A NEW JOINT WATERMARKING-ENCRYPTION-JPEG-LS COMPRESSION METHOD FOR A PRIORI & A POSTERIORI IMAGE PROTECTION

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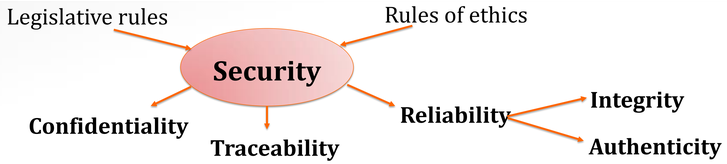
Objectives/Solution/Results Ensuring the traceability and integrity/authenticity control of medical images directly from their compressed and encrypted bitstream.// The proposed scheme allows message insertion during the joint JPEG-LS encoding and encryption of the image. This scheme grants message extraction from both encrypted and compressed bit-streams without having to parse them even partially.// Achieved capacities can provide different watermarking-based security services (e.g. traceability, integrity).

1. Issues



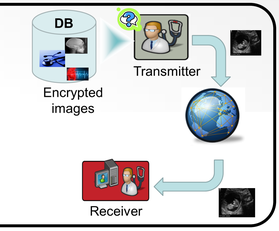
⟹ Objective: Merging encryption (*a priori* protection) and watermarking (*a posteriori* protection) into a single security mechanism.

Constraints

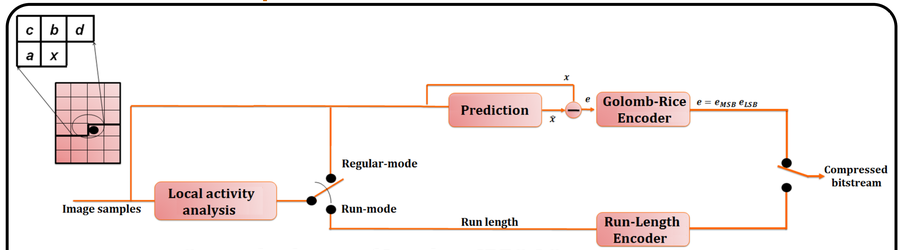
- Medical domain induces large volumes of medical images to protect.
- Needs for watermarking-based security services in both compressed and encrypted domains.

⟹ **Watermark extraction directly from the compressed or/and the encrypted image bitstreams.**

⟹ **Interest for joint watermarking, encryption and compression.**



2. JPEG-LS Compression



-General scheme of Lossless JPEG-LS compression-

- $\boldsymbol{x}$: current encoding pixel of an image ; $\{a, b, c, d\}$ the causal neighborhood of x.
- Based on the causal neighborhood of x, JPEG-LS works in 2 modes:

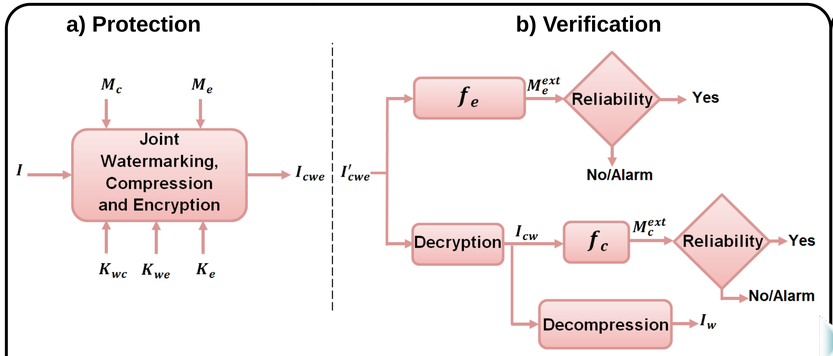
1) Run-mode (if $\boldsymbol{a = b = c = d}$) : Run length encoding (Encoding of the repetition number).
2) Regular-mode**:**
   i) Prediction of x based on the values of $\{a, b, c\}$ ➔ Prediction error : $e = x - \hat{x}$
   ii) Golomb-Rice encoding of the prediction-error e using the context-dependent factor k :

$$\boldsymbol{e = {}'e_{MSB}\ e_{LSB}'}$$

Unary code of $\lfloor e/2^k \rfloor$ $\boldsymbol{e_{MSB}} = 'X1'$; X : sequence of '0's

