Video Magnification

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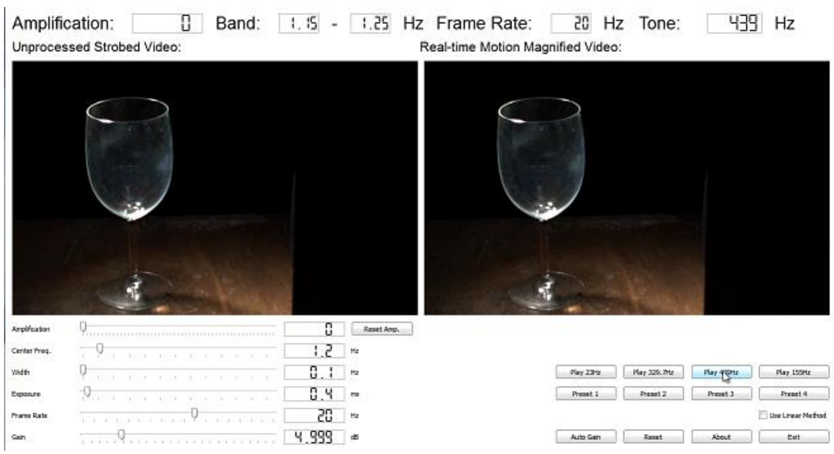
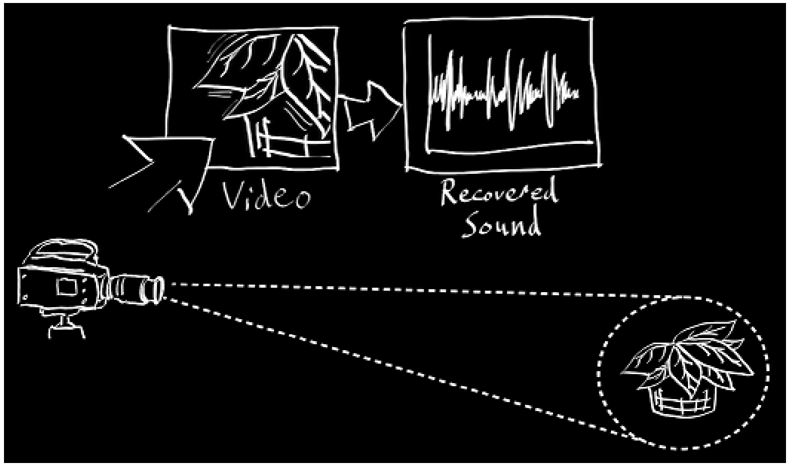
Video magnification

- A technique to detect tiny motion and then magnify or manipulate it
- Great resource from MIT (papers and source codes)
  - http://people.csail.mit.edu/mrub/vidmag/



Real-time Riesz pyramids

(CVPR'14 best demo)



Visual microphone

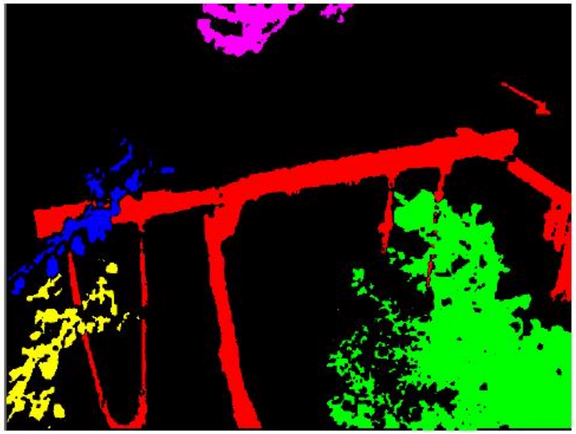
Outline

- Lagrangian motion magnification (SIGGRAPH’05)
- Linear Eulerian video magnification (SIGGRAPH’12)
- Phase-based video magnification (SIGGRAPH’13)

