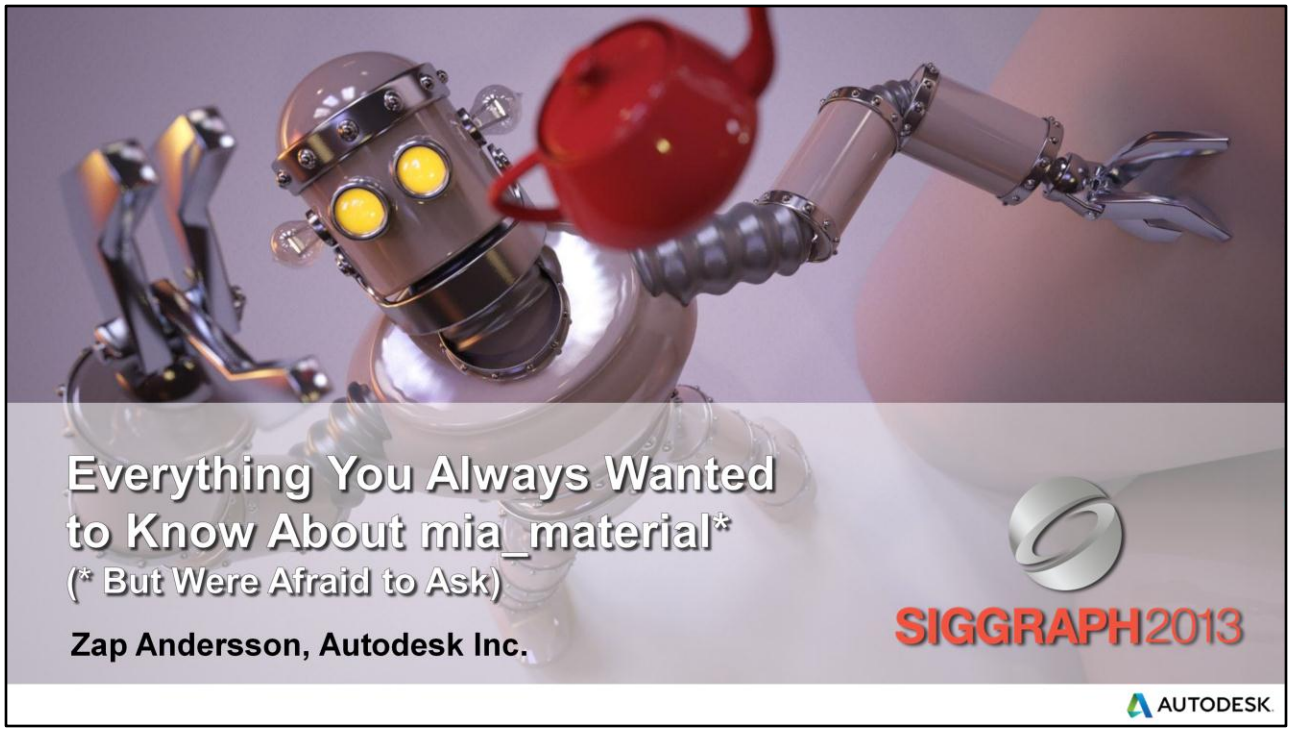

Everything You Always Wanted to Know About mia_material*

(* But Were Afraid to Ask)

Zap Andersson, Autodesk Inc.

SIGGRAPH2013

AUTODESK.

Background

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Background – Who Am I?

- Zap Andersson
  - 2011-present: Autodesk Inc
  - 2004-2011: mental images GmbH (= NVidia Advanced Rendering Center)
  - 1989-2003: Various in Mechanical CAD industry (incl. Autodesk)
    - (Although I did write a renderer – *RayTracker* – on the side)
  - *Electronics* Engineering Degree
    - Meaning: *Nothing I do professionally I've actually been trained for!*

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So who am I?

Zap Andersson.
Since 2011 at Autodesk
2004-2011 mental images. That's the era we will be talking about here.
Before this: Wasted decade-and-a-half in the mechanical CAD industry (deadly boring, athough I did write a renderer – *RayTracker* – on the side).
Before this: Electronics degree. Teacher did try to teach limited programming in BASIC (and Pascal!), but… no.

Background – Who Am I?

- Zap Andersson
  - Love of Computer Graphics
  - Access to computers Early
    - *Built my own Graphics Card*

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So who am I?

I always loved computer graphics. Creating images is in my blood.
Touched my first mainframe computer in 1976 and was hooked.
Then, since my Brother worked at Luxor, who built the swedish ABC80 computer, access to computers very early (1979-).
However, graphics of 78x72 pixels... not good enough.
Built my own graphics card, 240x240 pixels, 16 *glorious* shades of gray ☺
Wrote first raytracer. In BASIC. ☺

Building a graphics card!?!

