A scalable framework for image-based material representations

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Qualitätsmanagement zertifiziert nach DIN ISO 9001:2000

instantreality

WEB 3D 2012

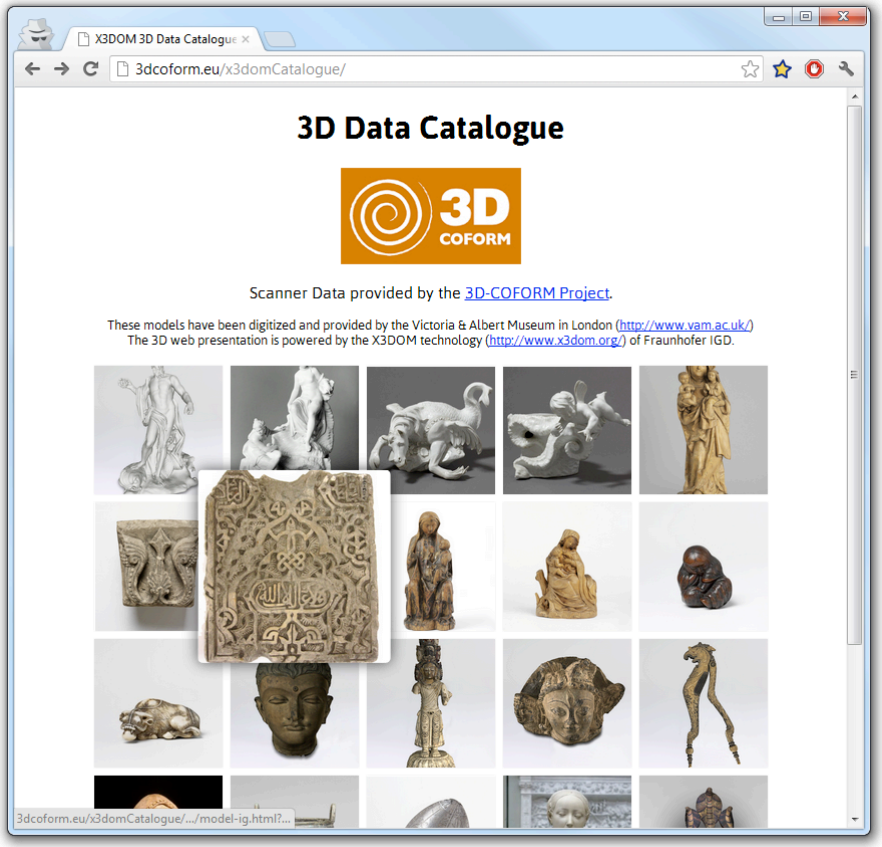
Introduction

Overview

- Faithful digital reproduction of real artifacts
  - E.g. online CH galleries
  - “Digital Replica”
  - Key ingredient: real world, measured material functions
    - No support in X3D
    - CSS and standard materials don’t address this
    - Usual option: write your own shader, not portable

Introduction
Problem definition

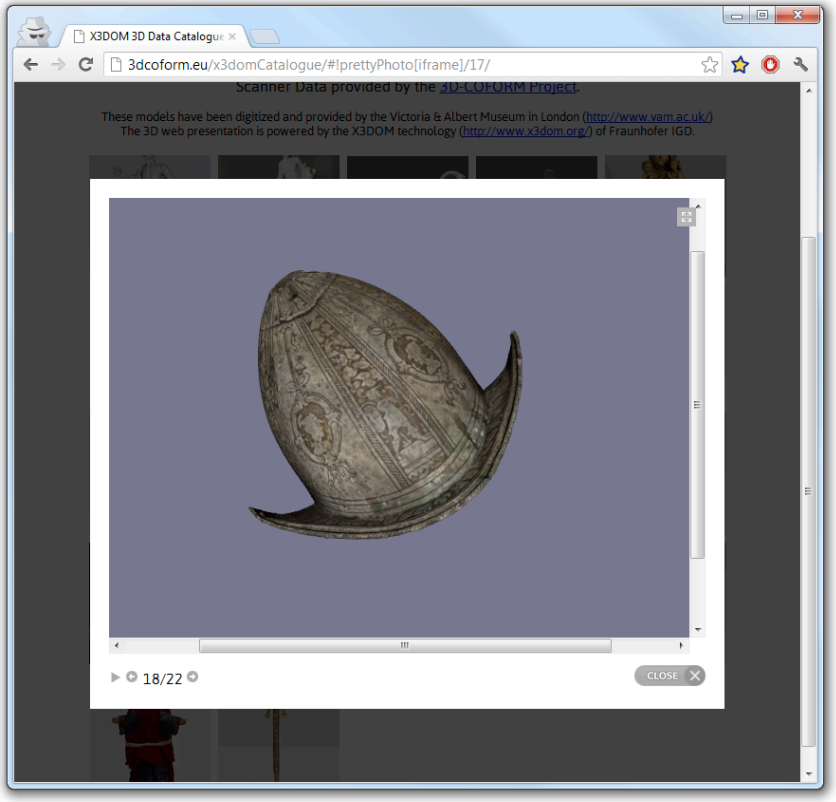
- 3D-Coform
  - Cultural Heritage gallery based on X3DOM
  - All materials are rendered with the standard X3D material



