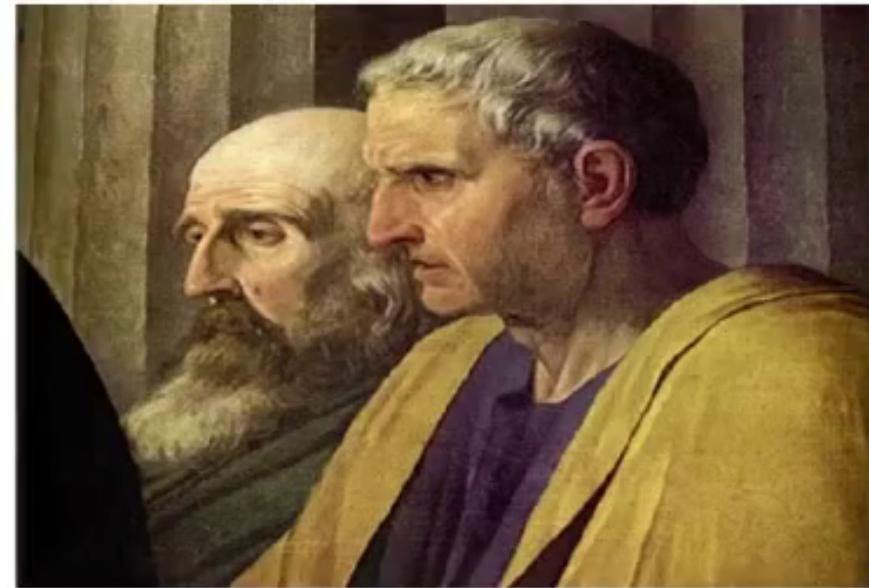
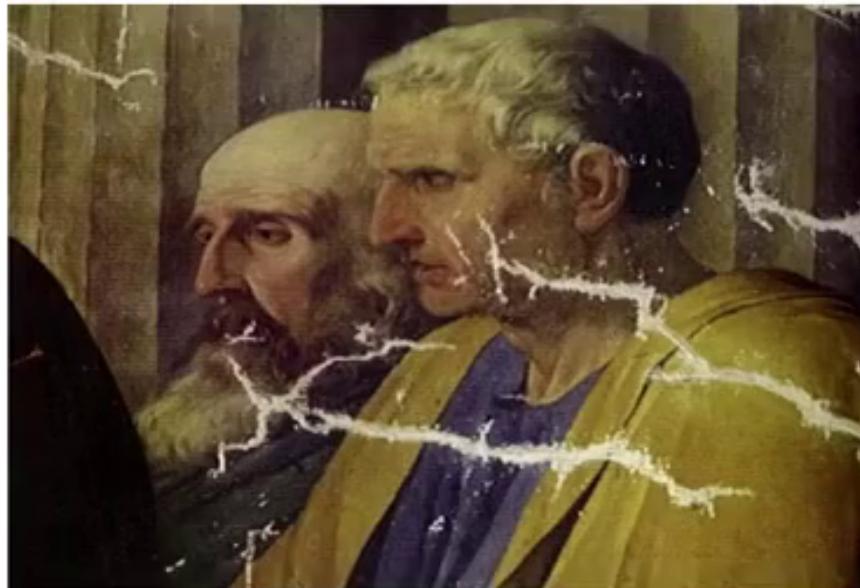




What is inpainting?

- **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

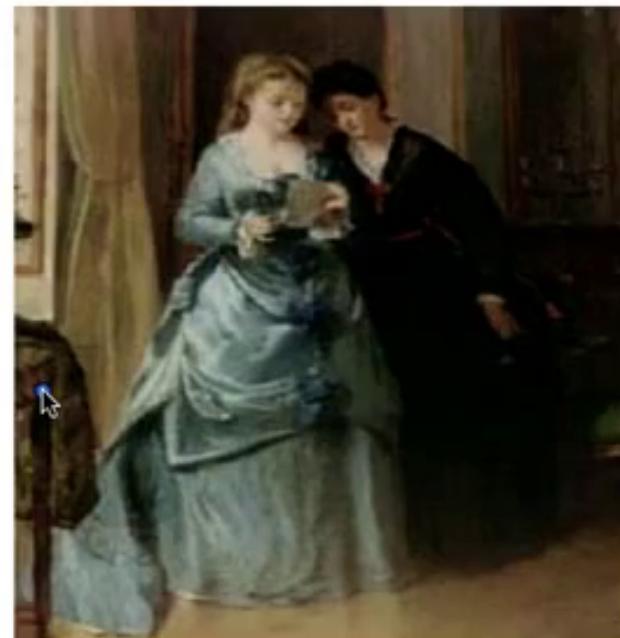
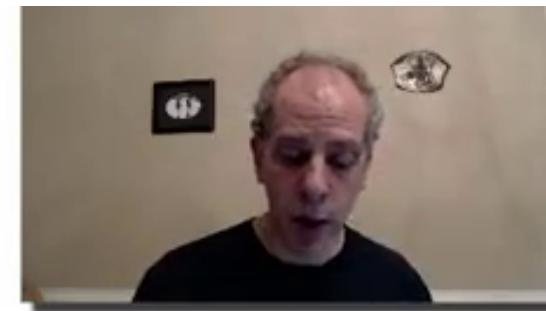


Photo restoration



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

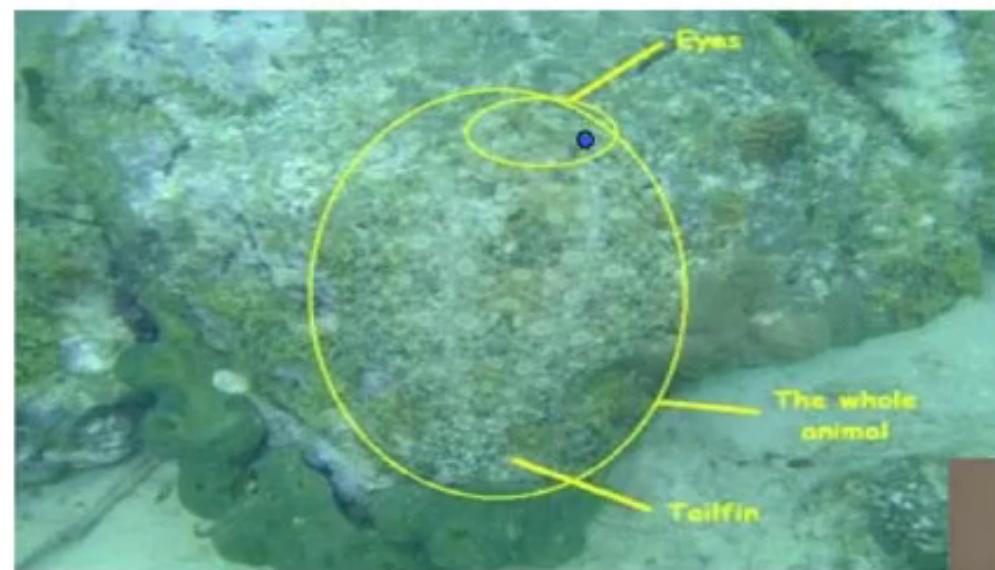
Object removal: What can't be done?