Lagrangian motion magnification

(a) Registered input frame

(b) Clustered trajectories of tracked features



(c) Layers of related motion and appearance

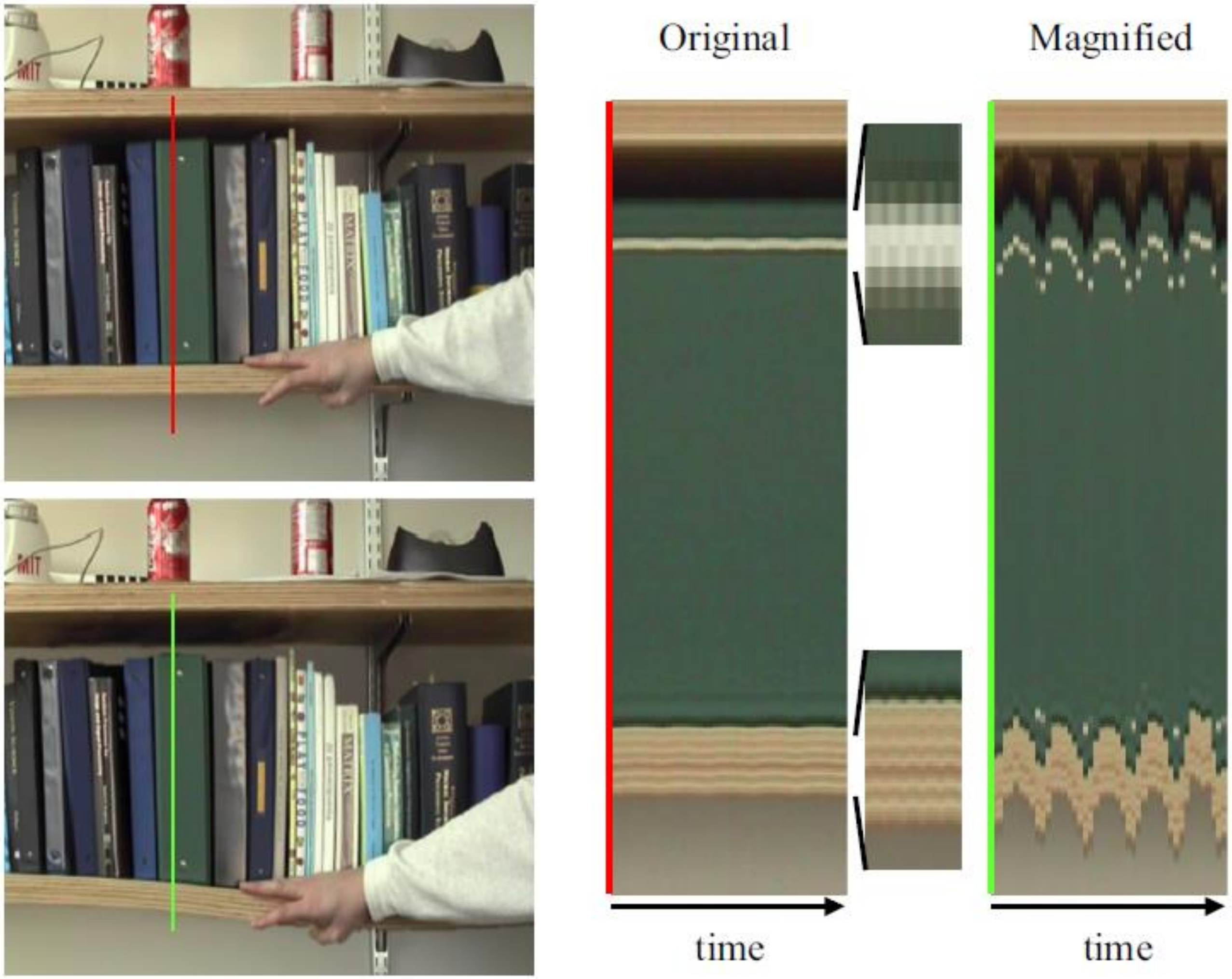
(d) Motion magnified, showing holes

(e) After texture in-painting to fill holes

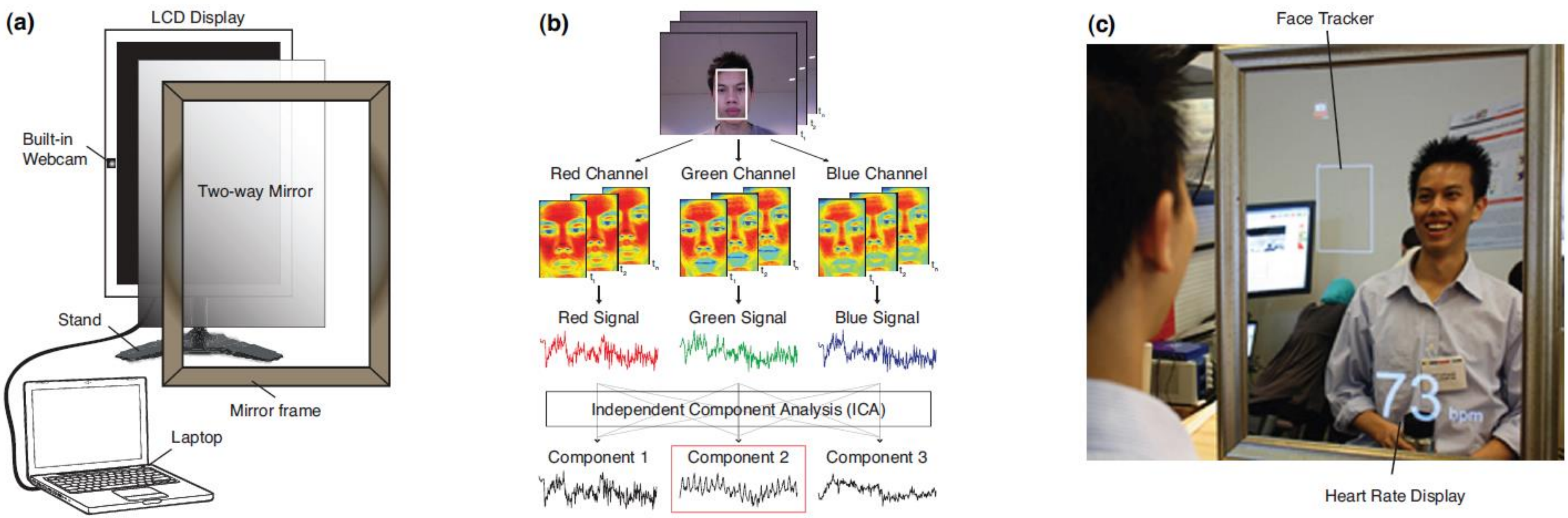
(f) After user's modifications to segmentation map in (c)

Ref: C. Liu, et. al., "Motion magnification," SIGGRAPH, 2005.

Result



Medical mirror (distraction)



Detect heart rate by analyzing vein color variation

Ref: M.Z. Poh, et. al., “A medical mirror for non-contact health monitoring,” ACM SIGGRAPH Emerging Technologies, 2011.

Outline

- Lagrangian motion magnification (SIGGRAPH'05)
- Linear Eulerian video magnification (SIGGRAPH'12)
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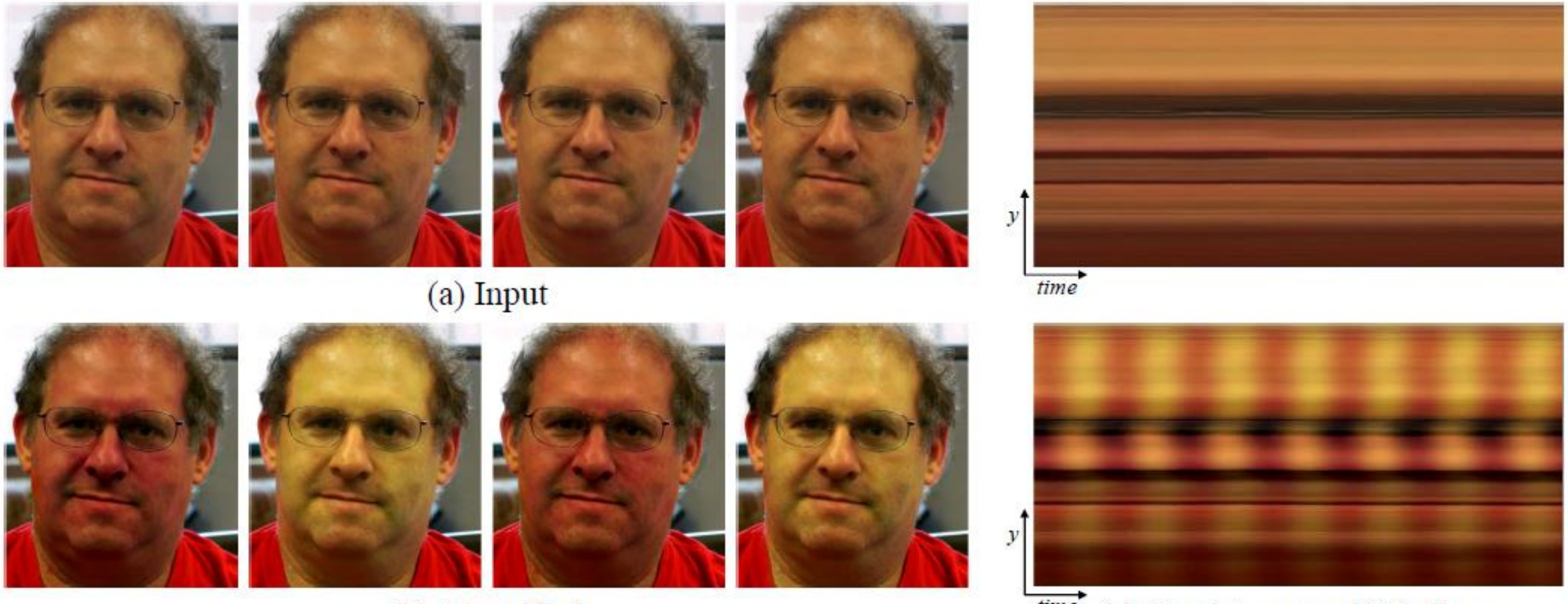
Eulerian video magnification