3D Data Catalogue
http://3dcoform.eu/x3domCatalogue/

Introduction

Problem definition



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Introduction

Problem definition

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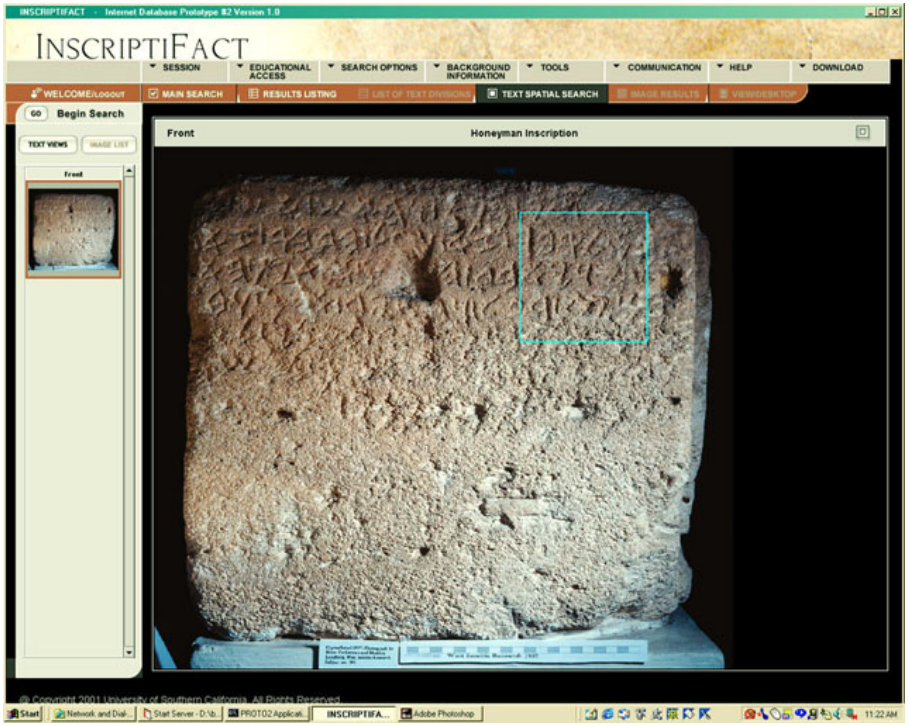
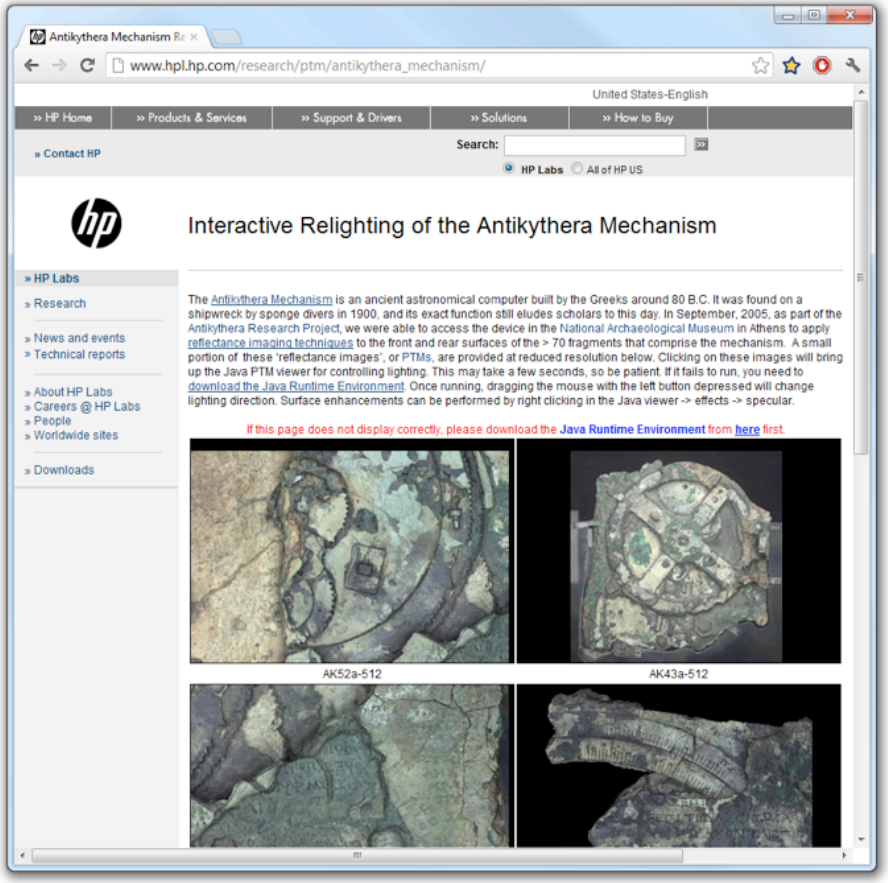


