Time Dependent Visual Adaptation for Fast, Realistic Image Display

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Program of Computer Graphics

Cornell University

SIGGRAPH 2000

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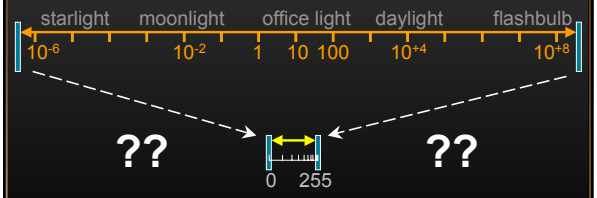
Tone Mapping Problem

Domain of Human Vision:
from ~10^{-6} to ~10^{+8} cd/m^2



Range of Typical Displays:
from ~1 to ~100 cd/m^2

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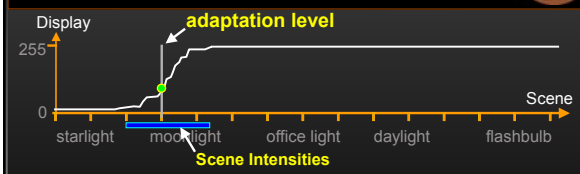
Tone Mapping Function



- Appearance-Preserving Scene-to-Display map
- Adaptation makes it possible
- **Adaptation level**: 'best vision' level

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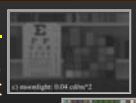
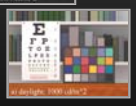
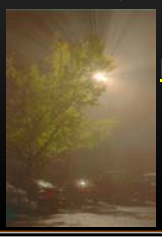
Previous Work: *Static* Models

Global Adaptation:

Tumblin&Rushmeier`93, Chiu et al.`93, Ward`94, Schlick`95, Ferwerda et al.`96, Tanaka&Ohnishi `97, ...



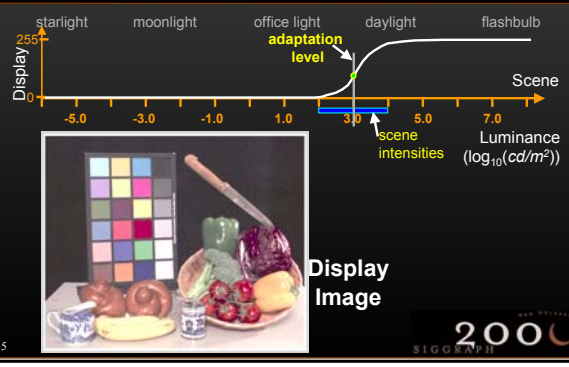




Local Adaptation:

Spencer et al.`95, Ward-Larson et al.`97, Pattanaik et al.`97, Jobson & Rahman et al. `97, Tumblin et al. `99, Tumblin&Turk `99, ...

Daylight Scene:Tone Mapped



Display Image

Moonlight Scene:Tone Mapped

Display Image

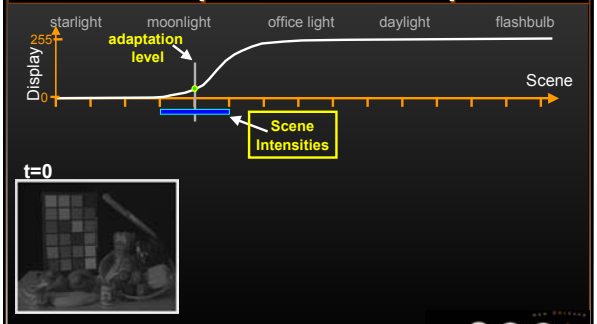
Our Goal

Time-varying tone-mapping function: recreates dynamic scene appearance on ordinary displays (CRTs, printers ,etc.)

- **Simple, practical, fast, general**
- **Built from published visual measurements**

Adelson`82, Baker`49, Dowling`87, Graham&Hood`92, Hunt`95, Hayhoe et al.`87, Hood et al.`86,79, Nelson`66, Valeton&Van Norren`83, Walraven et al.`84,`90, etc.…

GOAL: Time-Dependent Tone Map



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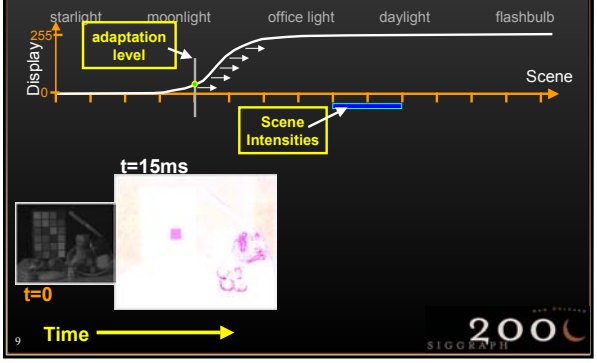

