COMMITTEE T1

CONTRIBUTION

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STANDARDS PROJECT: All Digital Video Performance Standards Projects

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TITLE: An Analysis Technique for Detecting Temporal Edge Noise

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1. Introduction

This contribution presents an analysis technique that can be used for detecting temporal edge noise in an output (i.e., destination) video sequence. The technique uses the Fourier transform to perform a comparative analysis of the frequencies present in the time history of the spatial information (SI) features measured from the source and destination video. The presence of temporal edge noise in the destination video is shown to result in high frequency information being added to the time history of the SI feature. The SI features that can be used are those presented in prior documents (e.g., T1A1.5/93-152) or in contribution T1A1.5/95-104. The composite SI feature presented in T1A1.5/93-152 includes edge energy from all angles and intensities while the SI features presented in T1A1.5/95-104 are “focused” in that they include only those edges within a specified range of angles and intensities.

2. An Analysis Technique for Detecting Temporal Edge Noise

Temporal edge noise is defined as a form of edge busyness characterized by time-varying sharpness (shimmering) of the edges of objects (see T1A1.5/95-108). The spatial information (SI) features presented in T1A1.5/93-152 quantify the amount of edge energy in a video scene. The sharper the edge, the greater the amount of edge energy, and thus the greater the value of the SI feature. Thus, time varying changes in edge sharpness cause time varying changes in the SI features. Figure 1 plots the SI time histories for the scene cirkit and HRC 22. The spatial information feature for the source (SI_S) is shown plotted with a solid line while the spatial information feature for the destination (SI_D) is shown plotted with a dashed line. This particular HRC x scene combination exhibits temporal edge noise similar to that found in the video clip chosen by T1A1.[1] Note how the spatial information feature for the destination video (SI_D) oscillates between sharper edges (larger SI_D values) and more blurred edges (smaller SI_D values).

Similarly, digital impairments such as spatial edge noise and mosquitoes (see T1A1.5/95-108 for definitions of these impairments) can cause time varying changes in the SI feature if these impairments appear and disappear in the video scene. Objects moving within the video scene can cause these impairments to exhibit a time varying nature. Figure 2 plots the time histories of the SI_S feature for the source scene vowels (solid line), and the corresponding SI_D feature for HRC 11 (dashed line). This particular HRC x scene combination was chosen by T1A1 as being representative of spatial edge noise. Figure 3 plots the time histories of the SI_S feature for the source scene inspec (solid line), and the corresponding SI_D feature for HRC 11 (dashed line). This particular HRC x scene combination was chosen by T1A1 as being representative of mosquito noise. By examining these figures, it can be seen that SI_D has a high frequency noise component that is not present in SI_S.

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1. In contribution T1A1.5/94-150, scene cirkit through HRC 9 was chosen by T1A1.5 as being representative of temporal edge noise. However, this contribution used scene cirkit through HRC 22 since this clip was felt to exhibit more temporal edge noise.

