Abstraction Techniques for Illustrative Visualization

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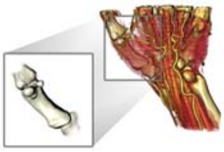
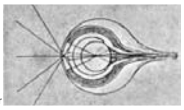
Outline

- Illustration and abstraction
- Low-level abstraction techniques
- High-level abstraction techniques
- Interactive illustrations
- VolumeShop: Direct Volume Illustration
- Conclusions and future directions



Illustration

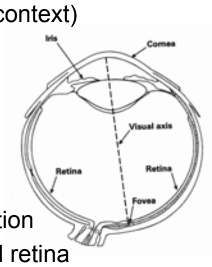
- An illustration is a picture with a communicative intent
- Conveys complex structures or procedures in an easily understandable way
- Uses abstraction to prevent visual overload – allows to focus on the essential parts
- Abstraction is visualized through distinct stylistic choices



Focus+Context Principle

Basic idea of Focus+Context Visualization:

- Important regions in great detail (focus)
- Global view with reduced detail (context)
- Dynamic integration



Rationale

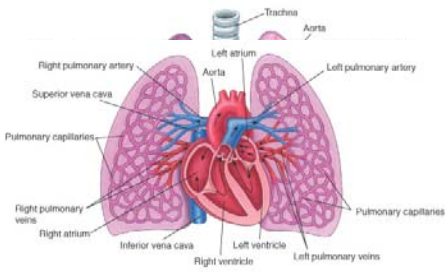
- Zooming hides the context
- Two separate displays split attention
- Human vision has both fovea and retina

Abstraction (1)

- Fundamental for creating an expressive illustration
- Introduces a distortion between visualization and underlying model
- Different degrees of abstraction introduced at different levels
- Task of an illustrator: find the necessary abstractions for the intent of the illustration

Abstraction (2)

- Different degrees of abstraction for different intents



schematic view of blood flow

Abstraction (3)

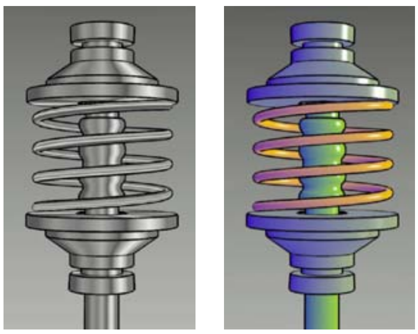
- Goals of abstraction techniques
  - Communicate shape and structure
  - Emphasize or de-emphasize
  - Prevent visual overload
  - Suggest artificiality
  - Ensure visibility of important structures
  - Provide spatial context
- **„As detailed as necessary - as simple as possible“**

Low-Level Abstraction Techniques (1)

- Concerned with **how** different objects are presented
- Stylized depiction
  - Silhouettes and contours, pen and ink, stippling, hatching, ...

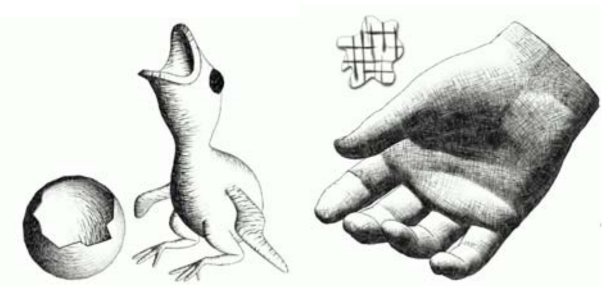
Low-Level Abstraction Techniques (2)

- Metal and tone shading [Gooch et al. 1998]



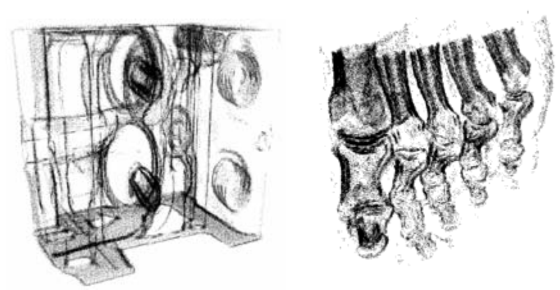
Low-Level Abstraction Techniques (3)

