Secure Information Delivery through High Bitrate Data Embedding within Digital Video and its Application to Audio/Video Synchronization

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ABSTRACT

Secure communication has traditionally been ensured with data encryption, which has become easier to break than before due to the advancement of computing power. For this reason, information hiding techniques have emerged as an alternative to achieve secure communication. In this research, a novel information hiding methodology is proposed to deliver secure information with the transmission/broadcasting of digital video. Secure data will be embedded within the video frames through vector quantization. At the receiver end, the embedded information can be extracted without the presence of the original video contents. In this system, the major performance goals include visual transparency, high bitrate, and robustness to lossy compression. Based on the proposed methodology, the authors have developed a novel synchronization scheme, which ensures audio/video synchronization through speech-in-video techniques. Compared to existing algorithms, the main contributions of the proposed methodology are: (1) it achieves both high bitrate and robustness against lossy compression; (2) it has investigated impact of embedded information to the performance of video compression, which has not been addressed in previous research. The proposed algorithm is very useful in practical applications such as secure communication, captioning, speech-in-video, video-in-video, etc.

Keywords: Bitrate, Channel Capacity, Compression, H.264/AVC, Information Hiding, Robustness, Video

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1. INTRODUCTION

Secure communication has been extensively studied in modern information and communication systems. Traditionally, the security of transmitted information is ensured with data encryption (Yang, Li & Bourbakis, 2004; Maniccam & Bourbakis, 2001). Nowadays, in order to enhance the level of security, researchers have started to utilize information hiding techniques, which conceal not only the content and location of the protected data, but also its very existence. In terms of the amount of data to be embedded, information hiding algorithms can be classified as high bitrate and low bitrate. According to modern information hiding theory, the embedding capability of the host video frames provides an additional communication channel with a certain capacity, which could be used to transmit secure data without degrading host video’s visual quality. The applications of high bitrate video information hiding include secure communication, captioning, speech-in-video, video-in-video, etc. (Yang & Bourbakis, 2005; Yang & Bourbakis, 2005). In high bitrate video information hiding, the following performance goals are mainly concerned:

1. **Visual Transparency:** The embedding data should not interfere with the visual fidelity of host video (Zhang, Cheung & Chen, 2005; Ni et al., 2004);
2. **High Bitrate (also known as Channel Capacity):** Large amount of data need to be effectively embedded (Cvejic & Seppiinen, 2004; Yang & Bourbakis, 2009; Kundur, 2000; Lin & Chang, 2001; Moulin & Milcak, 2002; Mukherjee, Chae & Mitra, 1998; Wang & Izquierdo, 2002; Briiffa & Das, 2002);
3. **Blind Retrieval:** The presence of original video contents should not be required for information extraction (Yang & Bourbakis, 2005; Yang & Bourbakis, 2005);
4. **Robustness to lossy video codec:** The embedded information should be robust to lossy video codec (Gunsel, Uludag & Tekalp, 2002; Fei, Kundur & Kwong, 2001; Ni et al., 2004);
5. **Minimum impact to video compression:** The impact to the performance of video codec should be minimized (Chang, Chen & Lin, 2004).

The most straightforward spatial-domain algorithm is Least-Significant-Bit (LSB) embedding. However, it is very sensitive to lossy compression. Maniccam and Bourbakis (2004) proposed a spatial-domain algorithm based on the texture analysis of each 3x3 neighborhood within the image. Transform-domain algorithms embed information in the frequency domain of host video. Swanson, Zhu, and Tewfik (1997) proposed a vector projection based high bitrate information hiding algorithm, which embeds data by the projection of Discrete Cosine Transform (DCT) coefficients vector. Alturki and Mersereau (2001) proposed to embed data by whitening the image and quantizing each DCT coefficient. Chae and Manjunath (1999) made use of lattice structure to embed information in the mid-frequency region of DCT block.

Existing research have not been able to achieve all of the above performance goals. Most of existing algorithms perform well in some aspects but cannot meet the other performance requirements. Also, the embedded information will inevitably alter the textural details of the image and thus degrade the performance of video compression. However, quantitative analysis of the impact has not been studied in previous research.

In this paper, our goal is trying to design a high bitrate video information hiding algorithm and obtain a balance between channel capacity and robustness. We are also trying to minimize the impact to the performance of video codec. The performance goals mentioned above are pursued and evaluated by the following methods:

1. **Visual Transparency:** We apply Weber’s Law and Watson’s Luminance/Contrast Masking to ensure visual transparency. The