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supervised by Alexander Wilkie

Layered Materials in Real-Time Rendering

CESCG 2010

Outline

- Introduction
- Related work
- Basic layered model
  - Formulation
  - Real-time adaptation
- Specialized model – Metallic paint
- Specialized model – Patina
- Results
- Conclusion
- Demo

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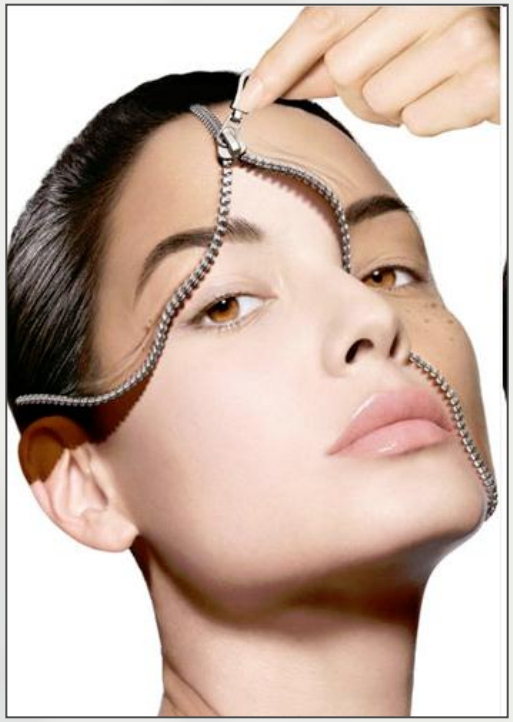
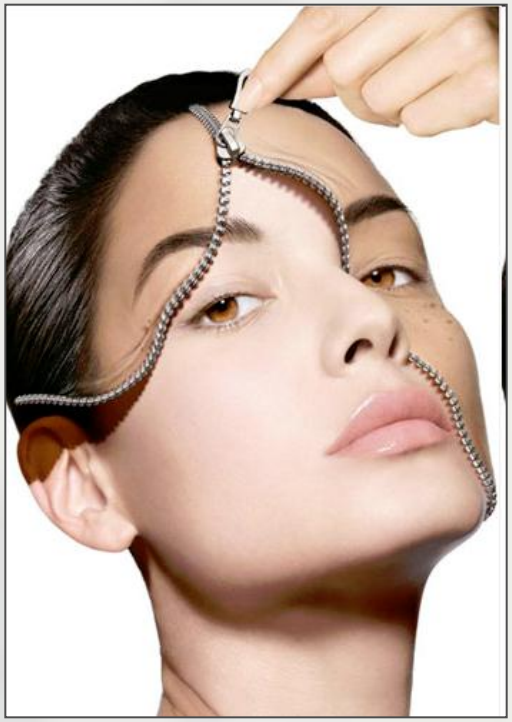
Introduction

- Layered materials



Introduction

- Layered materials
- Full solution complicated
  - Reflections
  - Refractions
  - TIR
  - Absorption
  - Light Scattering
  - Interference



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  - TIR
  - Absorption
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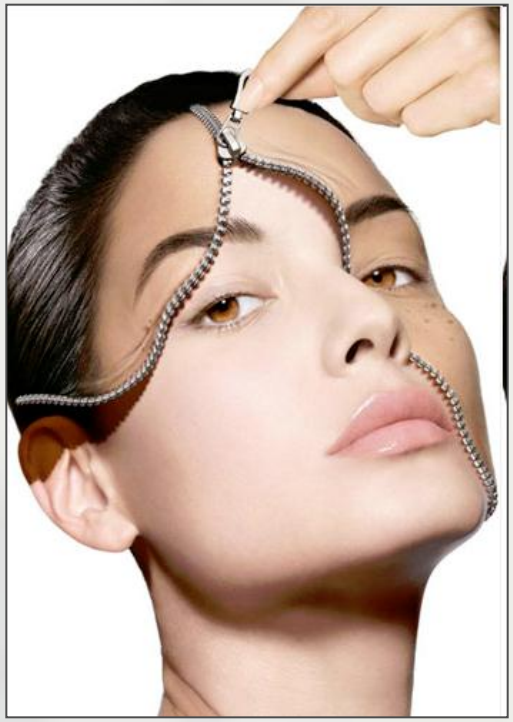
  - Interference
- Real-time



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Related Work

- BRDFs
  - Empirical – Phong 1975, Blinn 1977, Lafortune et al. 1997
  - Physically-based – Torrance-Sparrow 1992, Cook-Torrance 1992, Oren-Nayar 1994

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- Layered reflectance models
  - Kubelka-Munk 1931, Hanrahan-Krueger 1993
  - Neumann-Neumann 1989, Weidlich-Wilkie 2007

