What is inpainting?

- **Modifying an image in a non-detectable form**

Detail of "Cornelia, Mother of the Gracchi" by J. Suvee (Louvre). Courtesy of Emile-Male "The Restorer's Handbook of easel painting".

Another example

Photo restoration

Object removal

Real world example: Object removal

From D. King, “The Commissar vanishes”.

Object removal

Lenin and friend Trotsky

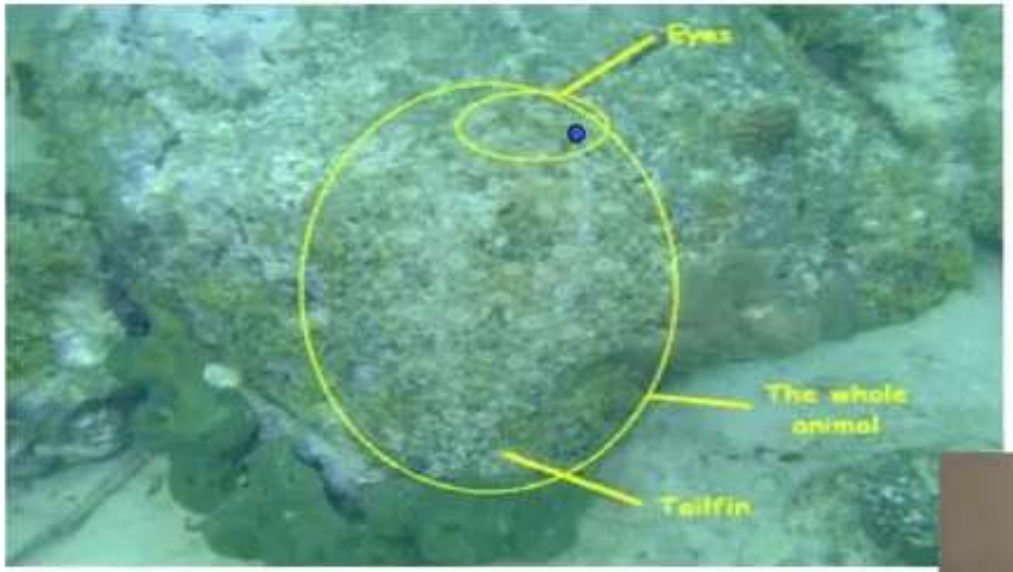
Where is ex-friend Trotsky?

From www.newseum.org

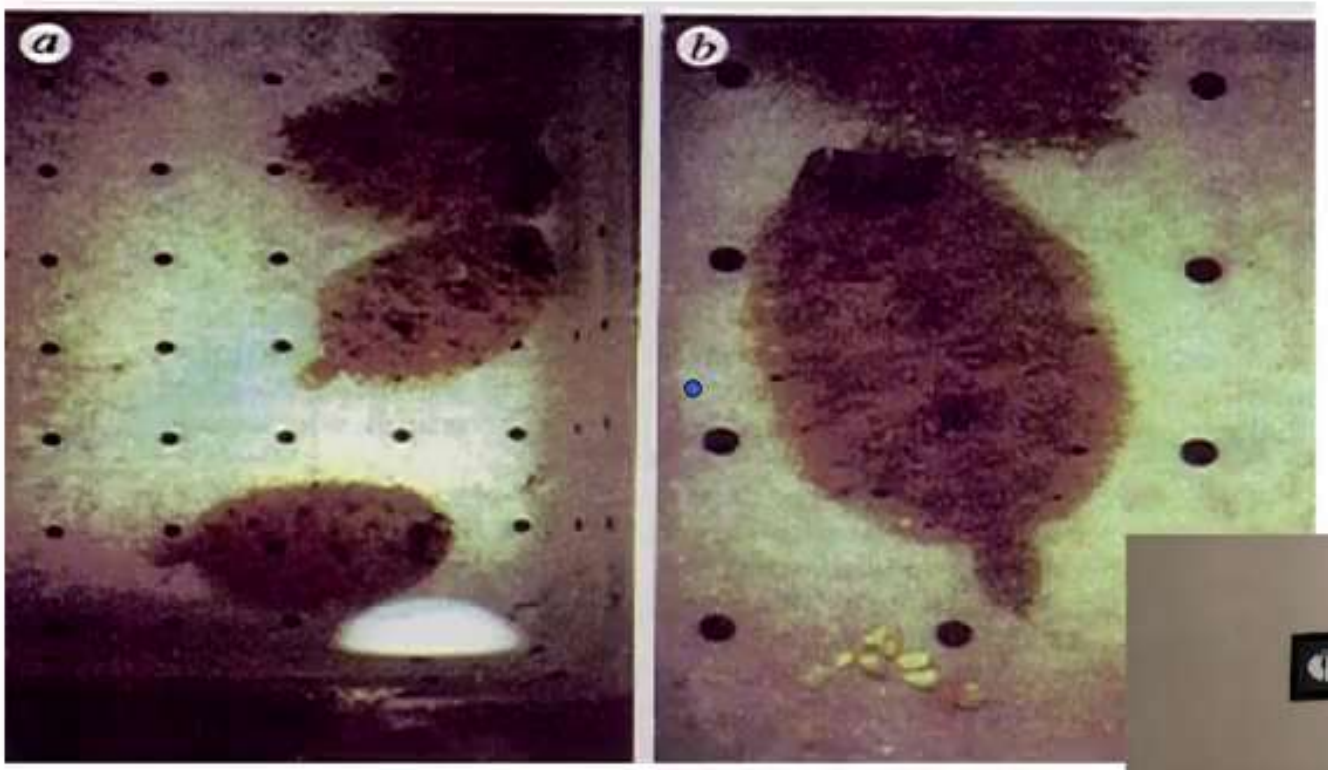
Object removal: What can't be done?

Biological inpainting

Biological inpainting



Biological inpainting

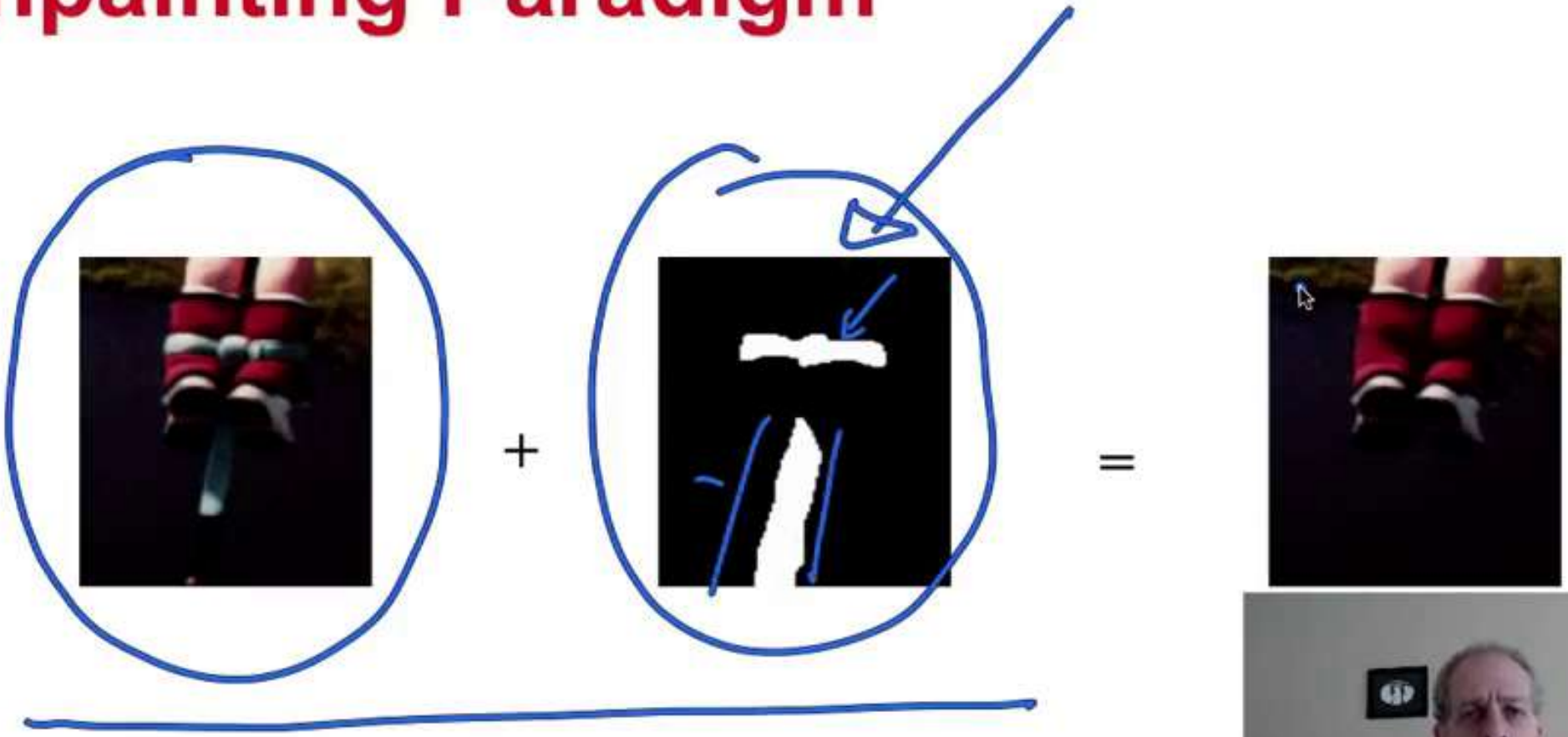


Courtesy of Ramachandran et al.