- Real-time hatching [Hoppe et al. 2001]



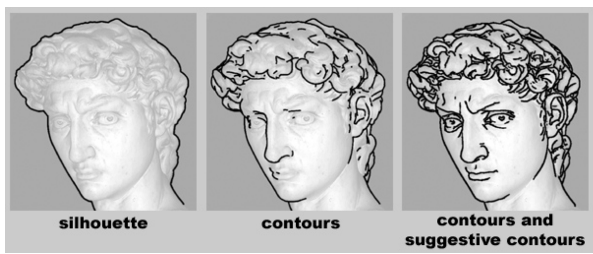
Low-Level Abstraction Techniques (4)

- Volume stippling [Lu et al. 2002]



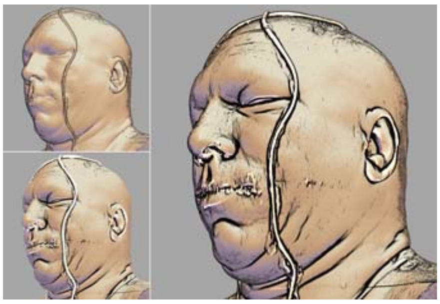
Low-Level Abstraction Techniques (5)

- Suggestive contours [DeCarlo et al. 2003]



Low-Level Abstraction Techniques (6)

- Curvature-based ridge and valley enhancement [Kindlmann et al. 2003]



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High-Level Abstraction Techniques (1)

- Deal with **what** should be visible and recognizeable
- Smart visibility
  - Cutaways, breakaways, ghosting, exploded views, ...

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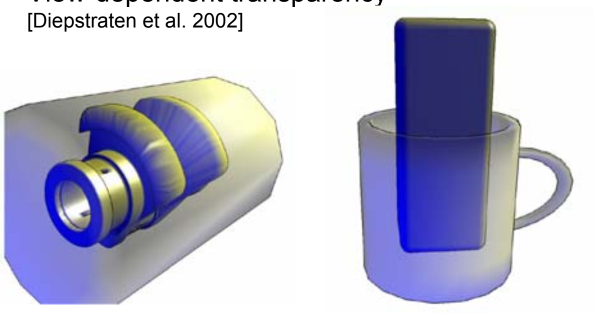
High-Level Abstraction Techniques (2)

- View-dependent transparency [Diepstraten et al. 2002]



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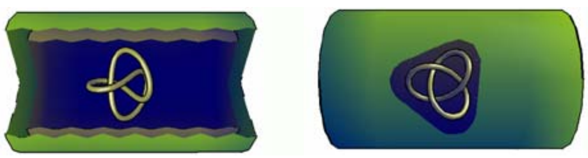
High-Level Abstraction Techniques (3)

- Cutaways and breakaways [Diepstraten et al. 2003]



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High-Level Abstraction Techniques (4)

- Volume splitting [Islam et al. 2004]

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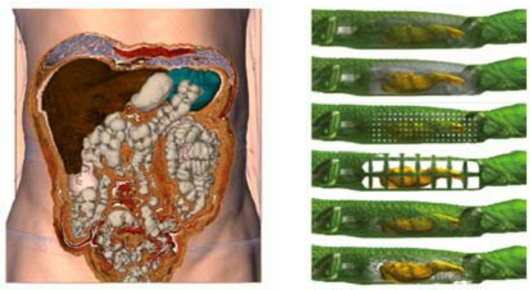
High-Level Abstraction Techniques (5)

- Importance-driven feature enhancement [Viola et al. 2004, 2005]