Magnify subtle color/motion changes in video



(a) Input

(b) Magnified

(c) Spatiotemporal YT slices

Ref: H.-Y. Wu, et. al., “Eulerian video magnification for revealing subtle changes in the world,” SIGGRAPH, 2012.

Eulerian motion magnification

- First-order Taylor series expansion as optical flow analysis

$$I(x,t) = f(x+\delta(t)) \text{ and } I(x,0) = f(x)$$

↓ First-order expansion

$$I(x,t) \approx f(x) + \delta(t)\frac{\partial f(x)}{\partial x}$$

↓ Temporal filtering (only keep the interesting $\delta(t)$)

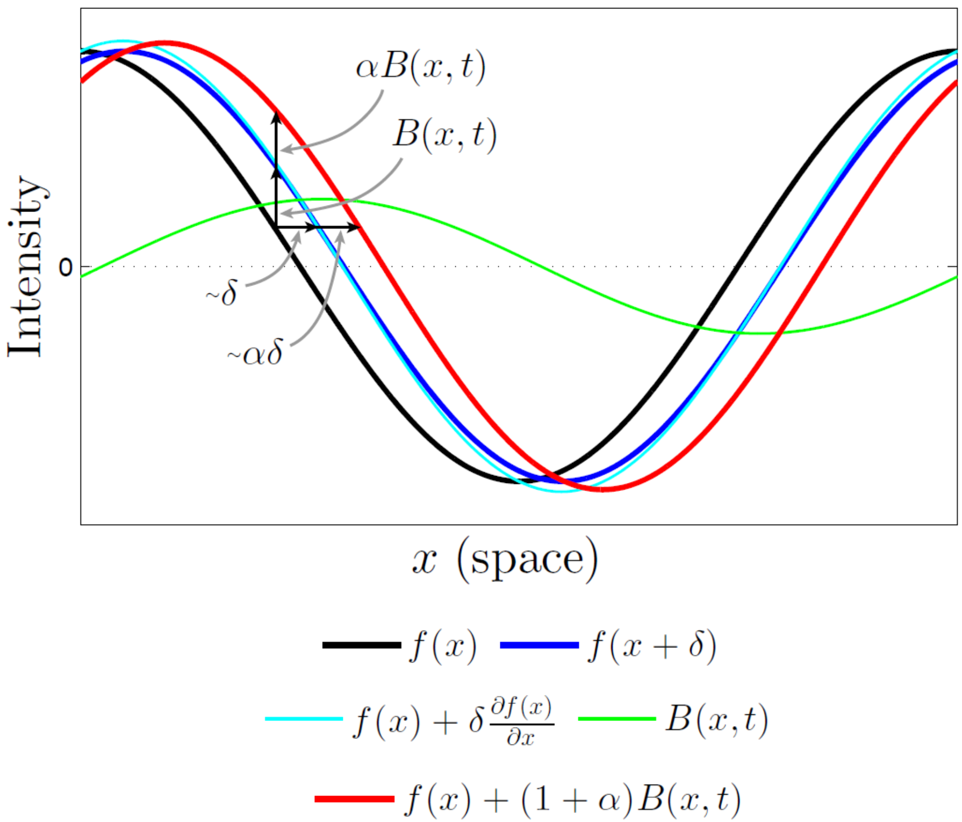
$$B(x,t) = \delta(t)\frac{\partial f(x)}{\partial x}$$