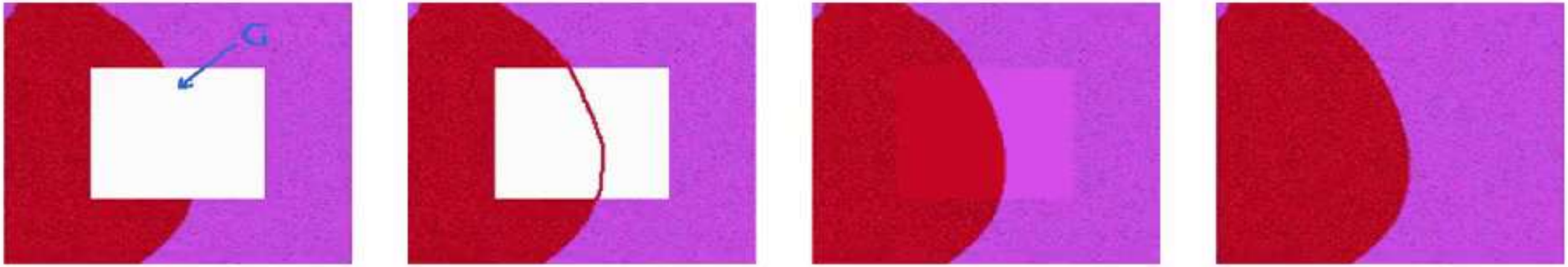
Human Blind Spot

http://info.med.yale.edu/neurobio/mccormick/fill_in_seminar/figure16.html

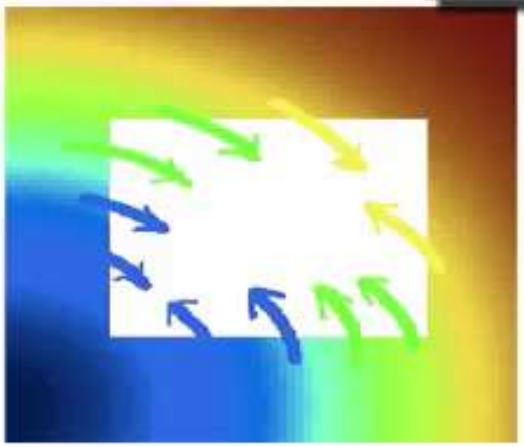
Inpainting Paradigm



How conservators inpaint?



Automatic digital inpainting

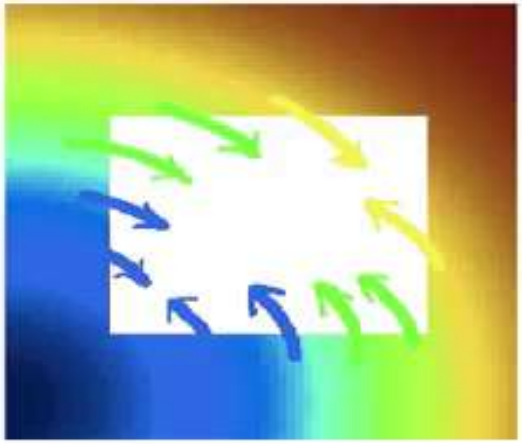


$$\nabla L \bullet \vec{N} = 0$$

L = Information

N = direction

Automatic digital inpainting



$A = 0$

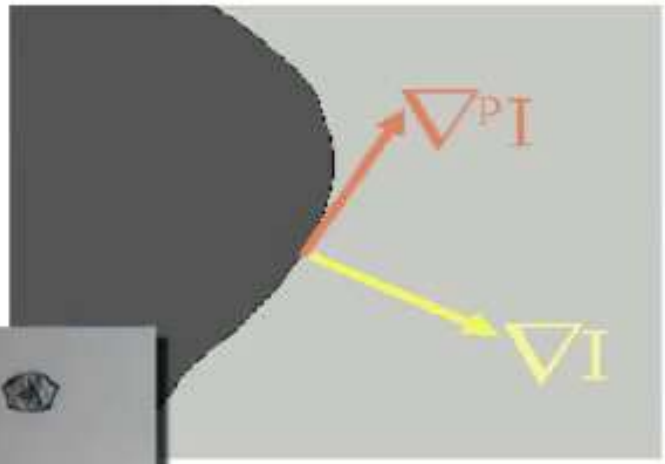
$\frac{\partial I}{\partial t} = A$

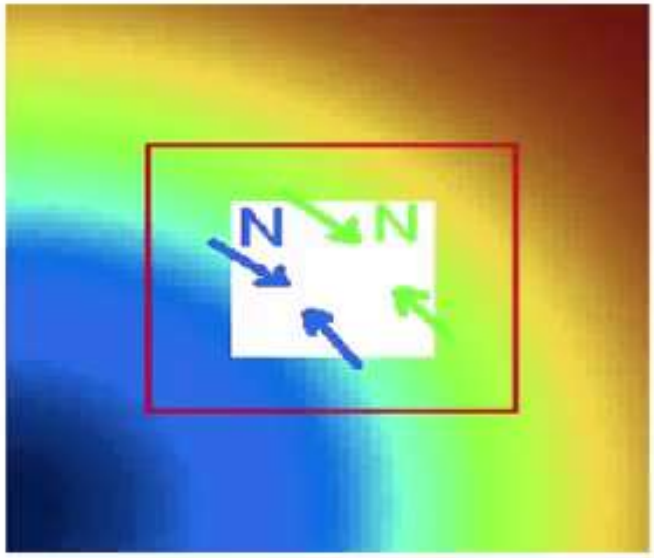
$$\nabla L \bullet \vec{N} = 0$$

$$0 = \frac{\partial I}{\partial t} = \nabla L \bullet \vec{N}$$

- L = smoothness estimator (Laplacian)
- N = isophote direction (time variant)

$N = \nabla I^{\perp}$

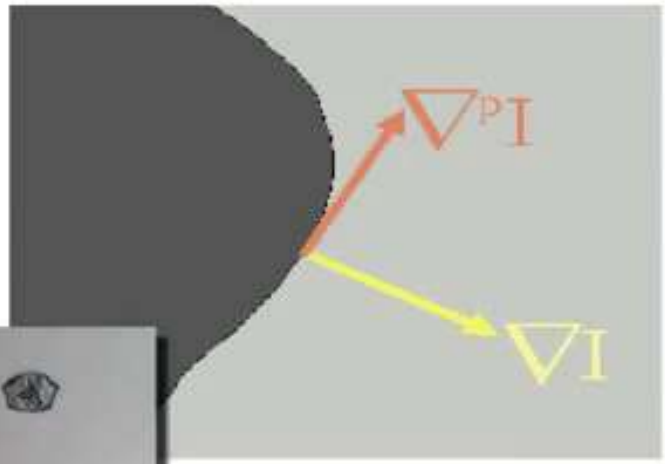


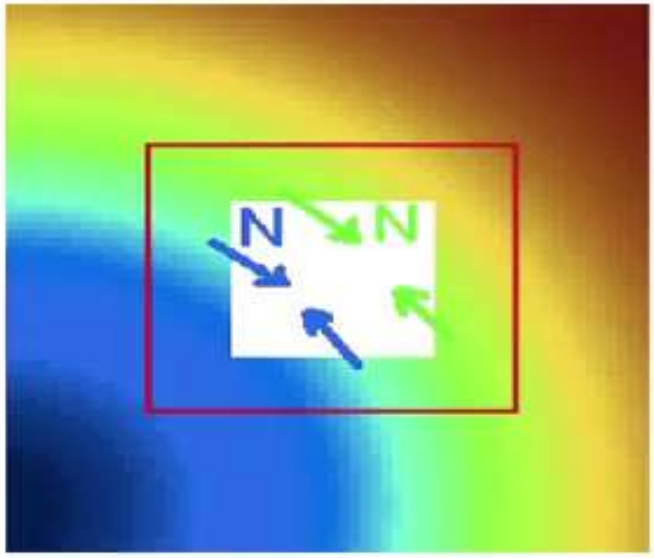


- L = smoothness estimator (Laplacian)
- N = isophote direction (time variant)