InscriptiFact
http://www.inscriptifact.com

- InscriptiFact
  - Archive for near eastern and mediterranean inscriptions
  - PTM based
  - Java viewer
  - 2D

Introduction
Problem definition



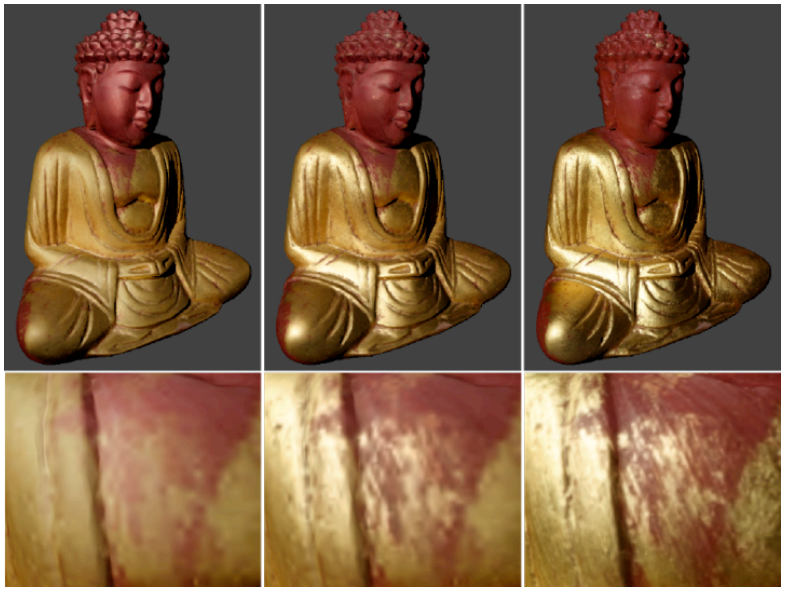
Interactive Relighting of the Antikythera Mechanism
http://www.hpl.hp.com/research/ptm/antikythera_mechanism/

- HP Antikythera Mechanism
  - Online gallery
  - PTM based
  - Java viewer
  - 2D

Introduction

Related Work

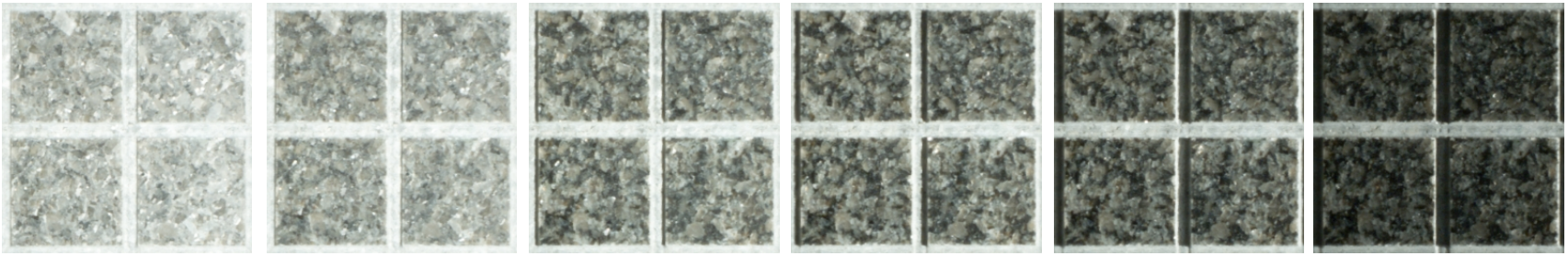
- BTFs
  - Approximated BTFs
  - WebGL streaming implementation
- Polynomial Texture Maps
- Precomputed Radiance Transfer
- CommonSurfaceShader



WebGL-based Streaming and Presentation Framework for Bidirectional Texture Functions
http://cg.cs.uni-bonn.de/en/publications/paper-details/schwartz-2011-webglbtfstreaming/

Case studies

Approximated BTFs



BTF Database Bonn and Measurement Lab
http://cg.cs.uni-bonn.de/en/projects/btfdbb/