- Original ABC80
  - 78x72
  - Black or White

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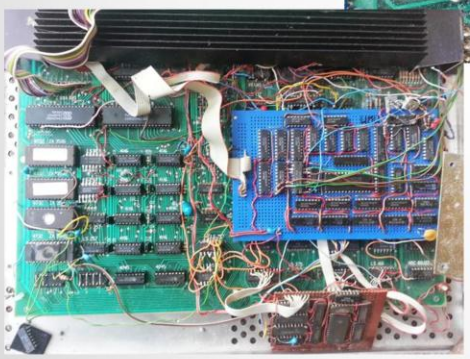
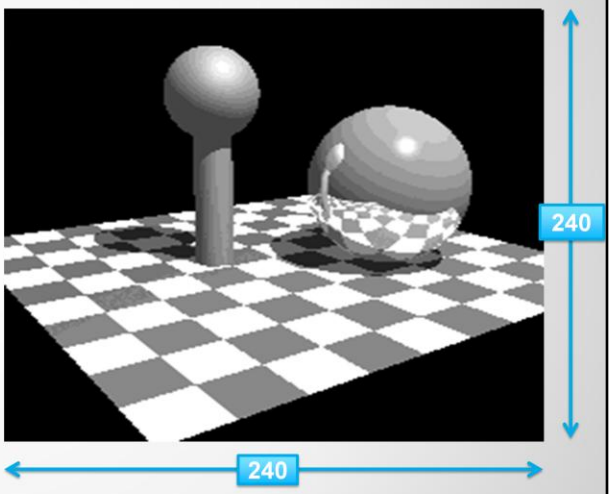
Building a graphics card!?!

- *My* ABC80
  - 240x240 ! ! !
  - 16 shades of gray ! ! !





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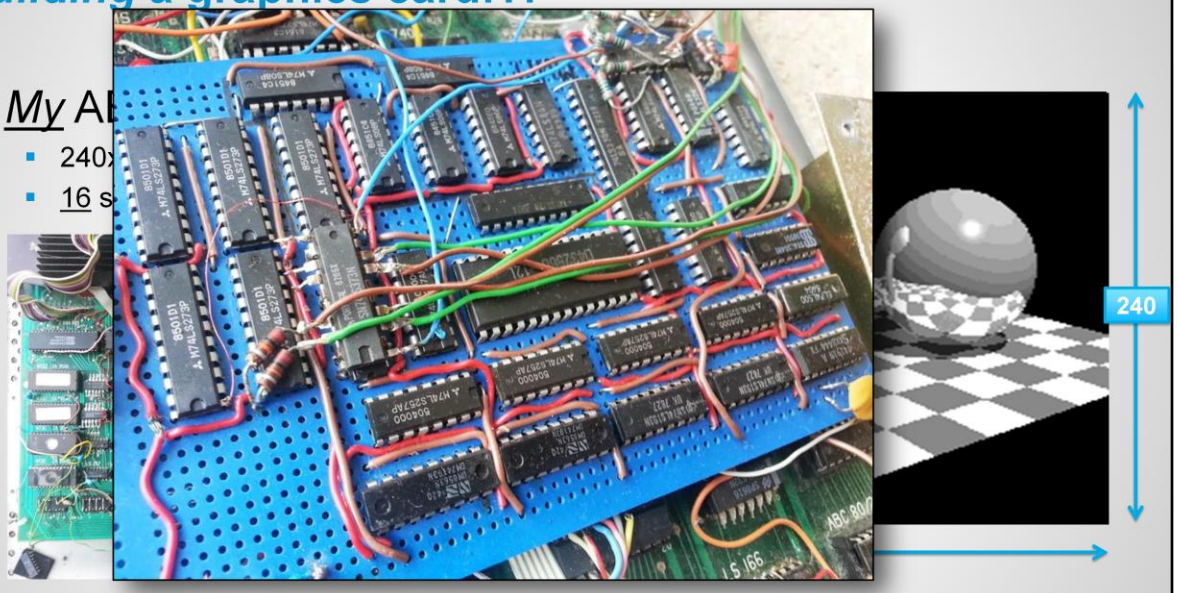
Building a graphics card!?!