$N = \nabla I^{\perp}$

$L = \nabla I$



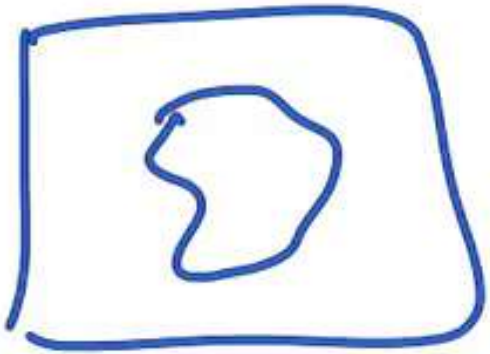


The equation

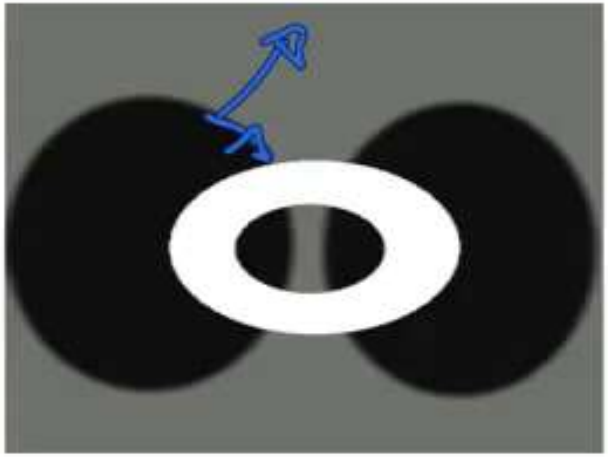
$$\Delta I = I_{xx} + I_{yy}$$

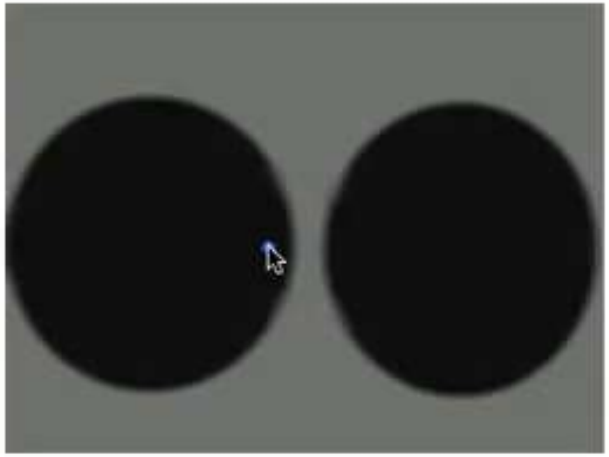
$$\frac{\partial I}{\partial t} = \nabla(\Delta I) \bullet \nabla^{\perp} I = 0$$