- Stack of textures
  - only one varying incident illumination angle theta
  - only one view
  - usually ~15 images
- At runtime
  - interpolate texel from stack according to incident lighting angle/lambert factor

Case studies

Polynomial Texture Maps

- Specialized texture format
  - 6 coefficients per pixel (per color channel)
  - One view, varying incident illumination
- At runtime
  - project lighting angle into texture space, evaluate polynomial

HP Labs
https://www.hpl.hp.com/research/ptm/

Case studies

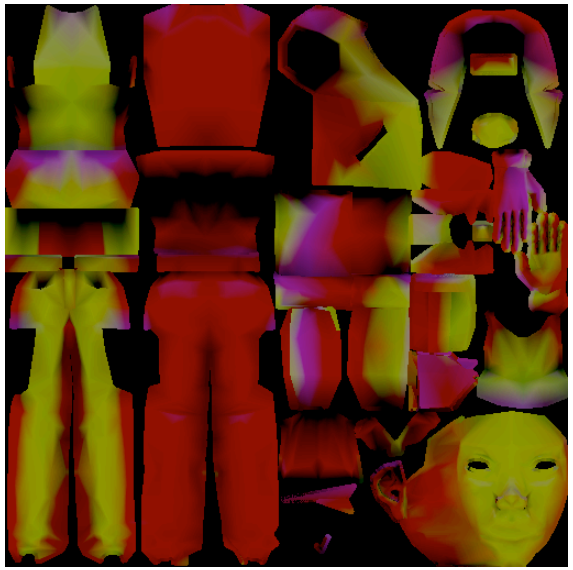
Sum of Gaussians

- Two textures encoding BRDF as sum of Gaussians
  - 1 texture for RGB weights
  - 1 texture for mean and standard deviation
- At runtime
  - Multiply with Gaussian-prefiltered environment map to calculate final value

Case studies

Precomputed Radiance Transfer

- Textures transmit coefficients
  - Each texel has n^2 coefficients
  - Divide up to RGB/RGBA textures
- At runtime
  - Multiply coefficients at each texel with distant environment lighting coefficient



Microsoft DirectX SDK
http://msdn.microsoft.com/en-us/directx/aa937788.aspx

Case studies

Similarities

- Image-based materials share common features
  - 1..N textures encoding material property/transfer
  - Preprocessing & shader program for interpretation
  - Usual traits
    - BRDF required for indexing
    - May be affected by texture transformations
    - May support/require relighting through environment map

Implementation

ImageMaterial node

```
ImageMaterial : X3DAppearanceNode
{
  MFNode   [in,out]  materialImages      NULL
  MFString [in,out]  materialTags        NULL
  SFString [in,out]  compression         "approxBTF"
  SFNode   [in,out]  environmentTexture  NULL
  SFString [in,out]  mapMode             "auto"
  SFBool   [in]      useRegularMaterial  FALSE
  MFFloat  [in]      scale               []
  MFFloat  [in]      bias                []

  ...
}
```

Implementation

ImageMaterial node

```
PolynomialTextureMap : X3DTextureNode
{
  SFNode   [in,out] textureProperties NULL
  MFString [in,out] url               NULL
  SFImage  [out]    image_changed
  MFImage  [out]    coefficientsHigh_changed
  MFImage  [out]    coefficientsLow_changed
  SFString [out]    format_changed
}
```

Implementation

Usage example

```
<X3D xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' …>
<Scene>
  <Shape>
    <ImageMaterial compression='gaussian' materialTags='"weights", "meanStdDev"'>
      <ImageTexture2D
        containerField='environmentTexture'
        url='env.png'/>

      <ImageTexture2D
        containerField='materialImages'
        url='weights.png' />

      <ImageTexture2D
        containerField='materialImages'
        url='meandev.png' />
    </ImageMaterial>

    <Teapot />
  </Shape>
</Scene>
</X3D>
```

