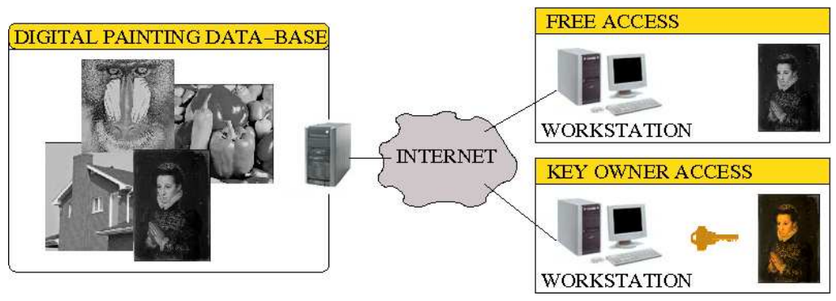
FAST PROTECTION OF THE COLOR OF HIGH DIMENSION DIGITAL PAINTING IMAGES

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

OBJECTIVE :
COLOR SECURED of image database.
↳ free access to grey-level images,
↳ key-manage access to the color information.
↳ fast approach for high dimension digital painting images.

PRINCIPLE :
A solution based on a DATA-HIDING method
where COLOR PALETTE is the message and INDEX IMAGE is the cover.



TWO MAIN STEPS:

1- Fast Decomposition Algorithm:

Find an index image and a color palette with :
- A **color quantized image** close to the **color image**

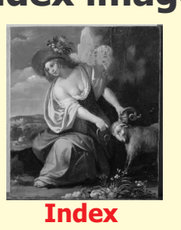

Quantified **C (Index)** *PSNR = 32.7 dB*

≈


Original **I** *(2450x2763) **

E1 fisrt term

- An **index image** close to the **luminance image**


Index *PSNR = 36.7 dB*

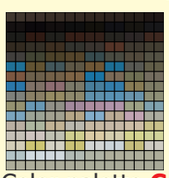
≈


Luminance **Y**

E1 second term

- A **color palette** owning **consecutive couple of close color**

(constraint for an unseen data-hiding)


Color palette **C**

E1 third term

Find an index image *Index* and a color palette *C* by minimizing ***E1***:

$$E1 = \underbrace{\sum_{i=1}^{N}(C(Index(i)) - I(i))^2}_{first\ term} + \underbrace{\lambda_1 \sum_{i=1}^{N}(Index(i) - Y(i))^2}_{second\ term} + \underbrace{\lambda_2 \sum_{k|k\in[1..K]\ and\ k\ is\ odd}(C(k) - C(k+1))^2}_{third\ term},$$

E1 is non-derivable ⇒ Introduction of a close equation ***E2*** :

$$E2 = \sum_{i=1}^{N}\sum_{k=1}^{K} P_{i,k}^{m}(C(k) - I(i))^2 + \lambda_1 \sum_{i=1}^{N}\sum_{k=1}^{K} P_{i,k}^{m}(Y(i) - k)^2 + \lambda_2 \sum_{k|k\in[1..K]\ and\ k\ is\ odd}(C(k) - C(k+1))^2$$

Fast Decomposition Algorithm:

LOOP NB time

1- Select randomly few pixels from the original color image
2- Minimize ***E2*** *:* [Chaumont, Puech, ICIP'2007]

LOOP UNTIL CONVERGENCE

- Compute C (solve linear system A.C = B) with:

$$A = \begin{pmatrix} \lambda_2 + \sum_{i=1}^{i=N} P_{i,1}^{m} & -\lambda_2 & 0 & \dots \\ -\lambda_2 & \lambda_2 + \sum_{i=1}^{i=N} P_{i,2}^{m} & 0 & \dots \\ 0 & 0 & \lambda_2 + \sum_{i=1}^{i=N} P_{i,3}^{m} & \dots \\ 0 & 0 & -\lambda_2 & \dots \\ \dots & \dots & \dots & \dots \end{pmatrix} \quad B = \begin{pmatrix} \sum_{i=1}^{i=N} P_{i,1}^{m} I(i) \\ \sum_{i=1}^{i=N} P_{i,2}^{m} I(i) \\ \dots \\ \sum_{i=1}^{i=N} P_{i,K-1}^{m} I(i) \\ \sum_{i=1}^{i=N} P_{i,K}^{m} I(i) \end{pmatrix}$$