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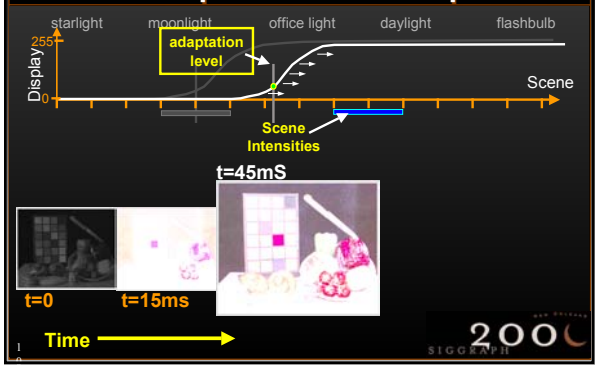

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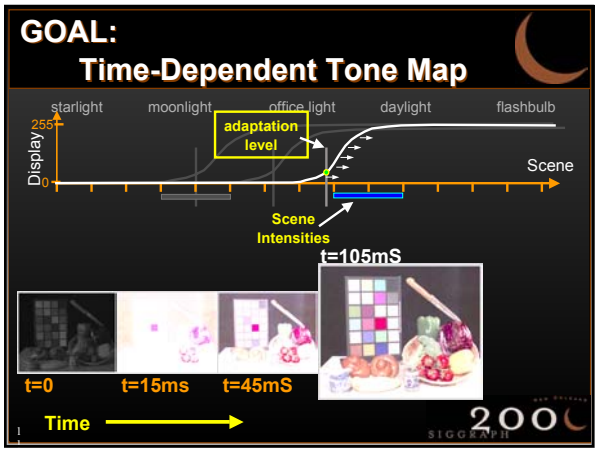

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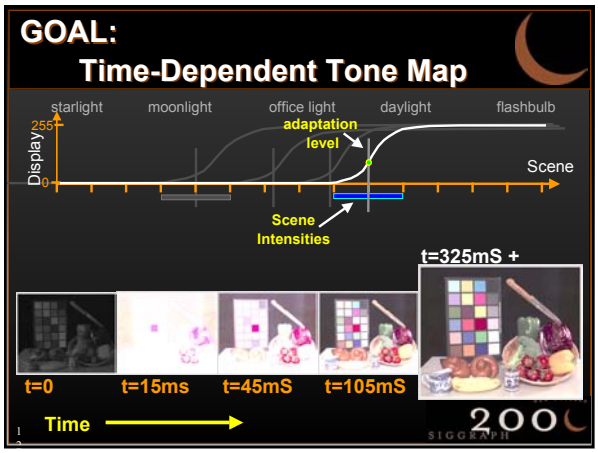
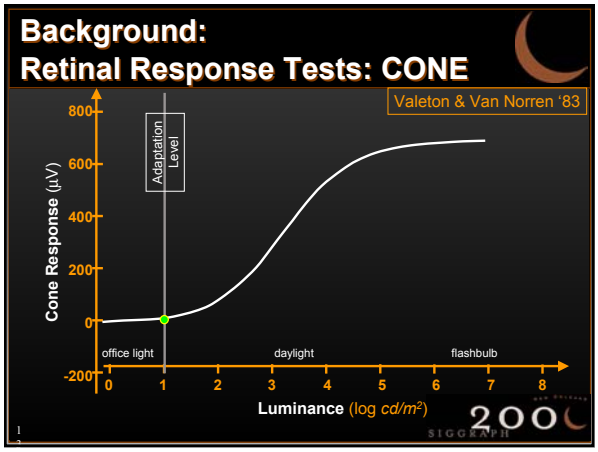