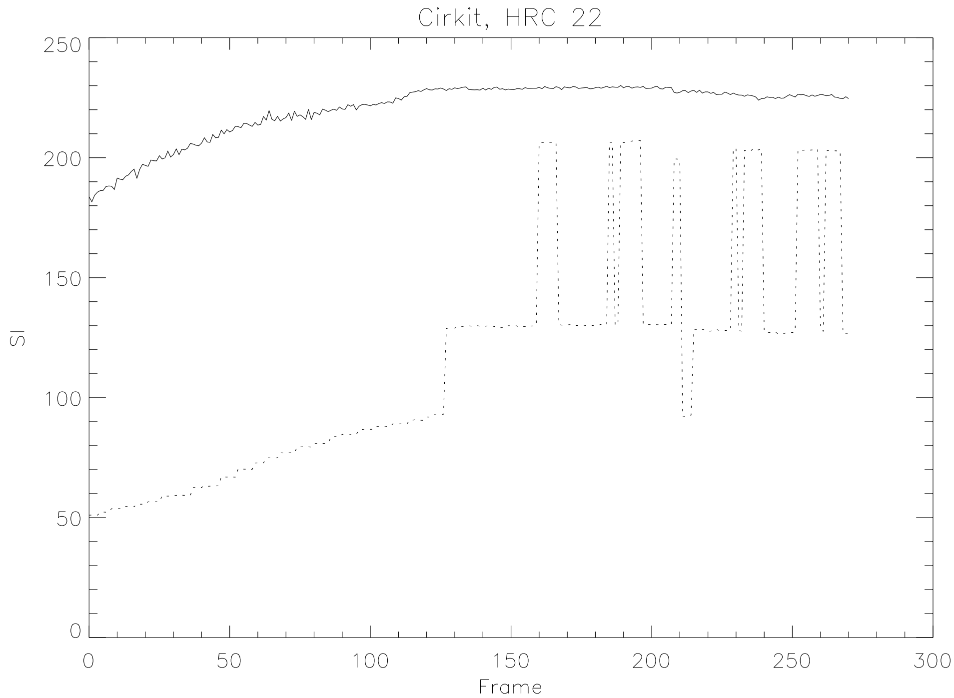

Figure 1 SI_S (solid line) and SI_D (dashed line) for Scene Cirkit, HRC 22

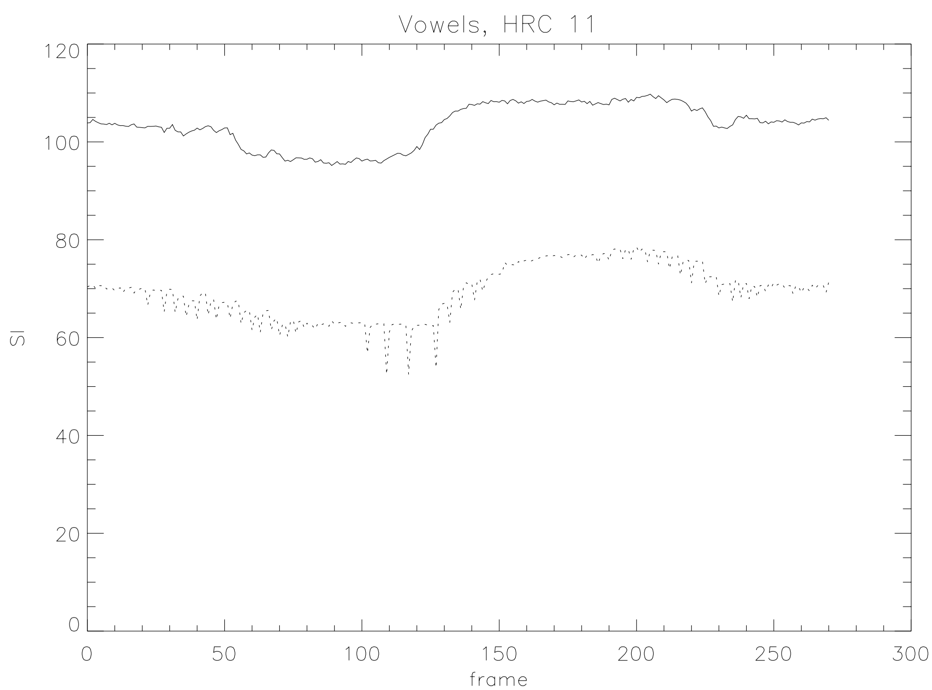

Figure 2 SI_S (solid line) and SI_D (dashed line) for Scene Vowels, HRC 11

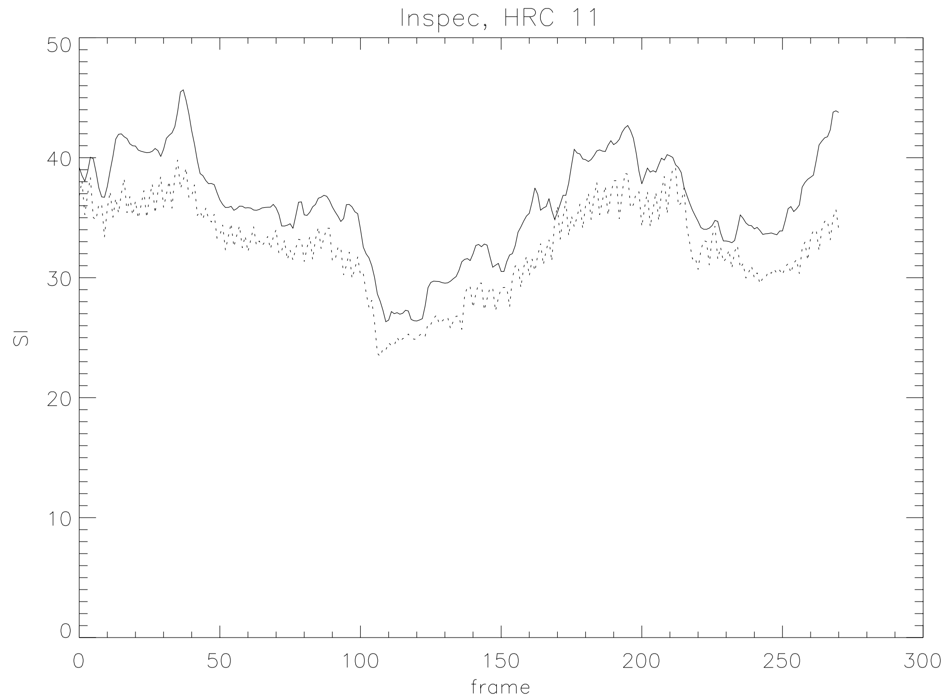

Figure 3 SI_S (solid line) and SI_D (dashed line) for Scene Inspec, HRC 11

The preceding figures suggest a method for detecting the effects of temporal edge noise that is based upon comparative frequency analysis of the time history of the SI feature. This method accumulates the energy of the non-dc frequencies that have been added to the SI_S time history. One possible method for performing this analysis is given by the following algorithm:

(1) Optionally, if one desires to examine the relative additions or deletions in the frequency spectrum of the SI time waveforms, then normalize the variance of the SI time waveforms to 1.0. To perform this normalization, divide the SI_S and SI_D time samples by their standard deviation over time (std_{time}), where the std_{time} is computed over the same time period as the spectral analysis in step 2. This optional step, where the SI samples are replaced by normalized SI samples, is specified in equation form as