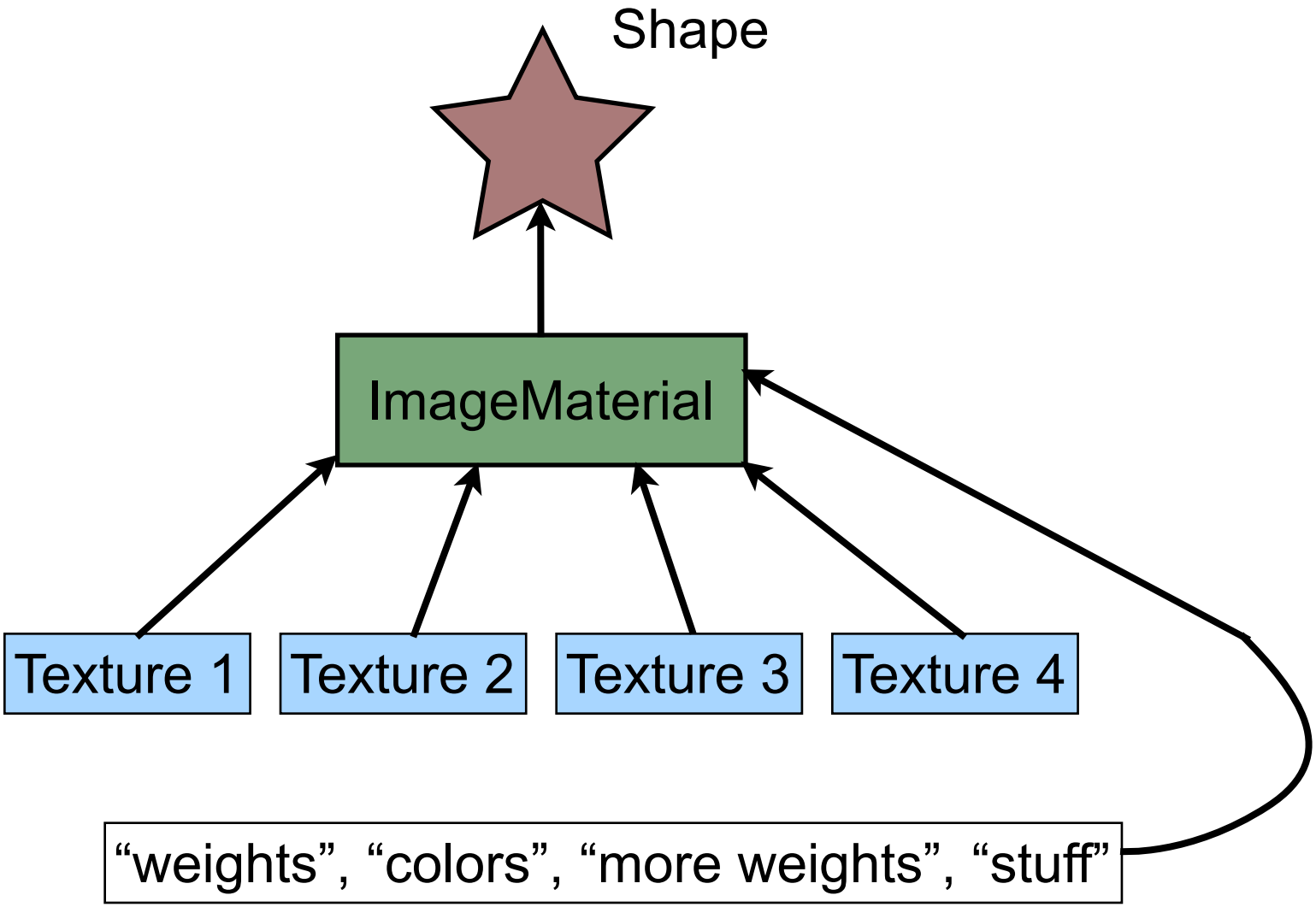
Discussion

Flexibility vs. self-descriptive interface

- Many other image-based schemes can be supported with the ImageMaterial rapidly
- Major point of critique: brdfImages field too broad
  - Do-it-all interface not self-descriptive
  - Distribution of responsibility not good
  - Can’t parameterize!
  - Possible solution: encapsulate special textures for material description in texture nodes