- *My* AI
  - 240
  - 16 s



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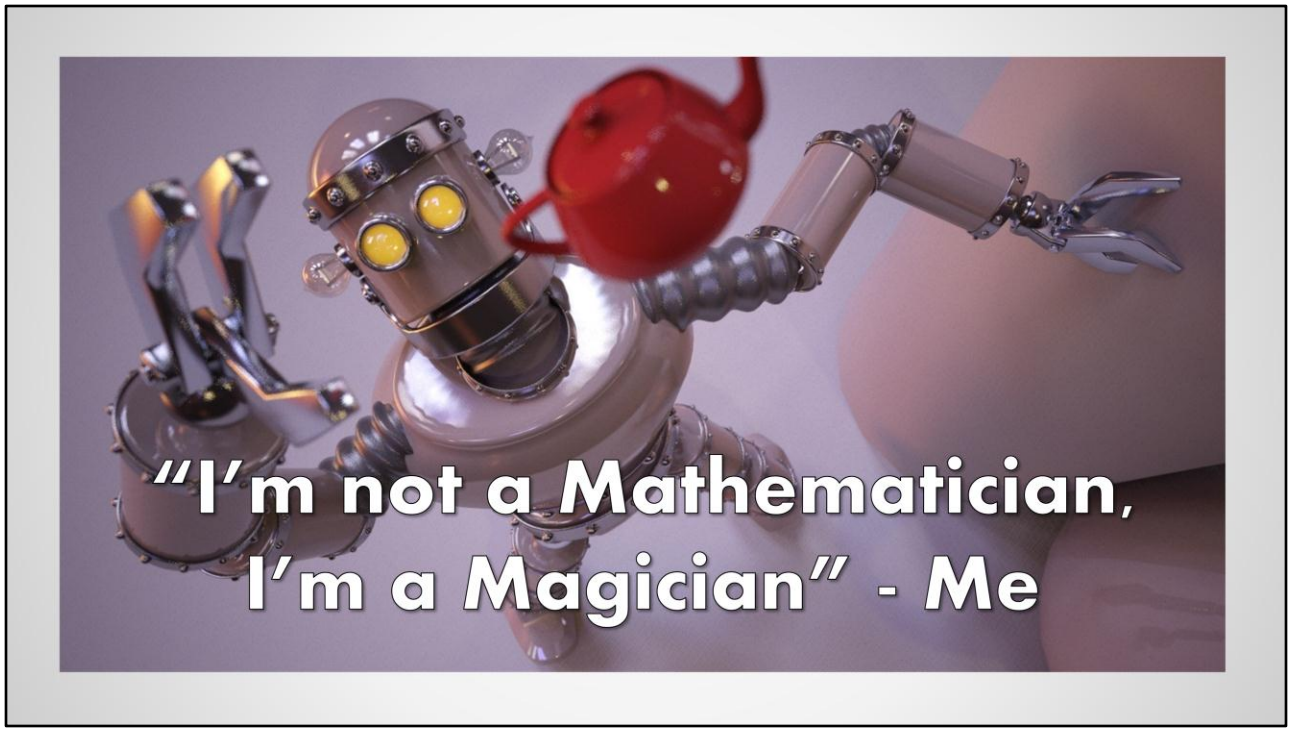
Background – Who Am I?

- Implications for this talk:
  - Not so many formulas* as the other guys ☺
  - Some code (but only in the course notes)

* Or as I normally call it: "squiggly stuff"


"I'm not a Mathematician,
I'm a Magician" - Me

About mia_material...

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What is mia_material?

- Physically plausible **mental ray** shader
- Widespread
  - Included in most applications that integrate mental ray
  - Incl. *many* Autodesk products (10+ million AutoCAD installations)
- Cloned, copied and emulated by many
  - Partners and competitors alike have made variants, interpretations and look-alikes

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What are we going to talk about?
The mental ray mia_material shader.
It's a physically plausible mental ray shader.

NOW, it is one of the most widespread shaders, included in pretty much every application that integrates mental ray.
Specifically, almost every Autodesk application – which includes 10+ million AutoCAD's – since it is the foundation of the "Autodesk materials".
Imitation is the sincerest form of flattery: the shader has been copied, cloned, interpreted or emulated from all sides – partners and competitors alike.

What is mia_material?

- Used Everywhere
  - Movies
  - Game cinematics
  - ArchViz
  - Etc.

<movie frames removed>

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The shader has been used in everything from architectural visualization and spoon commercials to game cinematics and big budget hollywood movies.

When was mia_material created?

- Development started in 2005
- Joint effort between mental images and Autodesk
  - Coded by mental images (= me ☺)
  - Design iterated with Autodesk
- Originally named “The X material”
  - “**mia**” simply stands for “**m**ental **i**mages **a**rchitectural”

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Originally written in 2005 by mental images, but with strong feedback from Autodesk. Special thanks to Pierre-Felix Breton and Daniel Levesque who were instrumental at the time.
Originally called “The X material”. This can still be seen internally in the source code.
“mia” simply means mental images architectural.