Related Work

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  - Physically-based – Torrance-Sparrow 1992, Cook-Torrance 1992, Oren-Nayar 1994
- Layered reflectance models
  - Kubelka-Munk 1931, Hanrahan-Krueger 1993
  - Neumann-Neumann 1989, Weidlich-Wilkie 2007
- Specialized models
  - Metallic paint – Rump et al. 2008
  - Patination – Dorsey and Hanrahan 1996

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Basic Layered Model - Introduction

- Weidlich and Wilkie 2007

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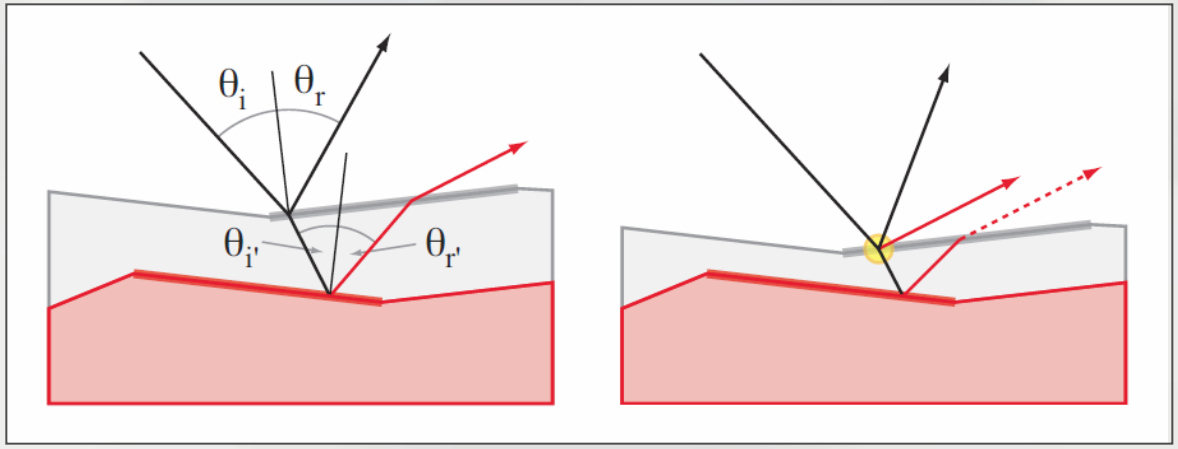
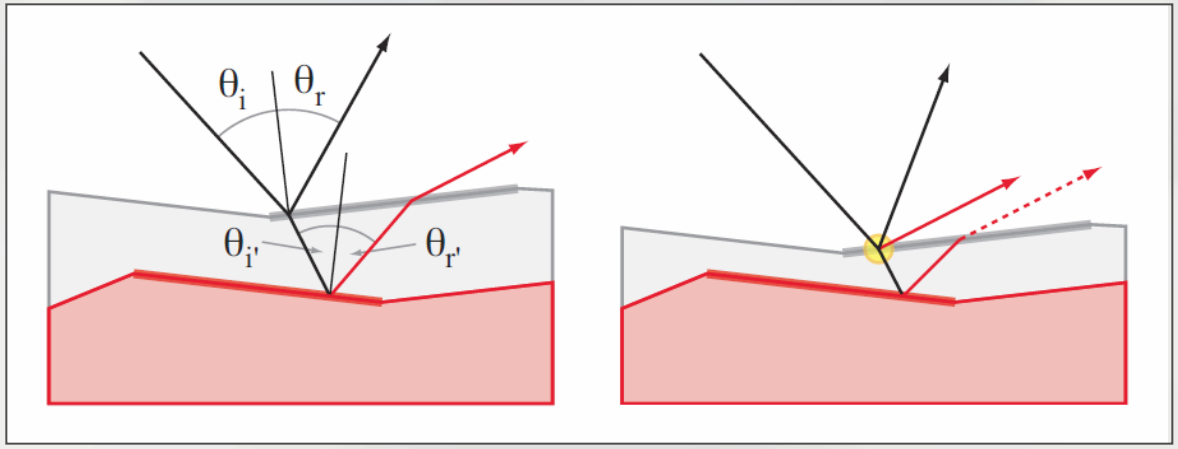
- Assumptions:
  - 1) Thin layers
    - Single point of incidence/exit
    - Local evaluation