↓ Magnification

$$\tilde{I}(x,t) = I(x,t) + \alpha B(x,t)$$

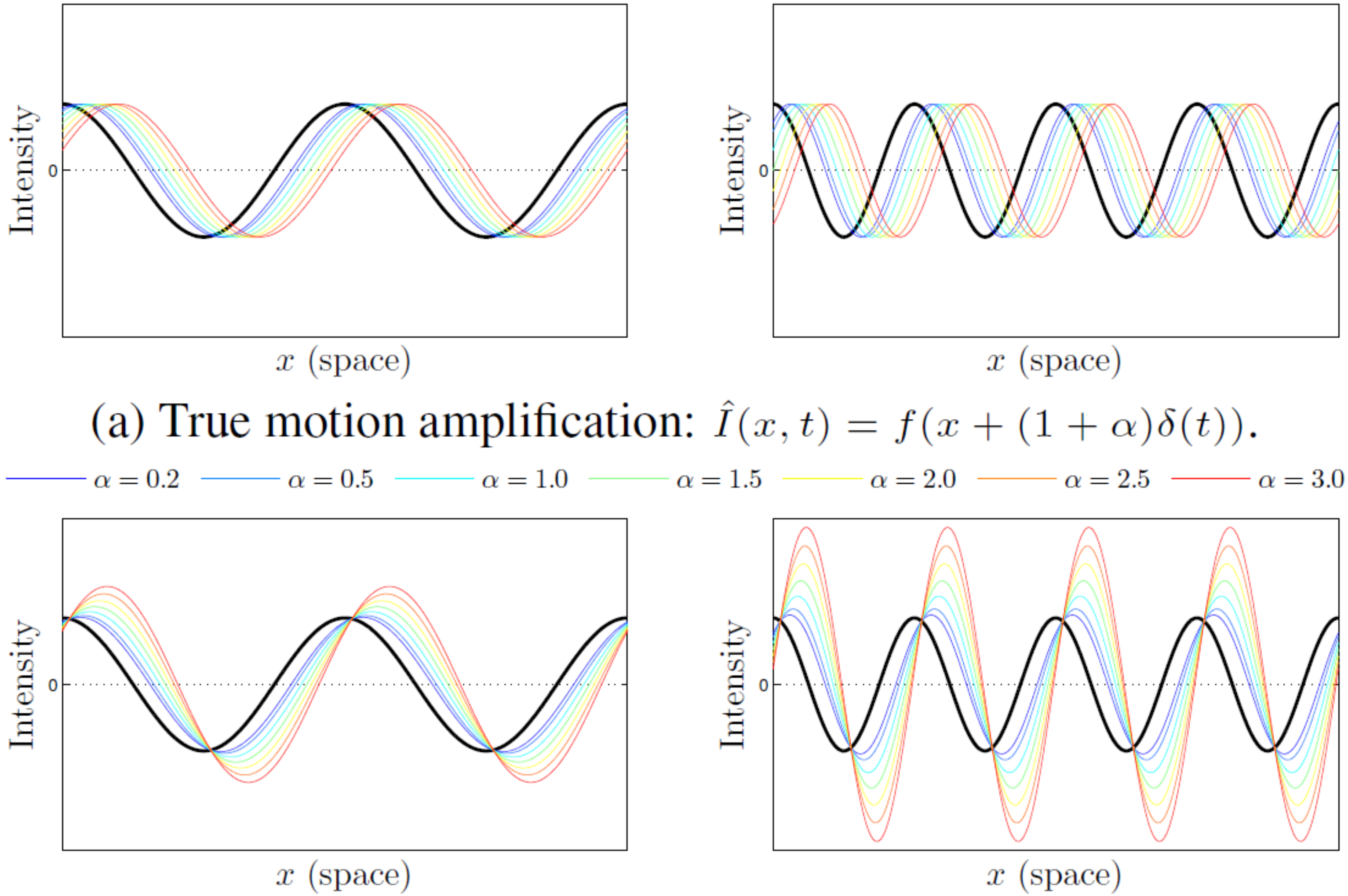
$$\tilde{I}(x,t) \approx f(x) + (1+\alpha)\delta(t)\frac{\partial f(x)}{\partial x}$$

$$\tilde{I}(x,t) \approx f(x+(1+\alpha)\delta(t))$$



Motion magnification bound

$$(1+\alpha)\delta(t) < \frac{\lambda}{8}$$



(a) True motion amplification: $\hat{I}(x,t) = f(x + (1+\alpha)\delta(t))$.

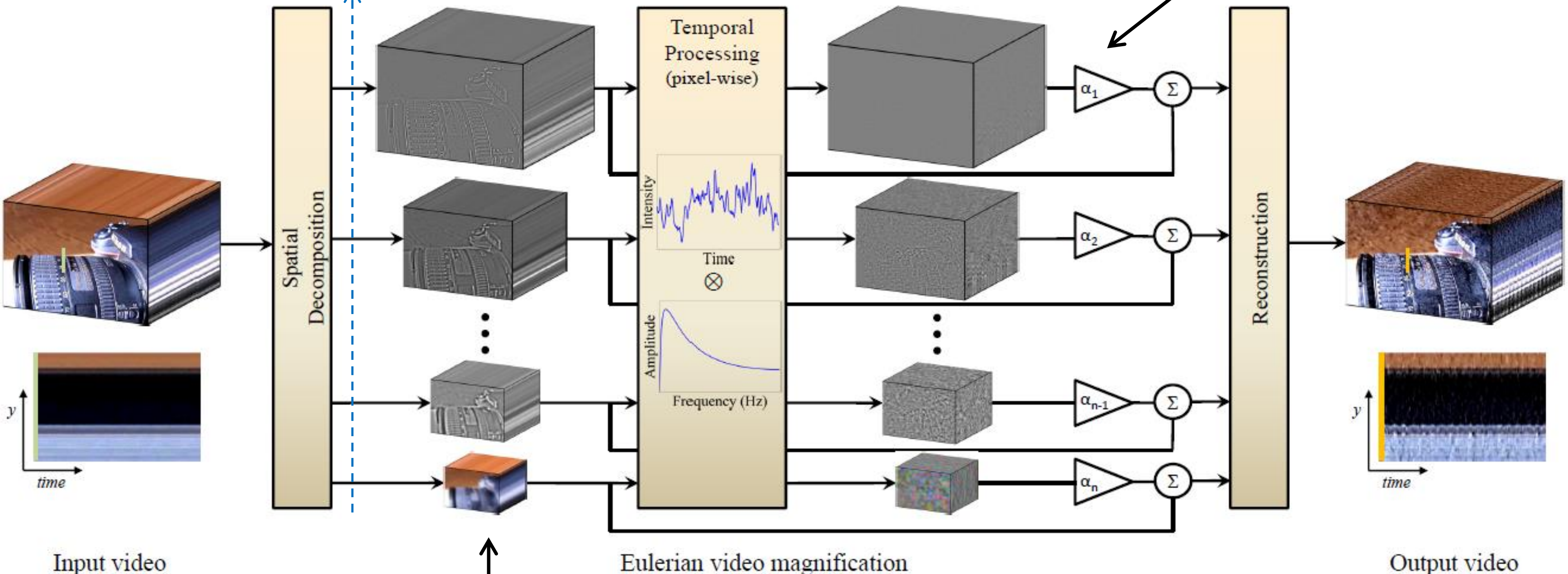
(b) Motion amplification via temporal filtering:
$\tilde{I}(x,t) = I(x,t) + \alpha B(x,t)$.

