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# Meet iCAM: A next-generation color appearance model

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## Meet iCAM: A Next-Generation Color Appearance Model

CIC X, 2002

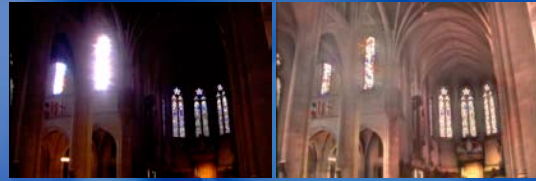


Say hello to  
iCAM



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## Why Are We Here?



- Spatial, Temporal, & Image Quality Questions Remain
  - *E.g. Pattanaik et al. 1998*

## Outline

- Very Brief History of Color Appearance Models
- Image Appearance Modeling
- iCAM: An Image Appearance Model
- Future Directions

## Very Brief History of Color Appearance Models

- You've just heard two talks on CIECAM02
- Enough said...

## What Does a Color Appearance Model Enable?

- Mapping from Measurements to Words (Physics to Perception)
- Prediction of Color Matches (or Changes) across Changes in Viewing Conditions

## Appearance Correlates

- Brightness, Lightness
- Colorfulness, Chroma, Saturation
- Hue



## History of Color Appearance Models

- 1970's: CIELAB and CIELUV
- Early 1980's: Initial Hunt and Nayatani Color Appearance Models
- Late 1980's: Revisions of Hunt and Nayatani Models
- Early 1990's: Model Testing, Further Revisions, New Models (e.g., RLAB, LLAB)
- Late 1990's: Convergence ... CIECAM97s
- Early 2000's: Widespread focused testing and refinement, CIECAM02, Practical Image Appearance Models

## A Next Generation CAM



CIECAM02 is an Evolution of CIECAM97s  
New Capabilities Require a New Approach ...

## What is an Image Appearance Model?

- Image appearance models extend color appearance models to include spatial vision, temporal vision, and image difference/quality properties.
- They account for more complex changes in visual response in a more automated manner



## What are Some of the Missing Links?

- Spatial Vision (Filtering & Adaptation)
- Scene Interpretation
- Computational Surround Effects
- Color/Image Difference Metrics
- Image Processing Efficiencies



## MOM

Pattanaik, Ferwerda, Fairchild, & Greenberg, SIGGRAPH and CIC (1998)

Multi-Scale Observer Model

- Comprehensive
- Extremely Complex
- Successfully Implemented 2-3 Times!!

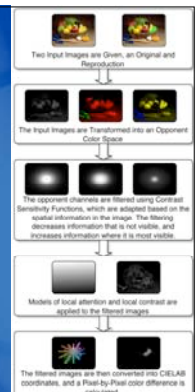


## Image Quality Measurement

Johnson & Fairchild, CIC (2001)

Modular Framework for IQ Scales

- Promising Framework for Image Differences
- Flexible Implementation



## Image Difference Process



Mean  $\Delta E_{ab}^*$  2.5

Mean  $\Delta E_{ab}^*$  1.25

Mean  $\Delta n$  0.5

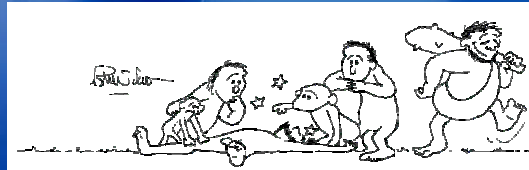
Mean  $\Delta n$  1.5

Spatial Filtering, Local Attention, Local & Global Contrast, CIE Color Difference

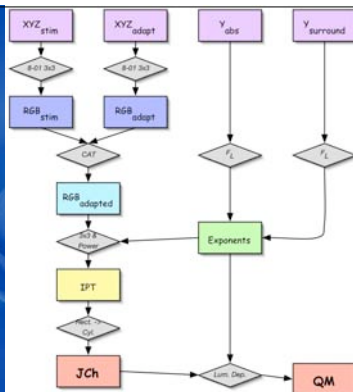
## Meet iCAM

### iCAM — *image Color Appearance Model*

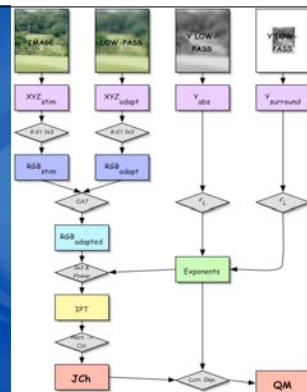
A simple framework for color appearance, spatial vision effects, image difference (quality), image processing, and temporal effects (eventually).