$$SI_S(t_n) \leftarrow \frac{[SI_S(t_n)]}{[std_{time}(SI_S)]} \tag{1}$$

$$SI_D(t_n + d_v) \leftarrow \frac{[SI_D(t_n + d_v)]}{[std_{time}(SI_D)]} \tag{2}$$

where t_n is the time at which the SI_S feature is sampled, $t_n + d_v$ is the time at which the

SI_D feature is sampled, and d_v is video delay of the HRC (see T1A1.5/93-152 for a method of measurement for d_v).

This normalization step is not performed if one desires to examine the absolute differences in the frequency spectra of the SI time waveforms.

(2) Take the Fourier transform of each SI time history. If there are N total time samples in the SI time waveform that one wishes to examine, then the magnitude of frequency bin (f_i) will be denoted $|F_S(f_i)|$ for the source video and $|F_D(f_i)|$ for the destination video. Here, the source frequency spectrum is obtained by taking the Fourier transform of the time history $\{SI_S(t_0), SI_S(t_1), ..., SI_S(t_{N-1})\}$ and the destination frequency spectrum is obtained by taking the Fourier transform of the time history $\{SI_D(t_0+d_v), SI_D(t_1+d_v), ..., SI_D(t_{N-1}+d_v)\}$.

Note: Since the input SI sequences are real, only frequency bins i=0 to i=N/2 need to be considered in the output Fourier spectrum (i.e., $f_0 \le f_i \le f_{N/2}$).