Biological inpainting



Biological inpainting

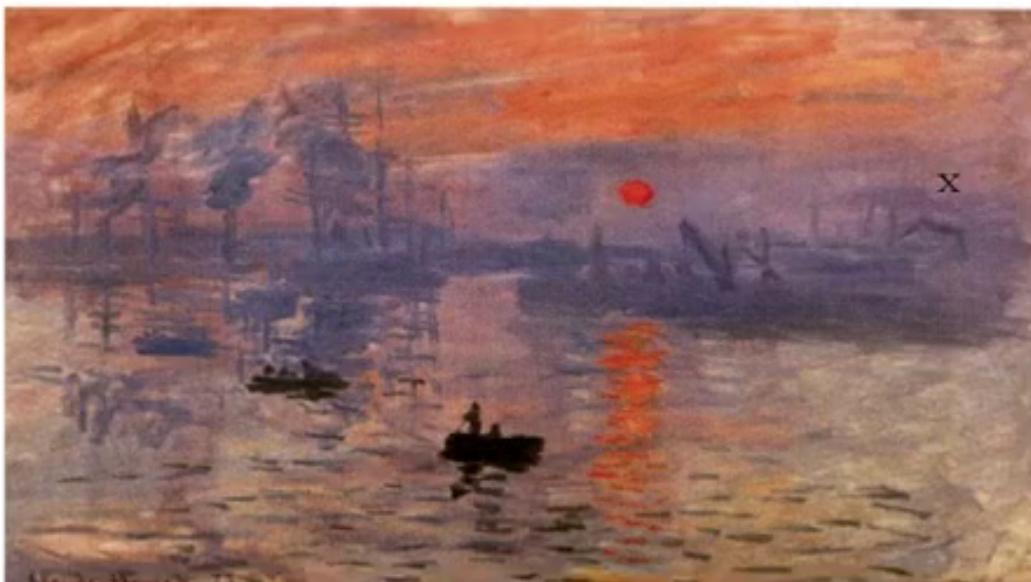


Biological inpainting



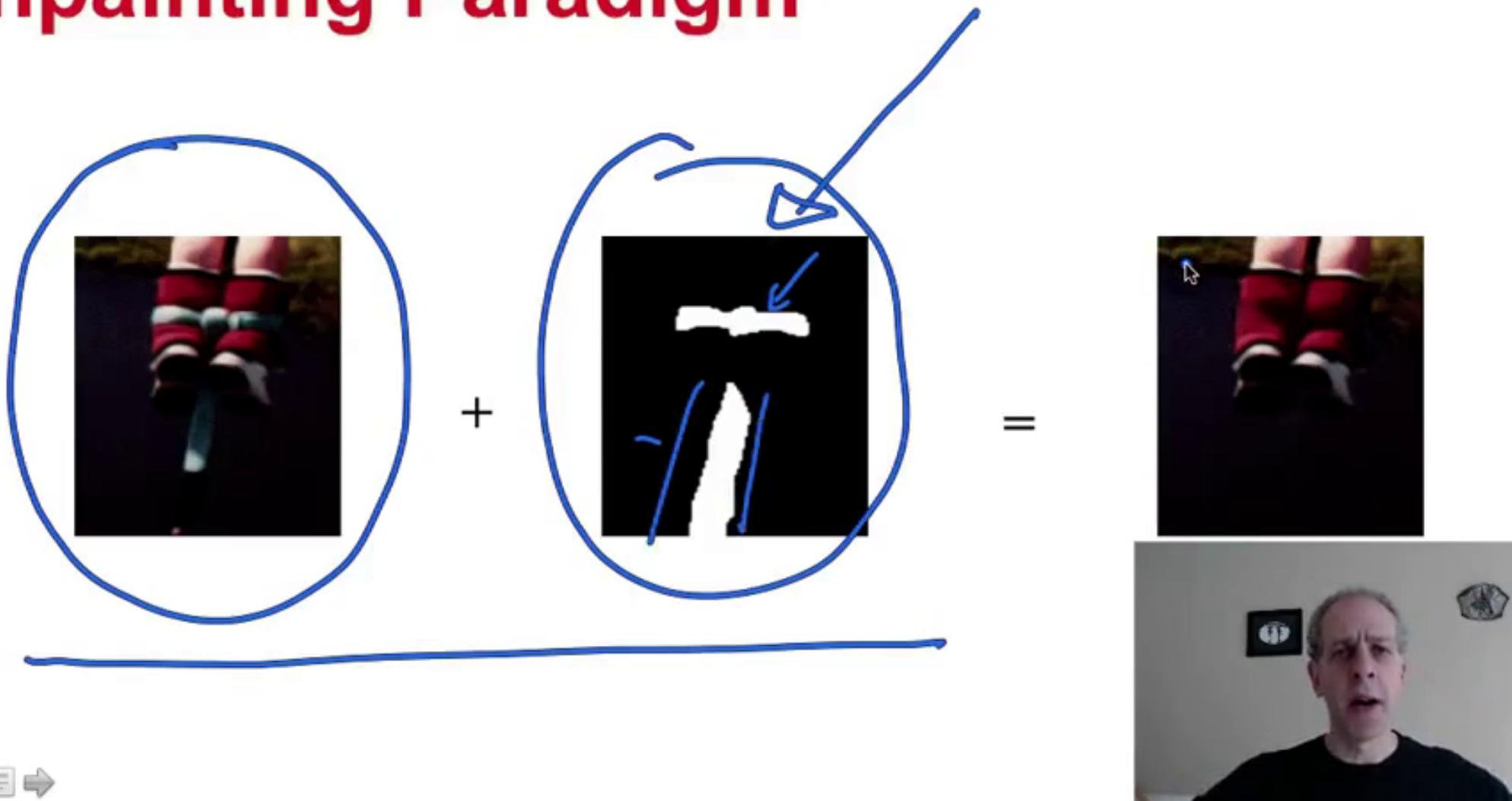
Courtesy of Ramachandran et al.

Human Blind Spot

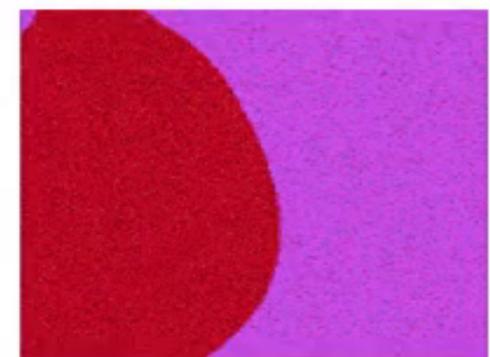
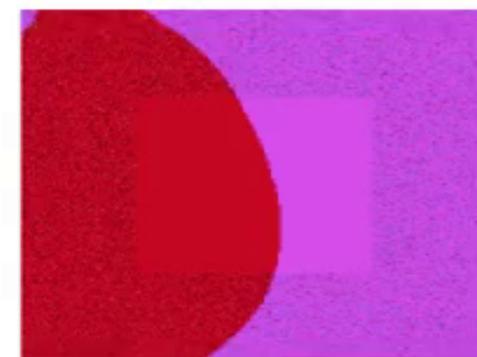
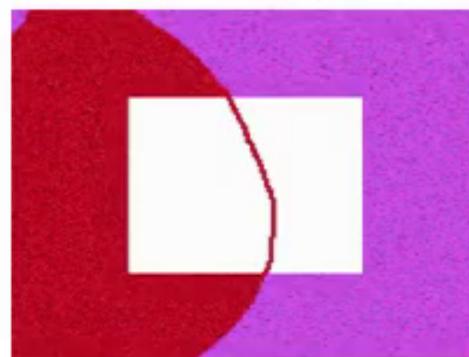
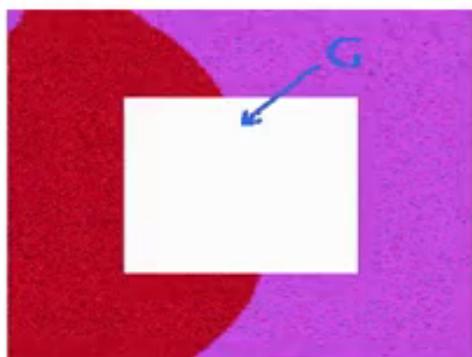


http://info.med.yale.edu/neurobio/mccormick/fill_in_seminar/figure16.html

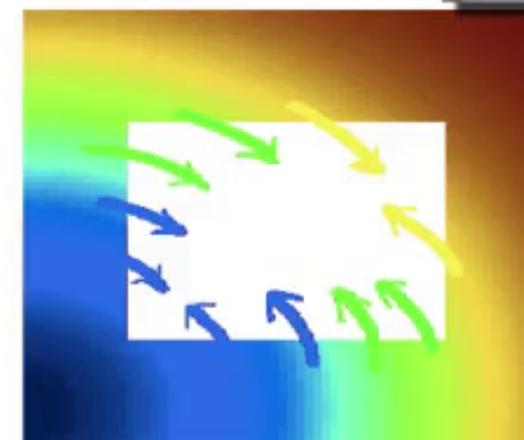
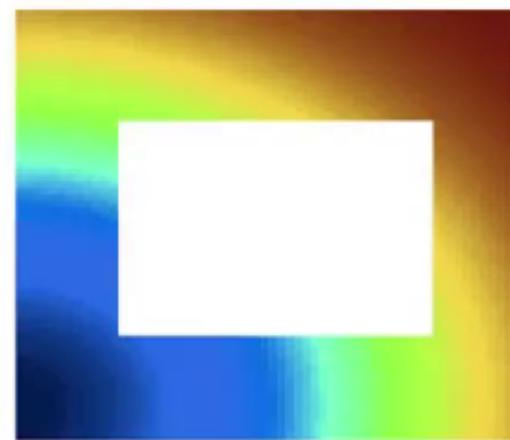
Inpainting Paradigm



How conservators inpaint?



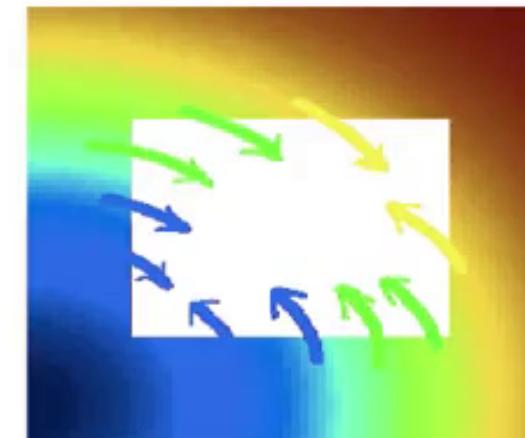
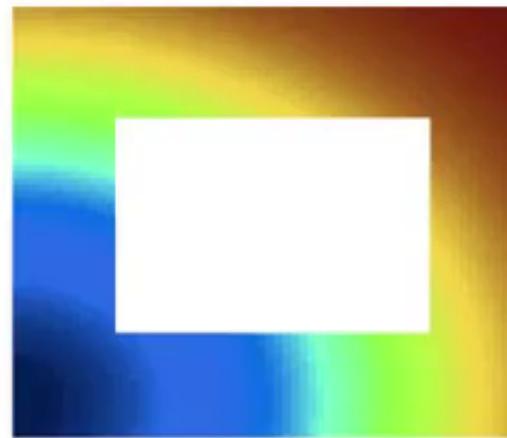
Automatic digital inpainting