Binary code of $(e/2^k)$ reminder represented on $\boldsymbol{k}$ bits

3. Joint Watermarking-Encryption-Compression (JWEC)



-General architecture of the proposed JWEC system-

- I: original image
- I_{cwe} : watermarked-encrypted-compressed image
- I_{cw} : decrypted-watermarked-compressed image
- I_w : decompressed-decrypted-watermarked image
- K_{wc} and K_{we} are the watermarking keys in compressed and encrypted domains, respectively.
- M_c and M_e: messages embedded in compressed and encrypted domains, *resp.*
- M_c^{ext} and M_e^{ext}: messages extracted from compressed and encrypted domains, *resp.*

Compressed-bitstream protection (Embedding of M_c) & verification

$\boldsymbol{e} = {}'\boldsymbol{e_{MSB}}\ \boldsymbol{e_{LSB}}'$: Golomb-Rice coding of the prediction-error.

- If $\boldsymbol{e_{MSB}} = 'X1'$ (reference sequence) ➔ $\boldsymbol{e^1{}_{LSB} = b_i}$; ($b_i : i^{th}$ bit of the message $\boldsymbol{M_c}$; $\boldsymbol{e^1{}_{LSB}}$ higher order bit of e_{LSB}.).
- To extract $\boldsymbol{M_c}$, the watermark reader just identifies the reference sequence $'X1'$ in the compressed bitstream and reads the immediate following bit.
- Example - reference sequence $'X1' = '0001'$ - watermarked-compressed bitstream :

'000010100**0001**0111010**0001**1000001111**0001**111**0001**1010011**0001**0**1**'

➔ The embedded message M_c corresponds to '01110'.

Encrypted-compressed-bitstream protection (Embedding of M_e) & verification

- Encryption based on AES in CBC mode ➔ Compliant with the DICOM standard.
- In the block B_{ci}^{w} (i^{th} block of consecutive bits of the previous watermarked-compressed JPEG-LS bitstream), one bit of $\boldsymbol{M}_e$ is embedded such that:

$$f_e(B_{ci}^{we}, K_{we}) = f_e(AES(B_{ci}^{w}, K_e), K_{we}) = M_{ei}$$

where, f_e is the watermark extraction function in the encrypted domain, K_e is the AES-encryption key and K_{we} is the watermarking key.

4. Experimental results

- **Image data set:** 1200 8-bit Retina images and over 700 16-bit X-ray images.
- **Performance criteria**
  - Image distortion measure between the original image I and its watermarked decompressed-decrypted counterpart I_{wd}

➔Peak Signal to Noise Ratio (dB): $PSNR(I, I_{wd}) = 10\log_{10}(\frac{(2^p-1)^2}{MSE})$; where $MSE = \frac{1}{MN}\sum_{k=1}^{M\times N}\left(I(k) - I_{wd}(k)\right)^2$

M×N corresponds to the number of pixels of the image.

  - Capacity rate in bpp (bits of message per image pixel).

- Obtained **PSNR** values are greater than 46 dB and 95 dB for retina and X-ray images, *resp.*
- **Achieved capacities in the encrypted domain:** 0.03 bpp and 0.05 bpp for retina and X-ray images, respectively.
- **Achieved capacities in the compressed domain:** 0.14 bpp and 0.18 bpp for retina and X-ray images, respectively.

5. Conclusions and future works

- The proposed joint watermarking-encryption-JPEG-LS scheme allows the access to watermarking-based security services directly from both encrypted and compressed domains.
- The proposed scheme guarantees an a priori as well as a posteriori image protection.
- The visual quality of the watermarked image is closed to its original version.
- Future works will focus on improving the robustness of the watermark to attacks (e.g. lossy image compression, additive noise,...) while preserving the image quality.

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