L $\vec{N}$



Example



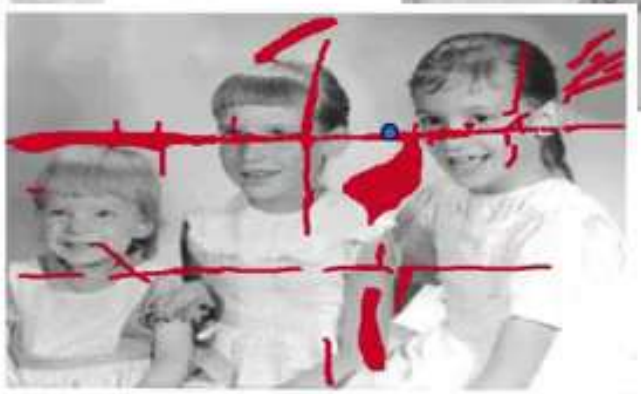


Courtesy of ACM

Example: Text removal

Courtesy of ACM

Example: Photo restoration

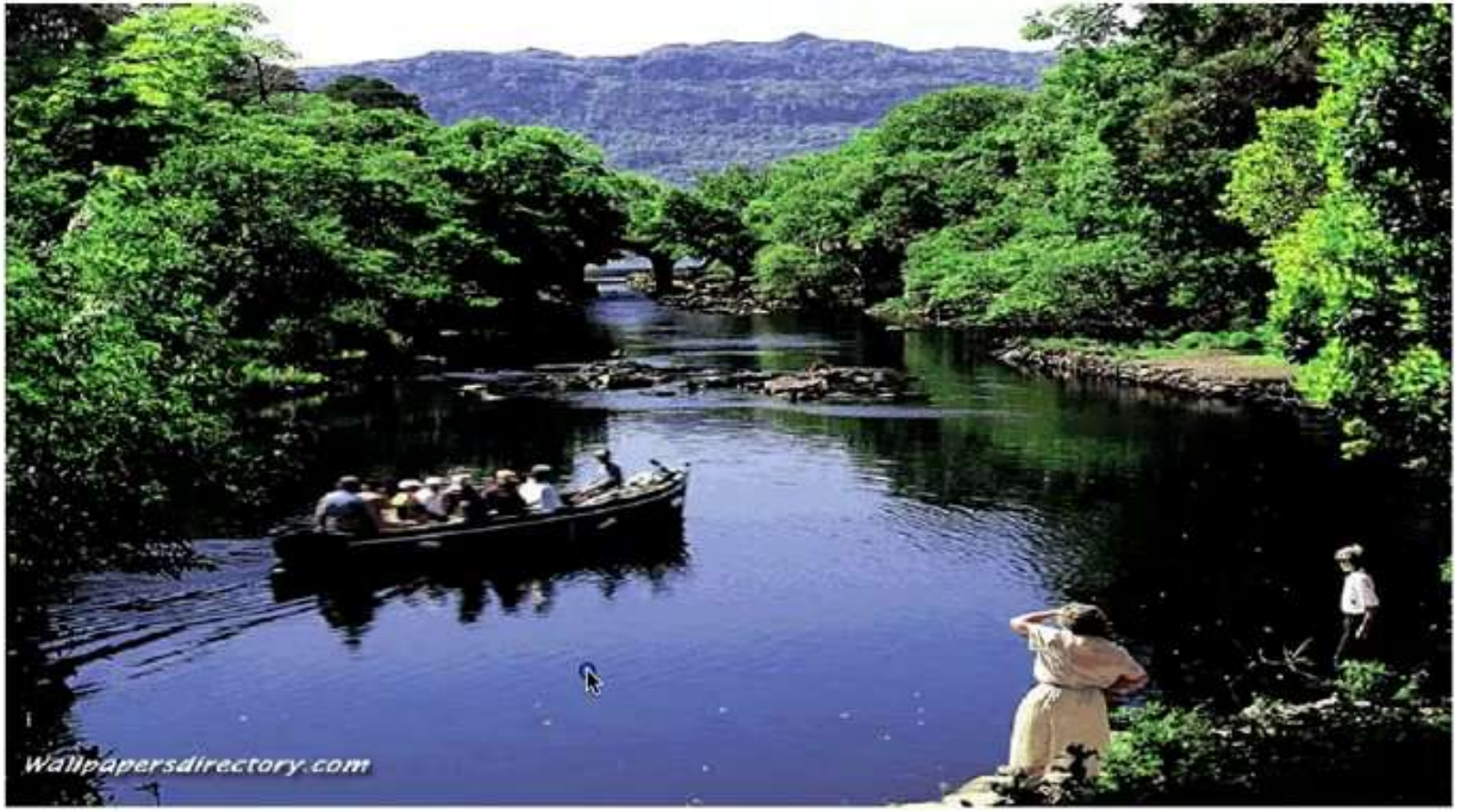


Courtesy of ACM

Example: Special effects

Courtesy of ACM

Example: Special effects



Example: Special effects

Example: Scratch removal

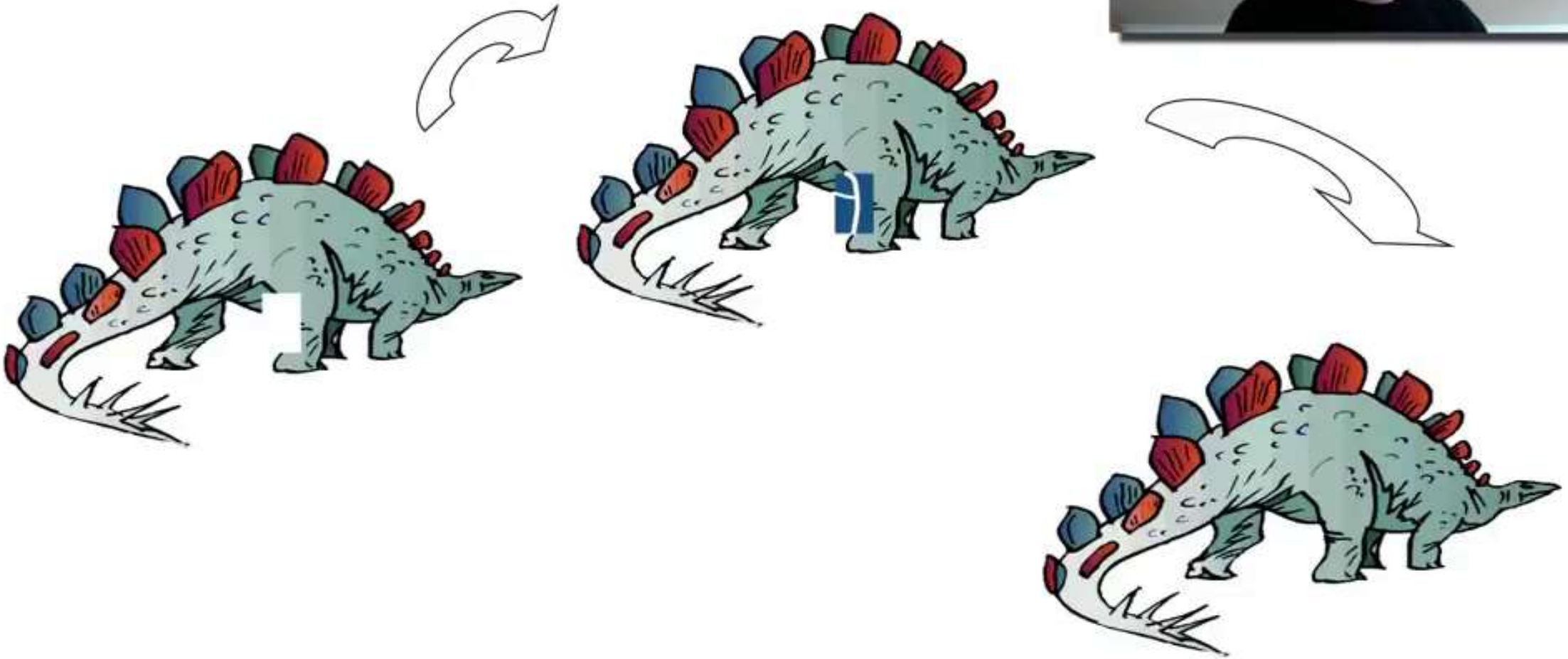
Automatic image inpainting/interpolation for compression and wireless transmission

Courtesy of IEEE

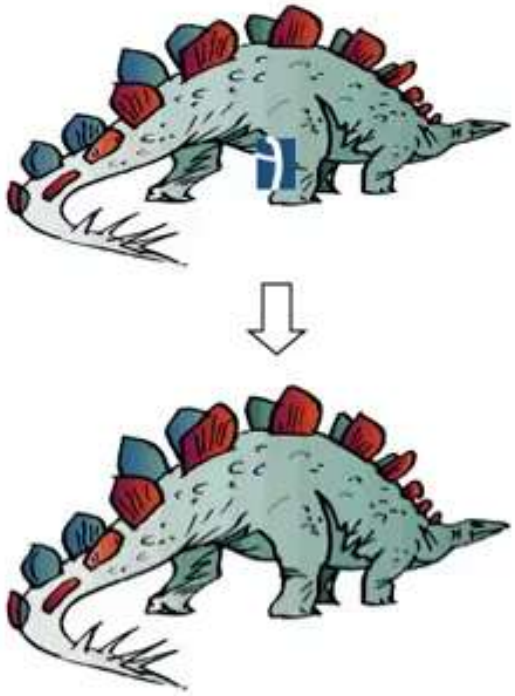
$$I_t = \nabla(\Delta I) \cdot (\nabla I)^{-1}$$

Courtesy of IEEE

How conservators fill-in



Interpolate the gray values given the edges



$$\theta = \text{normalized gradient} \Rightarrow \theta \bullet \nabla I = \|\nabla I\|$$

$$\min(I) \int_{\Omega \cup Band} (\|\nabla I\| - \theta \bullet \nabla I)\, d\Omega$$

$$\frac{\partial I}{\partial t} = div\left(\frac{\nabla I}{\|\nabla I\|}\right) - div(\theta)$$

$$\theta = \frac{\nabla I}{|\nabla I|}$$

$$= 0$$

Example

The full functional

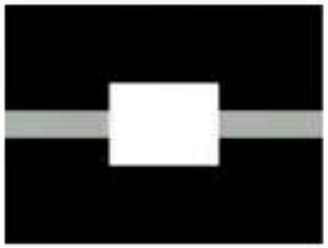
$$\min(I,\theta) \int_{\Omega \cup Band} div(\theta)^p (a + b\|\nabla G * I\|) + c(\|\nabla I\| - \theta \bullet \nabla I)$$

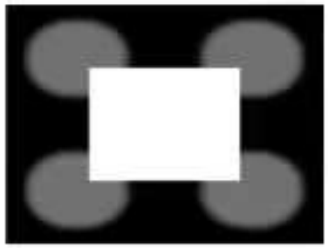
curvature.

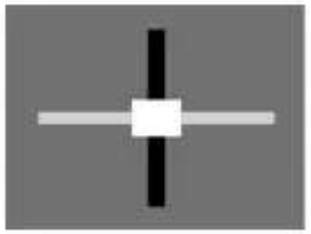
$\theta = \frac{\nabla I}{|\nabla I|}$

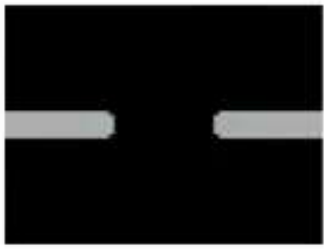
- **Solved via E-L: Coupled 2nd order PDEs**