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

L = Information
 N = direction

Automatic digital inpainting



$$A = 0$$

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

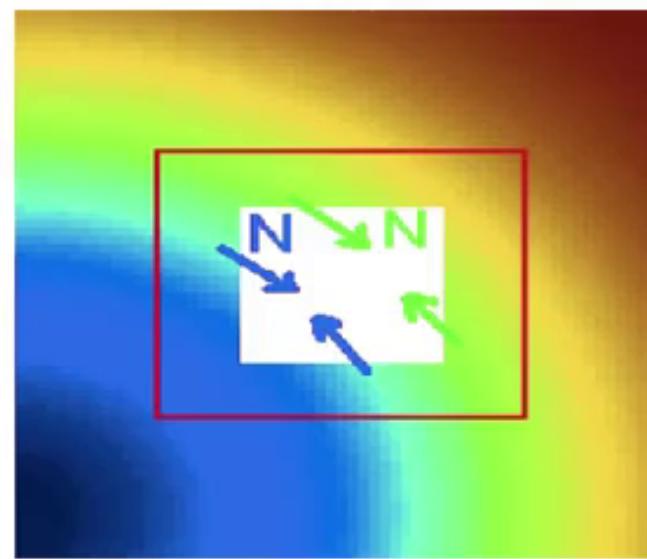
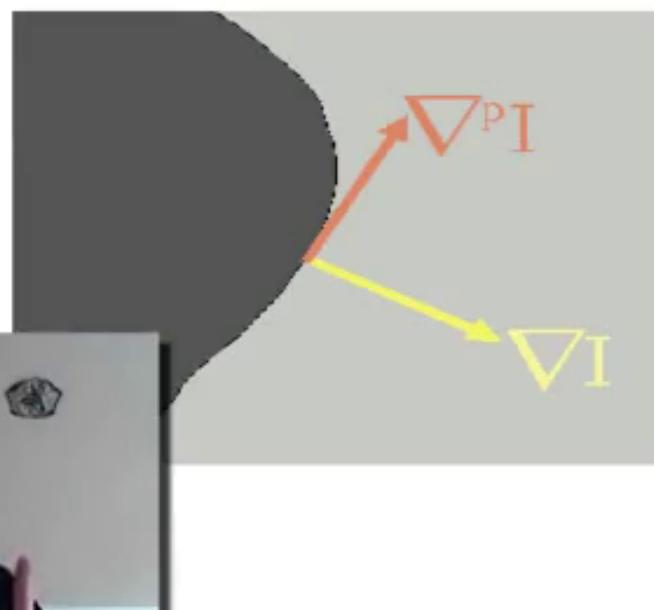


$$\nabla L \cdot \vec{N} = 0$$

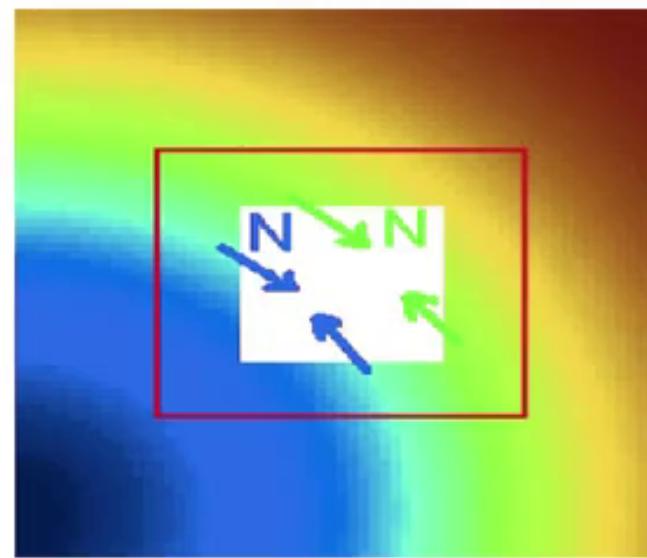
$$\textcircled{O} - \frac{\partial I}{\partial t} = \nabla L \cdot \vec{N}$$

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

$$N = \nabla I^+$$



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

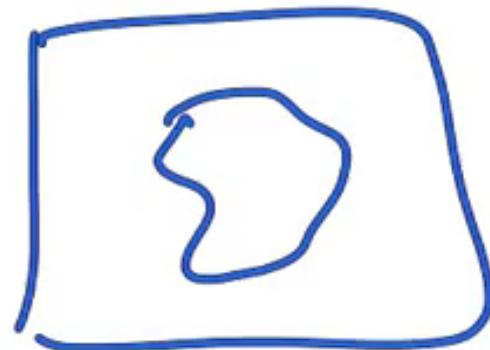


$$N = \nabla I^\perp$$
$$L = \nabla I$$

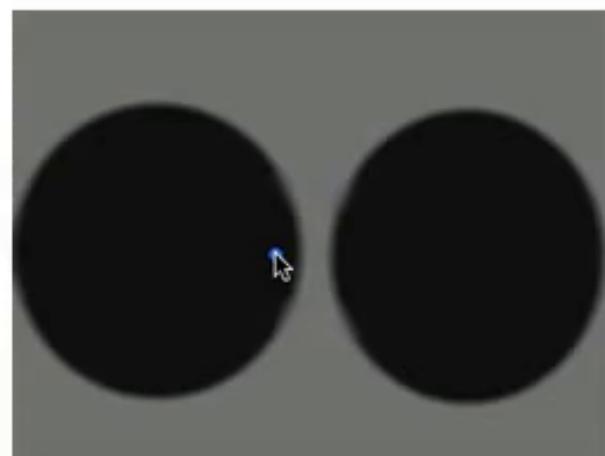
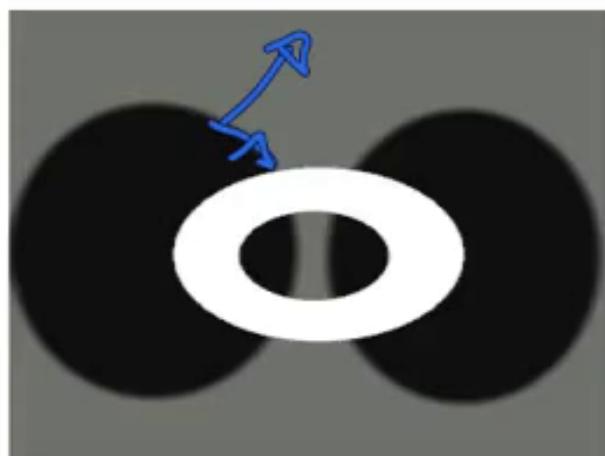
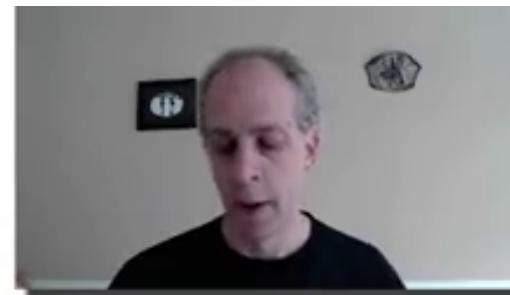
The equation

