

## Transferring Color to Greyscale Images

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## The Problem

- How to colorize greyscale images?

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- Is his tie blue or green?

## The Problem

- How to colorize greyscale images?



- Red!!

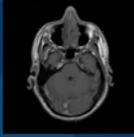
## The Problem

- How to colorize greyscale images?
- Issues:
  - No “correct” solution
  - Need to be creative
  - How to minimize the manual labor involved?

## Motivation



- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)



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  - Colorize black/white photographs and movies



## Motivation



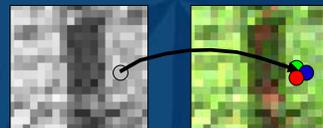
- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)
  - Satellite Images (Landsat)
  - Scanning Electron Microscopy (SEM)
- Colorize black/white photographs and movies
- Artistic Effects



## The Task



- The problem is fundamentally ill-posed
- It is an attempt to extrapolate from 1-D to 3-D
  - Map scalar luminance (intensity) to vector RGB



## Previous Methods



- Coloring Book Method
  - Photoshop: manually paint color with low opacity

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  - Movie Industry: track polygons [Cinesite Press Article]

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  - Global Transformation/Color Map

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  - Registration [R2V Software], Orthoimagery [Premeze]

## Previous Methods



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- Pseudo-coloring
  - Global Transformation/Color Map
- Satellite Images
  - Registration [R2V Software], Orthoimagery [Premeze]
- Image Analogies
  - Grey Source : Color Source :: Grey Target : Result

## Related Work



- “Color Transfer between Images”  
[Reinhard et al. 2001]



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Source

Target

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Source

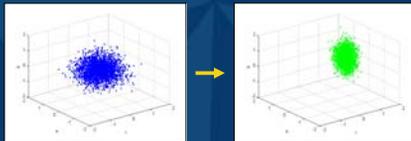
Target

Final

## Reinhard et al.



- Decorrelated color space ( $l\alpha\beta$ ) [Ruderman et al., 1998]
- Scale and shift color distributions globally  
(Using mean and standard deviation)



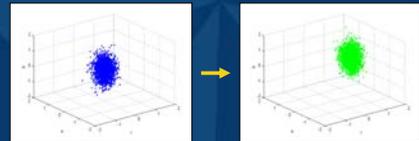
Target

Source

## Reinhard et al.



- Decorrelated color space ( $l\alpha\beta$ ) [Ruderman et al., 1998]
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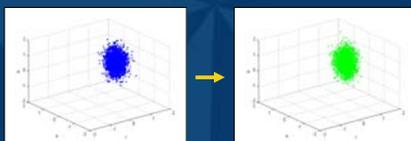
Target (Scaled)

Source

## Reinhard et al.



- Decorrelated color space ( $l\alpha\beta$ ) [Ruderman et al., 1998]
- Scale and shift color distributions globally  
(Using mean and standard deviation)



Target (Scaled & Shifted)

Source

## Our Approach



Target

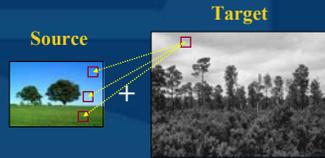


## Our Approach



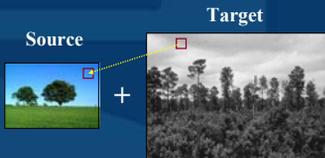
- Select color source image

## Our Approach



- Select color source image
- Match each target pixel with a few source pixels

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  - Choose best match using local pixel neighborhood statistics

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- Transfer color

## Our Approach



- Select color source image
- Match each target pixel with a few source pixels
  - Choose best match using local pixel neighborhood statistics
- Transfer color
- Repeat for all pixels

## Global Image Matching Procedure



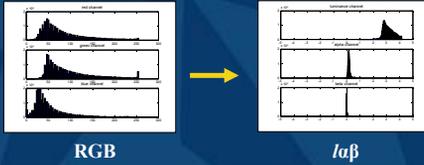
1. Convert images to  $l\alpha\beta$  color space
2. Image Matching
3. Color Transfer

## 1. Convert to $l\alpha\beta$ Space



- Luminance ( $l$ ), alpha ( $\alpha$ ) and beta ( $\beta$ ) channels
- Minimizes correlation between axes (i.e. cross-channel artifacts)

