

ICPR 2004

Best Industry Related Paper Award

Super-Resolving Compressed Video with Large Artifacts

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Super-Resolving Compressed Video

- Super-Resolution improve image quality: resolution, noise



Simple zoom-up



Cubic zoom-up



Electronic super-resolved

Super-Resolving Compressed Video

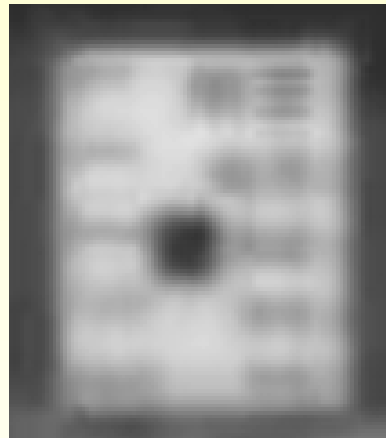
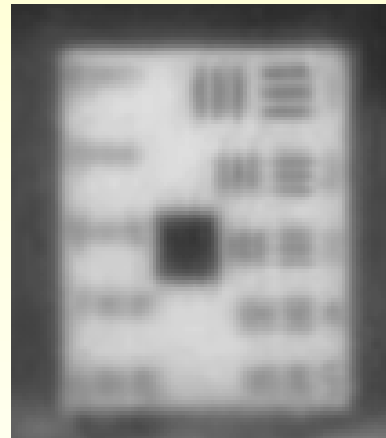
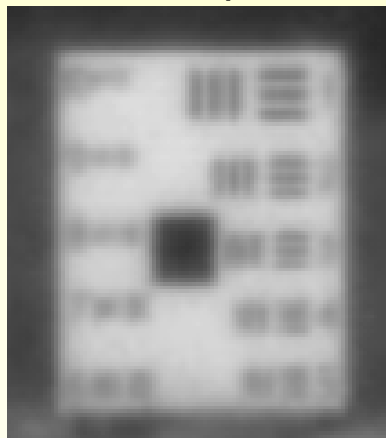
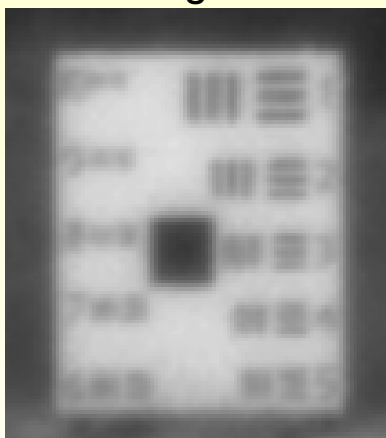
- Video, especially **compressed** video is ubiquitous

original

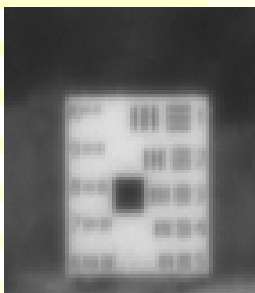
2Mbps

1Mbps

256Kbps

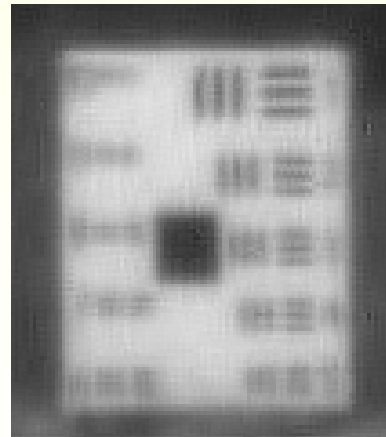
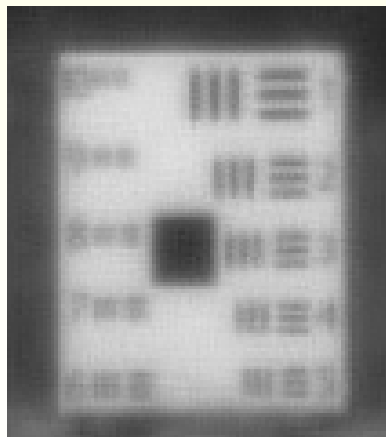
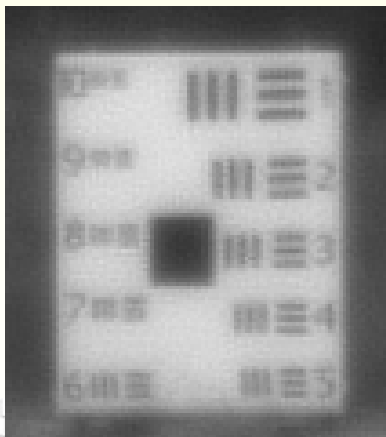