Background:
Retinal Response Tests: CONE



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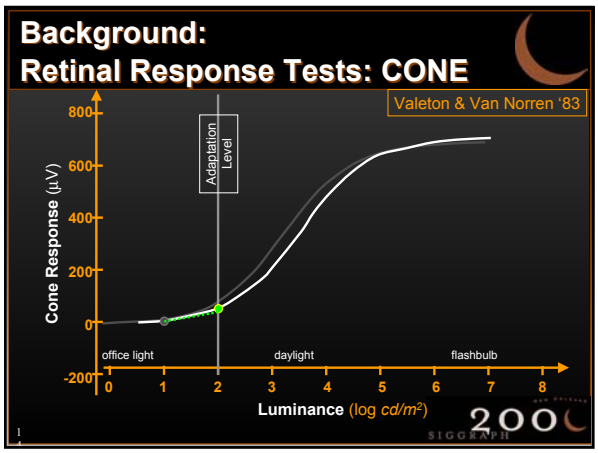

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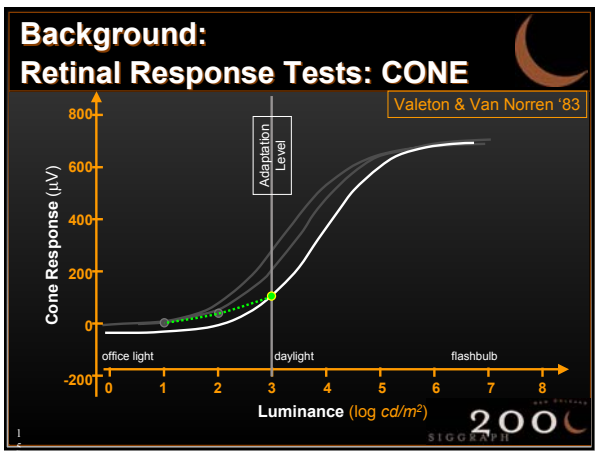

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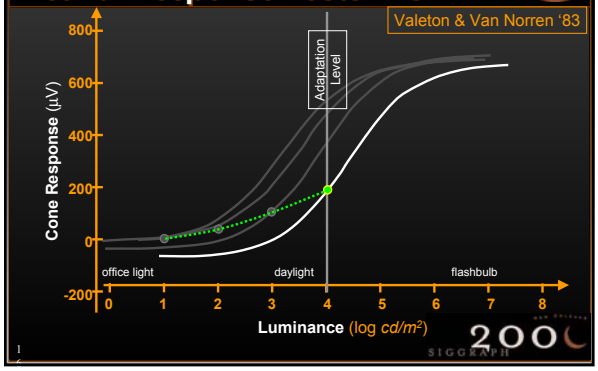

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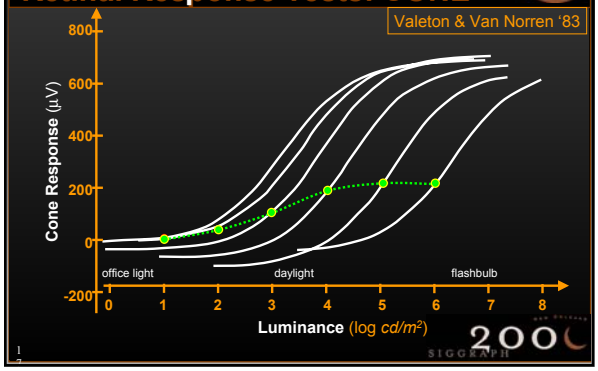
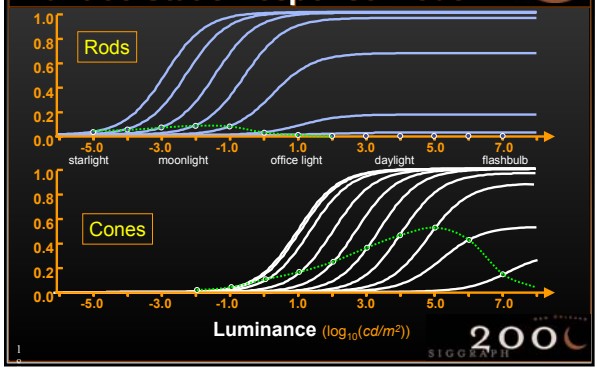


Background:
Hunt`95 Static Response Model



Background: Time-course of Adaptation

Two Dominant Mechanisms:

Bleaching & Recovery of Photopigment

- Slow, asymmetric reaction times (~1-1000 sec)
- separate time courses for rods, cones

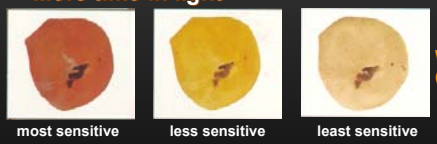
Neural Interactions within retina

- Multiple mechanisms
- Fast, ~symmetric reaction times (10 - 3000 mS)

