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The Use of Side Information in Image Steganography

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Abstract

The application of error correcting codes for steganographic techniques can improve the BER of the recovered hidden message. We show here several ways that side information can be extracted from the cover data to help improve the performance of the error correction.

1. Introduction

There are numerous steganographic techniques (e.g., data hiding and watermarking) that use digital images to cover the existence of information. Applications for such methods can provide the concealment of authentication data for the image itself, copyright protection, and image fingerprinting, among many other uses.

Some image steganographic methods embed information within white Gaussian noise (WGN) which is subsequently added to the digital image to form the *stego-image* [1]. Because the hidden data must be concealed, the added noise is of low power; therefore it is difficult to detect by the human visual system and difficult for the decoder to extract without knowing the original image. The recipient has no knowledge of the original image and possesses only the stego-image along with a key to extract the hidden data. Our system in particular uses error-control coding to achieve improved performance while maintaining a low noise power [2]. With this system, the hidden information is encoded by an error-control code before it is embedded into the WGN signal. The WGN signal with the embedded data, the *stego-signal*, is then added to the image. At the receiver, the embedded stego-signal is estimated as the difference between the stego-image and a denoised version of the stego-image. The embedded information is extracted from the estimated stego-signal and any remaining errors are corrected by the error-control decoder.

2. Obtaining Side Information

Unfortunately, the estimate of the stego-signal is typically poor because the power of the signal is very low compared to the image power, and the denoising process is not optimal. Consequently, decoding errors are made. In an effort to address this shortcoming without increasing the stego-signal power (and visual detectability), we found that the locations of poor signal estimation, and thus decoding errors correlate to the edges within the image. This can be easily attributed to the inability of the image processing filters used for denoising to estimate the value of noise in the vicinity of an edge. As an example, Figure 1 shows an original image using for our experimentation. Using the results of applying a hard decision decoder we were able to construct an error map to indicate where in the image decoding errors were made. The binary error map is depicted in Figure 2 with white pixels representing decoder bit errors. Notice the correlation between the edges in the image and the errors.

Figure 1: Original Eiger Image

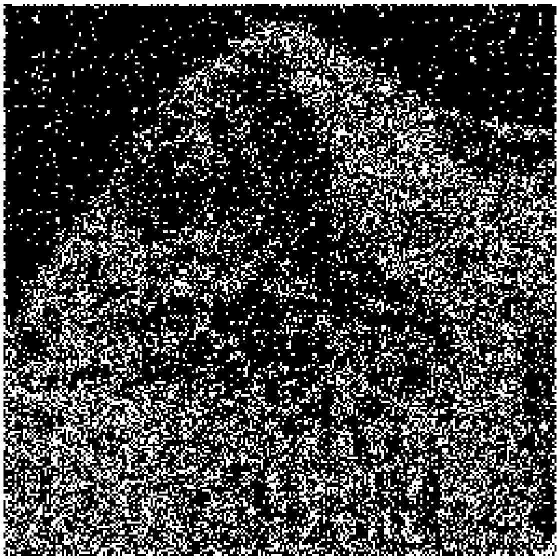

Figure 2: Error Map for Eiger Stegoimage

This phenomenon can be exploited to better correct bit errors by incorporating the edge information (extracted from the received stego-image) as side information input to the error-control decoder. In the following section, we demonstrate three different ways to extract and apply the side information.

3. Experimentation

Using the method described in [2], several stego-images were generated for a wide range of stego-signal powers to demonstrate the effect of side information. A rate 1/6 convolutional code was used to provide error correction. The Viterbi algorithm was used for decoding with both hard-decision and soft-decision (log-likelihood) data. In addition, side information was applied in three ways. First we used an edge detector to extract a binary edge map from the stego-image. Edge locations in the map were used to signify *erasures* and combined with the hard-decision data as inputs to the soft-decision decoder. In the second side information application, the edge detection was replaced by the results of filtering the stego-image with a variance filter to obtain what can be considered as *soft* edge information. This filter computes the local variance, or energy, in a group of pixels and is an indicator of edge and non-edge regions [3]. We used this variance information to weigh the log-likelihood ratio, and the result was used as input into the soft-decision decoder. Lastly, we used the actual errors from the hard-decision decoder as a priori information to create a probability of error statistic. This information was used to calculate the conditional probability of error for a given variance value. (Generic tables for this data could be constructed by averaging over several similar images and stego-signal power combinations. These tables could then become a static part of the decoder, thus eliminating the dependency on a priori information.) For our purposes, the conditional probabilities were derived for each specific image.

4. Results

A graph illustrating the relationship of decoder output BER to the steganographic SNR (Stego-SNR) is shown in Figure 3. Stego-SNR indicates the power ratio of the stego-signal to the image signal. Low Stego-SNR is proportional to low stego-signal power and reflects greater concealment of the hidden data.

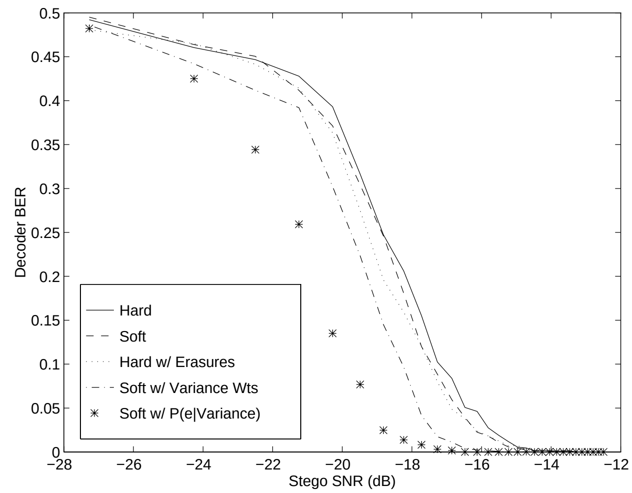

Figure 3: Comparison of Side Information Techniques

From this graph, we can see that as the Stego-SNR is increased, the BER decreases for all decoder implementations. This result is intuitive, in that as the power of the signal becomes stronger, fewer bit errors should occur. Next notice that when the Stego-SNR is very low, the BER value for all decoders approaches 0.5, indicating that the decoders are providing no information about the embedded signal. As the stego-signal power is increased, the varying performance of the different decoders is evident. The solid line represents the performance of the hard-decision Viterbi decoder without side information. The dashed line shows performance of the soft-decision decoding via the log-likelihood ratio and reflects an average increase in coding gain (over the hard-decision decoder) of 0.3 dB in Stego-SNR. The dotted line indicates the improvement obtained by using erasure side information to the Viterbi decoder, resulting in an average coding gain of 0.5 dB Stego-SNR. The dashed-dotted line illustrates the improvement of using the variance to weigh the log-likelihood ratio, providing a coding gain of 1.3 dB Stego-SNR over hard-decision decoder. Finally, the performance using $P(error|variance)$ side information, derived from a priori information, is represented by the asterisks. An average coding gain of 2.5 dB in Stego-SNR is achieved using the this last method. Side information improves the performance of this system by permitting the use of a lower stego-signal power for the same bit error rate, thus reducing the detectability of the hidden data. Conversely, the side information could be used to increase the amount of hidden information in the image for a given stego-signal power.

5. Conclusions

We have shown that the use of error correcting codes can help improve the BER of the hidden steganographic message. Several methods of using side information with soft decision decoding were compared with hard decision decoding.

References

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