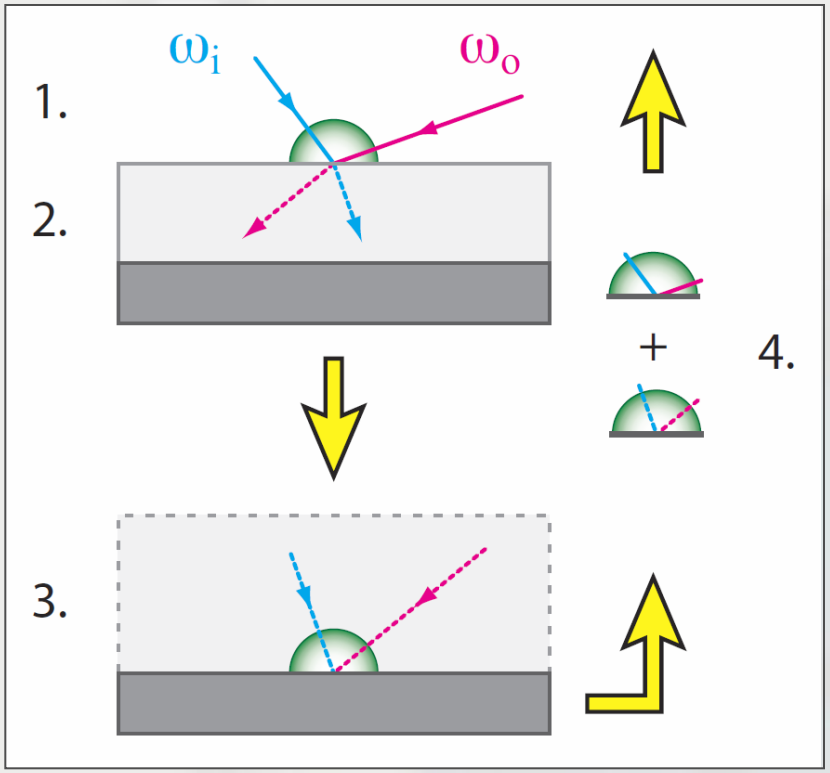


Basic Layered Model - Introduction

- Weidlich and Wilkie 2007
- Assumptions:
  - 1) Thin layers
    - Single point of incidence/exit
    - Local evaluation
  - 2) No scattering within layers

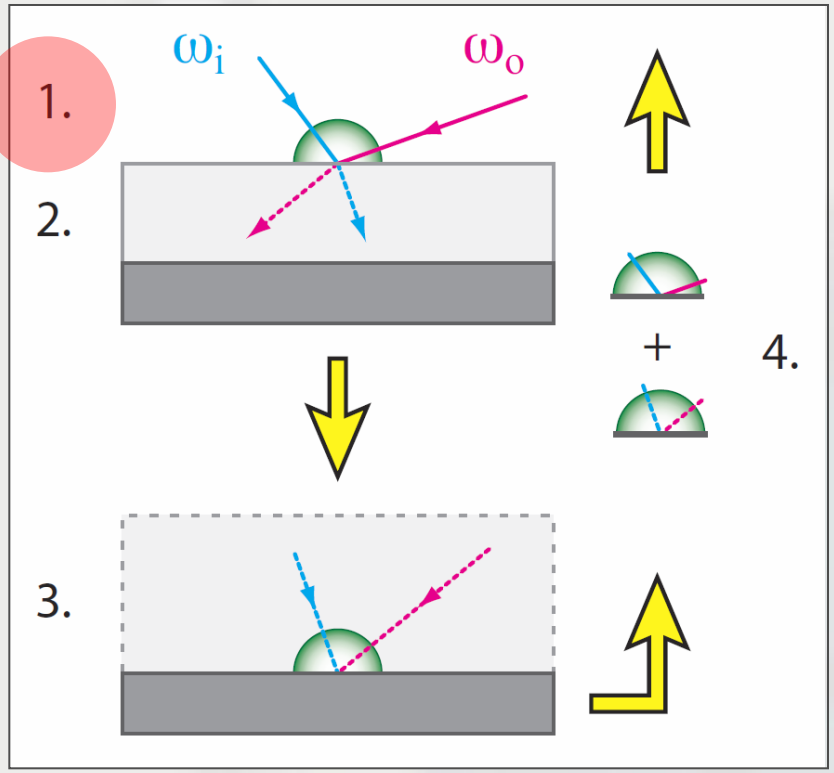


Basic Layered Model - Evaluation



$$f_r = f_{r_1}(\theta_i, \theta_r) + T_{12} \cdot f_{r_2}(\theta_{i'}, \theta_{r'}) \cdot a \cdot t$$