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

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

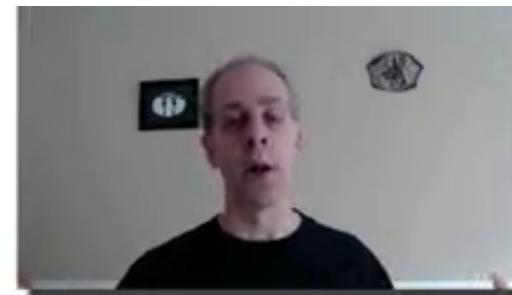


Example

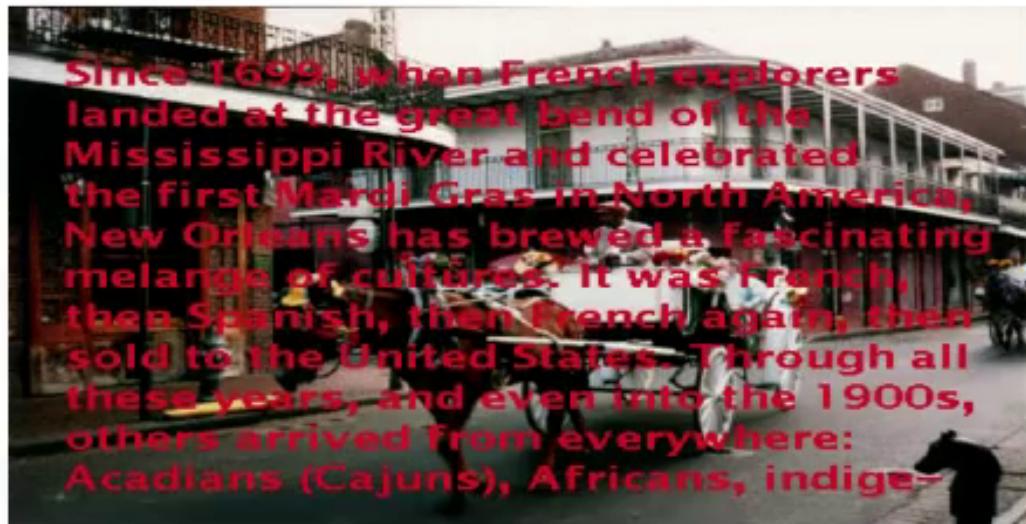


Courtesy of ACM





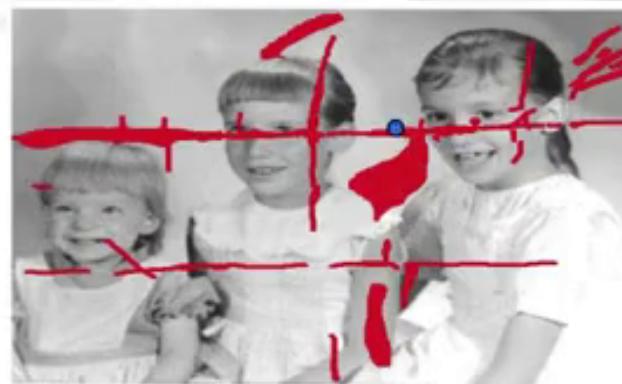
Example: Text removal



Courtesy of ACM

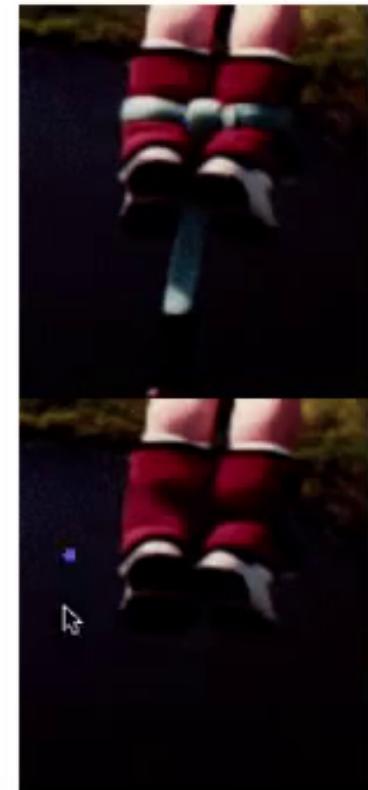


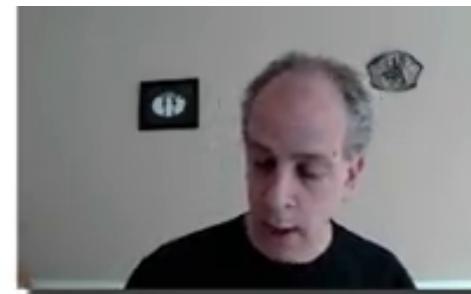
Example: Photo restoration



Courtesy of ACM

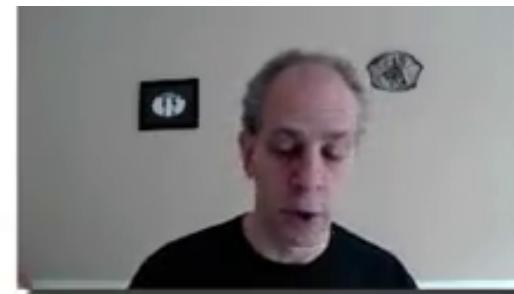
Example: Special effects





Example: Special effects



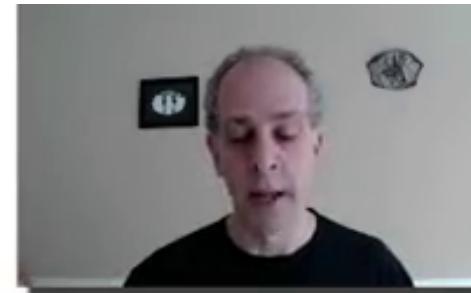


Example: Special effects

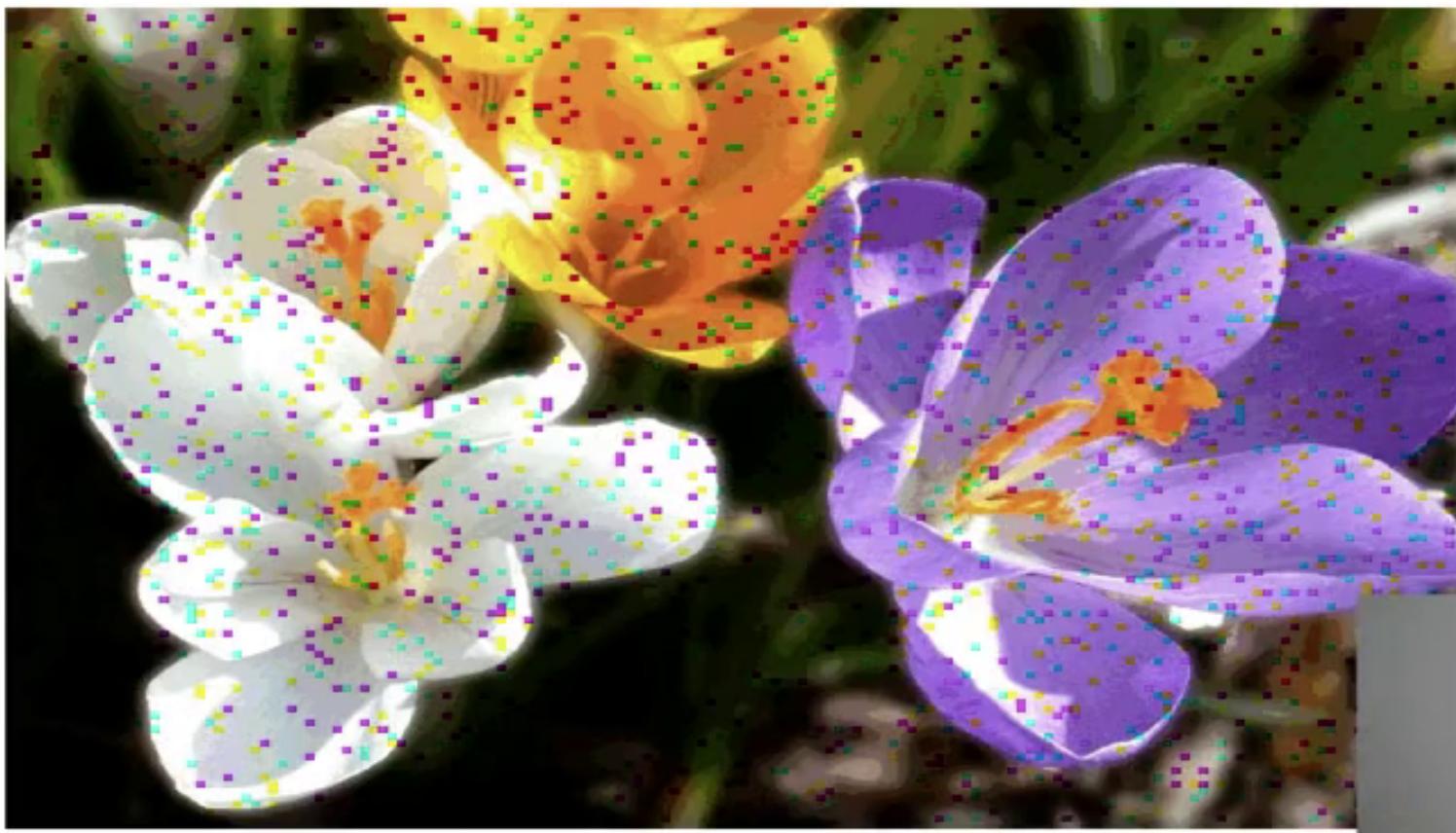


Wallpapersdirectory.com

Example: Scratch removal



Automatic image inpainting/interpolation for compression and wireless transmission



Courtesy
of IEEE



$$\mathbb{I}_t = \nabla(\Delta\mathbb{I}) \cdot (\nabla\mathbb{I})^\perp$$



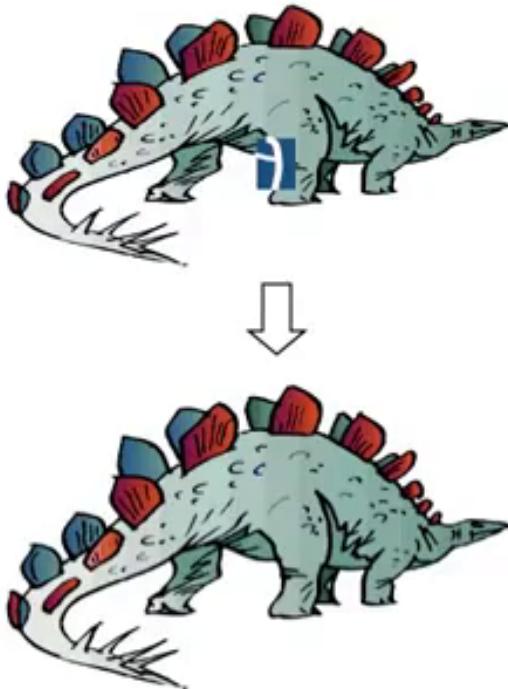
Courtesy
of IEEE



How conservators fill-in



Interpolate the gray values given the edges



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

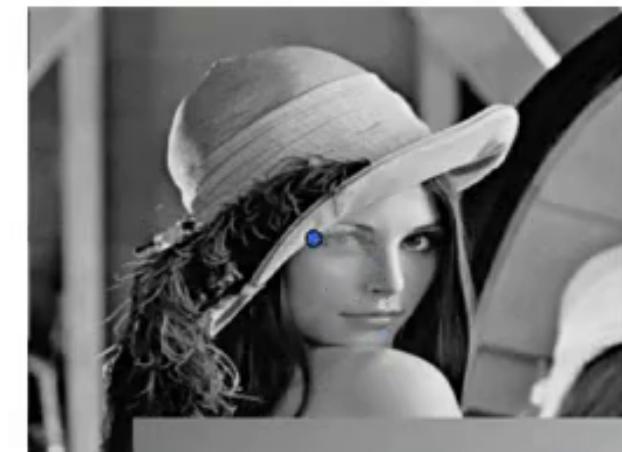
$$\theta = \text{normalized gradient} \Rightarrow \underline{\theta \cdot \nabla I = \|\nabla I\|}$$

$$\min(I) \int_{\Omega \cup \text{Band}} (\underline{\|\nabla I\| - \theta \cdot \nabla I}) d\Omega$$