Why was mia_material created?

- Problems with shading at the time (circa 2005)
  - Non-linear color space
    - Gamma correction was off by default!
  - Did not conserve energy
    - 100% diffuse + 75% reflection + 80% transparent =

  - Extremely inefficient
    - Glossy reflections tended to explode render time
  - Hard to use
    - User needed deep knowledge, e.g. Fresnel reflections etc.

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Why was mia_material created?

- Design goals of mia_material
  - Conceptual *layering*
  - Energy conserving
  - “Reflections” and “Specular Highlights” linked
  - Fresnel everywhere
  - Special options:
    - Thin vs. thick materials
    - Cut-outs
    - Metal mode

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Why was mia_material created?

- Design goals of mia_material (cont.)
  - Easy to use
    - E.g. Solve mental ray photon- and shadow-shader problem
  - (Reasonably) accurate
    - Inputting real world values should give real world(ish) results
  - Performance
    - Had to be *fast*.

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“Reasonably Accurate”

Early encouraging results

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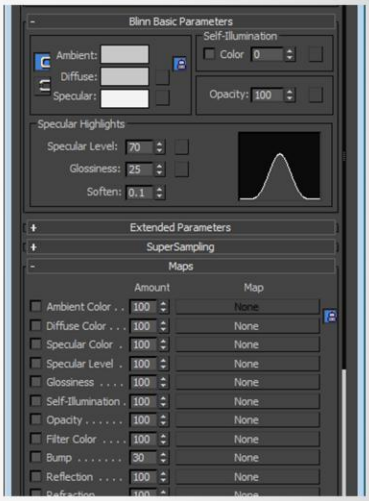
Sources of Inspiration

- 3ds max Standard Material
  - Used as “what not to do”
  - Bizarre old-school workflows
    - “Specular” and “Reflections” unrelated
    - Want a reflection? Put a “Raytrace” map in your “Reflection Map” slot
      - That made *complete* sense in 1986
    - No (discoverable) way to add Fresnel
  - Trivial to break energy conservation



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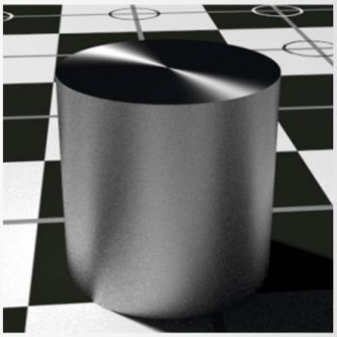
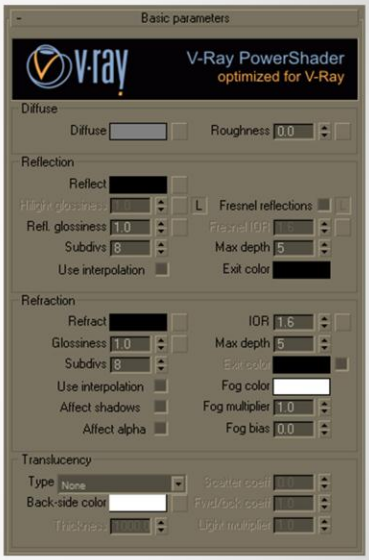
Sources of Inspiration

- Ashikhmin-Shirley
  - A-S shading not used directly
  - Seen as an acknowledgement that “Fresnel everywhere” made sense



Sources of Inspiration

- vRay material
  - Pretty good attempt
  - However:
    - “Specular highlights” and “Reflections” can be unlinked
    - Fresnel possible, but off by default



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How does mia_material work?

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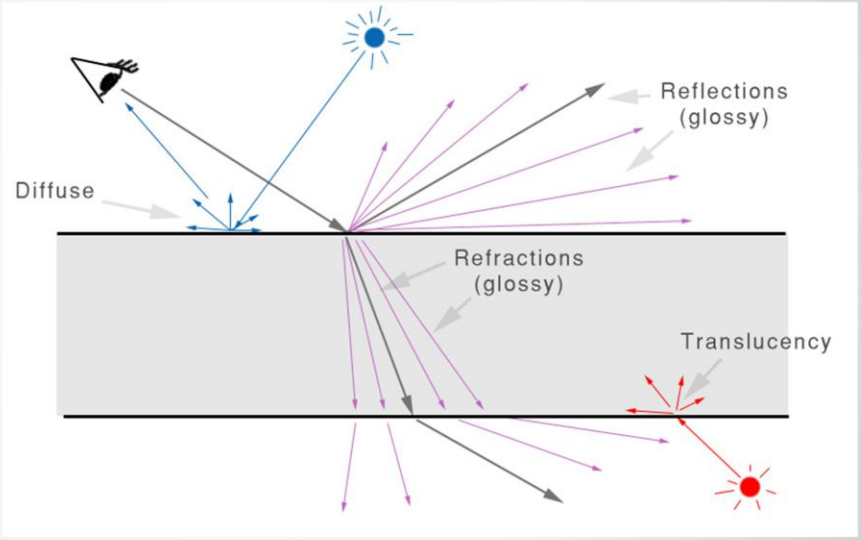
How does mia_material work?