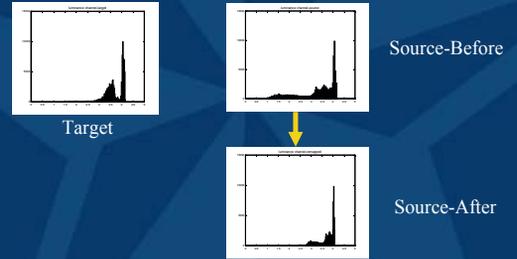
Color  
Image



## 2. Image Matching



1. Remap luminance histograms between src/target



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2. Precompute neighborhood statistics for images

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3. Reduce samples using jittered sampling
  - Faster computation due to smaller search space



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## 2. Image Matching



1. Remap luminance histograms between src/target
2. Precompute neighborhood statistics for images
3. Reduce samples using jittered sampling
  - Faster computation due to smaller search space
4. Find best neighborhood match from samples
  - Weighted metric of luminance, mean, standard deviation

## 3. Color Transfer



- Transfer only alpha and beta channels (color)



Target Image

Colorized Results

## 3. Color Transfer



- Transfer only alpha and beta channels (color)
- The original luminance value remains unchanged



Target Image

Colorized Results

Convert to Greyscale  
(Photoshop)

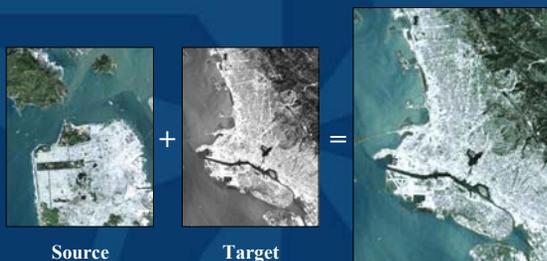
## Results: satellite



Source

Target

## Results: satellite



Source

Target

Final

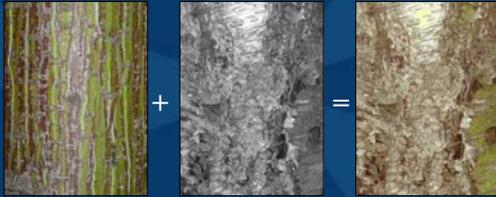
## Results: Textures



Source

Target

## Results: Textures

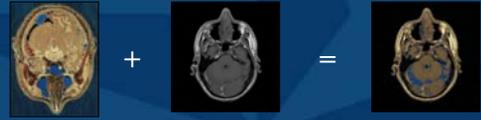


Source

Target

Final

## Limitations (Global Approach)

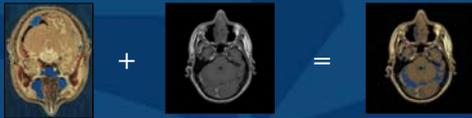


Source

Target

Final

## Limitations (Global Approach)

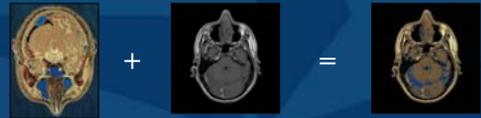


Source

Target

Final

## Limitations (Global Approach)



Source

Target

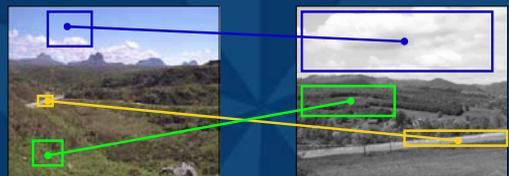
Final

## User-Assisted Approach



1. User selects small number of swatches
2. Transfer color only to swatches (Global Matching Procedure)
3. Color entire target image (Only use swatch samples)

## 1. Selection of Swatches



Source

Target

## 2. Transfer Color to Swatches



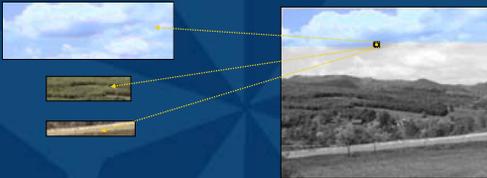
- Transfer color using Global Matching Procedure (described previously)

## 3. Colorize Entire Image



- Discard original source image

## 3. Colorize Entire Image



- Colorize the full image
  - Match using  $L_2$  Norm

## Swatches: Notes

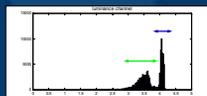
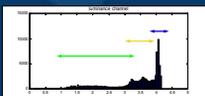
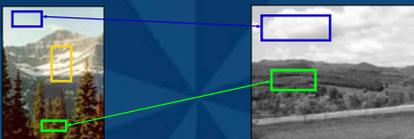