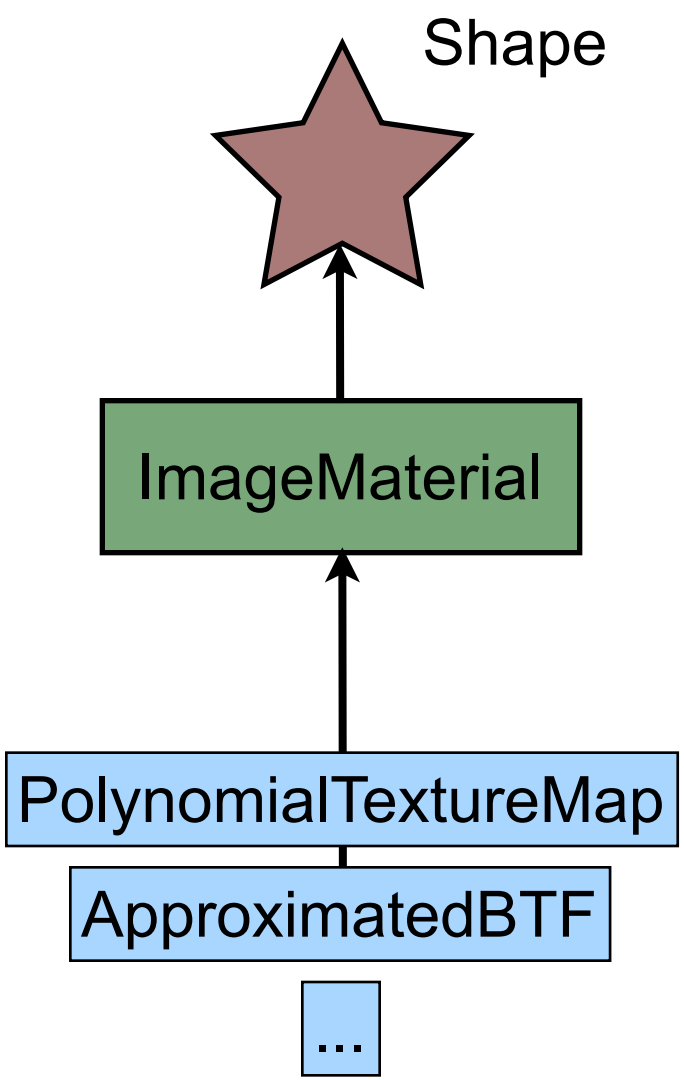
Discussion

Flexibility vs. self-descriptive interface



Discussion

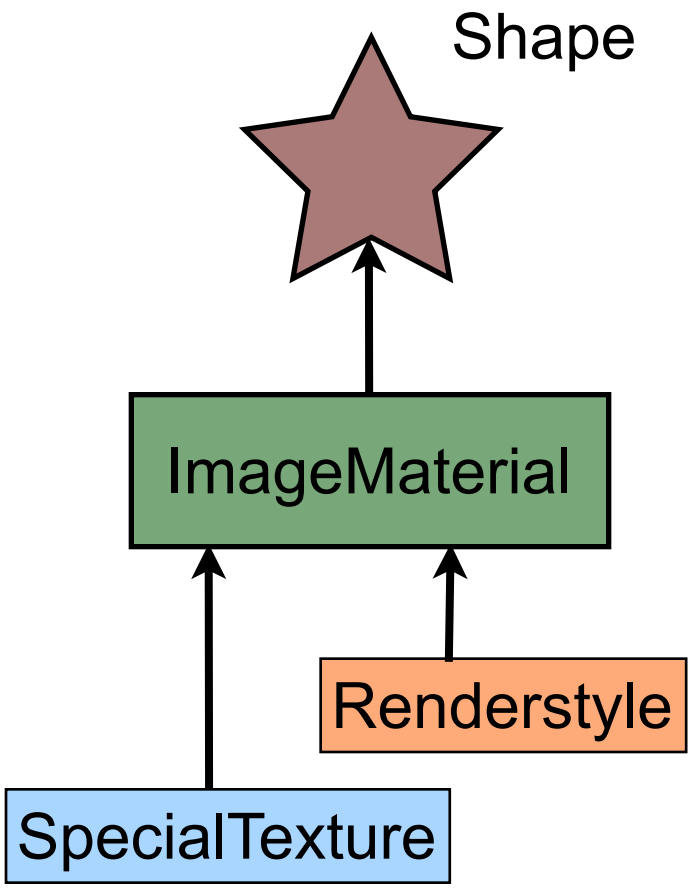
Alternative 1



- Solves
  - Parameterization at texture container level
  - Texture containers can provide specialized input slots for images
- Requires
  - Container for each image-based material