Bi-Cubic



Low-res video

Super-Res



Super-Resolving Compressed Video

- Video, especially **compressed** video is ubiquitous



Talk Outline

- Related Work
- Super-Resolution with Dynamic Masking
- Flow-based Image Repairing
- Experimental Results
- Conclusions and Directions

Related Work

- **Reconstruction-based Super-Resolution (parametric motion)**

Irani & Peleg (jvc 93), Schultz & Stevenson (tip96), Patti Sezan & Teklap (tip97)

Elad & Feuer (tip97), Hardie, Barrard & Armstrong (tip97)

Capel & Zisserman (cvpr00), Rav-Acha, Zomet & Peleg (cvpr01)

- **Flow-based Super-Resolution**

Baker & Kanade (CMU tr99), Zhao & Sawhney (eccv02)

- **Super-Resolving Compressed Images**

Segall, Molina, & Katsaggelos (spm03)

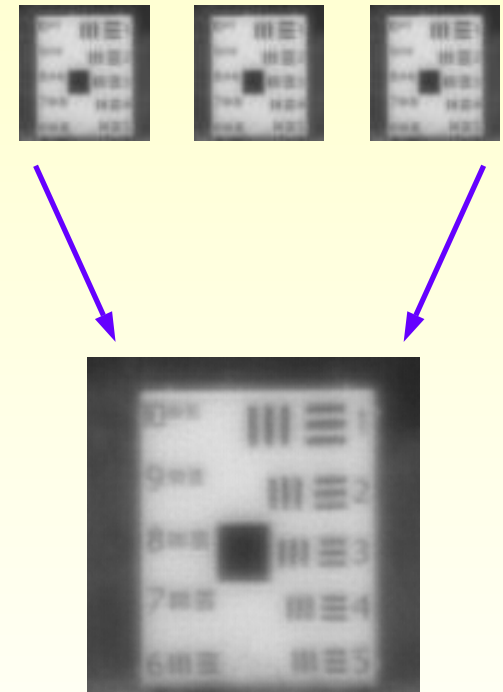
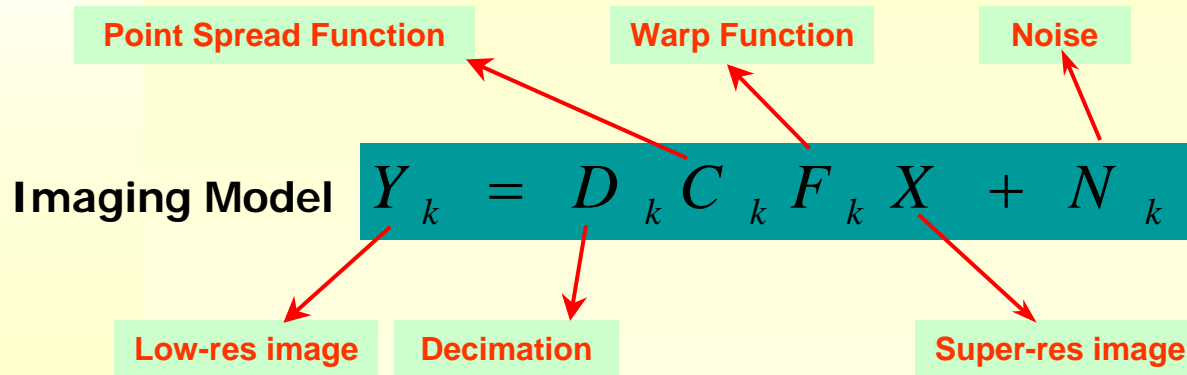
- **Image Repairing**