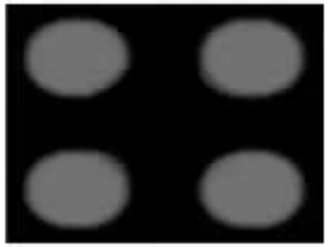
Examples

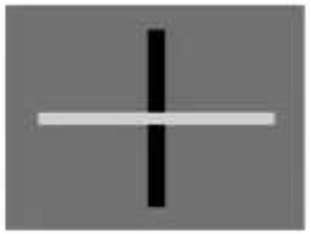


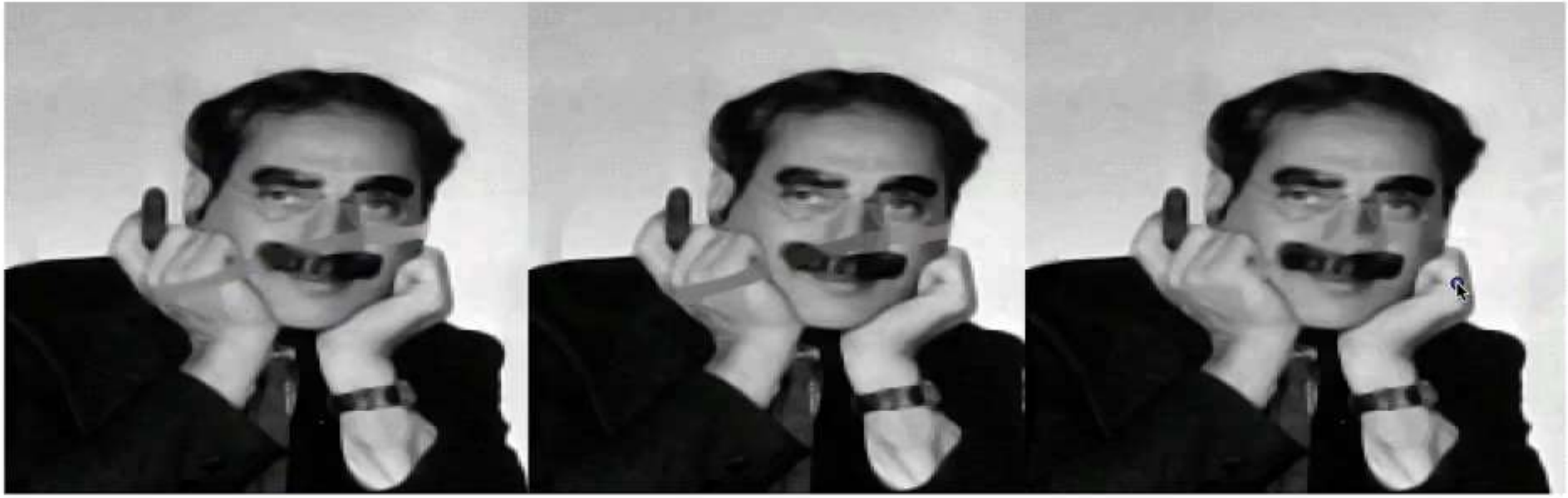








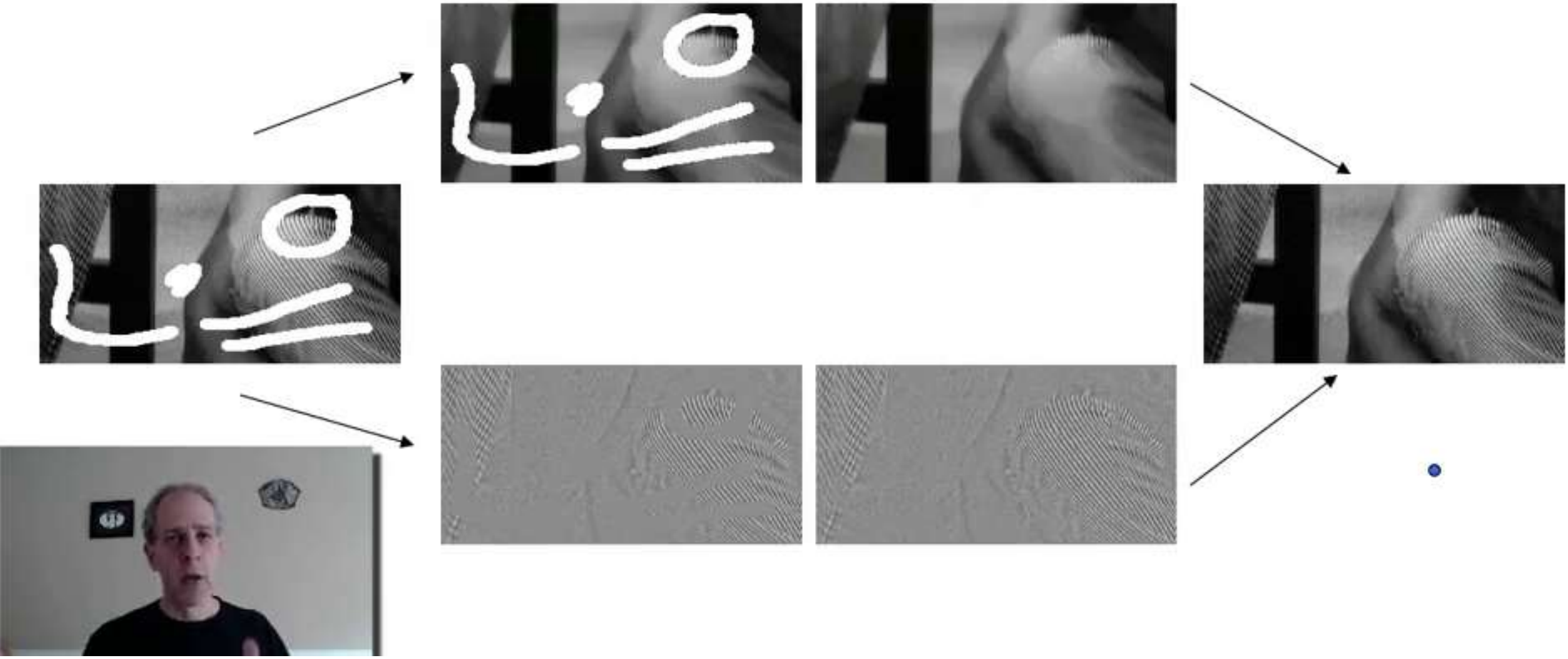




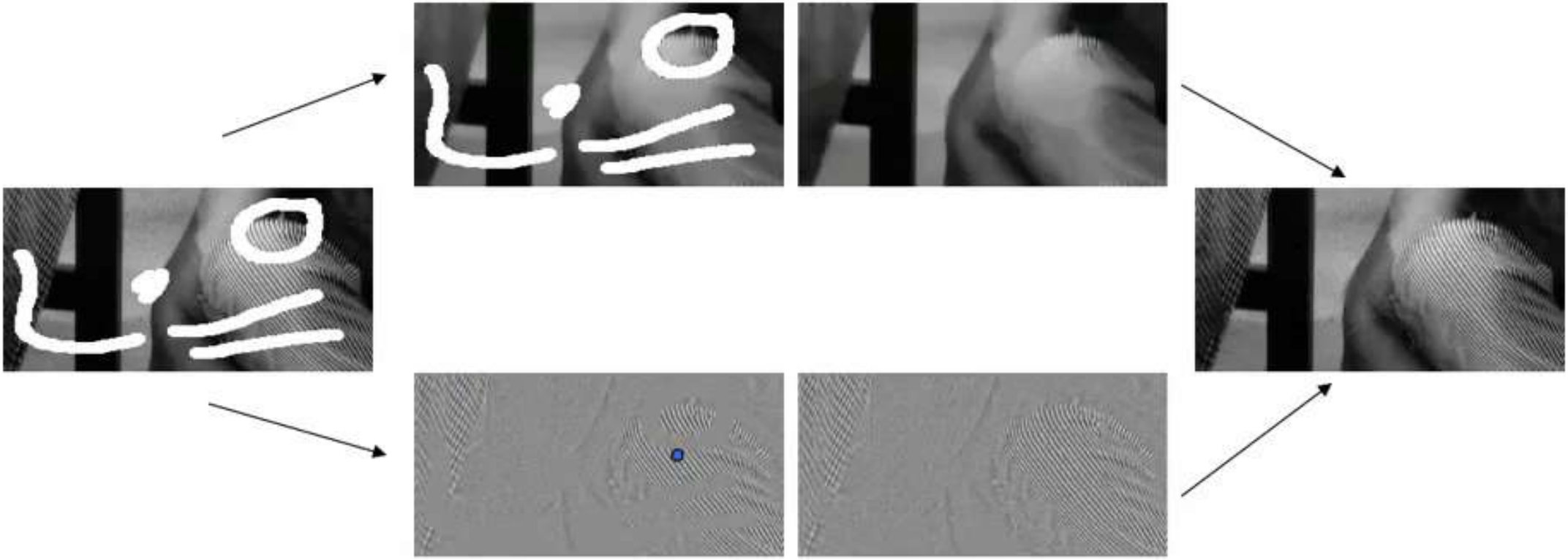
Examples

Il Castello di Miramare e i
suo parco sorsero sul promo
torio roccioso d'origine ca
sica di Grignano, per volon
dell' arciduca Ferdinando M
ssimiliano d'Asburgo (1832-
fratello minore dell'impera
austriaco Francesco Giusepp
Progettato nel 18[illegible] da Carl
terminato nell'aspetto este
nel 1860. La sistemazione d
e la decorazione interna, o
e Julius Hofmann, furono ul
dopo la partenza di Massimi
per il Messico nel 1864, de
imperatore del Messico. Mas
venne fucilato a Queretaro
1867. Tra i pochissimi esem
di una dimora reale conser
[illegible] arredamento, il Caste

Inpainting and Image Decomposition



Smart Cut and Paste



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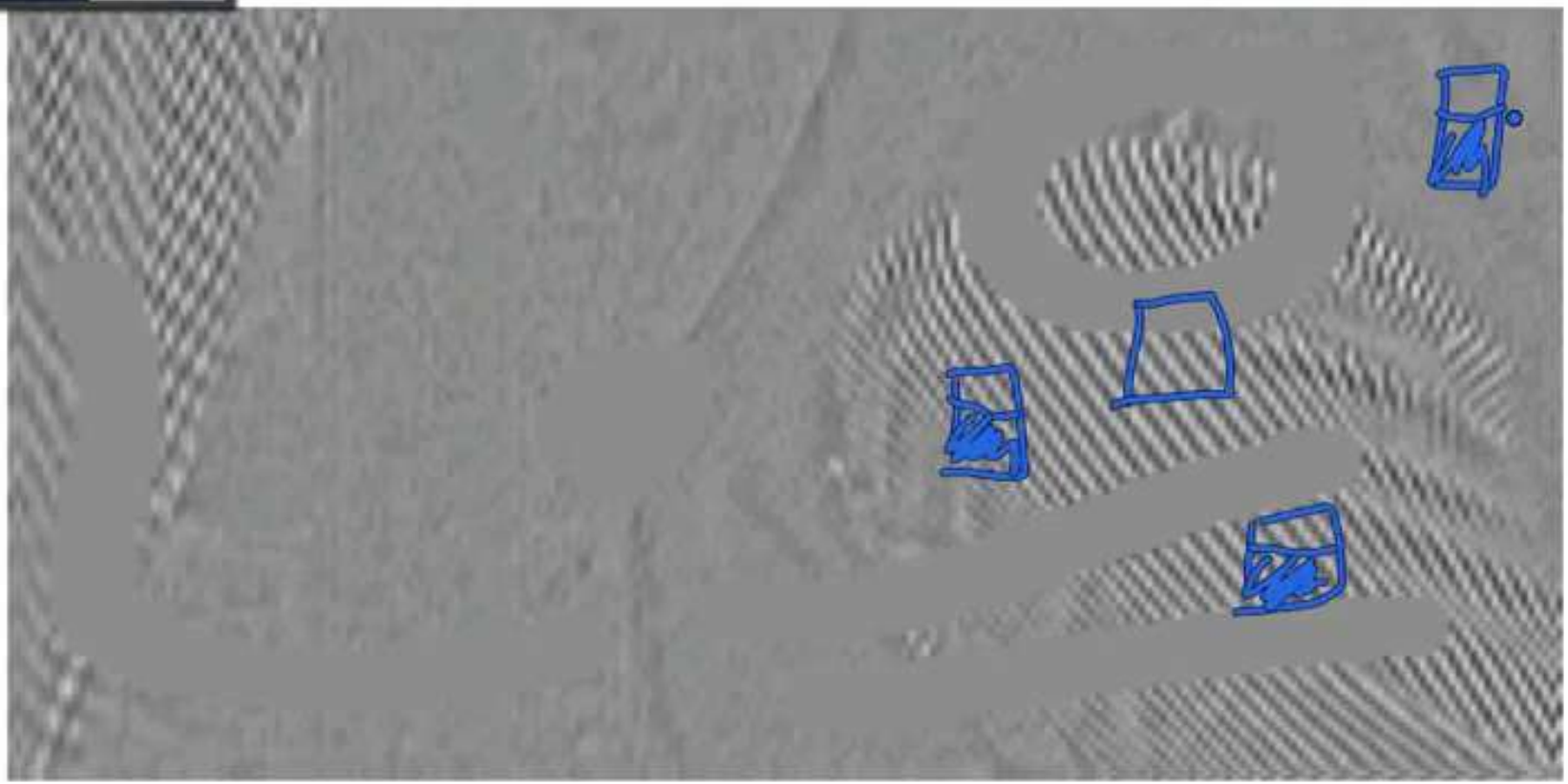