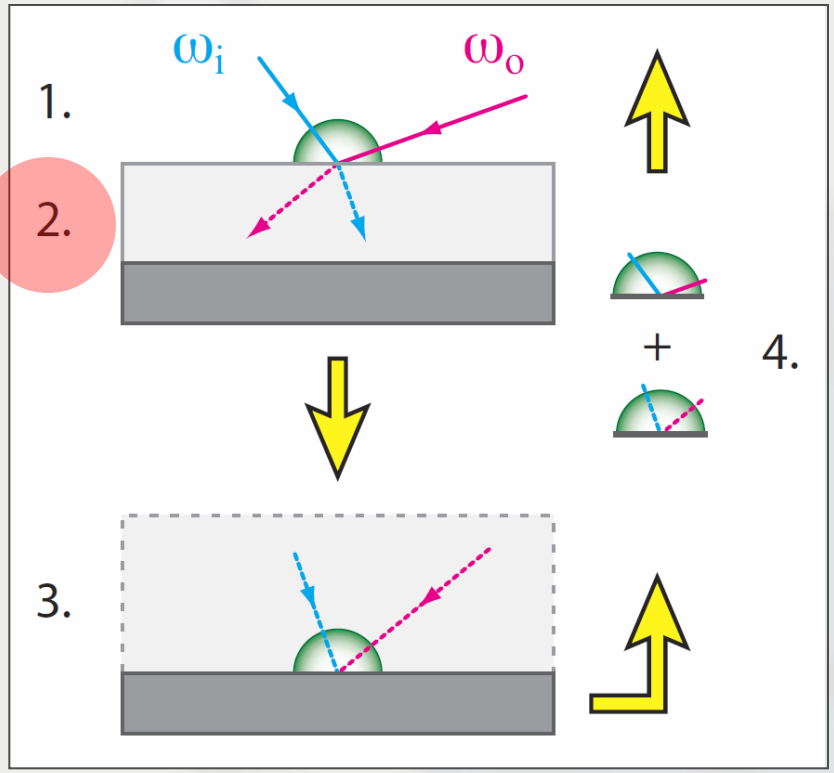
Basic Layered Model - Evaluation

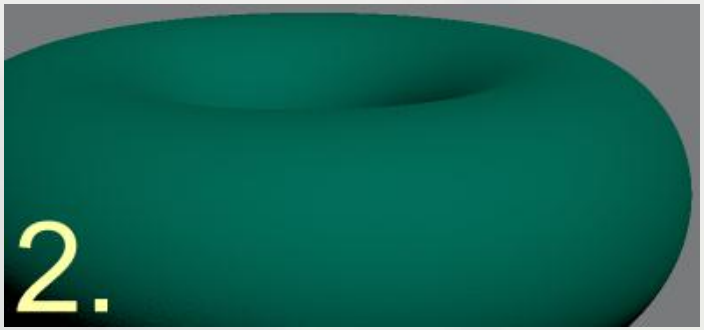


- Top layer BRDF

$$f_r = f_{r_1}(\theta_i, \theta_r) + T_{12} \cdot f_{r_2}(\theta_{i'}, \theta_{r'}) \cdot a \cdot t$$