Applying step 2 of the above process to the SI time histories shown in Figures 1-3 yields the frequency spectra shown in Figures 4-6, respectively. Note that the SI_D frequency spectra (dashed lines) have more high frequencies than the SI_S frequency spectra (solid lines).

(3) To detect temporal edge noise in the destination video (i.e., the added high frequency noise shown in Figures 4-6), compute the following summation:

$$\sum_{i \neq 0} \{ max(\log 10 [|F_D(f_i)|] - \log 10 [|F_S(f_i)|] - T_i, \quad 0) \} . \tag{3}$$

Here, the max (., 0) function limits the summation to include only those frequency bins in the destination frequency spectrum ($|F_D(f_i)|$) that have magnitudes (on the log10 scale) higher than threshold T_i above the source frequency spectrum ($|F_S(f_i)|$). The perceptibility threshold T_i, which in general is a function of frequency, allows one to adjust the sensitivity of the summation to these added frequencies.

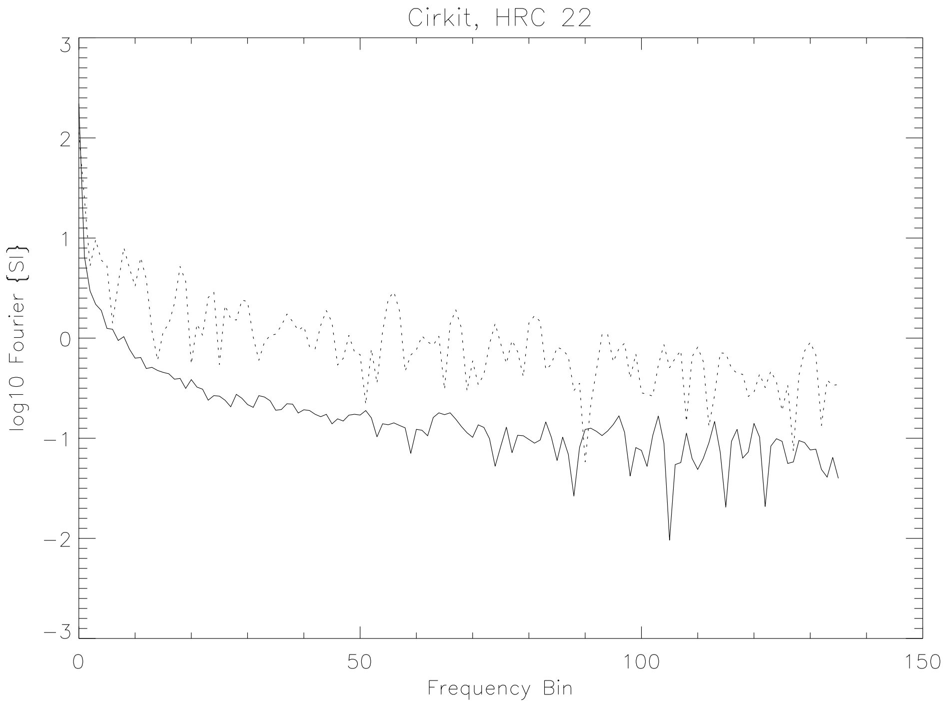

Figure 4 Frequency Spectrum of SI_S (solid line) and SI_D (dashed line) of Figure 1