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



Example



The full functional

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

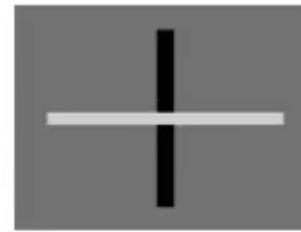
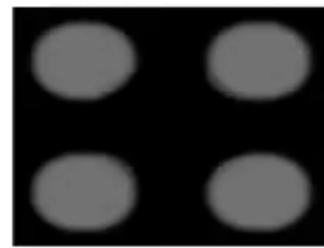
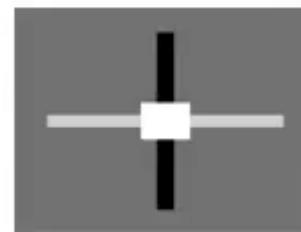
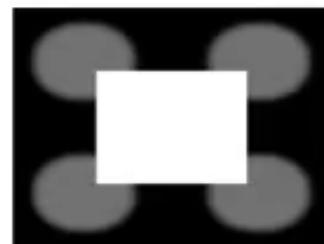
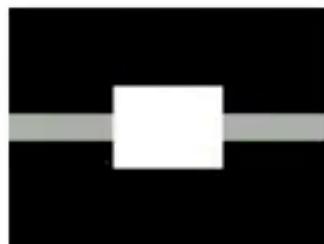
curvature.

$$\min(I, \theta) \int_{\Omega \cup \text{Banda}} \left[\text{div}(\theta)^p (a + b \|\nabla G * I\|) + c (\|\nabla I\| - \theta \cdot \nabla I) \right]$$

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



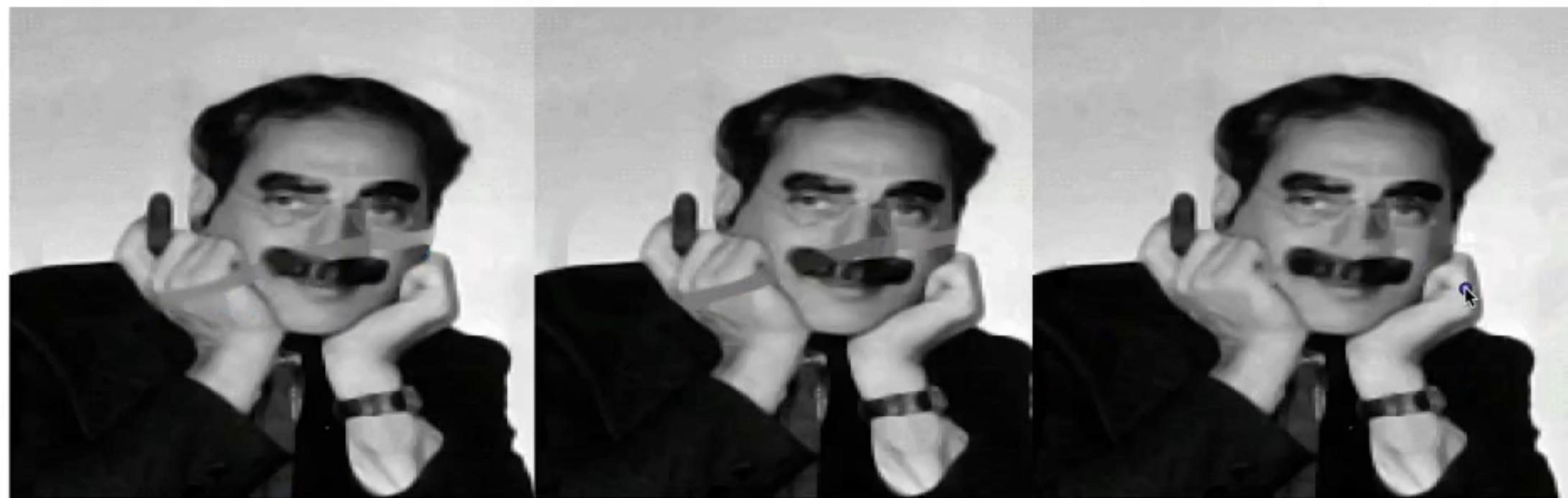
Examples



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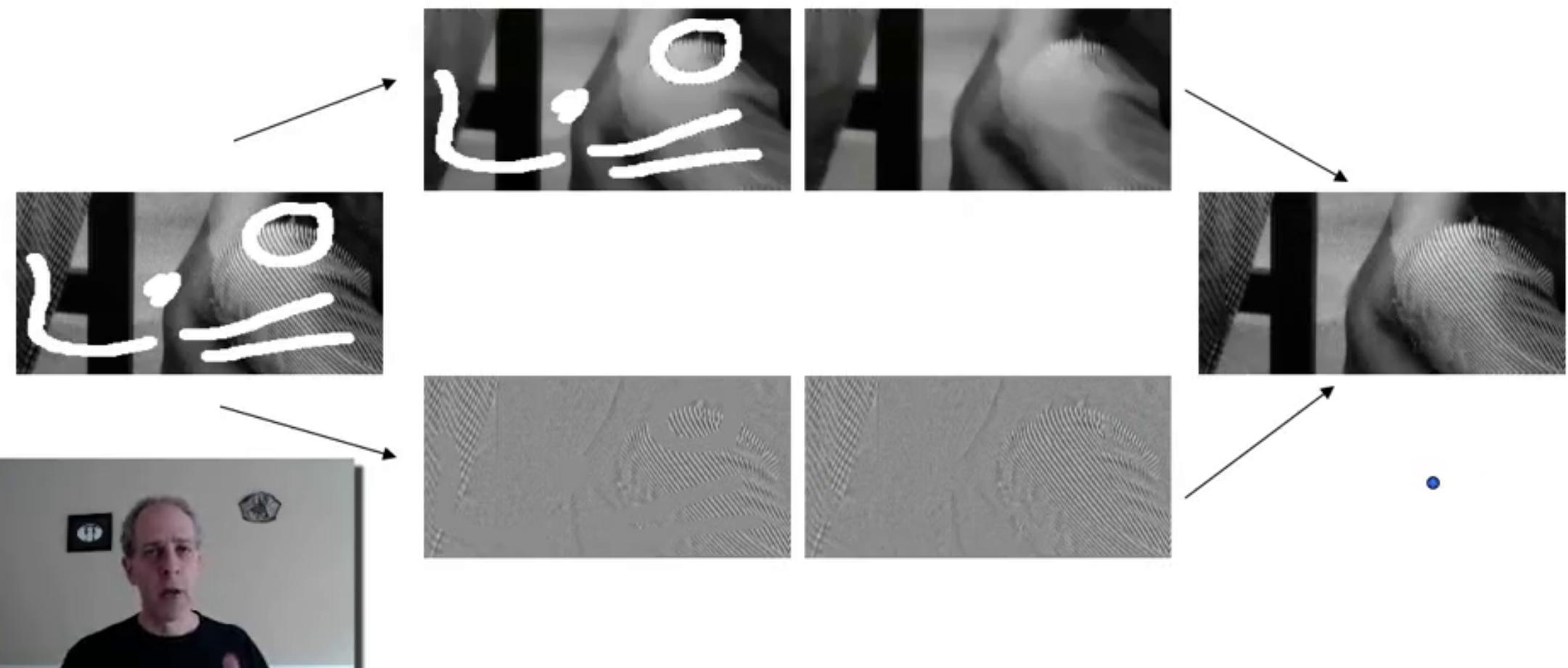
@