## Pointwise iCAM



## Spatial iCAM



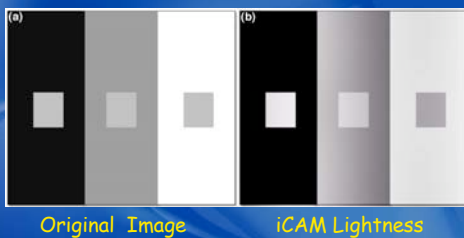
### iCAM Performance Examples

- Chromatic Adaptation Transform (CAT)
  - Color Appearance Scales
    - Constant Hue Lines
  - Simultaneous Contrast
  - Chroma Crispening
    - Hue Spreading
  - HDR Tone Mapping
- Image Difference (Quality)

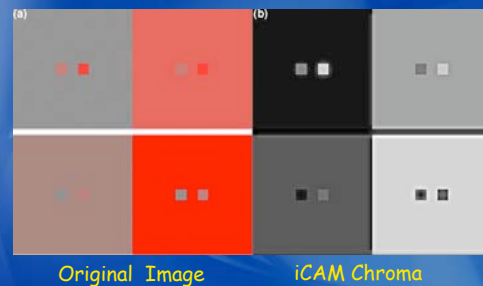
### Basic Appearance Attributes

- Chromatic Adaptation Transform (CAT)
  - Identical to CIECAM02
- Color Appearance Scales
  - Similar to Munsell / CIECAM02 (limited)
- Constant Hue Lines
  - Best Available (IPT)
  - Facilitates Gamut Mapping

### iCAM Simultaneous Contrast

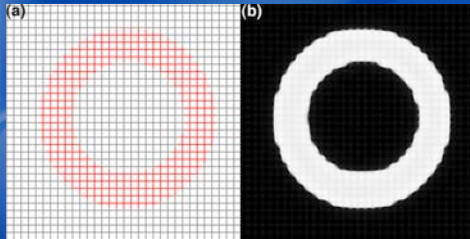


### iCAM Chroma Crispening



[http://www.hpl.hp.com/personal/Nathan\\_Moroney/](http://www.hpl.hp.com/personal/Nathan_Moroney/)

### iCAM Spreading



Original Image

iCAM Hue

### iCAM High-Dynamic-Range Tone Mapping



[www.debevec.org](http://www.debevec.org)

Earlier-Model Results

### iCAM Image Difference (Image Quality)

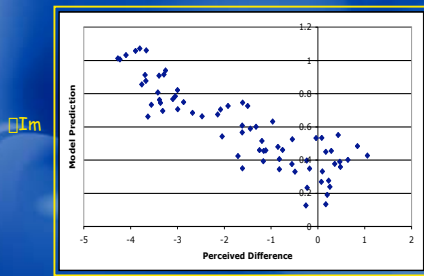


Image Difference Prediction (Sharpness Data)

### iCAM Image Difference (Image Quality)

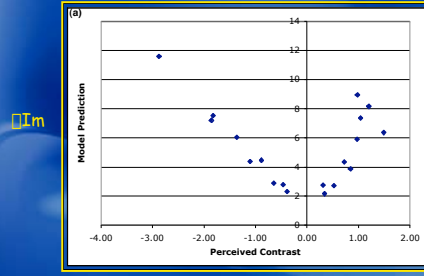
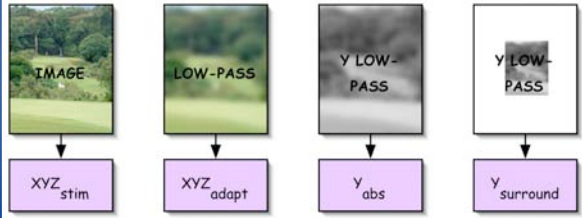