Kokaram & Morris (tip95), Ballester, Caselles, Verdera, Bertalmio, and Sapiro (iccv01)

Jia and Tang (iccv03)

Super-Resolution With Dynamic Masking

Principle of Super-Resolution



Estimate

$$\tilde{X} = \operatorname{argmin}\{(Y - HX)W^F(Y - HX)\}$$

where $H_k \stackrel{\text{def}}{=} D_k C_k F_k$

Video Compression

$$y_l = T^{-1}Q[T(g_l - MC_l(Y_l^p, v_l))] + MC_l(Y_l^p, v_l) \quad (\text{Segall'03})$$

Super-Resolving with Masking

Back Projection Method (Irani & Peleg, ivc93)

$$I_h^{(n+1)} = I_h^{(n)} + \frac{1}{K} \sum_{k=1}^K \{ [(g_k - g_k^{(n)}) \uparrow s]^{F_k} \cdot p \}$$

where $g_k^{(n)} = \{ [I_h^{(n)}]^{B_k} \cdot h \} \downarrow$

Flow-based BP Algorithm with Masking (Zhao & Sawhney, eccv02)

$$I_h^{(n+1)} = I_h^{(n)} + \frac{1}{K} \sum_{k=1}^K \text{●} \{ [(g_k - g_k^{(n)}) \uparrow s]^{F_k} \cdot p \}$$

Masking is practically very important!

Super-Resolving with Dynamic Masking

Dynamic Masking Algorithm

At each iteration n , re-compute masks $w_k^{(n)}$

$$g_k^r = \{[g]^{F_k}\} \xleftrightarrow{w_k^{(n)}} g^{(n)} = \{[I_h^{(n)}] \cdot h\} \downarrow$$

Dynamic masking helps to repair small artifacts

Original Reference Image



Artificially Modified Reference Image



Artificially Modified Reference Image



Super-Resolution with **Dynamic** Masking



Super-Resolution with **Static** Masking



Flow-based Image Repairing

Image Repairing



A simulation of perfect repairing only

Consider spatial information only

Image Tweening

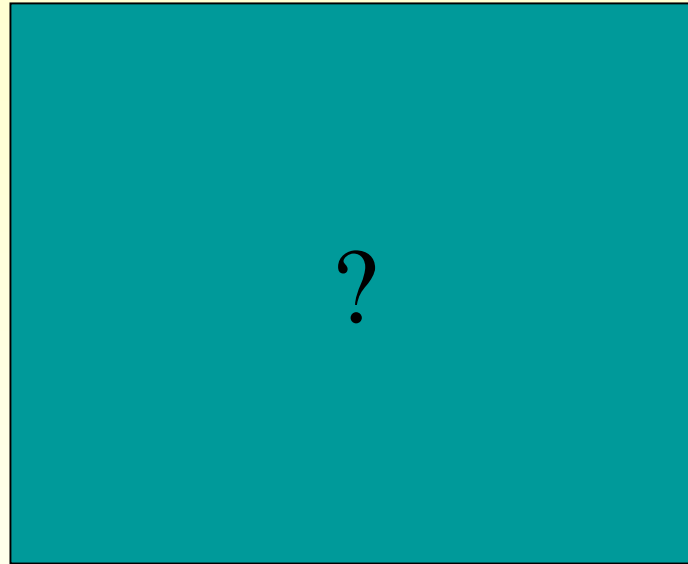


Image Tweening



Consider temporal information only

Flow-based Image Repairing



A simulation of perfect repairing only



Flow-based Image Repairing



Consider spatial information
&
Propagate temporal information

Traditional Flow vs. Consistent Flow

Traditional Flow $Err_i \stackrel{def}{=} \{ I_i(\mathbf{p}_i) - I_j(\mathbf{p}_i + \mathbf{u}_i[\mathbf{p}_i])^2 \}$

