces a ringing effect in the image domain which is caused by Gibbs phenomenon. The ringing effect (easier to see in a sequence rather than stills) is caused by discontinuities inserted in the Fourier domain at the location of the moiré frequencies.

4 Overlapped Processing

In order to minimize the ringing effect two approaches can be taken. One approach is to implement a soft thresholding operation in the spectral domain. This however, does not solve the problem entirely and it transpires that in fact, the greater problem is that the moiré pattern appears to be frequency modulated in both image directions. The other approach is to use overlapped blocks for processing. Within each block, the moiré pattern is then more regular and yields to this type of spectral processing.

The choice of analysis and synthesis windows for overlapped processing is important. The analysis window must allow good spectral resolution, while the synthesis window must allow the output data to overlap such that the overlapped portions of data show a net gain of unity through the system. The reader may see [4] for a treatment of overlapped processing for noise reduction in images. In this work, we have found that vertically overlapping image stripes by 2:1 gives good results since the moiré pattern is primarily horizontal. The analysis h_n^a and synthesis windows h_n^s chosen are the same, as follows

$$h_n = \cos^2\left(\frac{\pi n}{2N}\right),$$

$$\text{for } n = -\left(N - \frac{1}{2}\right), -\left(N - \frac{1}{2}\right) + 1, \ldots, \left(N - \frac{1}{2}\right).$$

They are both even length windows of N taps. The windows are applied vertically only since the overlapped blocks are in fact stripes that extend over the whole image width. The algorithm is then as follows

1. Split the frame into even length horizontal stripes that are overlapped by half their width.

2. Window each stripe by the analysis window (applied to each column) in the vertical direction.

3. Apply the spectrum domain based nonlinear filter (above) to each of the stripes.

4. Window the output stripe using the synthesis window (on each column).

5. Sum the overlapped stripes to generate the final processed image.

This algorithm provides ringing effect free results. Figure 5 shows the results of the overlapped processing algorithm operating on a real degraded image frame for real video sequence. In this example we use 100 pixels wide stripes and $\Omega = 5$. From the Figures 5 and 4 we can clearly see that overlapped processing algorithm provides visibly better results.

5 Final Comments and Conclusions

In this paper we have discussed removal of undesirable moiré patterns, which may occur in the analog to digital conversion of film recordings of Television. A model of the moiré distortion was presented and shown to produce convincing moiré patterns. A process for *blind* moiré removal was presented. It employs a simple manipulation in the spectral domain. This frequency domain filter was improved by using overlapped block processing. The final algorithm provides ringing effect free, and visibly pleasing results.

It is to be noted that Moiré removal is fundamentally difficult. This is because the patterns are not linear and are influenced by the (unavailable) TV monitor geometry. Tests on 1-D signals show indications that the moiré effect is not additive but multiplicative and our work continues in this direction.

Figure 4: Restored frame of the real sequence.

Figure 5: Result of overlapped processing.

Acknowledgments

This work is founded by the EU's IST research and technological development programme. It is carried out within the BRAVA project ("Broadcast Restoration Through Video Analysis")

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