# A Spatiotemporal Algorithm for Detection and Restoration of Defects in Old Color Films

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## Introduction

Old films are subject to degrade in quality due to bad environmental factors and repeated projection. **Dust and dirt** are major defects. They adhere to the film surface and appear as **blotches**.

**Blotches** are presented random shapes and positions in each frame and do not generally occupy the same spatial location in successive frames.

## Proposed Method

The method contains:

(a) Noise reduction (b) Motion estimation & motion vector repairing (c) Defect detection & restoration

## a) Image Sequence Denoising

**The spatiotemporal NL-means** method removes noise from image sequence without blurring fine details. However, it is not sufficient for removal of big defects in old films, so we only utilize it for **prefiltering**. The algorithm is defined as:

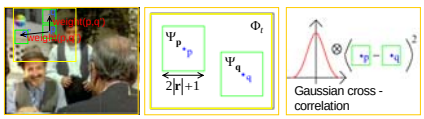
$$\tilde{\mathbf{I}}(\mathbf{p})=\frac{1}{J(\mathbf{p})}\sum_{\mathbf{q}\in\{\Phi_{t-1}\cup\Phi_t\cup\Phi_{t+1}\}} e^{-\frac{d(\mathbf{p},\mathbf{q})}{h^2}}\mathbf{I}(\mathbf{q})$$

Weight

$$J(\mathbf{p})=\sum_{\mathbf{q}} e^{-\frac{d(\mathbf{p},\mathbf{q})}{h^2}}$$

Normalizing factor

$$d(\mathbf{p},\mathbf{q})=\sum_{\mathbf{r}} G_a(\mathbf{r})\left\|\mathbf{I}(\mathbf{p}+\mathbf{r})-\mathbf{I}(\mathbf{q}+\mathbf{r})\right\|^2$$

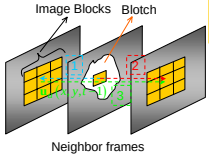



## b) Motion Estimation and Motion Vector Repairing

Motion does not change suddenly in any natural image sequence. This characteristic can be utilized in calculating correlation of motion vectors in the same spatial location within neighbor frames. The motion vector of the current image block can be calculated to find out whether it is correctly estimated or not, based on motion vectors of the current image block and its neigbors.

$$MV(x,y,t-1)=\frac{\sum_{i=-1}^{1}\sum_{j=-1}^{1} d(i,j)\left\|\mathbf{u}_a(x+k\times i,y+k\times j,t-1)\right\|}{\sum_{i=-1}^{1}\sum_{j=-1}^{1} d(i,j)}$$

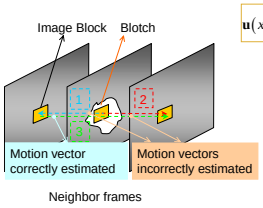
$$d(i,j)=\begin{cases}1 & \text{if } i=0 \text{ and } j=0\\ \left(i^2+j^2\right)^{1/2} & \text{otherwise}\end{cases}$$




If $2MV(x,y,t)>MV(x,y,t-1)$ the motion vector in the forward temporal direction pointed by arrow 2 is estimated incorrectly.

The motion vector of the current block in the forward temporal direction pointed by arrow 2 is reestimated as follows:

$$\mathbf{u}(x,y,t)=\frac{\mathbf{u}_a(x,y,t-1)}{2}$$

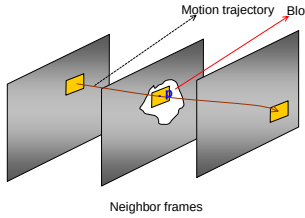



## c) Defect Detection and Restoration

**The spike detection index** (SDI), which is **the simplest detector**, perceives temporal discontinuities such as blotches.

$$A_{SDI}(\mathbf{p})=\begin{cases}1 & \text{if } \varepsilon(x,y,t\pm1)>T\\ 0 & \text{otherwise}\end{cases}$$

$$\varepsilon(x,y,t\pm1)=\sum_{i=1}^{c}\left|I_i(\mathbf{p})-\hat{I}_i(x,y,t\pm1)\right|$$




The **restoration method** is based on the existing **image inpainting** method.

$$P(\mathbf{p})=C(\mathbf{p})D(\mathbf{p})$$

Priority Confidence term Data term

$$C(\mathbf{p})=\frac{\sum_{\mathbf{q}\in\Psi_{\mathbf{p}}\cap\Phi_t} C(\mathbf{q})}{Area(\Psi_{\mathbf{p}})}$$

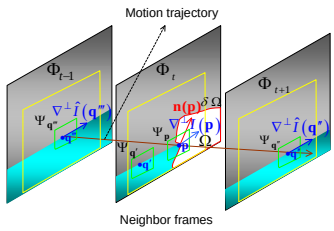
Normal vector

$$D(\mathbf{p})=\frac{\left|\nabla^{\perp}I\cdot\mathbf{n}(\mathbf{p})\right|}{\alpha}$$