- Four layers:
  - Reflections
  - Diffuse
  - Refraction
    A.k.a. *Transparency*
  - Translucency



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Basically four layers, top to bottom:

- Reflections (which can be glossy or specular)
- Diffuse (Oren Nayar <->Lambert)
- Transparency (also glossy or specular)
- Translucency (basically Lambertian shading on the ”flip side”)

How does mia_material work?

- Reflectivity depends on angle in two modes:
  - Fresnel function based on IOR
  - Custom curve control

Pseudocode in course notes!

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How does mia_material work?

- Energy conservation rules:
  - **Reflections** takes energy from everything else
  - **Transparency** takes energy from **Diffuse**
  - **Translucency** is considered a *kind of* **Transparency** and shares remaining energy with it

Pseudocode in course notes!

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The Shading Model

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The Shading Model

- *No* pre-existing shading model was used
- Two main problems:
  - Bad highlights
    - Highlights of most known shading models were deemed “ugly”
  - Not enough “stretchiness” of glossy reflections
    - Glossy reflections generally done wrong
    - The mental ray API didn’t exactly help

~~Blinn?~~ ~~Phong?~~ ~~Blong?~~
~~Ward?~~ ~~Torrance-Sparrow?~~
~~Cook-Torrance?~~ ~~Henkell-Trocken?~~
~~Ashikmin-Shirley?~~
Zap-Andersson!?!!??!

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The Shading Model: Refraction / Transparency

- Refraction/Transparency
  - Implemented using standard mental ray functions
  - Nothing special
  - Motivation:
    - Perceptually, anything vaguely the right color and distortion reads as “refraction” to a human. Accuracy is visually irrelevant.

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The Shading Model: Translucency

- Translucency
  - Implemented as computing a standard Lambert on the reverse side of the surface
  - Useful mostly for cheap faking of SSS
    - E.g. Leaves
    - Thin paper
    - Etc.
  - Nothing special

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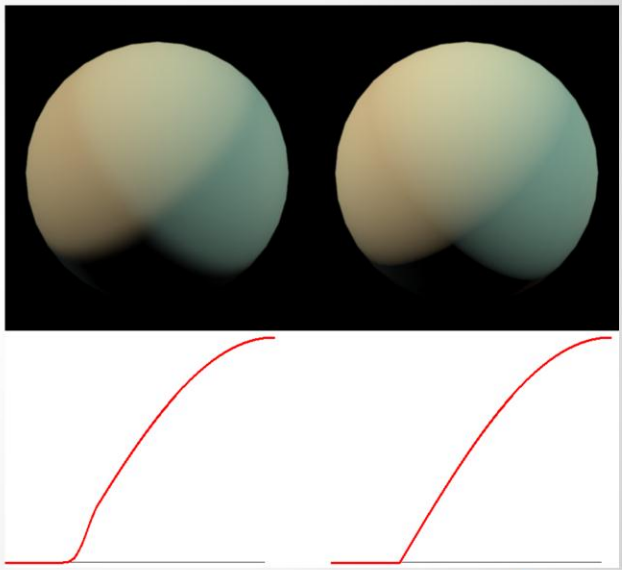
The Shading Model: Diffuse

- Diffuse
  - Standard Oren-Nayar
    - (Lambert for rougness=0)
  - Added a smoothstep to avoid discontinuity



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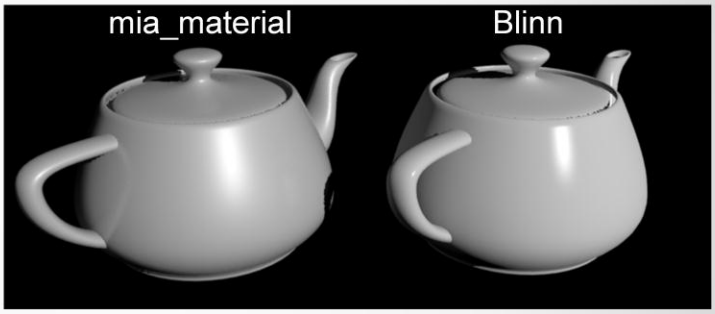
The Shading Model: Reflection

- Bad Highlights
  - Not “glowy” enough
  - Empirical observation
- Solution:
  - Mixing three different Ward highlights



Pseudocode in course notes!