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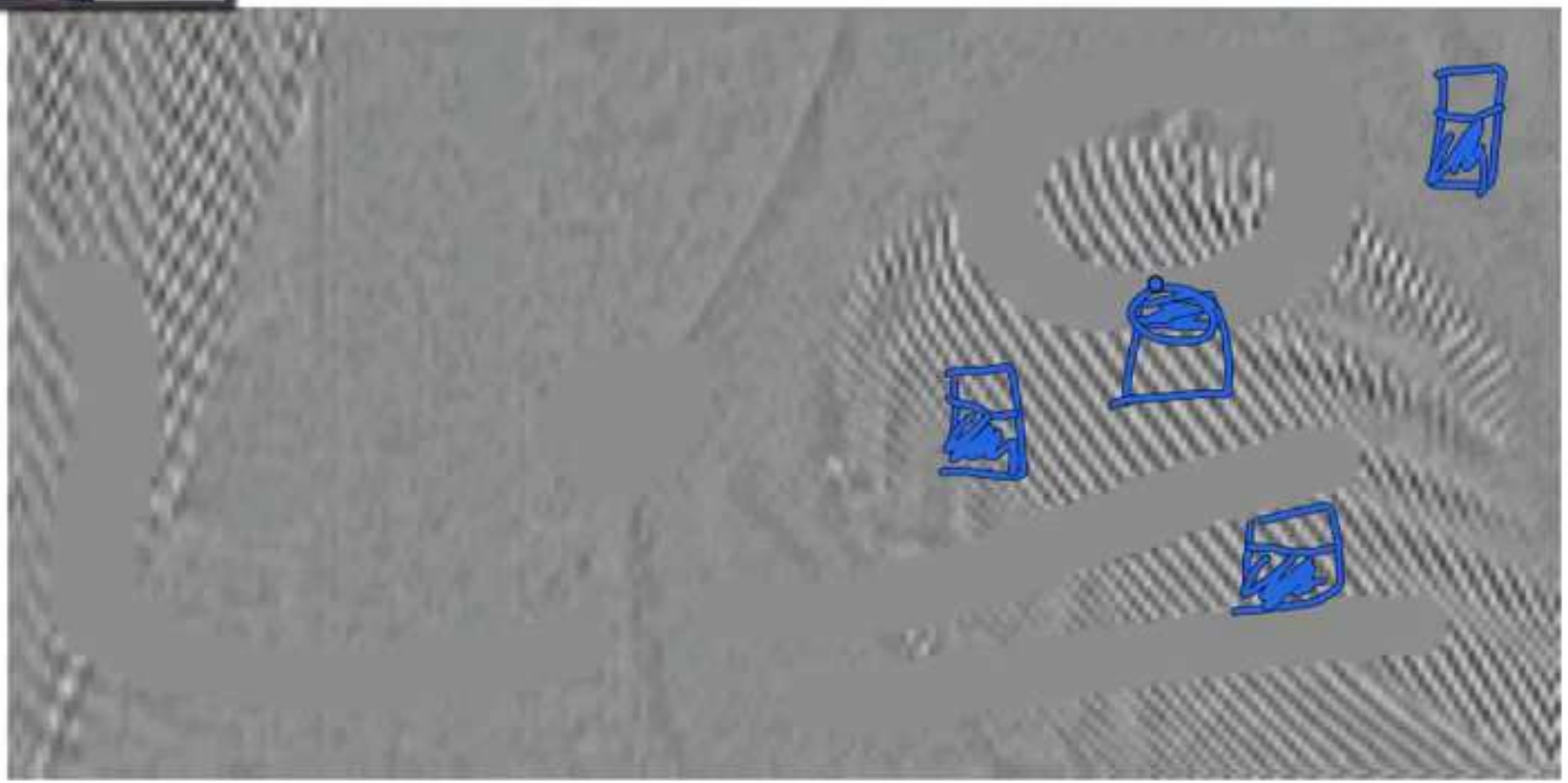

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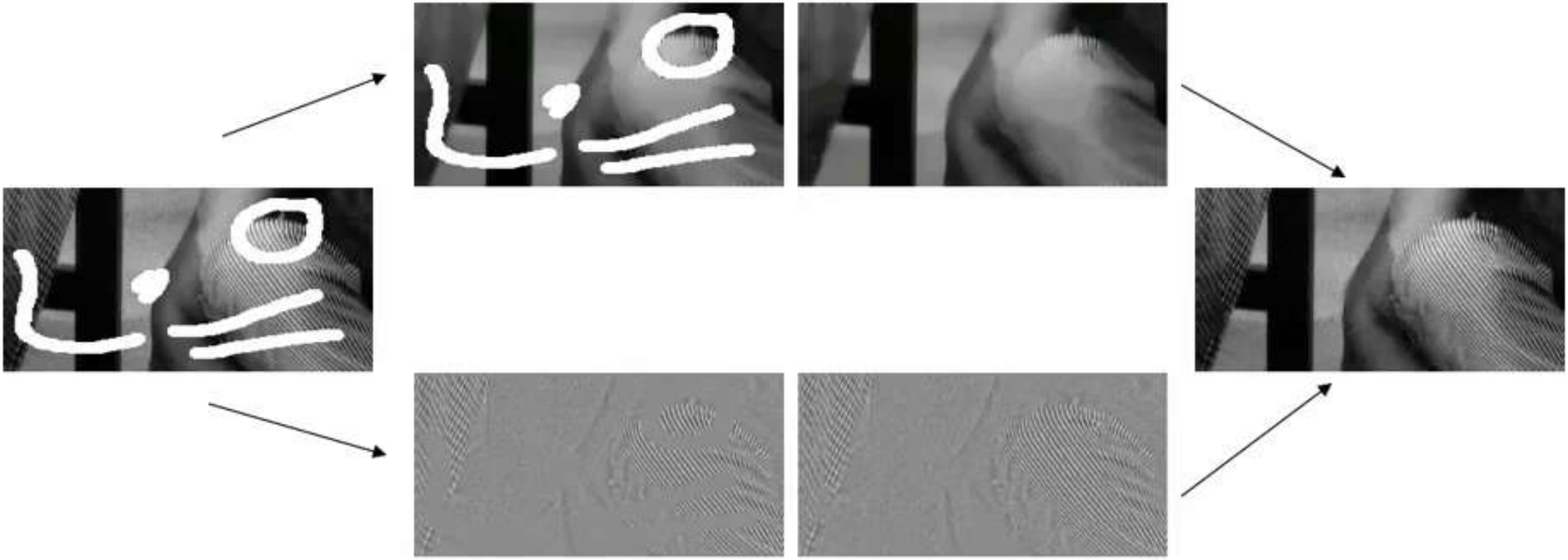