independently

$$\min Err_1$$

&

$$\min Err_2$$

Improvement

simultaneously

$$\min \{ Err_1 + Err_2 \}$$

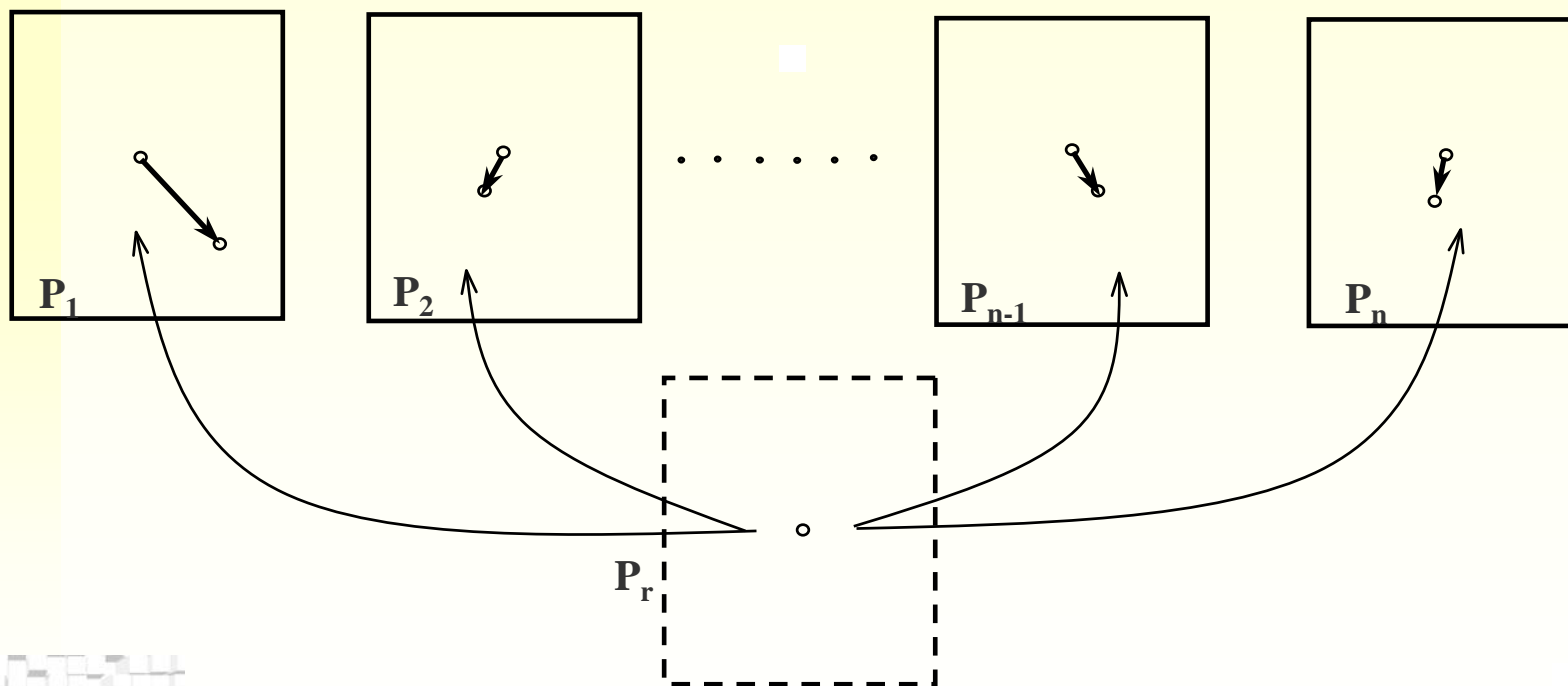
Consistent Flow (Zhao and Sawhney, ECCV 2002)

$$Err_{cons} \stackrel{def}{=} \{ I_1(\mathbf{p} - \alpha \mathbf{u}[\mathbf{p}]) - I_2(\mathbf{p} + (1 - \alpha) \mathbf{u}[\mathbf{p}])^2 \}$$