Discussion

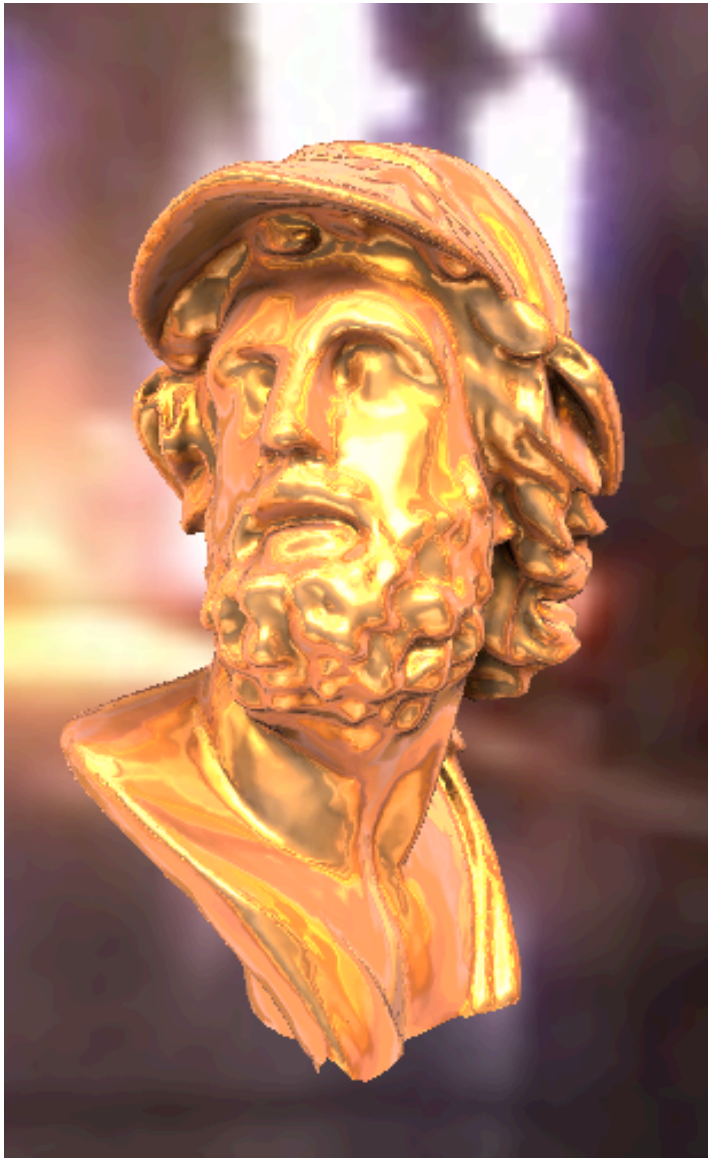
Alternative 2



- Additionally solves flexibility when handling multi-purpose descriptors
  - E.g. Sum of Gaussians can be combined with PRT