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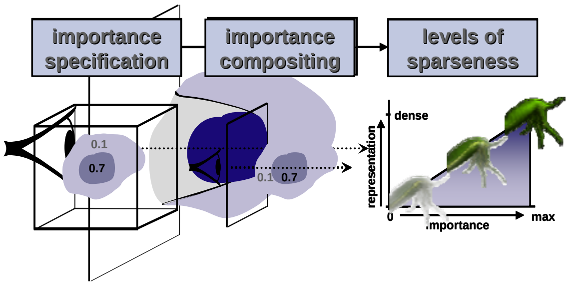
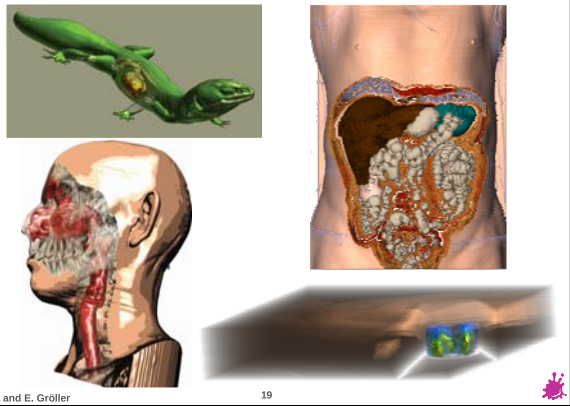
Importance-Driven Feature Enhancement

[Viola et al. '04 '05]



importance-driven feature enhancement

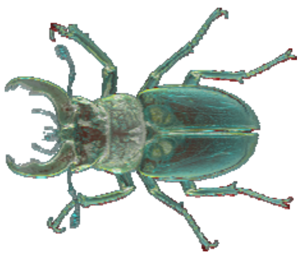
Applications



Illustrative Context-Preserving Exploration of Volume Data

[Bruckner et al. '05]

- Importance-Driven Feature Enhancement
  - **Explicit** emphasis of important features
- Illustrative Context-Preserving Exploration
  - **Implicit** emphasis of important features

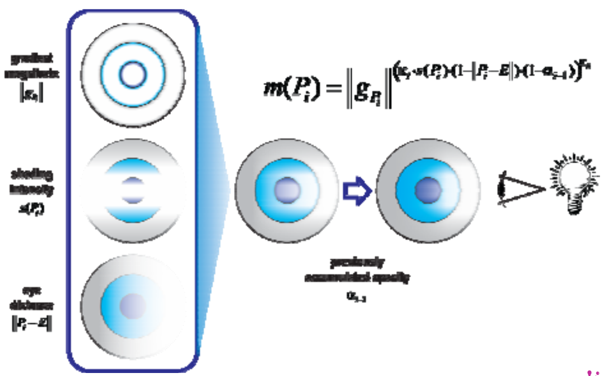


Inspiration - Context-Preserving Rendering

- Illustrators commonly use ghosting to simultaneously depict interior and exterior of an object
- „magic lamp" metaphor

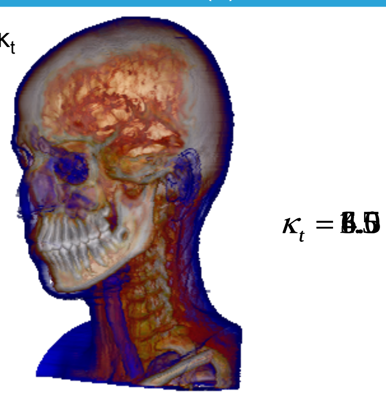
Context-Preserving Rendering Model

$$m(P_i) = \|g_{P_i}\|^{\left(\kappa_t \cdot s(P_i)(1-\|P_i - E\|)(1-\alpha_{i-1})\right)^{\kappa_s}}$$



User-Defined Parameters (1)

- Effect of κ_t

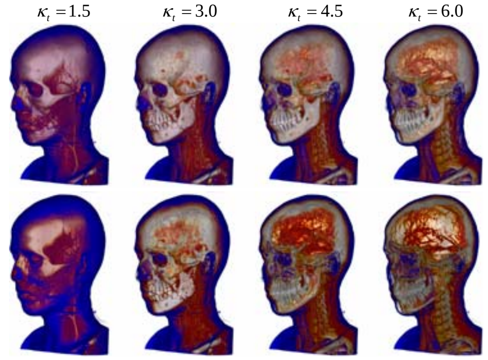


User-Defined Parameters (2)

- Effect of κ_s

$\kappa_s = 0.8$

User-Defined Parameters (3)