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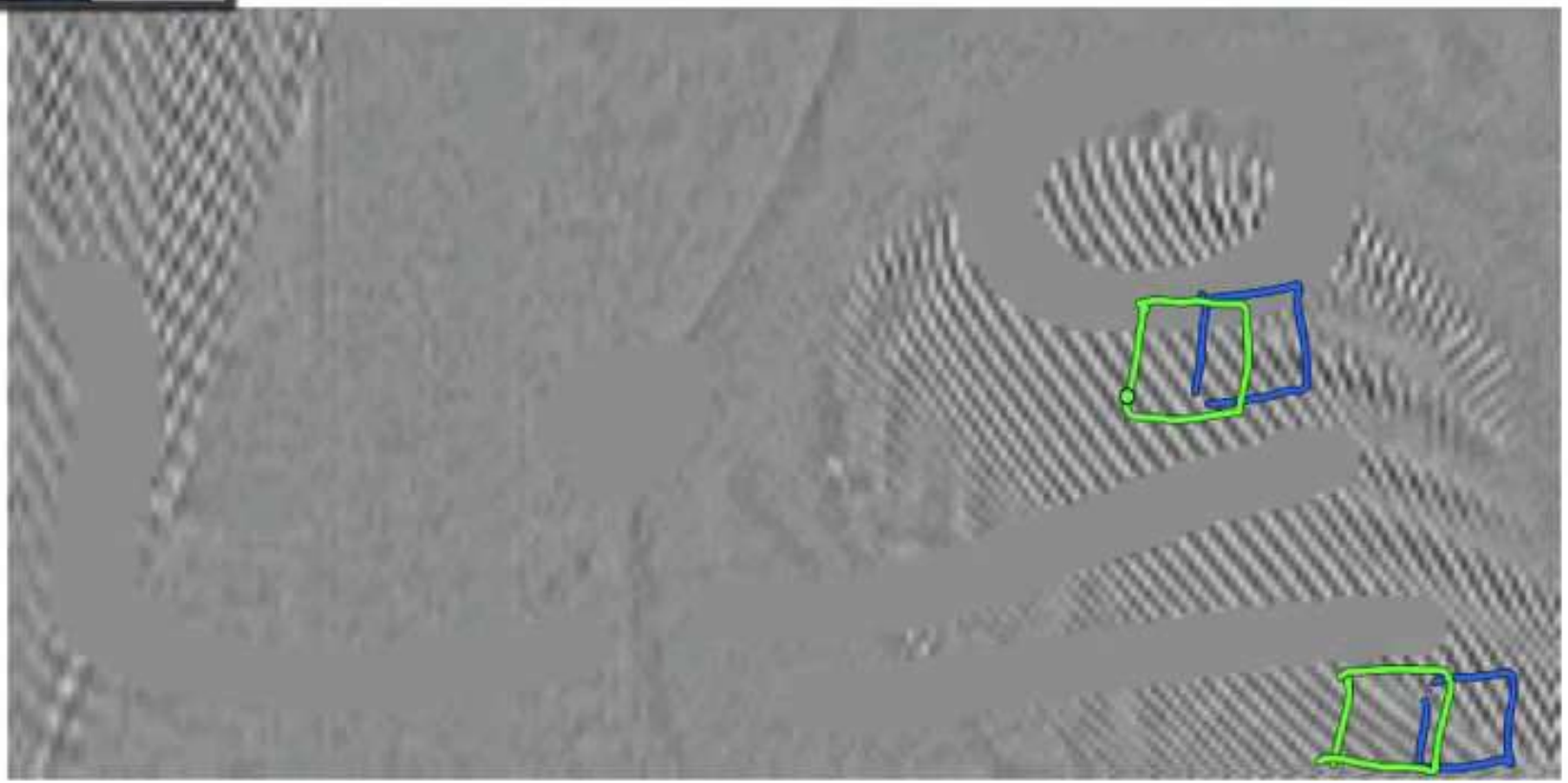
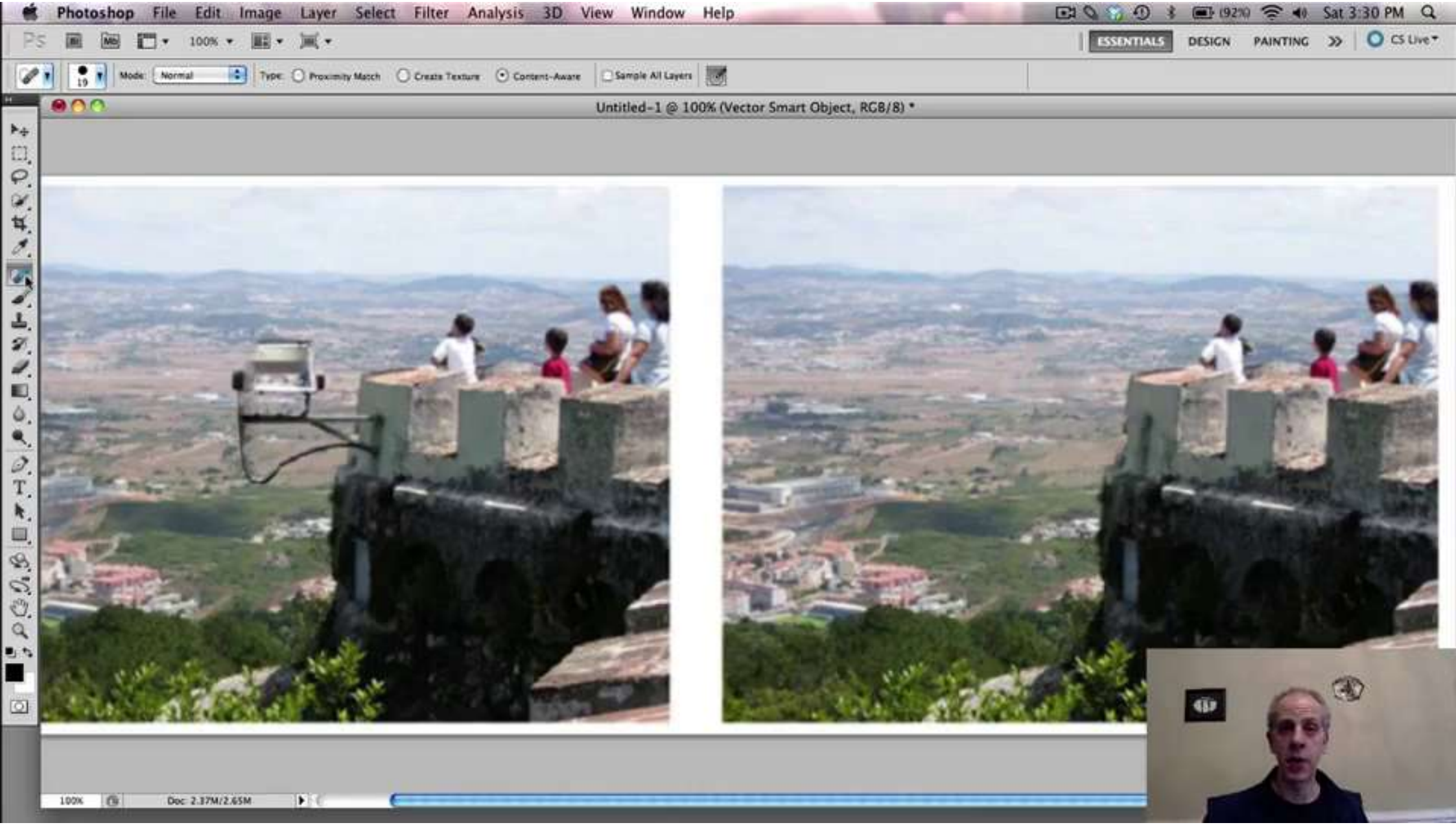


