Exploring Near IR

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Motivation

- Papers suggest infrared information is useful in post-processing
- Explore the proposed methods and ideas
- Determine if infrared is as useful as suggested
- Potential for reworking image pipeline
  - Should we start removing hot mirrors (or find a way to switch them on-off?)
Outline

- Skin Smoothing
- Haze Removal
- Contrast Improvement
- Future Work
- Conclusions
Skin Smoothing

- Currently, a post-processing feature
  - Photoshop
  - Some existing algorithms
- Remove unwanted features of facial image
- Visible spectrum reflects shallow
- Want images with important details in tact, but shallow wrinkles/blemishes removed

Source: http://www.tutorialwiz.com/smooth_skin
Using Near IR

- With longer wavelengths, further skin penetration
- Results in smoother image
- Utilize structure of IR image
- Combine data from IR and RGB to smooth

Source: Fredembach, “Automatic Skin Enhancement with Visible and Near-Infrared Image Fusion
Algorithms

- Explored several ideas, similar concepts
- Convert to YCbCr
- Bilateral Filtering
  - Manipulate width for smoothness
  - Apply to Y and NIR
- Conserving Details (IR usage)
  - Determined in two separate ways
  - 1) Res = IRfilt – IR_orig
  - 2) Detail = IR_filt1/IR_filt2
- Find Luminance and Chrominance
  - Luminance: threshold or multiply
- Revert to RGB

Source: Fredembach, “Automatic Skin Enhancement with Visible and Near-Infrared Image Fusion”
Eisemann, “Flash Photography Enhancement via Intrinsic Relighting”
Sample Outputs

- Algorithm 1
Sample Outputs

- Algorithm 2
Sample Outputs

- Joyce

Original  Algorithm 1  Algorithm 2
Haze Removal

- Image processors do what the camera and lens can’t do:
  - Remove noise
  - Compensate for camera motion
  - Mitigate atmospheric effects

- Haze
  - Haze is formed when the aerosol particles are smaller than $\lambda /10$ and the scattering follows Rayleigh’s law:
    $$E_s \propto E_0/(\lambda^4)$$

Why NIR?

- Scattering is significantly smaller in NIR
- Efficient dehazing by combining visible with NIR

Source: “http://ivrgwww.epfl.ch/research/topics/nir.html”
Haze reduction examples
Mouse Embryo

Colon Cancer cells

Removal of dust, mist, rain, snow

Algorithms – Image fusion

Filters Used:
Bilateral Filtering – Not good enough for progressive coarsening of images

WLS – decomposition of a base layer and detail layers of different scales.

Source: “http://www.merl.com/areas/bilateralfilters/”
Algorithm using NIR Information for Haze Removal

Analysis
- \( I_{k+1}^a = W_{\lambda_{oc}}(I_0) \)
- \( I_k^d = \left( I_{k-1}^a - I_k^a \right) / I_k^a \)

Criterion
- \( \text{Max}(V_{k}^d, N_{k}^d) \)

Synthesis
- \( F_0 = V_n^a \prod_{k=1}^{n} (\text{max}(V_{k}^d, N_{k}^d) + 1) \)

Source: Schaul et al, “Color Image Dehazing using the Near Infrared”
Results - Stanford Dish (NIR 903nm)
Results – San Francisco (NIR 903nm)
Achromatic SanFrancisco
(MSE = 0.5%)
Results – NIR 903nm
Contrast Improvement
So what’s the story

- For natural scenes, NIR images tend to have better contrast than the visual bands
- Or one might like to use an NIR flash to capture the contrast in the scene
- And not deal with artifacts from using a regular flash in low light conditions
Is it true

\[ \lambda = 450\text{nm} \quad \lambda = 550\text{nm} \quad \lambda = 593\text{nm} \quad \lambda = 775\text{nm} \]
Basic Algorithm Template

- Filter images (visual and NIR) to get a base layer and a detail layer

- Transfer (large-scale) contrast from NIR base layer to visual base layer – histogram matching

- Transfer texture information from NIR detail layer to visual detail layer

- Can get fancy – use an automatic mask, add gradient constraint, do all of these in a completely different space (like gradient magnitude)
Particular Implementation

Haar?

- Wavelet transform that does something like this
Metrics to select NIR band

- Compute Mean Lightness
- Compute Variance of Lightness
- Heuristic – pick a band where $|\mu - 0.5|$ is small(est) and $\sigma$ is large
Example 1 for choosing NIR

![Mean lightness graph](image)

![Sigma lightness graph](image)
Example 2 for choosing NIR
Weighted Mask

- Heuristic – Poor contrast in areas with
  1. High/Low Value
  2. Low Saturation
- Use functions to translate this behavior to a mask
  \[ W_v = 1 - \exp(-p_v \cdot |v - 0.5|) \]
  \[ W_s = 1 - \exp(-p_s \cdot |s - 1|) \]
- \( p_v \) is probability that pixel has value \( = v \),
- \( p_s \) is probability that pixel has saturation \( = s \).
- Final weight mask \( W = W_s \cdot W_v \)
Results - Indoor

Original Image

Contrast Improved Image
Results – Outdoor

San Francisco

Contrast Improved San Francisco
Future Work

- Illuminant detection
- Shadow detection
- Shadow Elimination
Conclusion

- Evidence suggests there are practical applications where NIR data is useful.

- For the applications considered, we didn’t quite need hyperspectral NIR data, just a broadband response would suffice.

- Except for dehazing, there are other (non-NIR) algorithms that do almost as well.

- Simultaneous capture of visible + NIR (by modifying the Bayer filter) would require changing the image pipeline considerably.

- Other hybrid schemes using more than one sensor are too complicated and we feel the gamut of applications discussed doesn’t quite justify NIR capture in digital cameras. Not just yet!