Spatio-temporal filtering framework

Temporal bandpass filtering
(target frequency selection)

Magnification
(in linear domain)

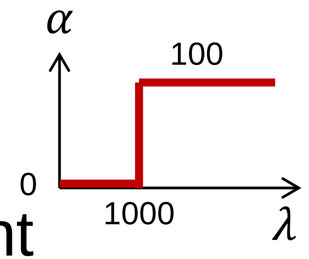
frequency ↗;
wavelength λ ↘



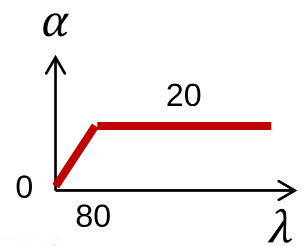
Laplacian pyramid
(spatial frequency decomposition)

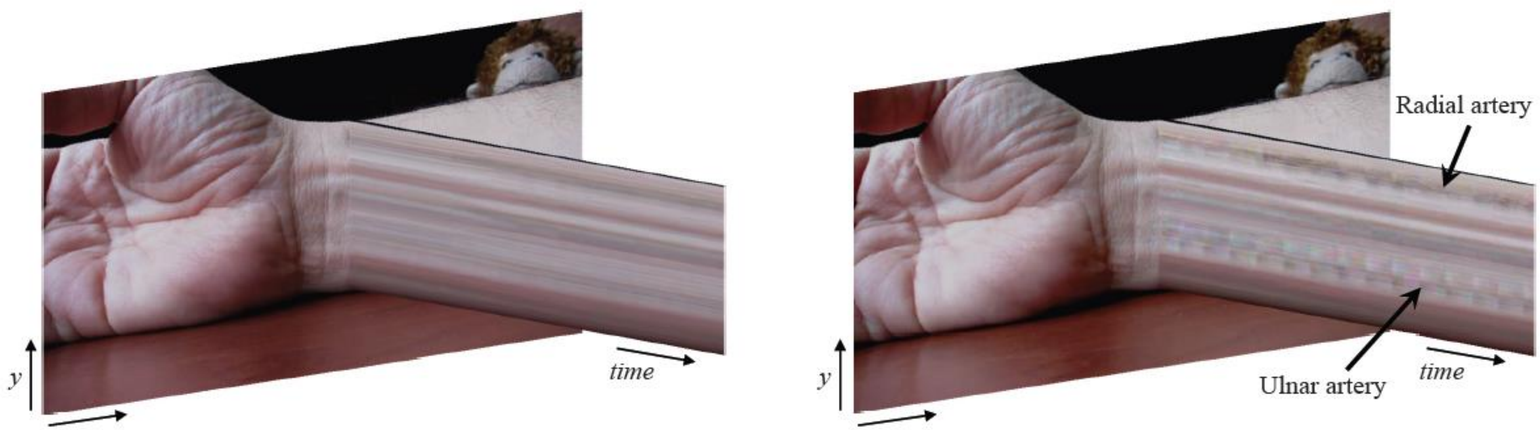
Magnification setting

- Color magnification
  - Large α, on low spatial-frequency component
  - Should register video to avoid motion magnification



- Motion magnification
  - Smaller α, wavelength-bound





(a) Input (*wrist*)   (b) Motion-amplified

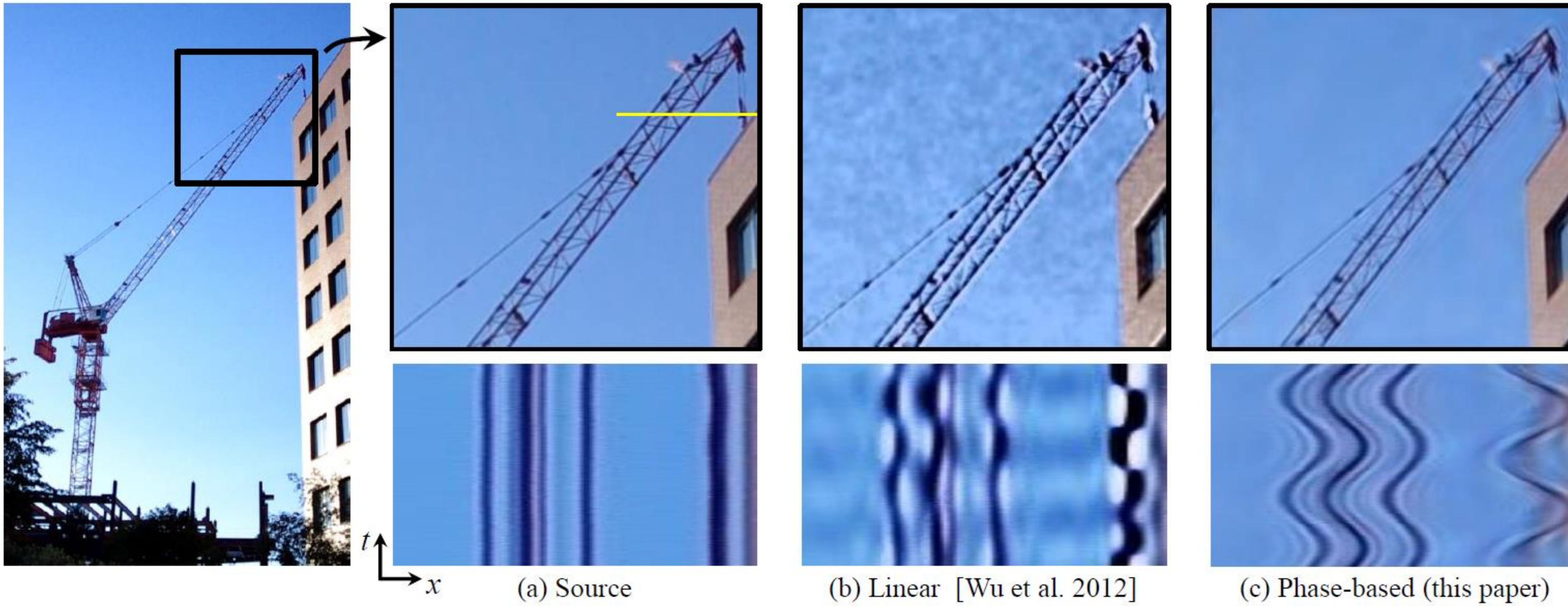
Result

Outline

- Lagrangian motion magnification (SIGGRAPH'05)
- Linear Eulerian video magnification (SIGGRAPH'12)
- Phase-based video magnification (SIGGRAPH'13)

Phase-based video magnification

- Amplify "phase shift", instead of amplitude (linear, Eulerian)
  - Support larger motion; less noise sensitive



Ref: N. Wadhwa, et. al., "Phase-based video motion processing," SIGGRAPH, 2013.

