Time Dependent Visual Adaptation for Fast, Realistic Image Display

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Tone Mapping Problem

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

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

Tone Mapping Function

Appearance-Preserving Scene-to-Display map
Adaptation makes it possible Adaptation level: ‘best vision’ level
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 Scene Luminance (log10(cd/m²))

Moonlight Scene: Tone Mapped

Display Scene Luminance (log10(cd/m²))
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**

- **t=0**: Scene intensities
- **t=15ms**: Scene intensities

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Display adaptation level
Scene intensities

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Display adaptation level
Scene intensities

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Scene intensities
GOAL: Time-Dependent Tone Map

Time  

Scene Intensities

adaptation level

Scene Intensities
**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

**Whole retina (bullfrog)**

**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 $\sigma$ set by Neural Interactions, and ...
• height $B$ set by Bleaching

Tone Mapper Construction

MATCHED!
Desktop CRT Response Range

Display the Scene Responses: How?

Find REF_WHT and REF_BLK
“Least Change” Linear Appearance Matching

Results:
Tunnel Video

WITHOUT Entry Lighting
New Dynamic Tone Map
Static Tone Map
Results:

**WITHOUT Entry Lighting**

**WITH Entry Lighting**

*New Dynamic Tone Map*

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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 ...

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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

This work was supported by

- The NSF Science and Technology Center for Computer Graphics and Scientific Visualization (ASC-8920219),
- MRA Parallel Global Illumination Project (ASC-9523483),
- Equipment generously donated by Hewlett-Packard and Intel Corporation, and
- Computer cluster time from Cornell Theory Center.

We also thank:

- SuAnne Fu for creating the 3D tunnel model, and
- Peggy Anderson and Jonathan Conson-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 $S^*\log(R/L, G/L, B/L)$