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The Shading Model: Reflection

- Reflection “stretchiness”
  - Example: sunset over sea

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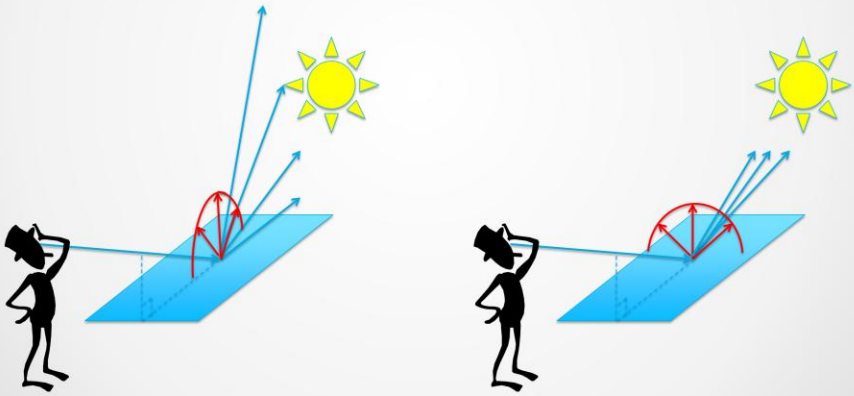
Stretchy reflection of the sun.

The Shading Model: Reflection

- Reflection “stretchiness”
  - Example: sunset over sea



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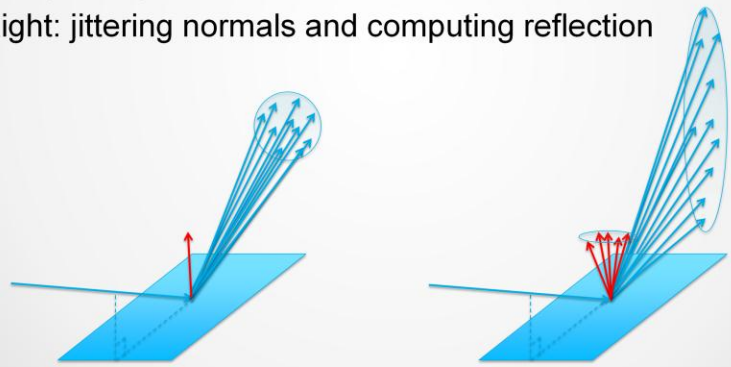
How reflection direction varies when the normal vector varies for near-grazing view angles.

The Shading Model: Reflection

- Reflection “stretchiness”
  - Solution: abuse mental ray API for generating glossy rays
    - Left: jittering reflection directions
    - Right: jittering normals and computing reflection



More details in course notes!

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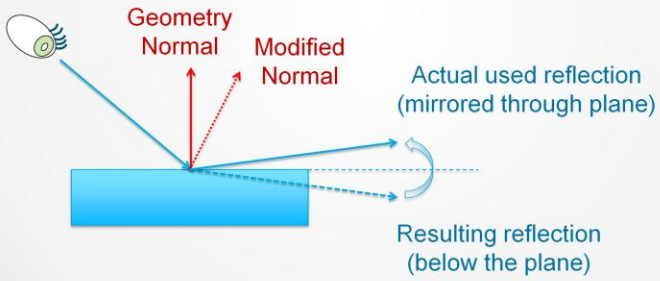
How this is implemented.

On left: Using mi_reflection_dir_anisglossy_x() as it was intended.
On right: ABusing mi_reflection_dir_anisglossy_x() to instead modify the normal

The Shading Model: Reflection

- Reflection “stretchiness”
  - What about reflection rays that go below the surface plane?
    - Just flip them back above the plane



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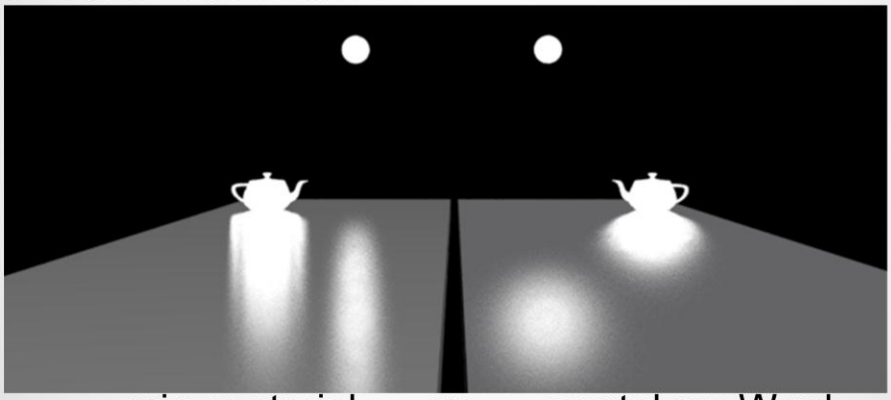
The Shading Model: Reflection