Phase magnification

for a single-frequency component

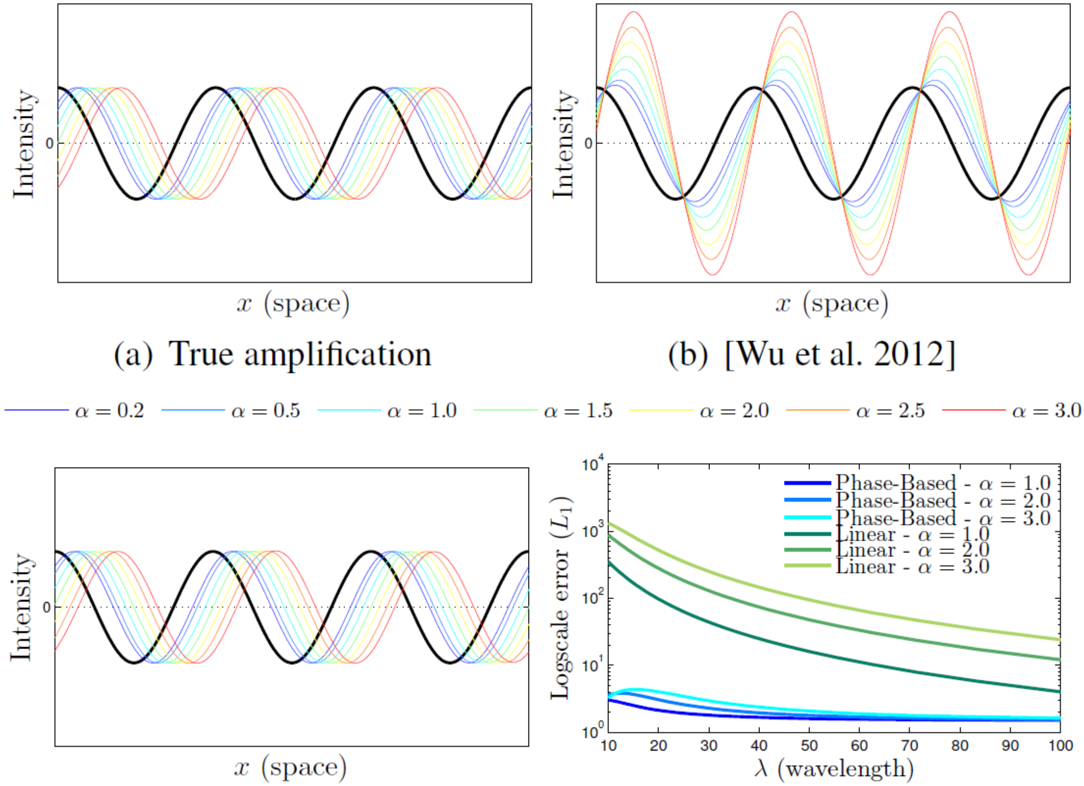
$$S_\omega(x,t) = A_\omega e^{i\omega(x+\delta(t))}$$

↓ Temporal filtering to keep interesting phase shift

$$B_\omega(x,t) = \omega\delta(t)$$

↓ Amplify the phase shift

$$\hat{S}_\omega(x,t) := S_\omega(x,t)e^{i\alpha B_\omega} = A_\omega e^{i\omega(x+(1+\alpha)\delta(t))}$$



(a) True amplification (b) [Wu et al. 2012]

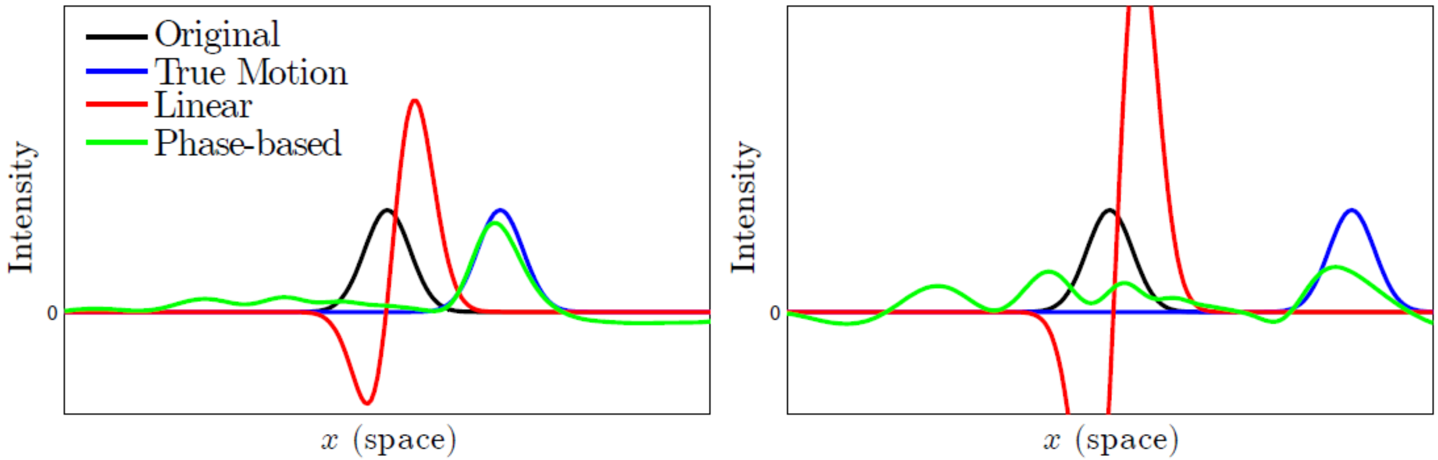
(c) Phase-based (d) Error as function of wavelength

