A HIGH CAPACITY REVERSIBLE WATERMARKING SCHEME

Marc CHAUMONT and William PUECH
marc.chaumont@lirmm.fr and william.puech@lirmm.fr
LIRMM, UMR CNRS 5506, Université de Montpellier II,
Université de Nîmes.

LIRMM

INTRODUCTION TO REVERSIBILITY CONCEPT:

> " The watermarked Works (in the case of reversible watermarking) need only to be recognizable, and **salt-and-pepper artifacts might not be a serious problem**."
> (Digital Watermarking and Steganography, Cox, Miller, Bloom, Fridrich, Kalker, 2007, p. 382)

- The 2 main **requirements** for a reversible watermarking are **capacity and rapidity**,
- 3 **categories** of reversible watermarking schemes: the **compression-based**, the **histogram-based** and the **expansion-based**,
- The current paper is an **improvement of** the expansion-based algorithm of D. Coltuc: **"Improved Capacity Reversible Watermarking", ICIP'2007**.

ALGORITHM:

Mathematical part:

- $n \geq 3$
- $T : \mathbb{N} \times \mathbb{N} \rightarrow \mathbb{N}$

$$T(x_1, x_2) = (n+1).x_1 - n.x_2.$$

- the image is noted *I and the watermarked image I_w*

General embedding algorithm:

STEP 1: Classify pixels into 3 different classes: *embedding*, *to-correct* and *original.*

embedding pixel $\equiv$ $0 \leq T(I(i), I(i+1))$ *and* $T(I(i), I(i+1)) + n \leq 255$,
to-correct pixel $\equiv$ $T(I(i), I(i+1)) < 0$ *or* $T(I(i), I(i+1)) + n > 255$,
original pixel $\equiv$ stand before a *to-correct* pixel.

STEP 2: Embed into *embedding* pixels the corrective-codes + the message.

Note that *embedding* pixels:
- are T transformed : $I_T(i) = T(I(i), I(i+1))$.
- must embed a coefficient w belonging to [1, n]: $I_w(i) = I_T(i) + w$.

General extraction algorithm:

STEP 1: Classify pixels into 3 different classes: *embedding*, *to-correct* and *original*,
Extract from *embedding* pixels the corrective-codes + the message.

STEP 2: Correct the *to-correct* pixels.

Details of STEP 1 of embedding:

Scan image I from left to right and top to bottom
begin
if pixel **i** is an *embedding pixel*
then apply transformation to I : $I_T(i) = T(I(i), I(i+1))$
else - find next pixel **j** which is an *embedding pixel*
- alternate *unmodified pixel* and *to-correct* pixel between **i** and **j-1** or between **i-1** and **j-1** (depending of **j-i** parity)
end-if
end

All pixels in the *to-correct* state are modified such that:

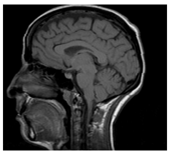
$$c \leftarrow (I(i) + n.I(i+1)) \ mod \ (n+1);$$
$$if \ (I(i) - c) < 0 \ then \ c \leftarrow -(n+1-c);$$
$$I_w(i) \leftarrow I(i) - c.$$

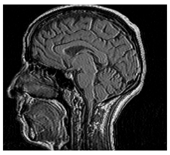
with c a corrective-code which will have to be embedded.

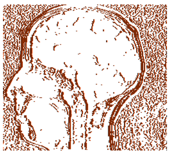
Details of STEP 1 of extraction:

Scan image I from right to left and bottom to top
begin
if pixel **i** is such that $(I_w(i) + n.I(i+1)) \ mod \ (n+1) \neq 0$
then pixel **i** is an *embedding pixel*
- extract coefficient w
- correct pixel i
else - alternate *unmodified pixel* and *to-correct* pixel until finding an *embedding pixel*
end-if
end

RESULTS AND CONCLUSIONS:

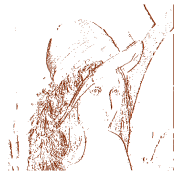

228x256 *head* image

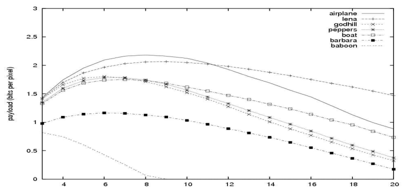

watermarked image, n=4, PSNR=19.8 dB, payload=0.99 bpp


states map
white: embedding pixels
red: to-correct pixels
black: original pixels


512x512 Lena image


watermarked image, n=4, PSNR=19.6 dB, payload=1.7 bpp


states map
white: embedding pixels
red: to-correct pixels
black: original pixels



Real payload in function of parameter **n** for few classical 512x512, 8-bits images

Image	payload		PSNR
Airplane	457 256 bits	1.74 bpp	20.90 dB
Lena	445 294 bits	1.70 bpp	19.60 dB
Godhill	435 040 bits	1.66 bpp	18.56 dB
Peppers	418 710 bits	1.60 bpp	19.56 dB
Boat	409 444 bits	1.56 bpp	19.52 dB
Barbara	285 620 bits	1.09 bpp	18.82 dB
Baboon	195 608 bits	0.75 bpp	16.10 dB

Payload on few classical grey-level images, 512x512, 8-bits per pixel with **n=4**

Conclusion:

- One of the **highest** reversible watermarking schemes for its **capacity**,
- A **very low complexity approach**.

↳ Future work should take into account *corrective-codes* compression, security with order-scan, tradeoff between distortion and payload.

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