Combine it All

Courtesy of IEEE

Courtesy of IEEE

Courtesy of IEEE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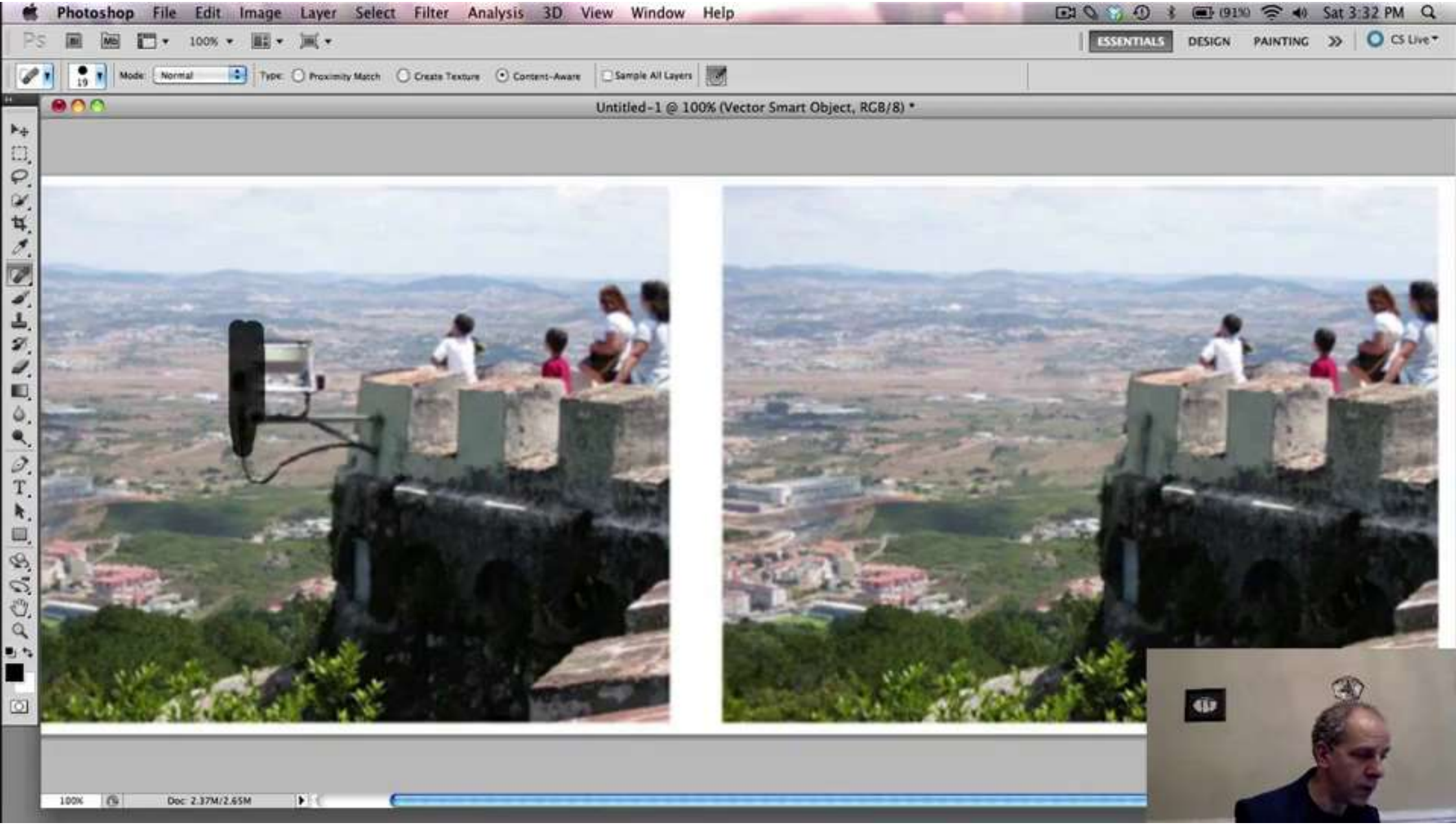
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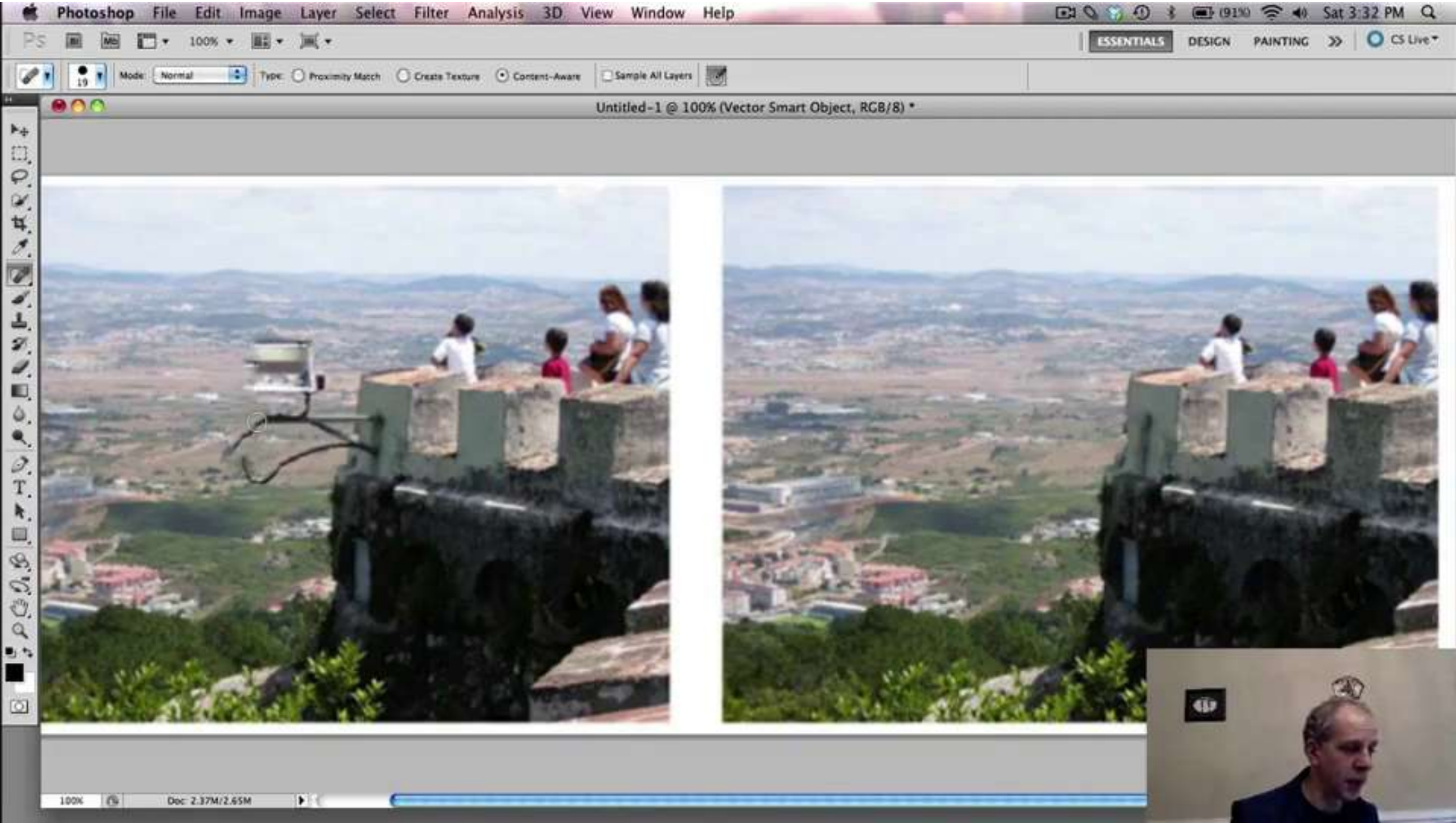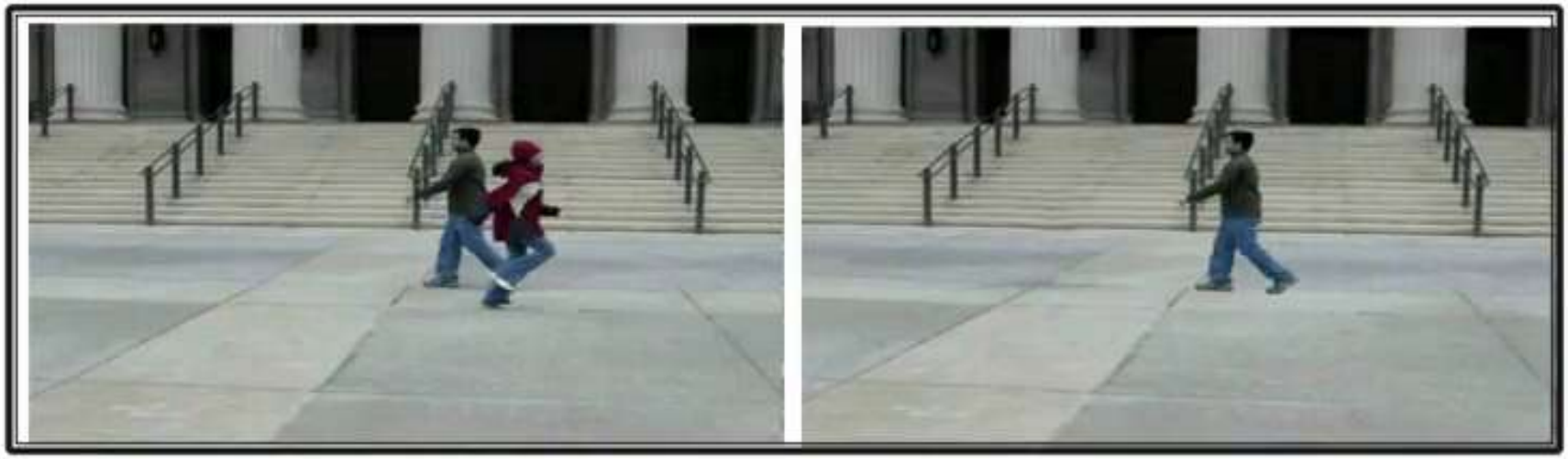
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