Limitations on spatial frequency

- Magnification bound

$$\alpha\delta(t) < \frac{\lambda}{4}$$

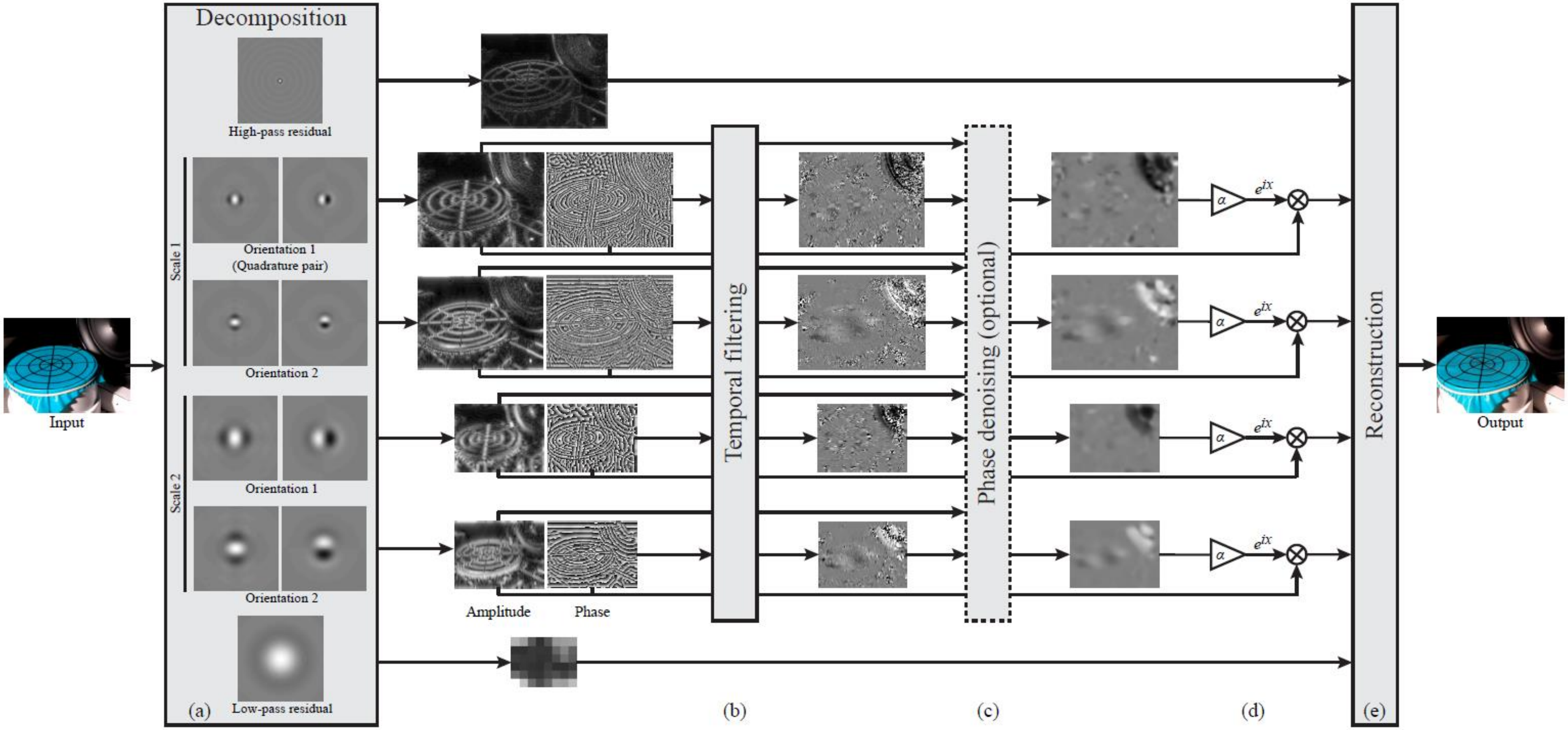
  - At least two times better than linear magnification



(a) $\alpha = 6$ (b) $\alpha = 14$

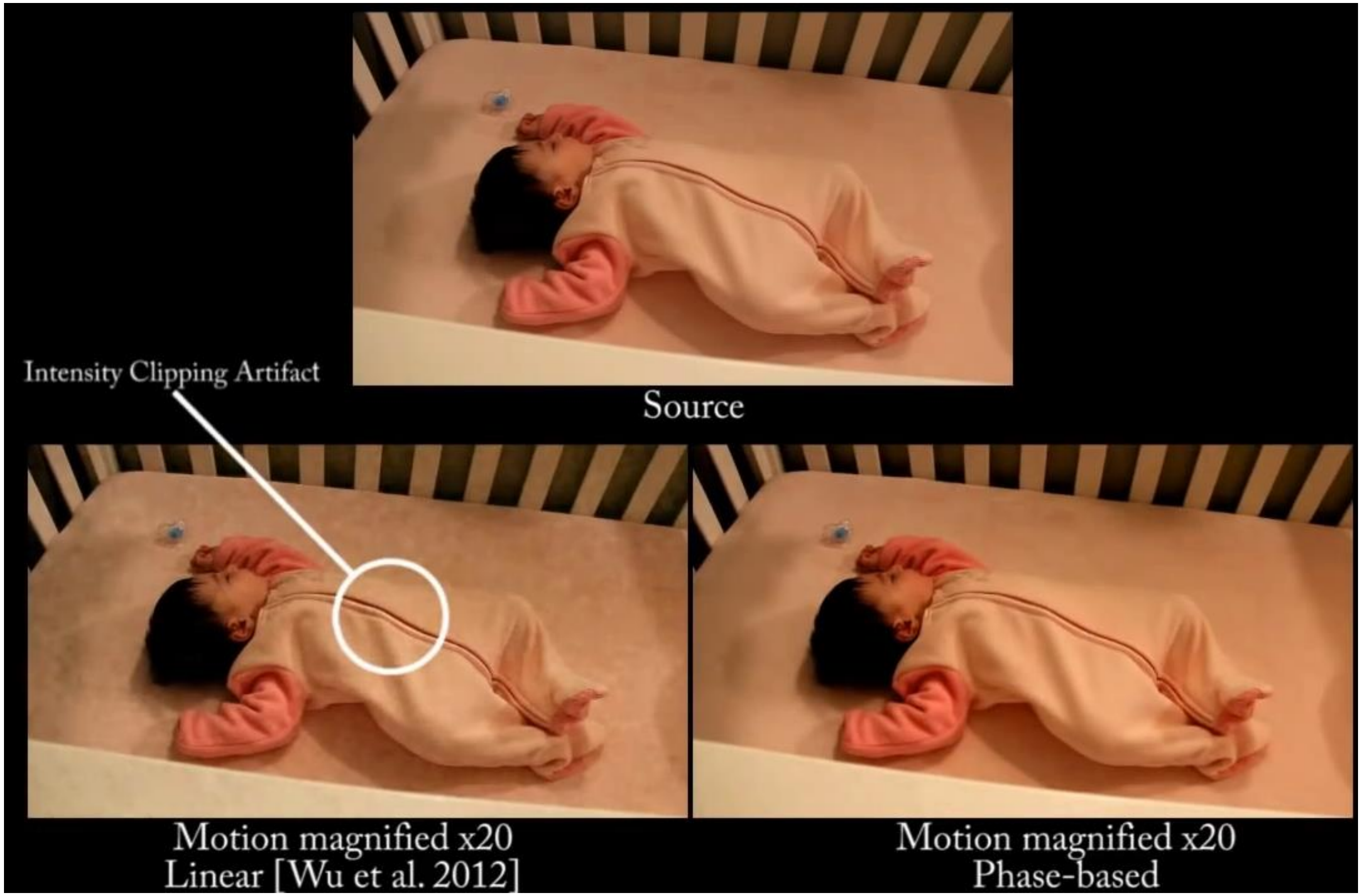
- Mind the single-frequency assumption
  - Phase shift = motion * spatial frequency