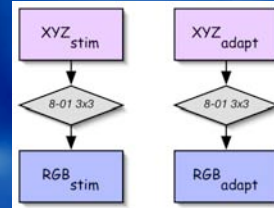
Image Difference Prediction (Contrast Data)

### Image Input Data



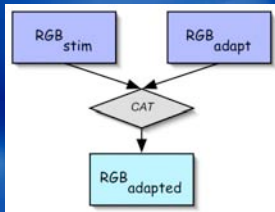
*XYZ<sub>adapt</sub>: Different Filters for luminance & chromaticity TBD  
All Filters: Viewing-Distance Dependent*

### Transform to "Sharpened Cone Responses"



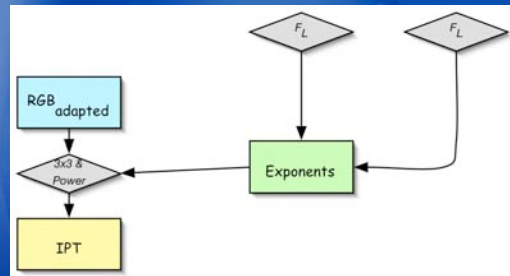
*The same 3x3 as adopted for CIECAM02.*

### TC8-01 (CIECAM02) Linear CAT



*The same CAT as CIECAM02 for simple conditions.*

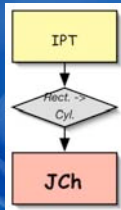
### Surround & Luminance Dependent Transform to IPT Color Space



*"Contrast" depends on luminance and surround.*

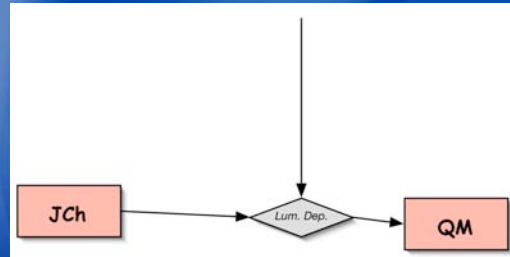


### Rectangular-to-Cylindrical Lightness, Chroma, Hue



*Just plain geometry.*

### Conversion to Brightness, Colorfulness



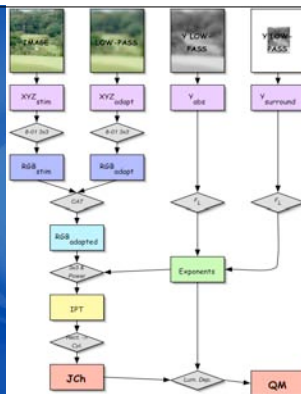
*Dependency on absolute luminance.*

### Spatial iCAM

Detailed references to each step in proceedings.

Coded examples on the internet.

Open-Source Science



### Mathematica Notebooks



- Can be read and executed with free "MathReader".
- Other code (Matlab, IDL) forthcoming.
- Updates

## Conclusions

- iCAM Represents an Example of a New Generation of Color Appearance Model
- Image Appearance Model
- Incorporates Spatial Vision
- Can Be Extended for Temporal Vision (EI 2003)
- Image Difference Metric,  $\Delta Im$  (EI 2003)
- Basis for a Fundamental Image Quality Metric

## Future Directions

- HDR Digital Photography (Capture & Processing)
- Video iCAM (Temporal Adaptation & Filtering)
  - HDR Digital Video (Processing)
  - Better Understanding of Surround Effects
  - Image-Content Dependent Reproduction
- Refined Image Difference & Image Quality Metrics
  - Extension to Preferred Image Reproduction
  - Psychophysics, Psychophysics, Psychophysics

*Suggestions and Help Welcome and Encouraged*