On Ryabko and Ryabko asymptotically optimal perfect steganographic scheme in a noisy channel

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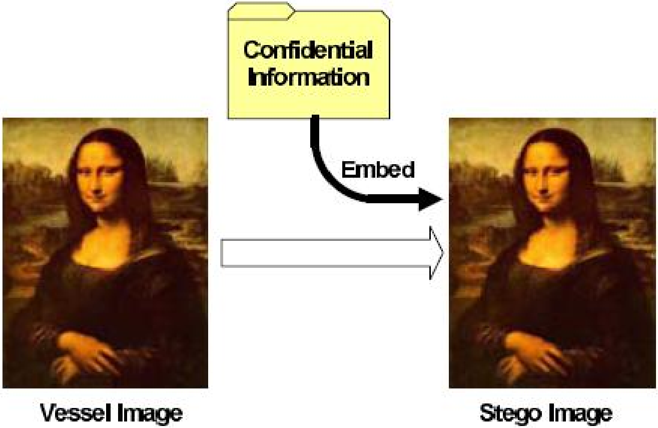
Outline

The Idea of Steganography



Formal Definition

Definition

An *embedding scheme* of quality T is a pair of mappings $E : V \times X \to S$ and $D : S \to X$ such that for any message $x \in X$ and any container $v \in V$ the stegoword $s = E(v, x)$ possesses the following properties:

(1) $D(s) = x$

(2) $d(v, s) \leq T$

Ryabko and Ryabko Scheme

There is a source μ of containers v. Containers are generated as strings of symbols which are i.i.d. random variables from some finite alphabet $\mathbb{A}$. Secret binary messages are independent and generated equiprobably by a source ω. In the channel the warden can intercept and then reads all messages.

Ryabko and Ryabko Scheme. Construction for the Binary Case

The binary message $x = x_1x_2x_3\ldots$ is embedded into the container $v = v_1v_2v_3v_4\ldots,\ v_i \in \mathbb{A} = \{a, b\}$.

- The symbols of v are divided into pairs and renamed in the following way:

$$aa = u,\ bb = u,\ ab = y_0,\ ba = y_1.$$

- The pairs, corresponding to u, are idle, but the pairs y_i are changed into pairs associated with $y_{x_1}y_{x_2}y_{x_3}\ldots$ in the following way:

$$(s_{2i-1}, s_{2i}) = (\min\{v_{2i-1}, v_{2i}\}, \max\{v_{2i-1}, v_{2i}\}) \text{ if the embedded } x_k = 0 \text{ and}$$

$$(s_{2i-1}, s_{2i}) = (\max\{v_{2i-1}, v_{2i}\}, \min\{v_{2i-1}, v_{2i}\}) \text{ if the embedded } x_k = 1.$$

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Ryabko and Ryabko Scheme. Construction for the Binary Case

Example

Let the secret message be $x = 0110\ldots$ and the container $v = aababaaaabaaaabb\ldots$. By renaming pairs we get $v = uy_1y_1uy_0y_1uuu\ldots$. We embed x and end up with the stegoword $s = uy_0y_1uy_1y_0uuu\ldots = aaabbaaabaabaaaabb\ldots$.

Single Errors on a Pair of Symbols of the Stegoword

With a single error pairs

- *aa* and *bb* turn to pairs *ab* or *ba*
- *ab* and *ba* turn to pairs *aa* or *bb*

Example

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Generalized Scheme for Non-binary Case

Symbols of the container are from the alphabet $\mathbb{A} = \{0, 1, 2, ..., q-1\}$, which symbols are ordered as integers. The two stages of embedding are the same as for the binary case.

- The symbols of v are divided into pairs and renamed in the following way:

$$\alpha\alpha = u \text{ for all } \alpha \in \mathbb{A}$$
$$\alpha\beta = y_0 \text{ if } \alpha < \beta$$
$$\alpha\beta = y_1 \text{ if } \alpha > \beta.$$

- The pairs, corresponding to u, are idle, but the pairs y_i are changed into pairs associated with $y_{x_1} y_{x_2} y_{x_3} \ldots$ in the following way:

$$(s_{2i-1}, s_{2i}) = (\min\{v_{2i-1}, v_{2i}\}, \max\{v_{2i-1}, v_{2i}\}) \text{ if the embedded } x_k = 0 \text{ and}$$
$$(s_{2i-1}, s_{2i}) = (\max\{v_{2i-1}, v_{2i}\}, \min\{v_{2i-1}, v_{2i}\}) \text{ if the embedded } x_k = 1.$$

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The Model of Errors for the Non-binary Case

- With a single error pairs $\alpha\alpha$ turns to $\alpha\beta$ or $\beta\alpha$
- If $\alpha < \beta$, a pair $\alpha\beta$ contains 0. With the conditional probability $\frac{2}{q-1}$ the pair turns into $\alpha\alpha$. If α turns into α' and $\alpha' > \beta$ or β turns into β' such that $\alpha > \beta'$, the regular reversal happens. The probability of reversal depends on the pair! Say α is k-th symbol in the alphabet and β is l-th symbol ($k < l$). The conditional probability of the reversal is $\frac{q-1-l}{q-1} + \frac{k}{q-1}$.

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Conclusion

We have investigated the universal perfect steganographic system and its behavior during the transmission via a noisy channel or, the same, a channel with an active warden . If an error in transmitted stegoword happens during the transmission, an insertion/deletion takes place in the embedded secret message.

Thank you for your attention!

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