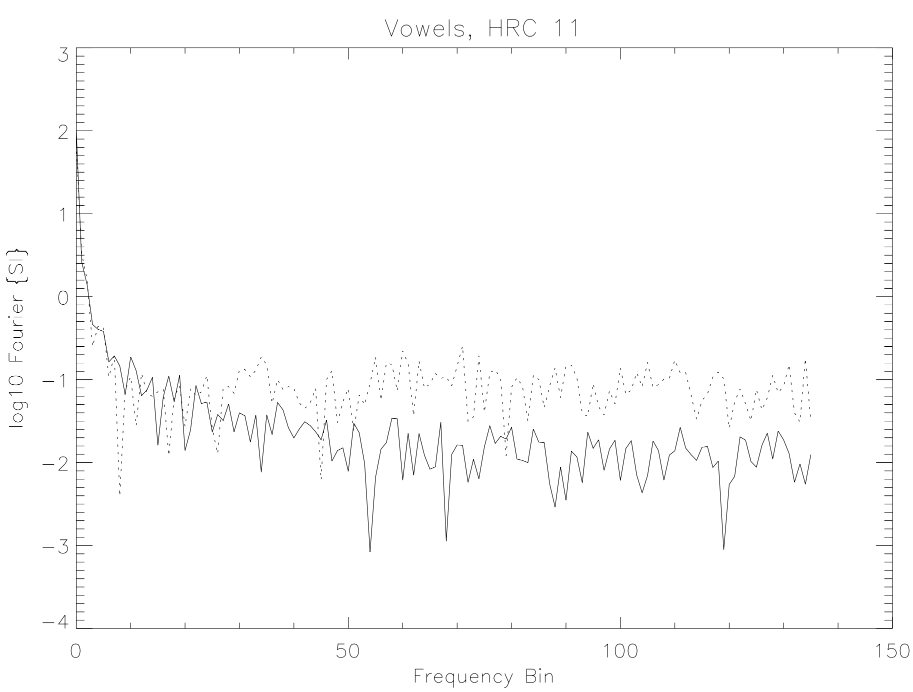

Figure 5 Frequency Spectrum of SI_S (solid line) and SI_D (dashed line) of Figure 2

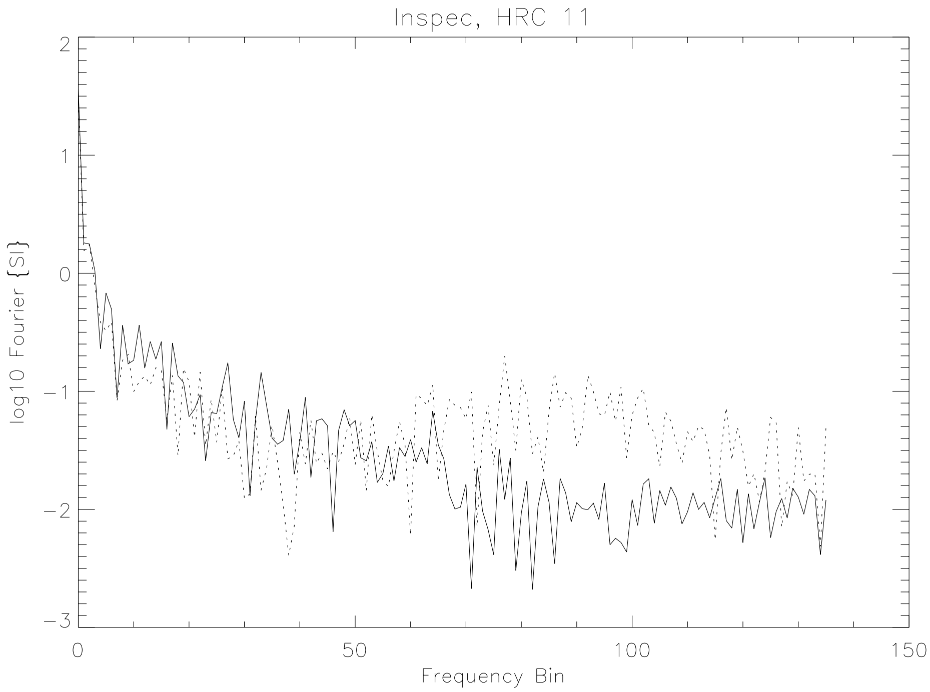

Figure 6 Frequency Spectrum of SI_S (solid line) and SI_D (dashed line) of Figure 3

3. Conclusion

This contribution has presented a new analysis technique for detecting the temporal edge noise digital video impairment. The analysis technique uses the Fourier transform of the SI time histories to detect the high frequency components which have been added as a result of temporal edge noise.