$$\min Err_{cons}$$

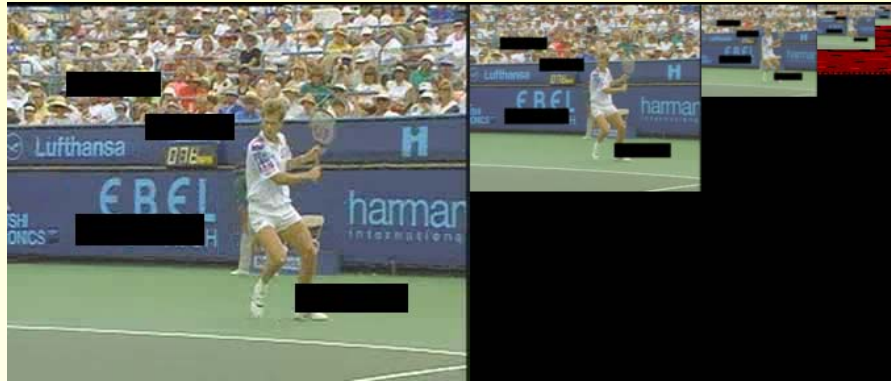
Multi-Frame Consistent Flow

$$\begin{aligned}
 Err_{cons} &= \sum Err_{f2r} + Err_{f2f} \\
 &= \sum_{i \neq r} [(I_i(\mathbf{p} - \mathbf{u}_i[\mathbf{p}]) - I_r(\mathbf{p}))^2 \\
 &\quad + \sum_{i \neq j} (I_i(\mathbf{p} - \mathbf{u}_i[\mathbf{p}]) - I_j(\mathbf{p} - \mathbf{u}_j[\mathbf{p}]))^2
 \end{aligned}$$



Multi-Frame Consistent Flow with Damaged Frames

- Exploring spatial information



- Propagating temporal information

Gradient information

Multi-Frame Consistent Flow with Damaged Frames

- Exploring spatial information

A multi-resolution iterative scheme

$$\begin{bmatrix} 2 \sum (\nabla I'_1)(\nabla I'_1)^T & - \sum (\nabla I'_1)(\nabla I'_3)^T \\ - \sum (\nabla I'_3)(\nabla I'_1)^T & 2 \sum (\nabla I'_3)(\nabla I'_3)^T \end{bmatrix} \begin{bmatrix} \delta \mathbf{u}_1 \\ \delta \mathbf{u}_3 \end{bmatrix} = \begin{bmatrix} I_{t1} \nabla I'_1 + I_{t13} \nabla I'_1 \\ I_{t3} \nabla I'_3 + I_{t31} \nabla I'_3 \end{bmatrix}$$

- Propagating temporal information

$$\nabla I'_i = (m_i^w \nabla I_i^w + m_r \nabla I_r) / (2[m_i^w + m_r])$$

Experimental Results

Stefan MPEG sequence of five frames
(CIF format: 352x288)



Foreman MPEG sequence of
nine frames (CIF format)



Super-Resolution **without** Masking



Foreman
sequence

Super-Resolution with **Static** Masking



Foreman
sequence

Super-Resolution with **Dynamic** Masking



Foreman
sequence

Bi-cubic Interpolation



Foreman
sequence

Flow-based Image Repairing

Stefan
sequence

(half the size)



Reference - 1

(original size)



Damaged Reference Image

(half the size)



Reference + 1

Flow-based Image Repairing

Stefan
sequence



Repaired Reference Image

(Based on three images and **temporal propagation**)

Flow-based Image Repairing

Stefan
sequence



Original Reference Image

Flow-based Image Repairing

Stefan
sequence



Repaired Reference Image

(Based on three images but no **temporal propagation**)

Flow-based Image Repairing

Stefan
sequence



Tweened Reference Image

(Based on two images)

Flow-based Image Repairing

Stefan
sequence



Original Reference Image

Conclusion and Future Directions

Two complementary approaches

- Dynamic masking to handle artifacts in super-resolving compressed video
- Flow-based image repairing to handle significant artifacts/missing blocks
- Exploring motion vectors already available in bit stream
- Automatic detection of unknown missing or damaged blocks