Basic Layered Model - Evaluation

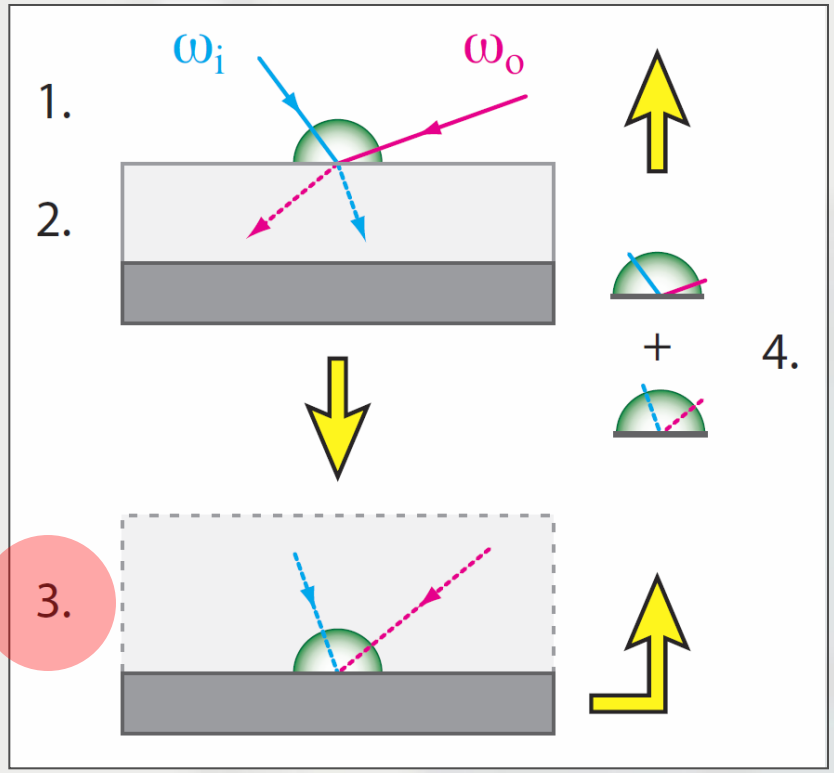


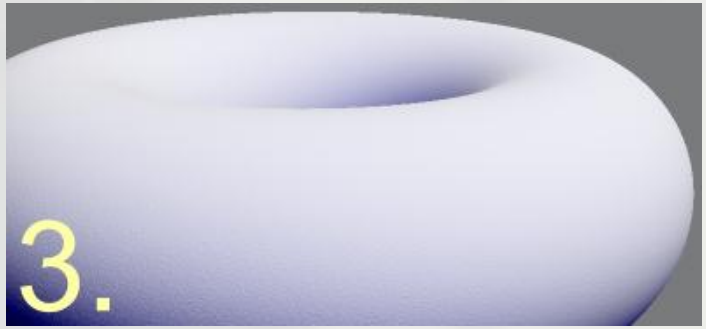


- Transmission & absorption

$$f_r = f_{r_1}(\theta_i, \theta_r) + T_{12} \cdot f_{r_2}(\theta_{i'}, \theta_{r'}) \cdot a \cdot t$$

Basic Layered Model - Evaluation

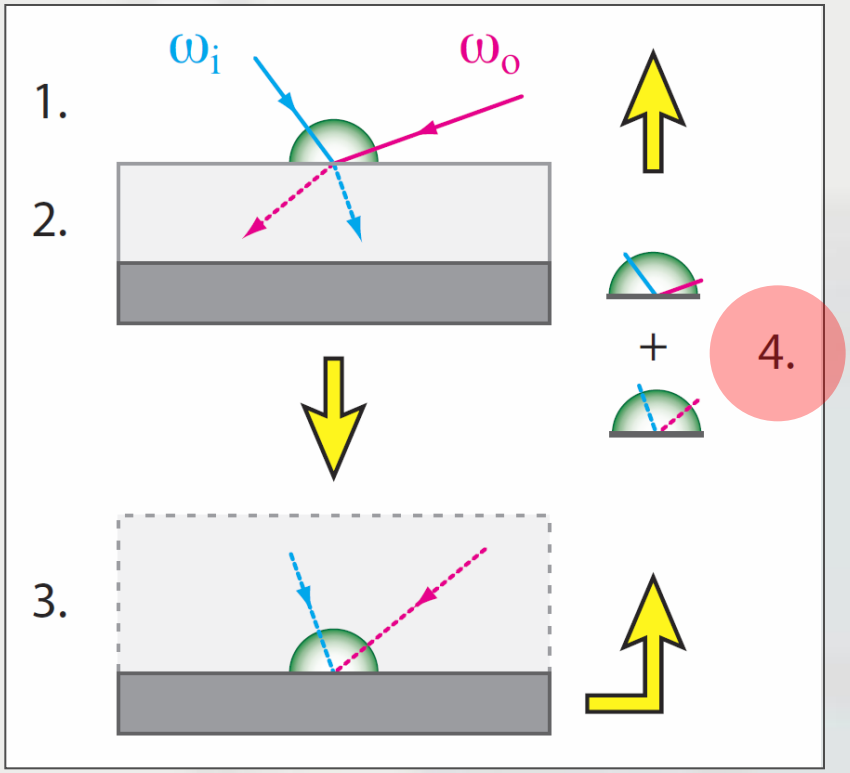


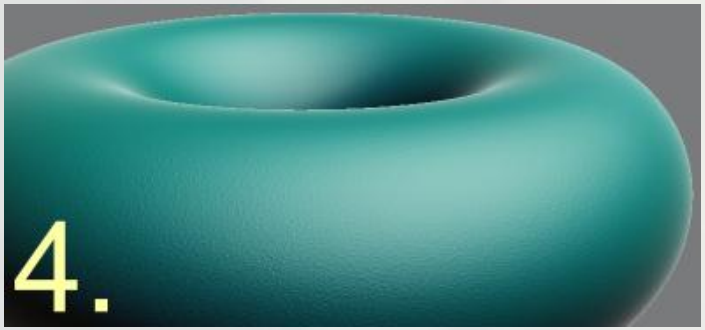


- Bottom layer BRDF

$$f_r = f_{r_1}(\theta_i, \theta_r) + T_{12} \cdot f_{r_2}(\theta_{i'}, \theta_{r'}) \cdot a \cdot t$$

Basic Layered Model - Evaluation





- TIR & Final summation

$$f_r = f_{r_1}(\theta_i, \theta_r) + T_{12} \cdot f_{r_2}(\theta_{i'}, \theta_{r'}) \cdot a \cdot t$$

Real-Time Adaptation

- Fragment shader evaluation
- Cook-Torrance BRDF
  - D term – precomputed
  - F term – precomputed or approximation (Lazanyi and Szirmay-Kalos 2005)