- Expect good results *between* swatches

## Swatches: Notes



- Expect good results *between* swatches



## Swatches: Notes



- Expect good results *between* swatches
- Expect better matching within an image (Allows more precise metric:  $L_2$  Norm)

$$L_2 = \sum ( \text{[swatch]} - \text{[swatch]} )$$

## Swatches: Notes



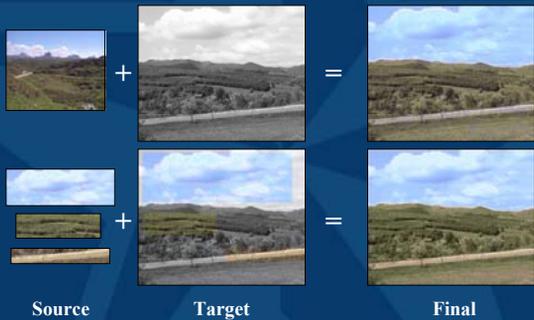
- Expect good results *between* swatches
- Expect better matching *within* an image  
( $L_2$  Norm is more sensitive to image differences)



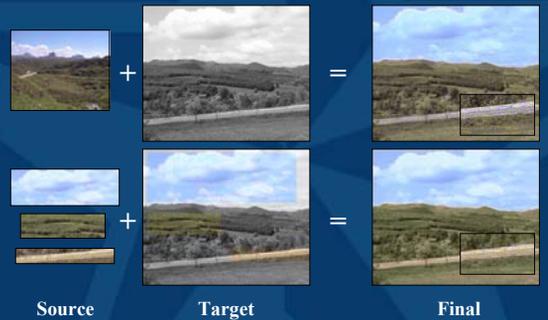
## Results: Swatches



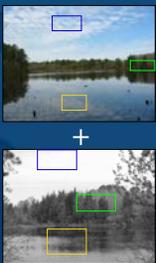
## Results: Swatches



## Results: Swatches



## Results: Swatches



+

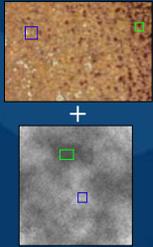


=



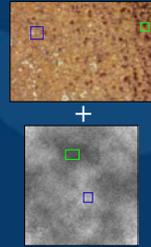
Final

## Results: Textures



+

## Results: Textures



+

=



Final

## Results: Swatches



+



Source

Target

## Results: Swatches



+



Source

Target



Final

## Limitations



## Comments



- Works well when *target* can be segmented well



## Comments



- Works well when *target* can be segmented well
- Large shadows present a problem
  - (partial volume effect)
- To be more useful, combine with other tools

## Running Time



- Pentium 3 (800 Mhz): 15 sec – 1 min
- Typical Image size: 640x480
- Implemented using MATLAB (Optimized)
- Factors:
  - Image size
  - Neighborhood Size

## Video



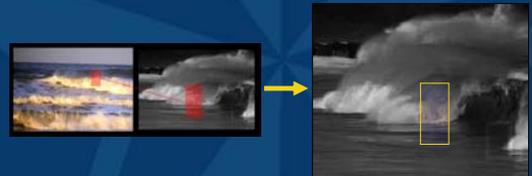
1. Colorize one frame using swatches
2. Use swatches to colorize the entire sequence

If a single frame in a sequence is colorized well, then the entire sequence can be colorized well

## Video Procedure



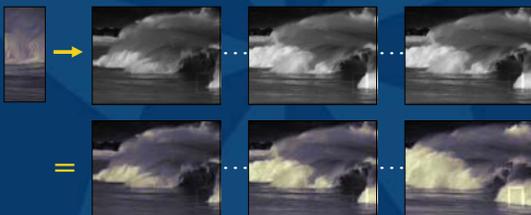
1. Colorize one frame using swatches



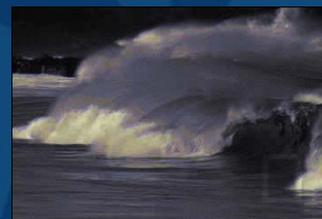
## Video Procedure



1. Colorize one frame using swatches
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## Video: Waves



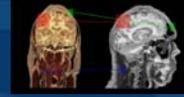
## Video: Horses

BYRON  
MICHAEL  
2002



## Video: Visible Human

BYRON  
MICHAEL  
2002



## Conclusions

BYRON  
MICHAEL  
2002

- Keep original luminance values
- Use local pixel neighborhood statistics to match
- Simple algorithms provide fast (and good) results

## Future Work

BYRON  
MICHAEL  
2002

- Robustness: more sophisticated matching
  - Multi-resolution, other pattern matching metrics
- Volumes
- Color Correction
  - Use local neighborhood statistics
  - Color correct movies automatically

## Questions?

BYRON  
MICHAEL  
2002