- Reflection “stretchiness”



mia_material vs. mental ray Ward

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The Shading Model: Reflection

- The problem with all this:

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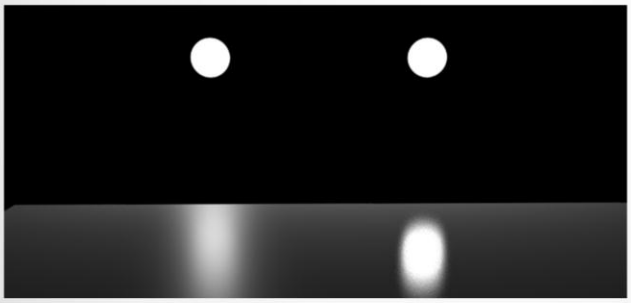
The Shading Model: Reflection

- The problem with all this:
  - Reflections and highlights *do not match:*



Specular Highlights
Glossiness = 0.54

Glossy Reflection
Glossiness = 0.54

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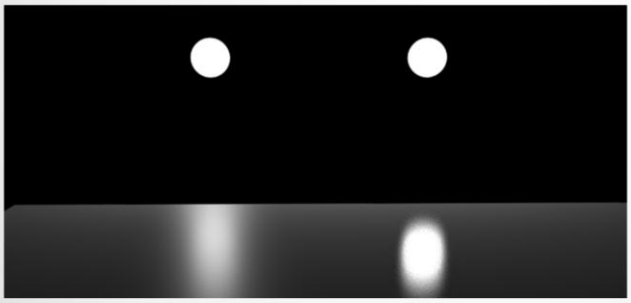
The Shading Model: Reflection

- The problem with all this:
  - Reflections and highlights *do not match:*



Specular Highlights
Glossiness = 0.54

Glossy Reflection
Glossiness = 0.54

...what's my excuse?

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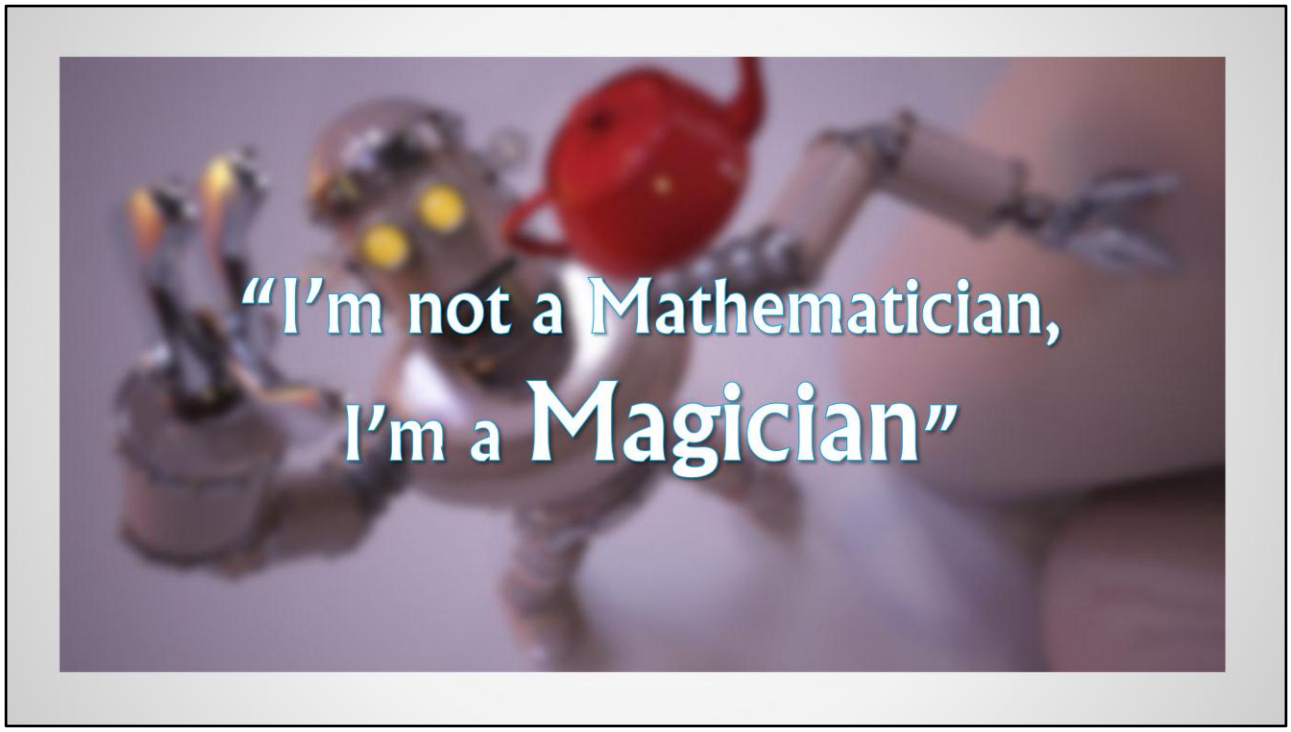
"I'm not a Mathematician,
I'm a Magician"