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- Layered model

$$f_r = f_{r_1}(\theta_i, \theta_r) + T_{12} \cdot f_{r_2}(\theta_{i'}, \theta_{r'}) \cdot a \cdot t$$

$$a = e^{-\alpha d \cdot \left(\frac{1}{\theta_{i'}} + \frac{1}{\theta_{r'}}\right)}$$

$$t = (1 - G) + T_{21} \cdot G$$

Real-Time Adaptation

- Fragment shader evaluation
- Cook-Torrance BRDF
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- Layered model

Model	GPU cycles	MPix/s
Layered (full)	436	348
Layered (precomp.)	236	757
Phong	104	1648

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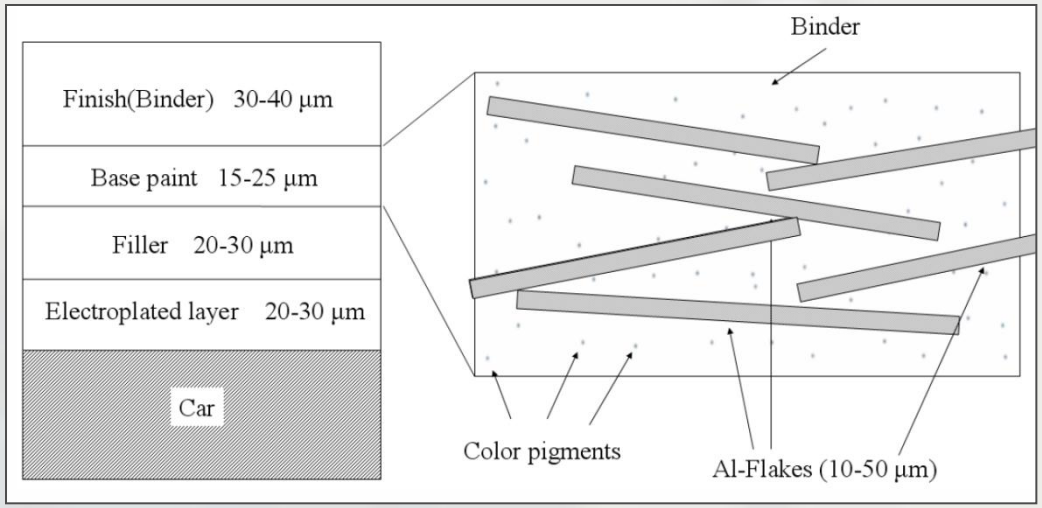
Specialized Model - Metallic Paint

- Layered structure



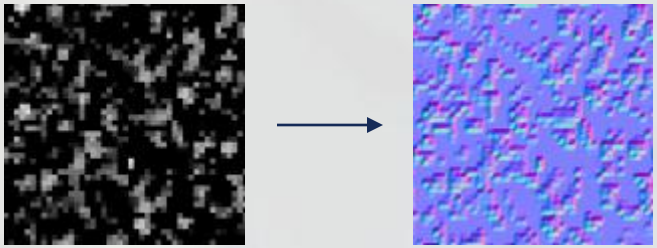
Images from Rump et al. 2008

Specialized Model - Metallic Paint

- Layered structure
- Modelling:
  - 2 layers

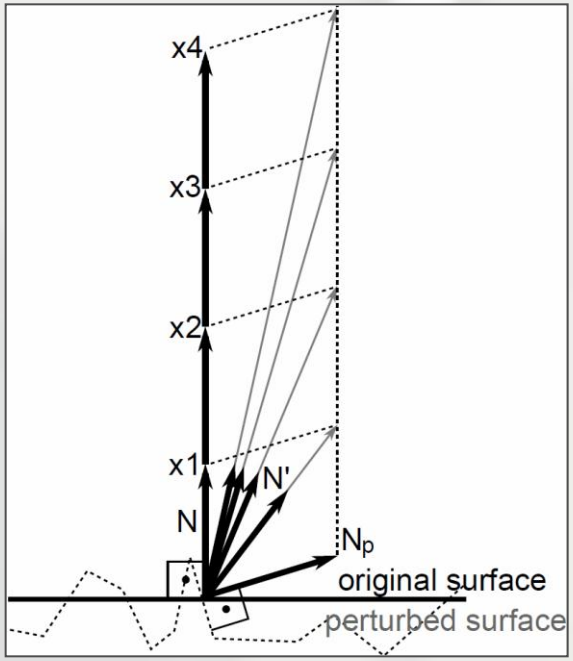
Specialized Model - Metallic Paint

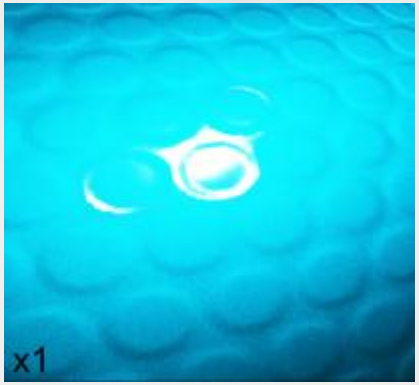
- Layered structure
- Modelling:
  - 2 layers
  - Perturbation of bottom layer normals (no filtering!)

