Colorization Using Optimization

Anat Levin  Dani Lischinski  Yair Weiss

School of Computer Science and Engineering
The Hebrew University of Jerusalem, Israel

Motivation

- Colorizing black and white movies and TV shows

Colorization: a computer-assisted process of adding color to a monochrome image or movie. (Invented by Wilson Markle, 1970)

Motivation

- Colorizing black and white movies and TV shows

- Recoloring color images for special effects
Typical Colorization Process

- Delineate region boundary

Images from:
"Yet Another Colorization Tutorial"
http://www.worth1000.com/tutorial.asp
?sid=161018

Typical Colorization Process

- Delineate region boundary
- Choose region color from palette.

Images from:
"Yet Another Colorization Tutorial"
http://www.worth1000.com/tutorial.asp
?sid=161018

Video Colorization Process

- Delineate region boundary
- Choose region color from palette.
- Track regions across video frames

Images from:
"Yet Another Colorization Tutorial"
http://www.worth1000.com/tutorial.asp
?sid=161018
Colorization by Analogy

**A : A'**

**B : B'**

Hertzmann et al. 2001, Welsh et al. 2002

**Colorization Process Discussion**

- Time consuming and labor intensive
  - Fine boundaries.
  - Failures in tracking.

**Colorization by Analogy**

**A : A'**

**B : B'**

Hertzmann et al. 2001, Welsh et al. 2002

**Colorization by Analogy - Discussion**

- Indirect artistic control
- No spatial continuity constraint

**Our approach**

Artist scribbles desired colors inside regions
Our approach

Colors are propagated to all pixels
"Nearby pixels with similar intensities should have the same color"

Minimizing cost function

Minimize:

\[ J ( U ) = \sum_{r} \left( U ( r ) - \sum_{s \in N ( r )} w_{rs} U ( s ) \right)^2 \]

Subject to labeling constraints

Since cost is quadratic, minimum can be found by solving sparse system of linear equations.

Affinity Functions

\[ W_{rs} \propto e^{-\frac{(Y ( r ) - Y ( s ))^2}{\sigma^2}} \]

\( \sigma_r \) proportional to local variance

Affinity Functions in Space-Time

\[ W_{rs} \propto e^{-\frac{(Y ( r ) - Y ( s ))^2}{2 \sigma^2}} \]

Propagation using Optimization

\[ Y \Rightarrow U, V \]

Intensity channel  Color channels

"Neighboring pixels with similar intensities should have similar colors"
Coloring Stills

Color Interpolation

Coloring Stills

Colorization Challenges

Original

Colorized

Coloring Stills
Recoloring

Affinity between pixels – based on intensity AND color similarities.

c.f. “Poisson image editing” Perez et al. SIGGRAPH 2003
Common Concept
Manipulating the Space Time Volume

Dynamic Mosaics
Video Editing, Non-chronological Time

Making a Long Video Short:
Dynamic Video Synopsis

Shmuel Peleg
Dani Liscinski
Alex Rav-Acha
Yael Pritch

Dynamic Mosaics
• Cancel Camera Motion
• Preserve Scene Motion
• Non Chronological Time

Summary
• Interface: User scribbles color on a small number of pixels
• Colors propagate in space-time volume respecting intensity boundaries
• Convincing colorization with a small amount of user effort

Future Work:
• Import image segmentation advantages: affinity functions, optimization techniques.
• Alternative color spaces, propagating hue and saturation differently

Code & examples available:
www.cs.huji.ac.il/~yweiss/Colorization/
Preprocessing: Constructing an aligned Space-Time Volume

Alignment with Parallax and Moving Objects.

Dynamic Mosaics
Motion Parallax
- Cancel Camera Motion
- Preserve Scene Motion
- Non Chronological Time

Stereo Mosaicing

Generate Output Video
Sweeping “Evolving Time Front” surface

Time is not chronological any more

Stationary Camera
Panning Camera

Evolving Time Fronts

Mapping each TF to a new frame

Generate Output Video
Sweeping “Evolving Time Front” surface

Time is not chronological any more
Some Related Work

The Space Time Volume Representation [Baker & Bolts, UCV'99]

The technique is similar to the “Video Cubes” [Cohen at el, Microsoft TR], later used for “photomontage” [Siggraph]

- Aligning the video
- Create new videos (not only a single image)

Many existing methods which were applied on static scenes [X-slits, Zomet at el., PAMI 2003]

Example: Demolition
(KingDome – Seattle)

Example: Racing

Spatio-Temporal Magnifying Glass
1D Elastic Magnification

- Source image
- Destination
- Focus Area (Magnified)
- Margins (Compressed)
- Outside Glass (Normal)

Elastic Magnification in Context
(Carpendale et al., ACM User Interface 2004)

Spatio-temporal magnification

- Dunks Video
- Iguazu Falls

Note the bright expanding rings: they are caused by photography flashes in the source video.
Summary

Mapping from an input video to an output video using the following steps:
Generation of an Aligned Space-Time Volume
Sweeping an “Evolving Time Front” surface in the Space-Time Volume
Possible Effects:
  • Dynamic Panoramic Mosaics
  • Ability to selectively control time progress
  • Spatio-Temporal Video Warping