- Compute $P_{i,k}$: $P_{i,k} = \frac{(\sum_{l=1}^{l=K} \frac{1}{2\times((C(l)-I(i))^2+\lambda_1(Y(i)-l)^2}\,)^{-1}}{2 \times ((C(k) - I(i))^2 + \lambda_1(Y(i) - k)^2)}$

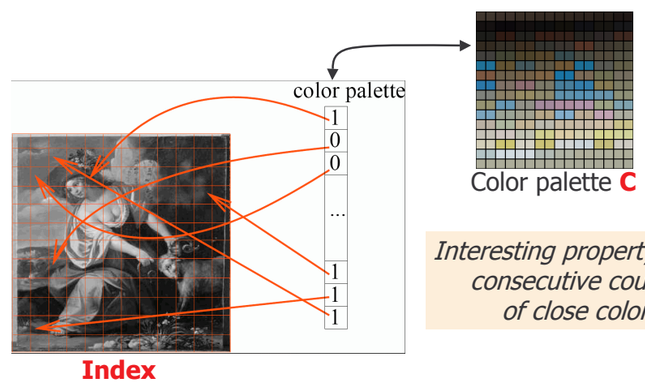
obtain *C* and *Index* / $\forall i, Index(i) = \arg\min_k (C(k)-I(i))^2+\lambda_1(k-Y(i))^2$

3- Evaluate ***E1*** (with another random sub-sampling) knowing *C* and *Index* ;
Keep this solution if it is the best one

2- Data-Hiding:

b_j : the bit to embed,
Index(i) : the index value of pixel *i*
$Index_W(i)$: the index marked value of pixel *i*

$$Index_W(i) = Index(i) - Index(i)\ mod\ 2 + b_j.$$



Interesting property of C: consecutive couple of close color

RESULTS & CONCLUSION:

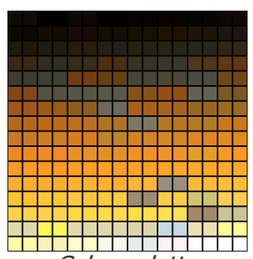
Results: On an Intel Pentium 4, 3.2 GHz with 1GB RAM (10 loops)


Luminance image 8248x11816 = 97 458 368 pixels


Indexed and marked image; PSNR = 39.3dB


Color image **


Rebuild image from index and marked image; PSNR = 34.2dB


Color palette of K=256 colors

images	$PSNR^{lum}$	$PSNR^{color}$
baboon (512×512)	30.9 dB	27.6 dB
airplane (512×512)	38 dB	32.8 dB
pepper (512×512)	33.1 dB	31.8 dB
house (256×256)	36.4 dB	31 dB
barbara (787×576)	32.1 dB	29.8 dB

Obtain in less than 1 minute on an Intel Pentium 4, 3.2 GHz with 1GB RAM (10 loops)

Memory complexity reduction:
- Full image (97 458 368 pixels) : Minimization of *E2* ≈ 186 GB
- Sub-sampled image (9 604 pixels) : Minimization of *E2* ≈ 19 MB

CPU complexity reduction:
- Full image (97 458 368 pixels) : Computations of $P_{i,k}$ ≈ 1.4 hour
- Sub-sampled image (9 604 pixels) : Computations of $P_{i,k}$ ≈ 0.5 second

Conclusion:

- An original **representation of an indexed image,**
- A **fast decomposition (index+palette) algorithm** even on **High Dimension** images,
- An efficient way to **securely hide color** information in an image.

(*) Saint-Germain-en-Laye museum; « *a young woman holding a ram* », Jan van Bylert (1603-1671), oil on oak.
(**) Louvre museum; « *a woman praying* », anonymous, flandres, XVI century, oil on oak.

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