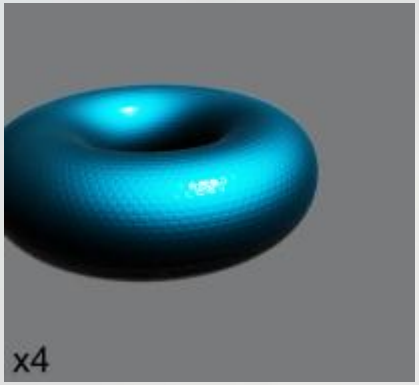


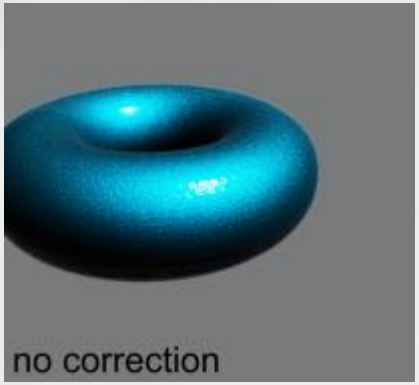
Specialized Model - Metallic Paint

- Layered structure
- Modelling:
  - 2 layers
  - Perturbation of bottom layer normals (no filtering!)
  - Scaling of normal with distance









Specialized Model - Patina

- Structure

Specialized Model - Patina

- Structure
- Modelling:
  - 2 layers (Cu & Cu_2O)

Specialized Model - Patina

- Structure
- Modelling:
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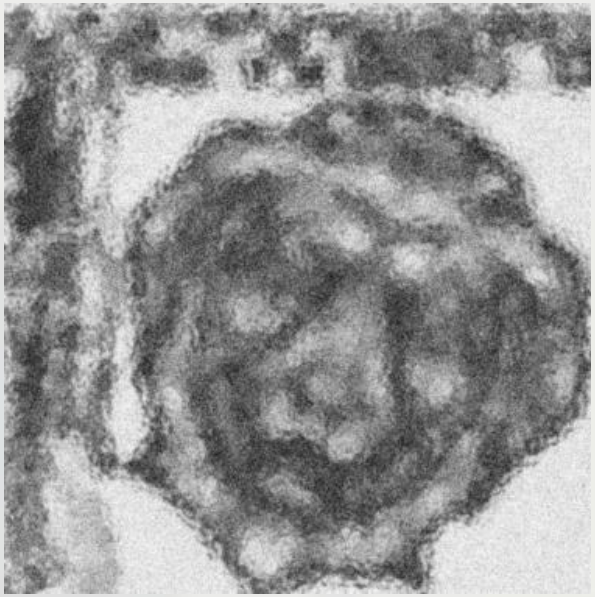
  - Scattering term

Specialized Model - Patina

- Structure
- Modelling:
  - 2 layers (Cu & Cu_2O)
  - Scattering term
  - Temporal development (thresholding)



