A Theoretical Framework for Data-Hiding in Digital and Printed Text Documents

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In this work, we consider the text data-hiding problem as a particular instance of the well-known Gel'fand-Pinsker problem [1]. The text, where some message $m \in \mathcal{M}$ is to be hidden, is represented by $\mathbf{x}$ and called cover text. Each component x_i, $i = 1, 2, \ldots, N$, of $\mathbf{x}$ represents one character from this text. Here, we define a character as an element from a given language alphabet (e.g. the latin alphabet {A, B, ..., Z}). To be more precise, we conceive each character x_i as a data structure consisting of multiple component fields (features): *name*, *shape*, *position*, *orientation*, *size*, *color*, etc.

Assuming the knowledge of the conditional probability distribution $p(u|x)$, $|\mathcal{M}||\mathcal{J}|$ codewords $\mathbf{u}$ are generated independently at random and located into $|\mathcal{M}|$ bins, each of them with $|\mathcal{J}|$ codewords. Once generated, the codebook is revealed to both the encoder and the decoder. Given m to be communicated, the encoder produces the watermark $\mathbf{w}$ by finding first a jointly strongly typical pair $(\mathbf{x}, \mathbf{u}(m, j))$, where $\mathbf{u}(m, j)$ is the j-th codeword inside the bin corresponding to m, and then, by using a deterministic mapping $\mathbf{w} = \varphi^N(\mathbf{x}, \mathbf{u})$. The influence of the channel $p(v|w, x)$ is divided in two stages. In the first stage, $\mathbf{w}$ and $\mathbf{x}$ are combined via a deterministic mapping $\psi^N(\mathbf{w}, \mathbf{x})$ to give the stego text $\mathbf{y}$. In the second stage, $\mathbf{y}$ may suffer from some intentional or unintentional distortions. We denote by $\mathbf{v}$ the resulting distorted version of $\mathbf{y}$. Finally, $\mathbf{v}$ is fed to the decoder, which tries to obtain an estimate $\hat{m}$ of message m by using the jointly strongly typical decoding rule.

As a particular example of the Gel'fand-Pinsker scheme, let us consider the Scalar Costa Scheme (SCS) [2] where the stego text Y is obtained as $Y = W + X = \alpha' Q_m(X) + (1-\alpha')X$, where $Q_m(\cdot)$ is a scalar quantizer corresponding to m and α' is a compensation parameter. For a practical implementation based on the SCS, we only need to select a character feature (e.g. color), and use it as the cover character X. We show in Fig. 1 the resulting SCS codebook and an illustration of how to use it for text data-hiding.

Based on the above framework, we propose two new methods for text data-hiding: *color quantization* and *halftone quantization*. The exploited character features are, respectively, *color* and *halftone pattern* (see Fig. 2). The main idea of these methods is to quantize the character feature in such a manner that the human visual system is not able to distinguish between the original and quantized characters, but it is still possible to do it by a specialized reader, e.g. a high dynamic range and/or high resolution scanner in the case of printed

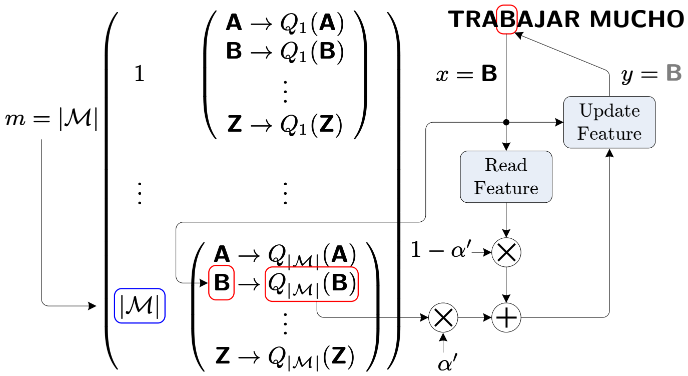

Fig. 1. SCS text data-hiding.

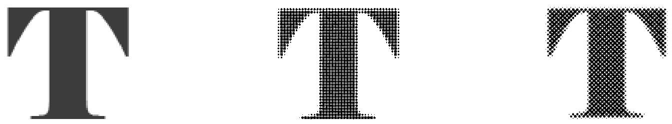

Fig. 2. Halftone quantization: (a) original character; (b) marked character for $m = 0$, screen angle $= 0°$; (c) marked character for $m = 1$, screen angle $= 45°$.

documents. In particular, we show that the color quantization method works both for digital and printed documents, has high information embedding rate, is perceptually invisible, and is fully automatable.

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