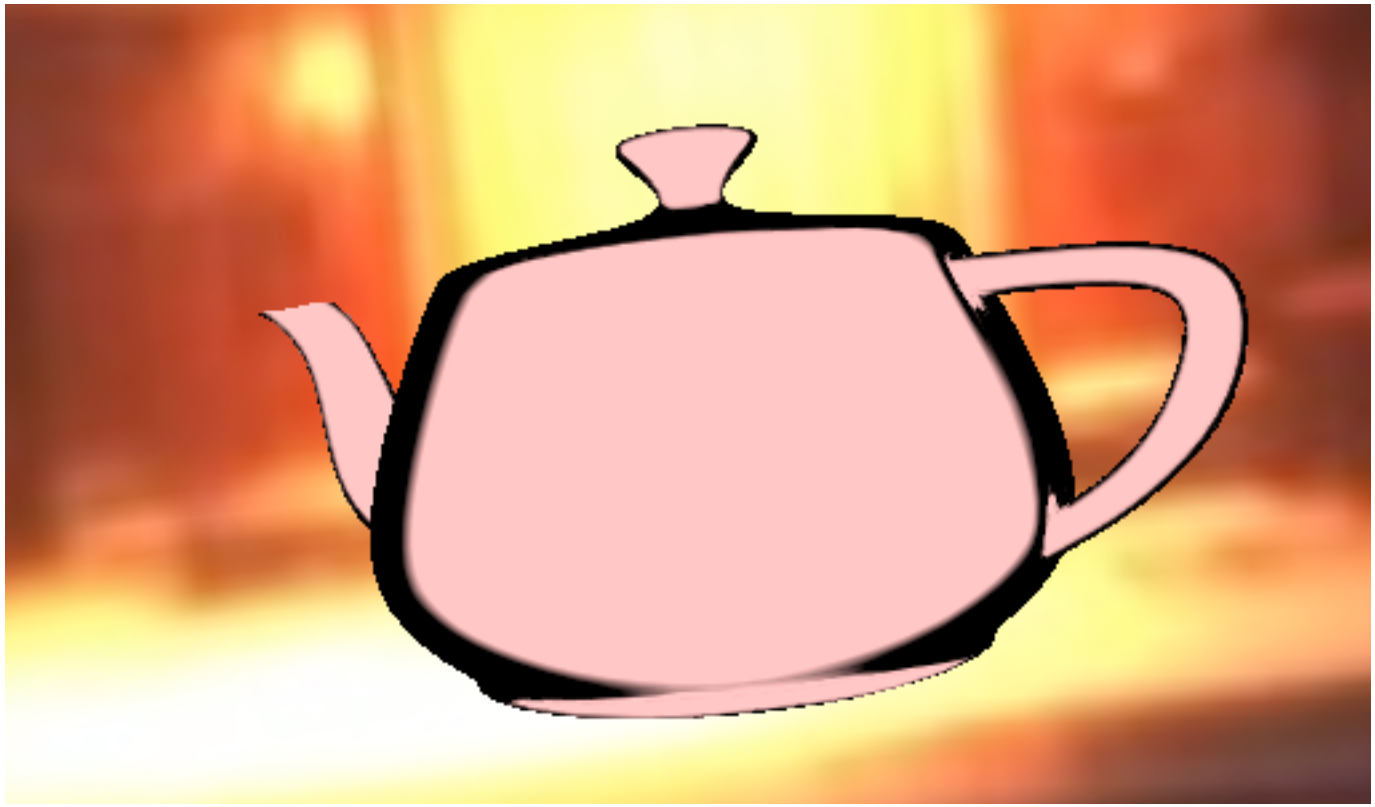
Examples

Sum of Gaussians without/with visibility term



Examples

Sum of Gaussians NPR-like appearance

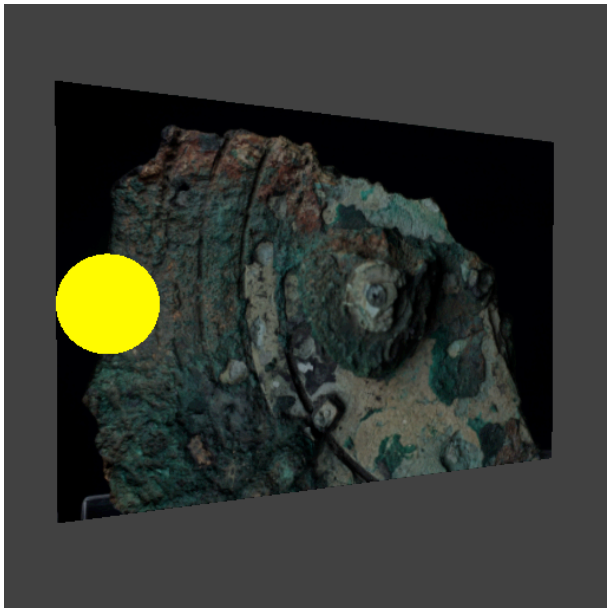


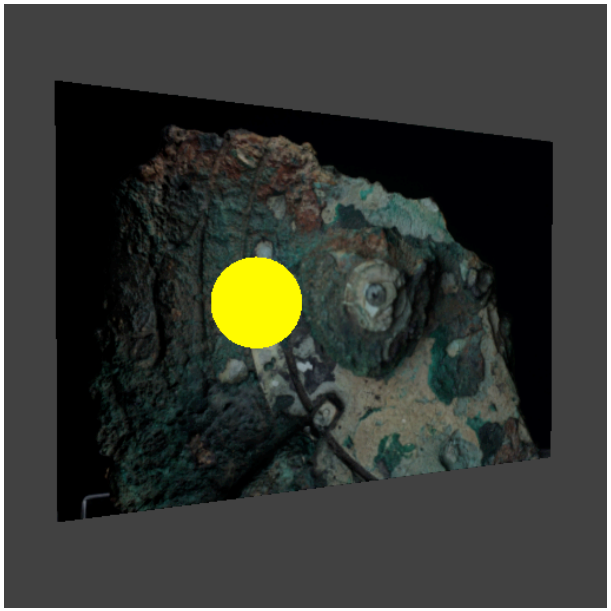
Mean & StdDev

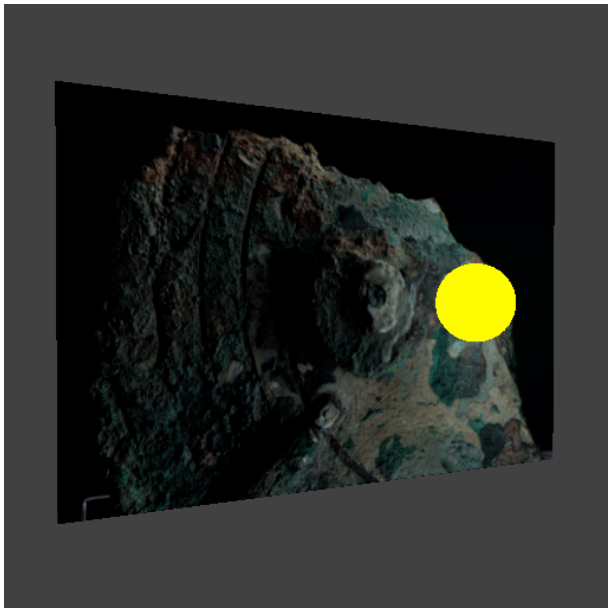
Weights

Examples

Polynomial Texture Mapping







Examples

Approximated Translucency

Conclusion

… and Future Work

- Flexible solution to incorporate upcoming image-based methods to represent materials
- Need more experience if custom render styles are needed or texture containers can provide enough information
- Add more rendering methods
  - Abundance of PRT methods
  - Other BTF compression schemes, i.e. WebGL implementation of Klein et. al

Thanks for listening.

PTMConvert Code:
http://code.google.com/p/ptmconvert/

Questions?

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