What does this mean?

- Matching mia_material *exactly* in e.g. a pathtracer is *impossible*
  - ...but should you?
- The trick is to pick:
  - Do I match reflections... or highlights?

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Going Forward

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Lessons Learned

- Highlight “look” is important
  - Gaussian “blob” / cosine-raised-to-a-power is desperately wrong
  - Real highlight falloff is much more “exponential” in nature
  - Nowadays, academic papers vindicate our empirical decision

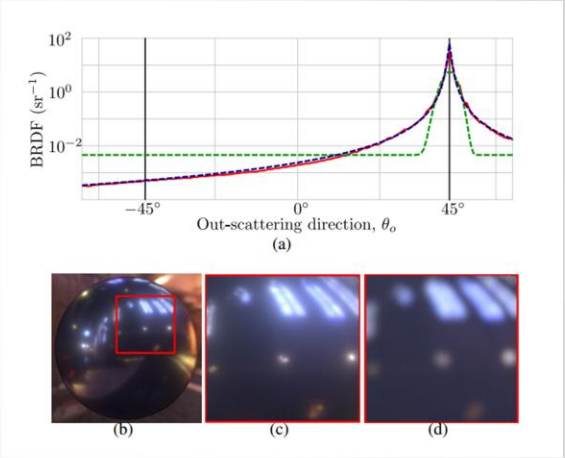

Figure from
"BRDF Models for Accurate and Efficient Rendering of Glossy Surfaces" from Linköping University

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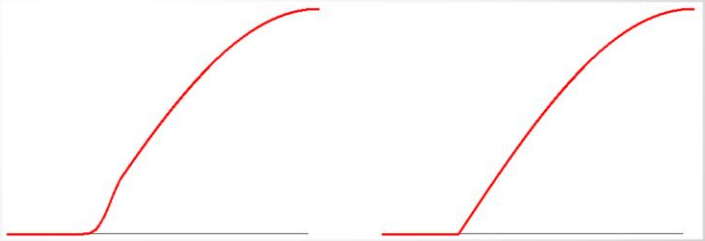
Lessons Learned

- Perceptions is important
  - Remember how the human eye *sees* things, and make sure the shading aligns with that perception
  - Hear me ramble for many hours about Perception in my fxphd course ”mry201” at fxphd.com



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Lessons Learned

- Flexibility is important
  - mia_material is limited to its four built-in layers
  - It is missing certain effects (SSS, etc.)
  - It is inefficient if mixed “traditionally”
  - A better solution is needed
    - ...especially across platforms / renderers.
      - OSL? MDL?
  - mr users can look at MILA shader library:
    - http://forums.nvidia-arc.com

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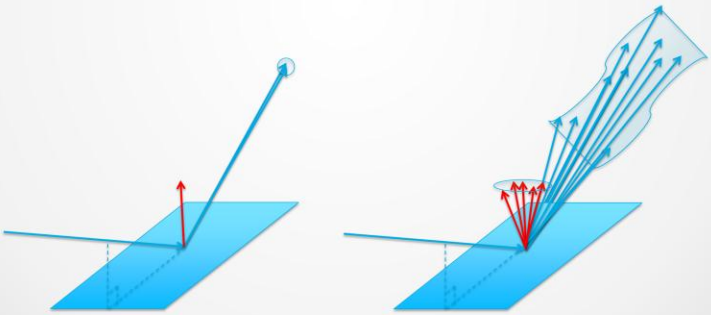
Lessons Learned

- Small bumps get filtered too much
- LEAN mapping to the rescue?



More details in course notes!

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Useful links:

www.mentalraytips.com
twitter.com/MasterZap