But, the existing algorithm is unable to fill in missing regions perfectly due to complex textures and structures in the current frame. For this reason, **three successive frames** are used to restore degraded image sequence:

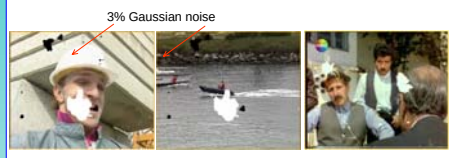
$$D(\mathbf{p})=\sum_{i=-1}^{1} D_i$$

$$D_i=\begin{cases}\dfrac{\left|\nabla^{\perp}I(x,y,t+i).\mathbf{n}(\mathbf{p})\right|}{2\alpha} & \text{for } i=0\\ \dfrac{\left|\nabla^{\perp}\hat{I}(x,y,t+i).\mathbf{n}(\mathbf{p})\right|}{4\alpha} & \text{for } i=-1,1\end{cases}$$

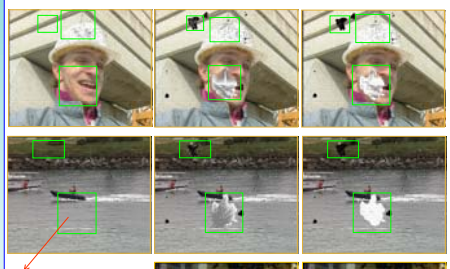



The proposed spatiotemporal exemplar-based inpainting method

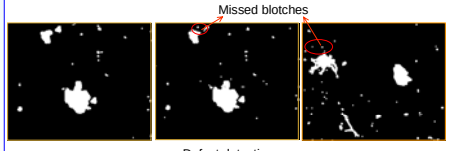
## Results




Noise reduction: Foreman, Coastguard and real image sequences

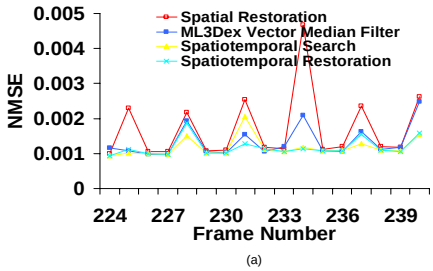



Motion vectors

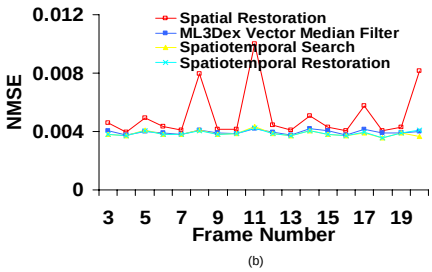



Defect detection

$$NMSE(t)=\frac{\sum_{\mathbf{p}\in B}\left\|\mathbf{I}(\mathbf{p})-\tilde{\mathbf{I}}(\mathbf{p})\right\|^2}{\sum_{\mathbf{p}\in B}\left\|\mathbf{I}(\mathbf{p})\right\|^2}=\frac{\sum_{\mathbf{p}\in B}\sum_{i=1}^{c}\left(I_i(\mathbf{p})-\tilde{I}_i(\mathbf{p})\right)^2}{\sum_{\mathbf{p}\in B}\sum_{i=1}^{c} I_i(\mathbf{p})^2}$$

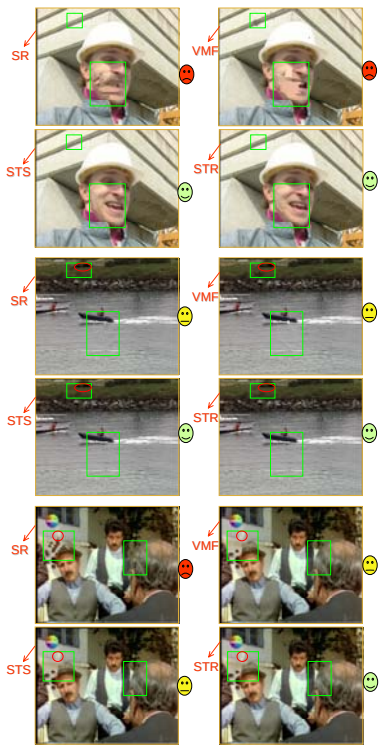



(a)




(b)

Normalized mean squared error : a) Foreman and b) Coastguard




Comleted frames: **Spatial restoration, ML3Dex vector median filter, spatiotemporal search and spatiotemporal restoration methods**

## Conclusion

We proposed **a spatiotemporal method** for restoration of damaged old color films. Results showed that the method removes blotches from the degraded frame by reconstructing the visually possible and coherent patches.
It is clear that detection and correction of defect regions could be done better if the performance of repairing of motion vectors is further improved in the complex motion areas.