Background: Bleaching Dynamics

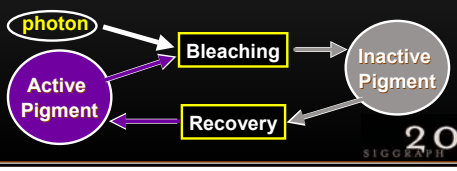
More time in light →

Boll (1876), Kuhne (1878)

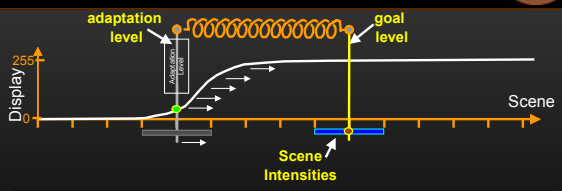


Whole retina (bullfrog)

most sensitive | less sensitive | least sensitive



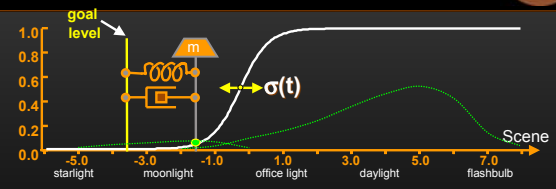
New: Dynamic Response Model



Response curve follows scene intensities

- **But slowly, smoothly; lags behind**
- **Curve shape changes as it moves**
- **static response = Hunt'95 model**

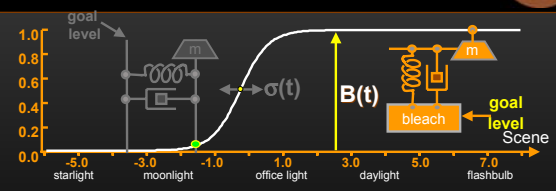
New: Dynamic Response Model



Goal level drives rate equations
(exponential filters) **that set curve parameters:**

- **offset σ set by Neural Interactions, and ...**

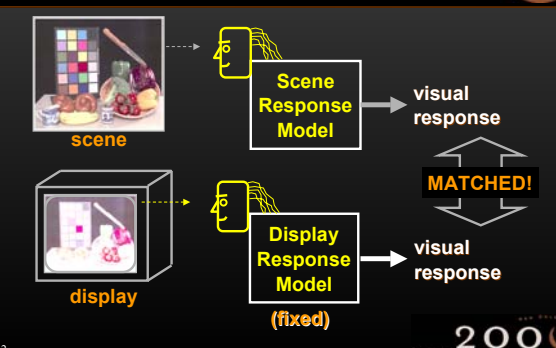
New: Dynamic Response Model



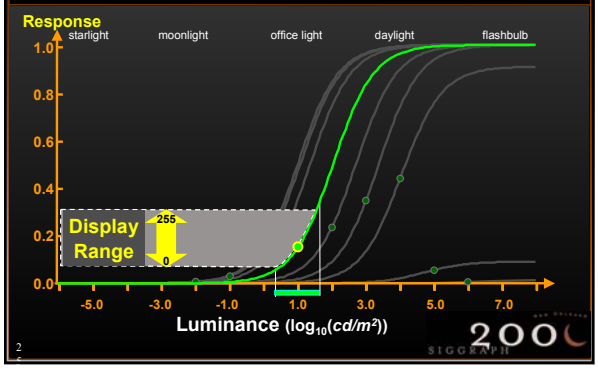
Goal level drives rate equations
(exponential filters) **that set curve parameters:**

- **offset σ set by Neural Interactions, and ...**
- **height B set by Bleaching**