Examples

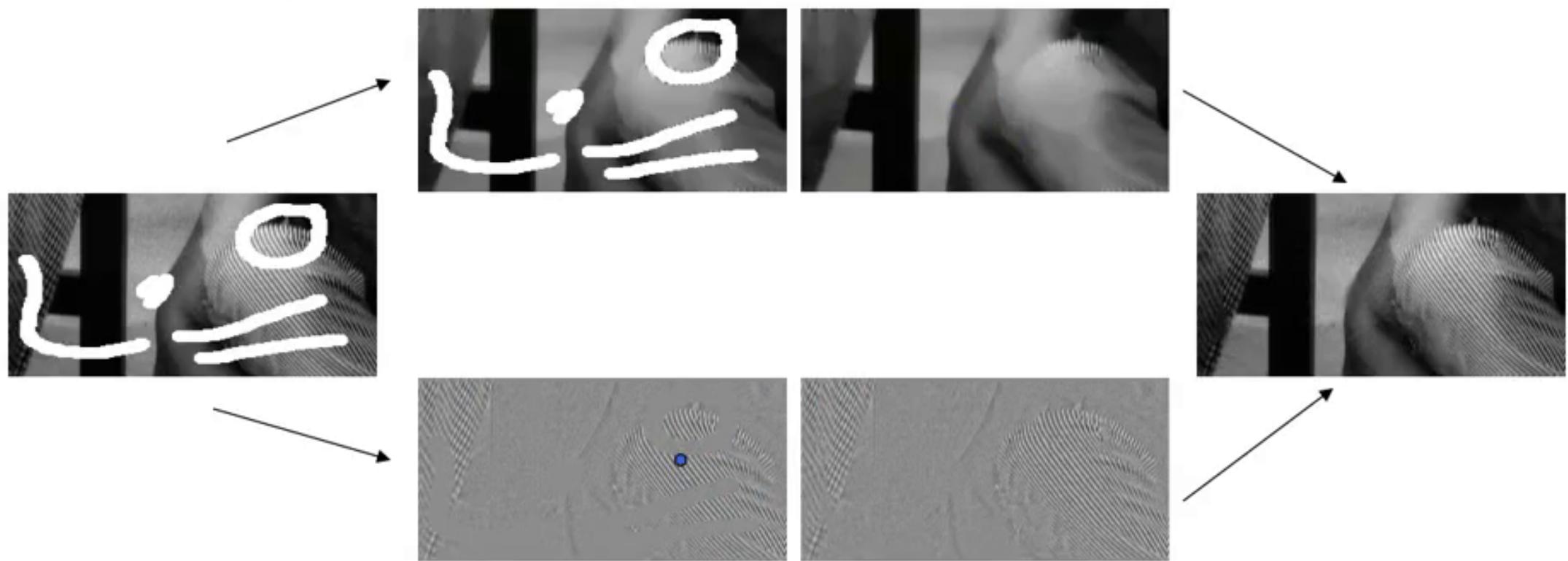


Inpainting and Image Decomposition



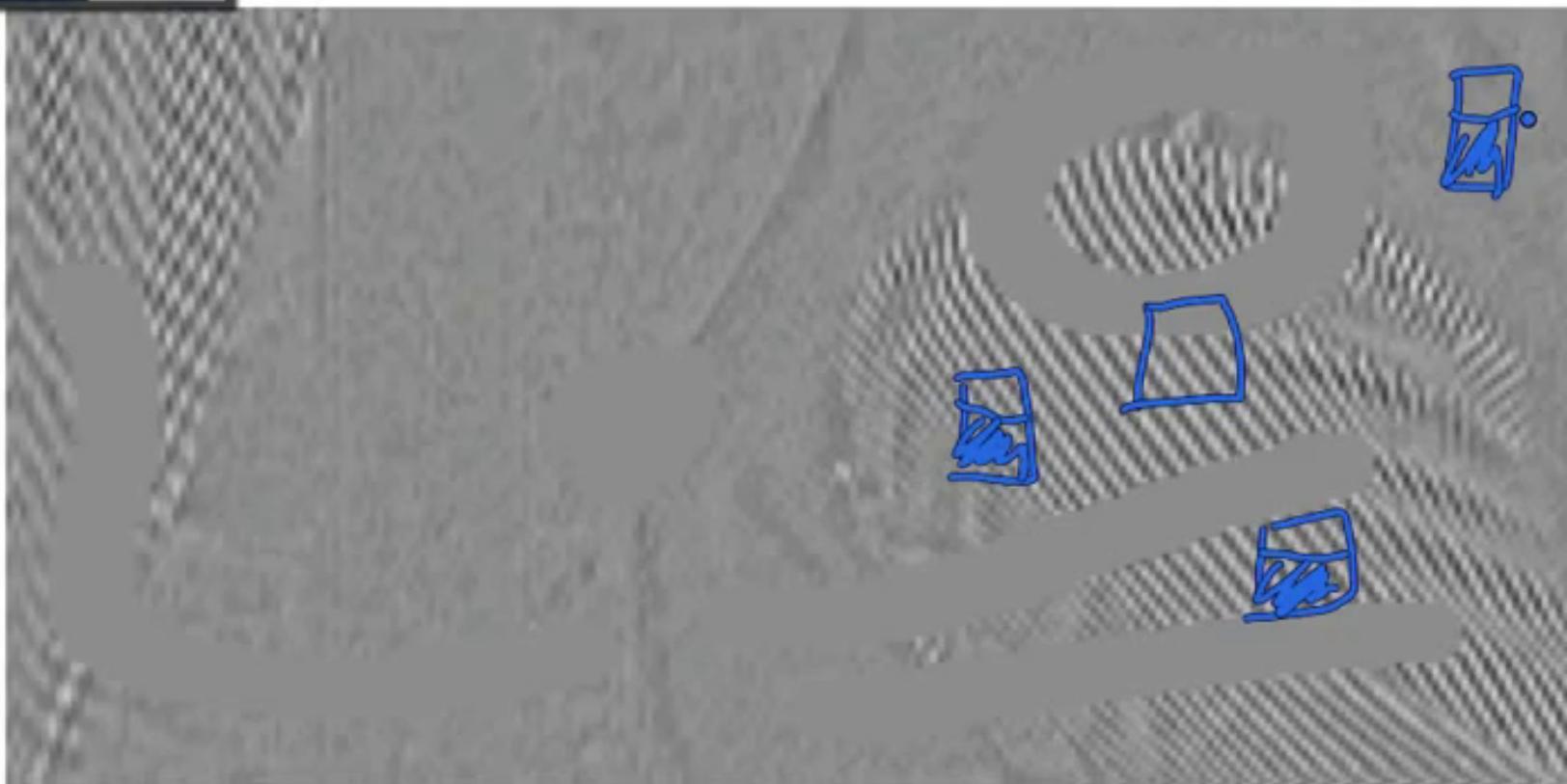


Smart Cut and Paste



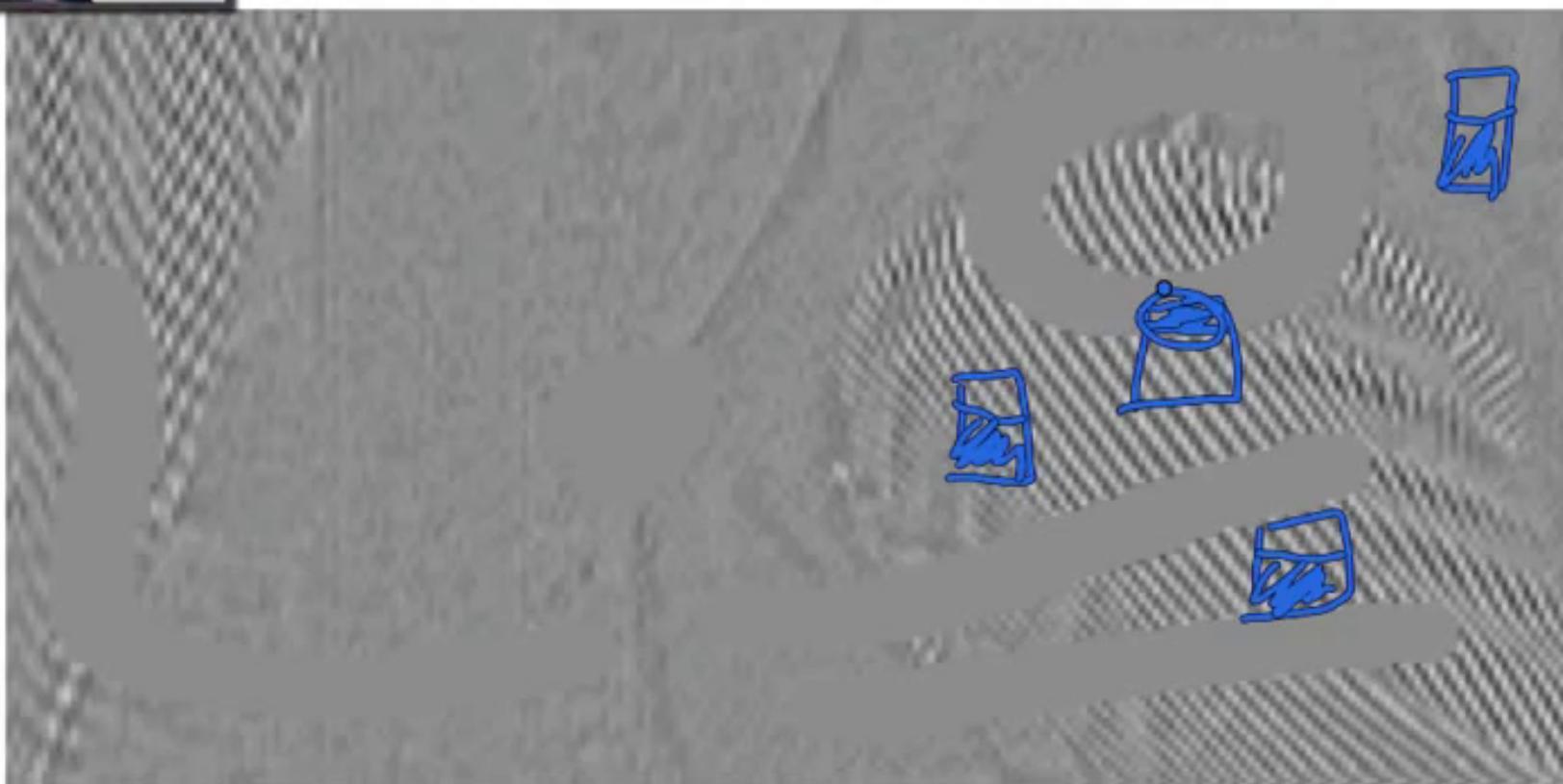


Smart Cut and Paste