Results (1)

Direct Volume Rendering

Gradient-Magnitude Opacity-Modulation

Direct Volume Rendering with Clipping Planes

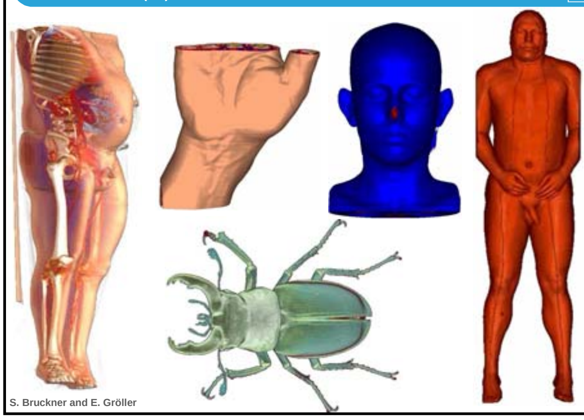
Context-Preserving Volume Rendering

Results (2)

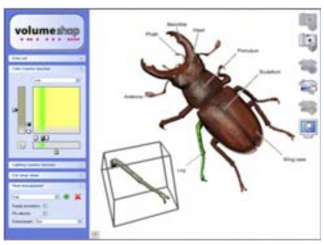
medical illustration

context-preserving volume rendering

Results (3)



VolumeShop



interactive application for the generation of illustrations directly from volume data

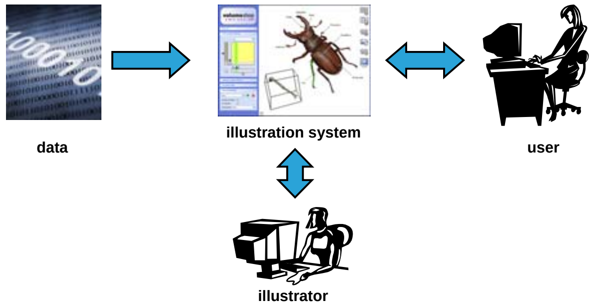
- http://www.cg.tuwien.ac.at/volumeshop/

Traditional Illustration

- Application of abstraction techiques
  → artistic skills
- Selection of abstraction techniques
  → domain knowledge

Direct Volume Illustration (1)

- Application of abstraction techniques



- Selection of abstraction techniques

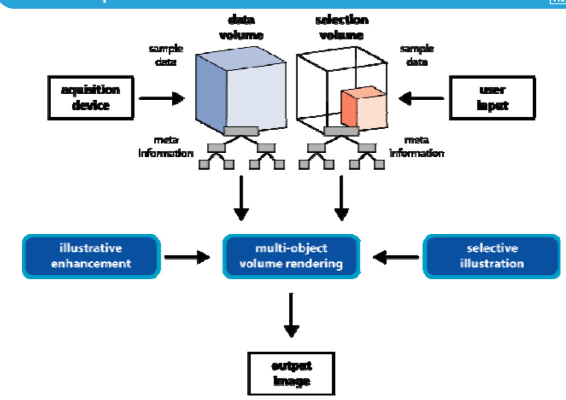
Direct Volume Illustration (2)

- Detailed volume data is readily available (medicine, biology, etc.)
- The illustrator's research process is significantly shortened
- Possibility to easily explore different stylistic choices
- Customized illustrations depicting particular pathologies
- Static illustrations, animations, interactive illustrations

VolumeShop

- An interactive system for direct volume illustration
- Generate interactive illustrations directly from volume data
- Combine stylized depiction and smart visibility in a focus+context approach
- Single images should have the aestetic appeal of traditional illustrations

Conceptual Overview



Multi-Object Volume Rendering (1)

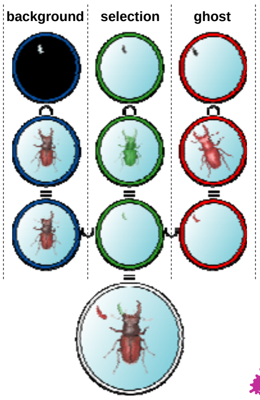
- Three basic objects for interaction
  - Selection: currently active, possibly transformed region
  - Ghost: selection positioned at its original location
  - Background: remaining volume
- Appearance of intersection regions is specified using two-dimensional transfer functions