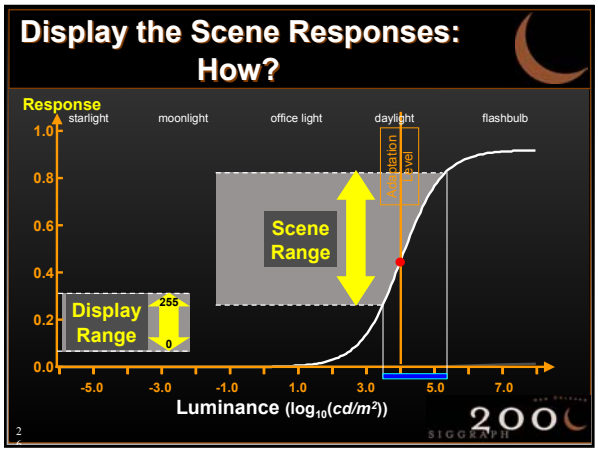
Tone Mapper Construction



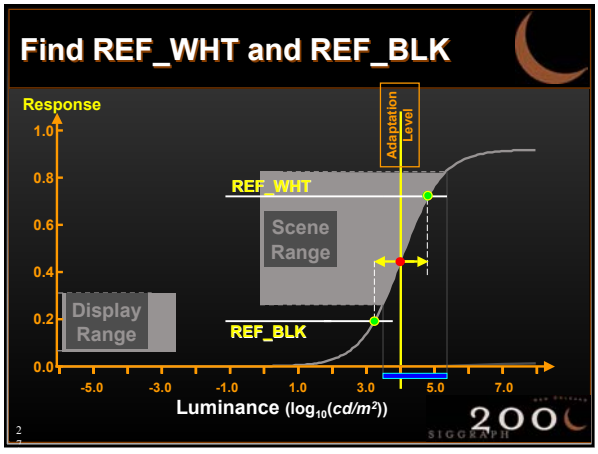
Desktop CRT Response Range



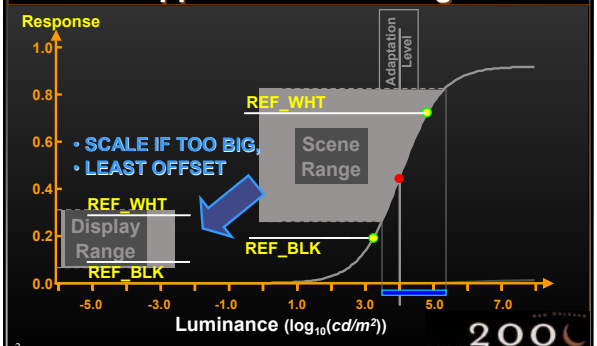
Display the Scene Responses: How?



Find REF_WHT and REF_BLK



"Least Change" Linear Appearance Matching

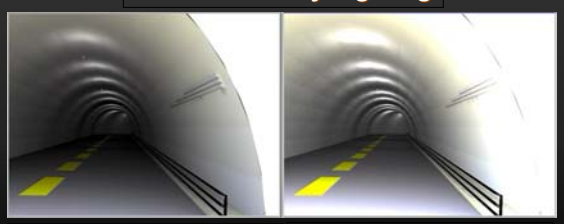


----Results---

Tunnel Video

Results:

WITHOUT Entry Lighting



New Dynamic Tone Map

Static Tone Map

Results:

New Dynamic Tone Map

Results:
Time-Varying Tone Mapper

Dynamic appearance effects:

- Exaggerate Fast Changes (lights on/off)
- Minimize Slow Changes (late afternoon)
- (Dark ⇒ Light) is faster than (Light ⇒ Dark)

More accurate animation:

- Useful aid to traditional lighting methods
- Visibility predictions for engineering, safety …

Conclusions

New Time-varying Tone Mapping Operator

- **Models bleaching & neural dynamics**
- **Improves animation accuracy**
- **Simple, fast, general**

- **Please use it! free source code:**
  - see SIGGRAPH 2000 Proceedings CD-ROM, or
  - website: www.graphics.cornell.edu/~jet

Future Work

- **Better ways to find goal levels**
  mouse, eye trackers, HMDs, saliency maps (Yee2000)
- **Include more visual properties**
  chromatic adaptation, acuity, afterimages, ...
- **Local adaptation for high contrast scenes**

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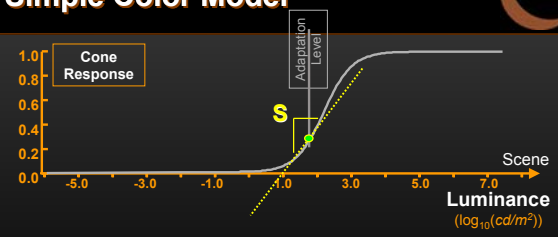
- **We also thank:**
  - SuAnne Fu for creating the 3D tunnel model, and
  - Peggy Anderson and Jonathan Corson-Rikert for careful editing and proofreading

Simple Color Model



- **Cone response slope S sets 'colorfulness'**
- **Find scene color ratios** log(R/L, G/L, B/L)
- **Scale by S for response** S*log(R/L, G/L, B/L)