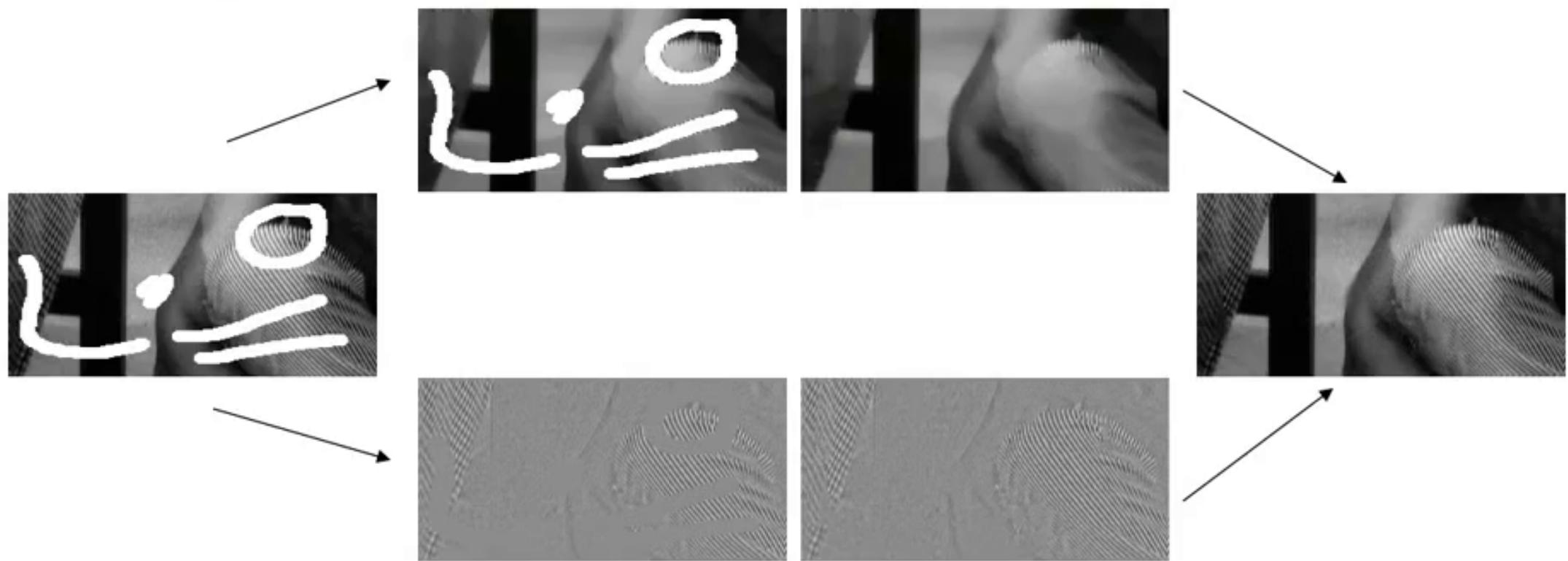


Smart Cut and Paste



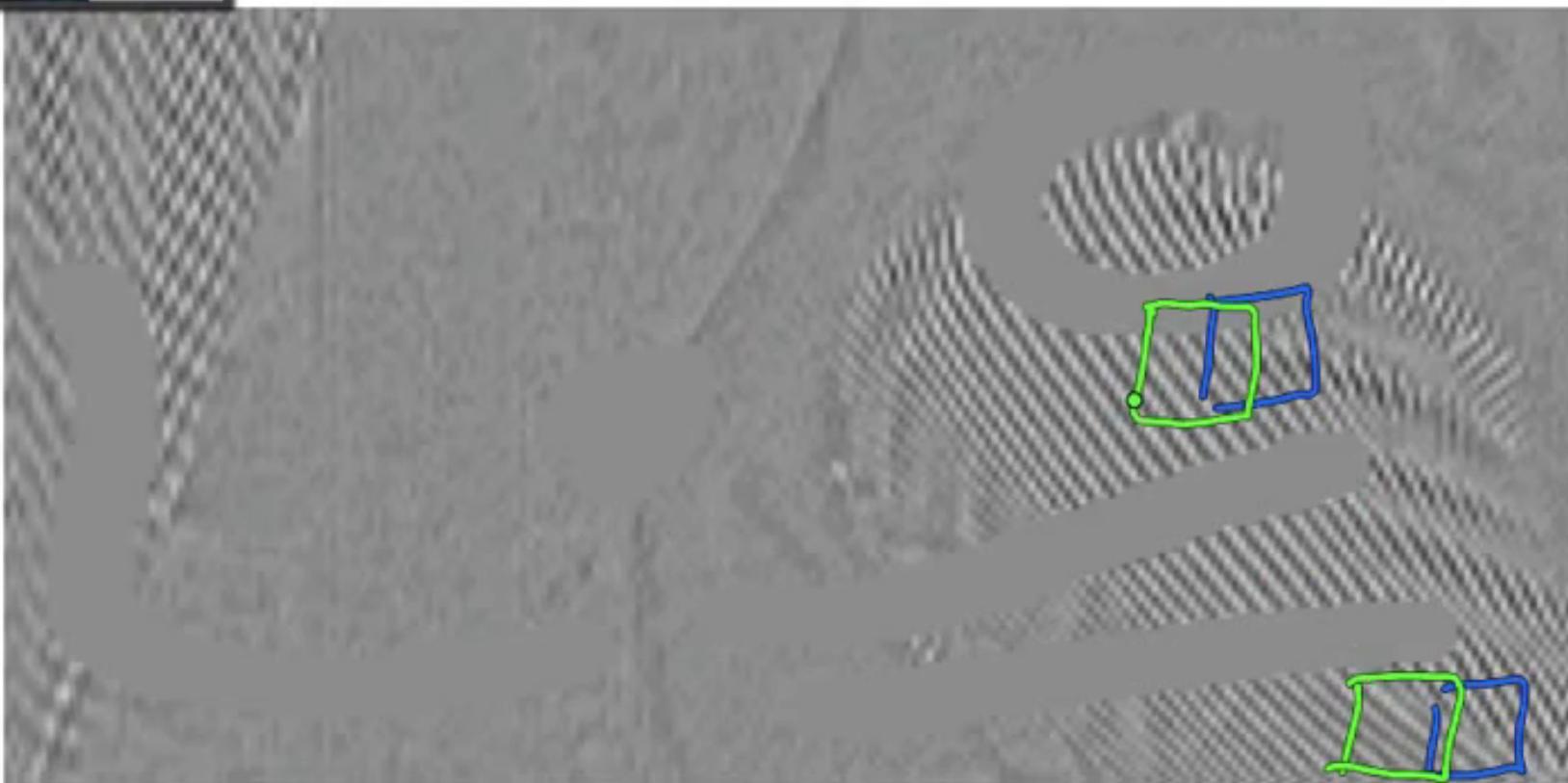


Smart Cut and Paste





Smart Cut and Paste



Combine it All



Courtesy of IEEE