Phase-based framework



Complex steerable pyramid
(decompose localized phase/amplitude in different directions and spatial frequencies)

Result


Intensity Clipping Artifact
Source
Motion magnified x20
Linear [Wu et al. 2012]
Motion magnified x20
Phase-based

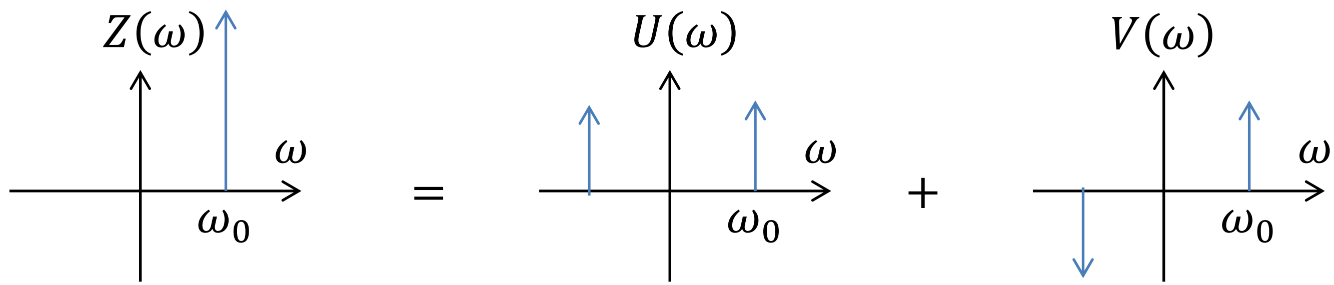
Appendix

Fourier analysis

- Simple example (note the single-frequency assumption)

$u(t) = \cos\omega_0 t$ => quadrature pair (90° shift): $v(t) = \sin\omega_0 t$

Consider a **complex** signal $z(t) = u(t) + i\ v(t)$



$$\mathrm{Z}(\omega) = 2U(\omega)\mathbf{1}_{\{\omega\geq 0\}}$$

Hilbert transform

$$\mathcal{H}(u)(t) = v(t) = \frac{1}{\pi t} * u(t) \Rightarrow V(\omega) = -i \operatorname{sgn} \omega \cdot U(\omega)$$

Hilbert transform is to find the quadrature pair

$$\therefore for\ z(t) = u(t) + iv(t) \Rightarrow \mathrm{Z}(\omega) = 2U(\omega)\mathbf{1}_{\{\omega \geq 0\}}$$

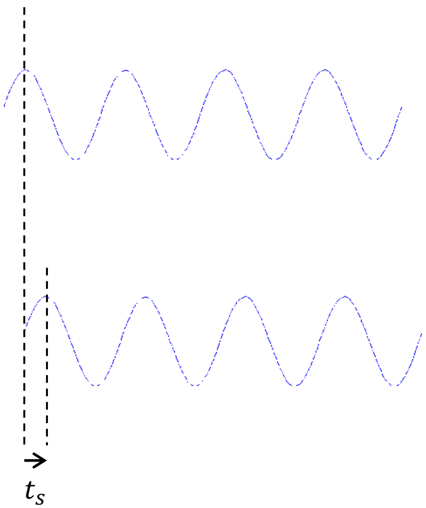
Here we only need this simpler derivation

Let $\mathrm{Z}(\omega) = 2U(\omega)\mathbf{1}_{\{\omega \geq 0\}} \Rightarrow z(t) = u(t) + iv(t)$

where $u(t) = \mathrm{Re}\{z(t)\}$ and $v(t) = \mathcal{H}(u)(t) = \mathrm{Im}\{z(t)\}$

Q: How to derive complex $z(t)$ for real $\mathrm{u}(t)$? **A**: $\mathcal{F}^{-1}\{2U(\omega)\mathbf{1}_{\{\omega \geq 0\}}\}$.

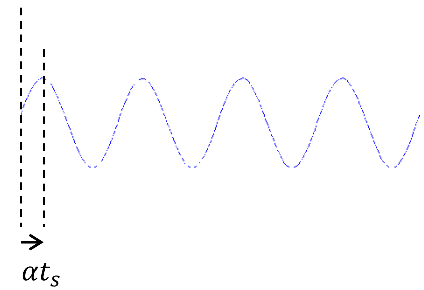
Toy example for phase-based signal interpolation

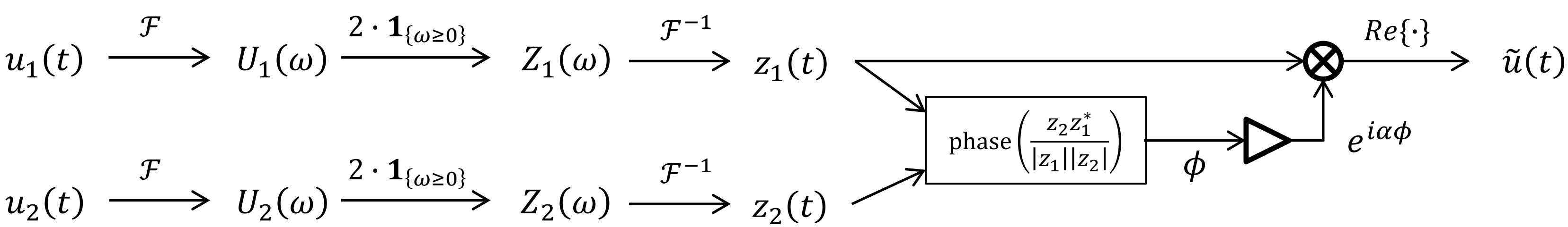


$u_1(t) = \cos\omega_0 t$

$u_2(t) = \cos\omega_0(t - t_s) = \cos(\omega_0 t + \phi)$

$\tilde{u}(t) = \cos\omega_0(t - \alpha t_s) = \cos(\omega_0 t + \alpha\phi)$





Q: How about multi-frequency signals? **A**: Filter bank decomposition.