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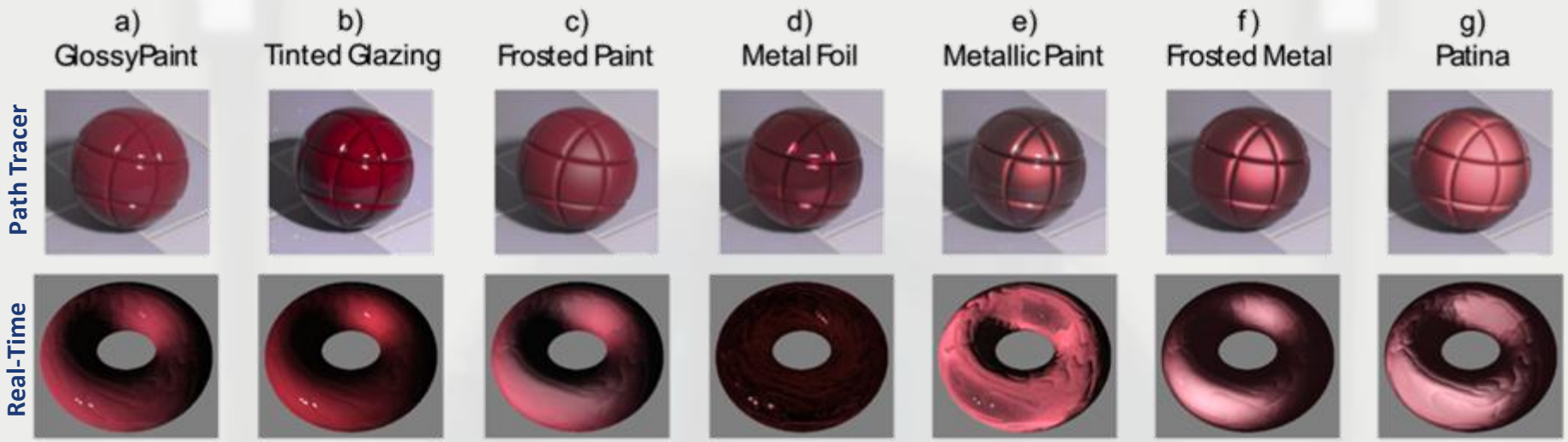
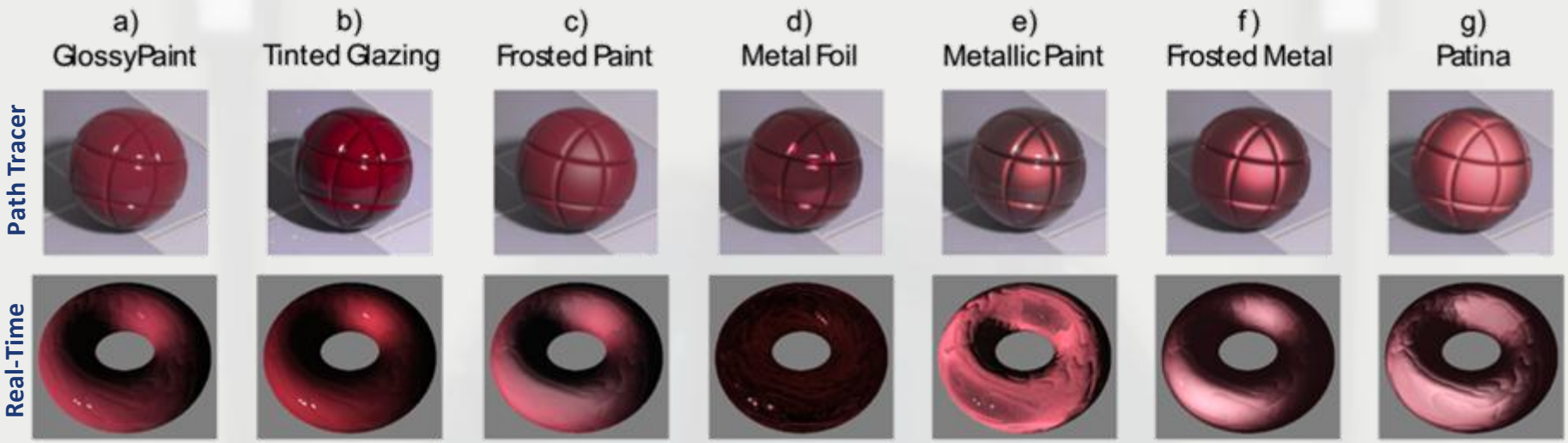
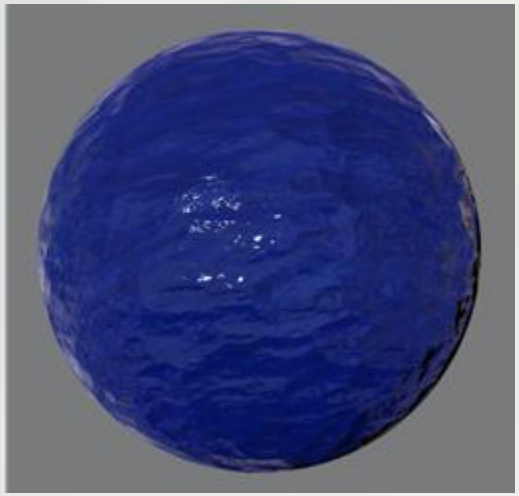

a) GlossyPaint
b) Tinted Glazing
c) Frosted Paint
d) Metal Foil
e) Metallic Paint
f) Frosted Metal
g) Patina
Path Tracer
Real-Time

Results



Car paint example

Varying varnish thickness



Coated concrete ball

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- Contributions:
  - Real-time adaptation of the layered model of Weidlich and Wilkie
    - Only 2.3 times slower than basic Phong
    - Useful in 3D games and other R-T applications
  - Two specialized models for metallic paint and patina
    - Add minimal overhead

Conclusion

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  - Two specialized models for metallic paint and patina
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- Future work
  - Scattering

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End

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Thanks!

Questions?