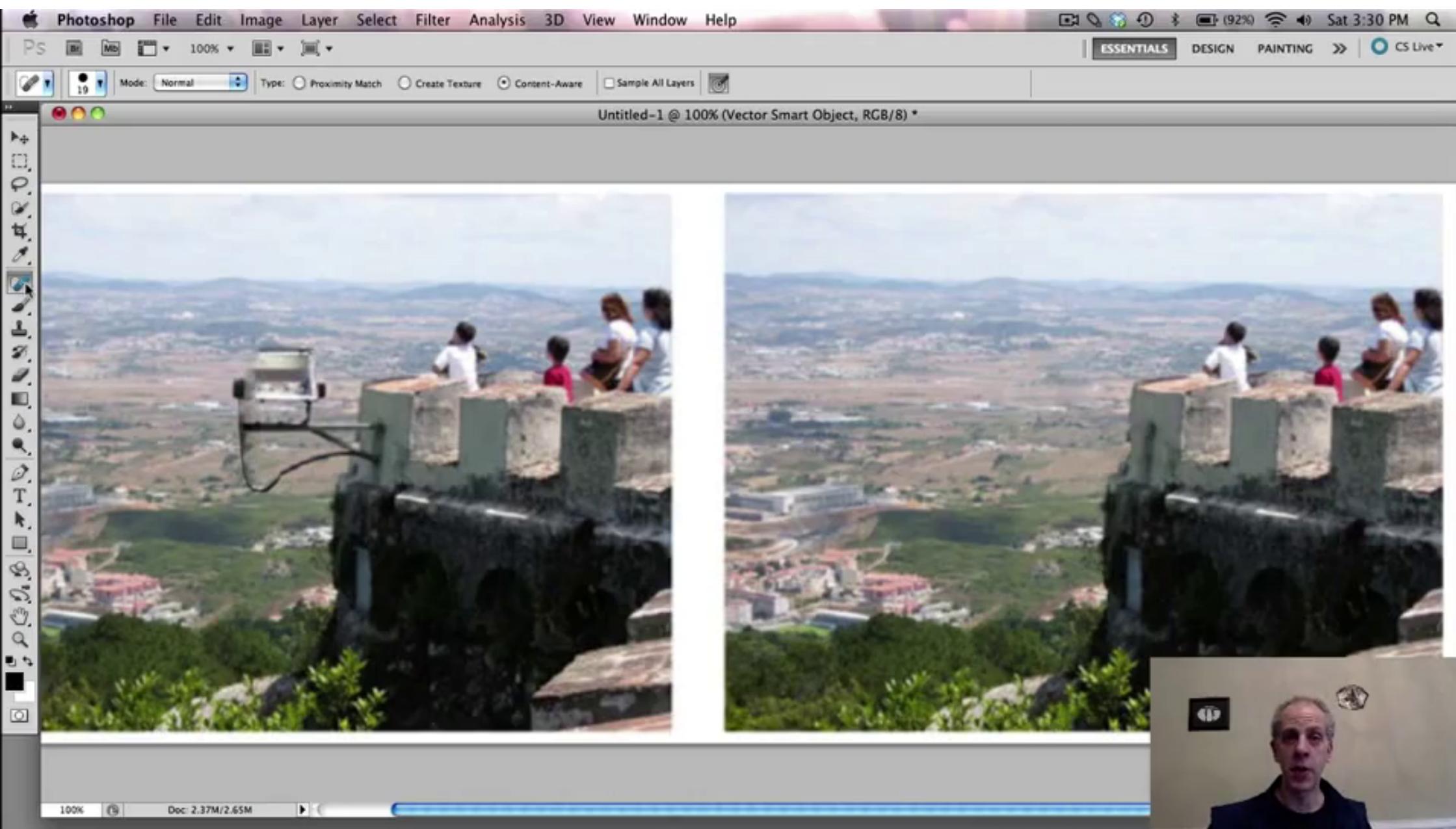


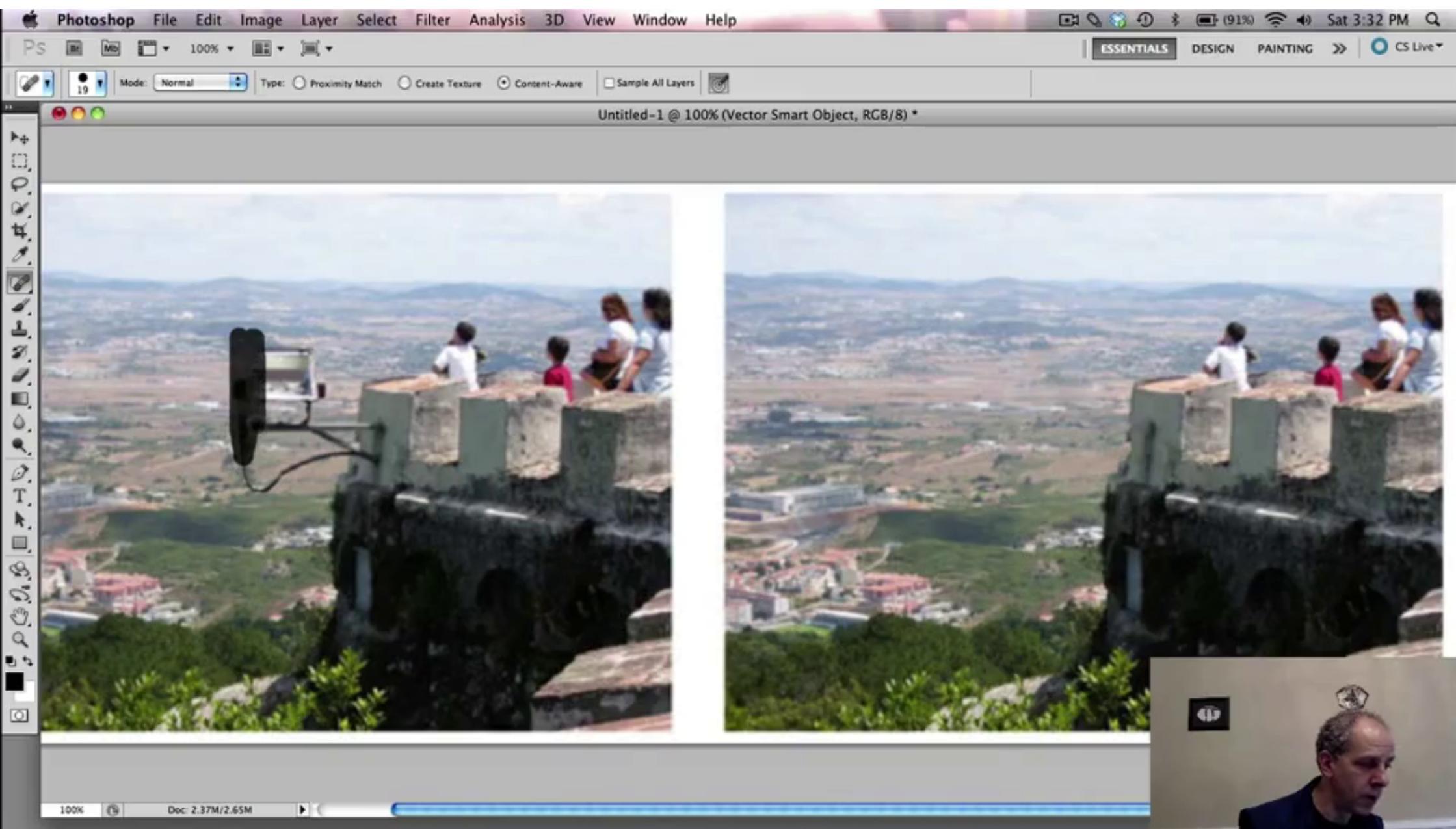
Courtesy of IEEE

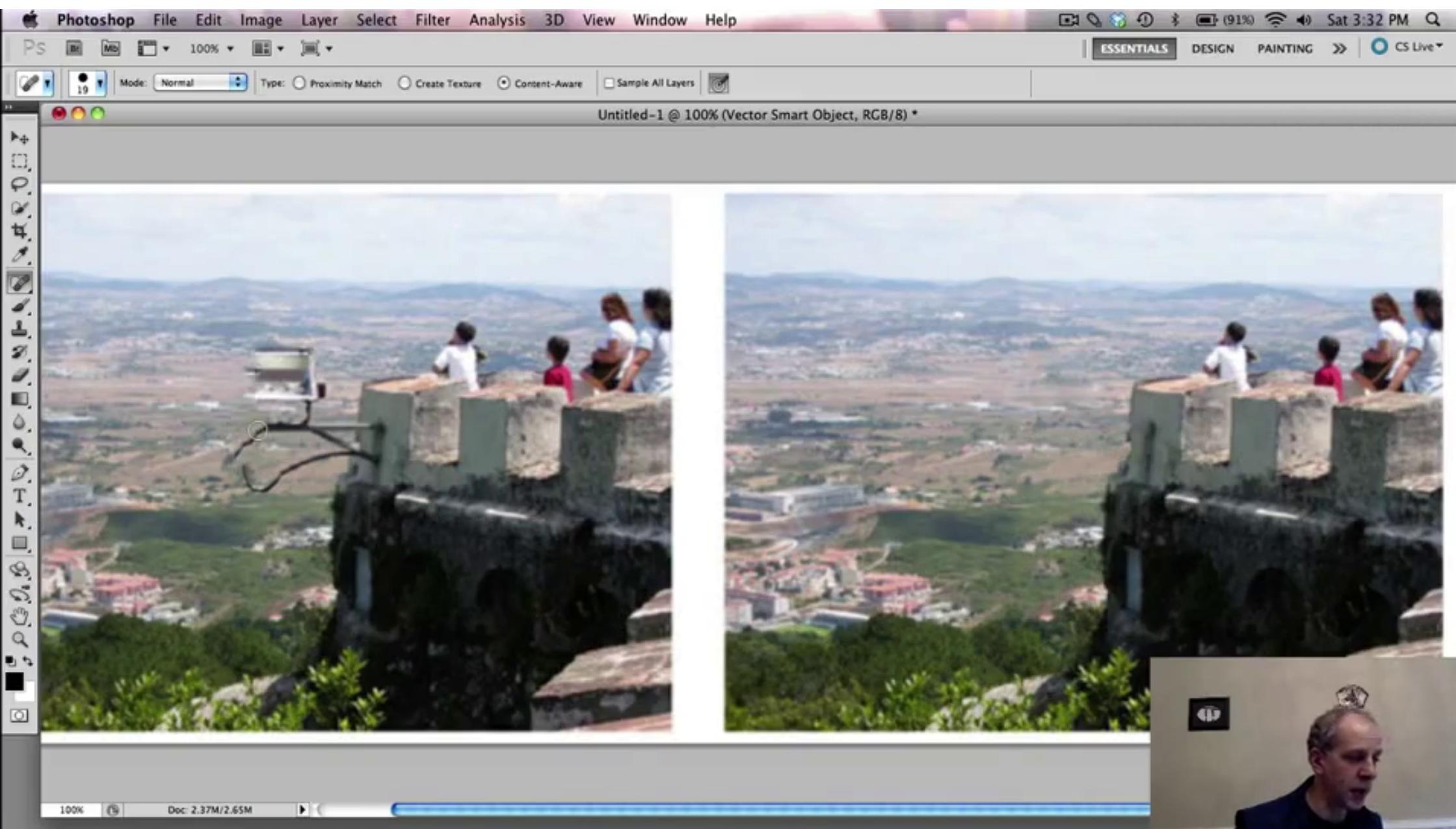


Courtesy of IEEE















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