Multi-Object Volume Rendering (2)

selection sets: defined by a selection volume

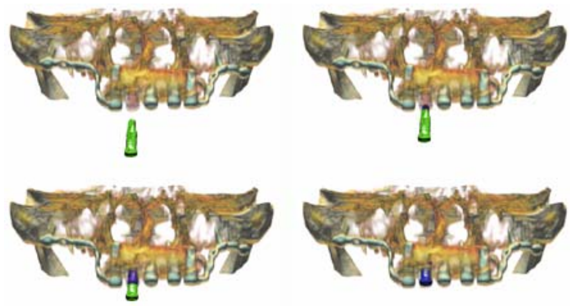
volume sets: defined by the transfer function

object sets: intersection between selection and volume sets



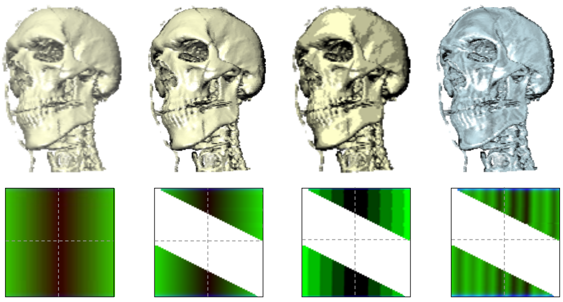
Multi-Object Volume Rendering (3)

- Emphasized regions of interpenetration



Illustrative Enhancement (1)

- Artistic rendering styles are integrated using lighting transfer functions



Illustrative Enhancement (2)

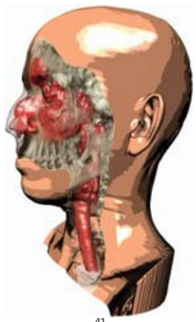
- Apply different styles independently to background, selection, and ghost

Selective Illustration (1)

- Smart visibility: view-dependent cutaways and ghosting
- Interactive importance-driven volume rendering

Selective Illustration (2)

- Ghosting: opacity of occluder is selectively reduced where information content is low

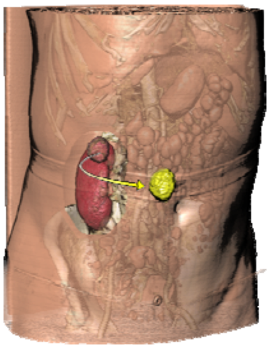


Selective Illustration (3)

- Apply artistic visual conventions to establish the look and feel of a traditional illustration
  - Arrows indicate insertion or removal of an object
  - „Fans“ are used to depict an alternative or enlarged version of an object
  - Textual labels are used to annotate depicted objects

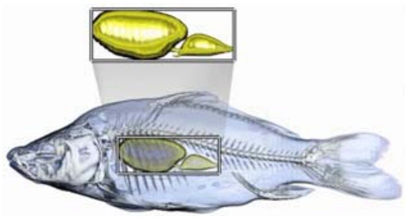
Selective Illustration (4)

- Using an arrow to illustrate a tumor resection prodedure
- Screen-space depth difference controls curvature of the arrow



Selective Illustration (5)

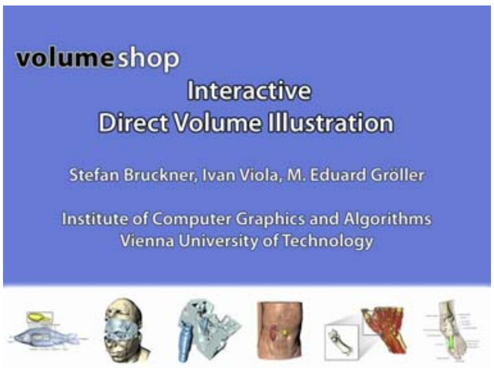
- Using a fan to display an alternative depiction of an object
- Viewing transformation of the enlarged object is linked to the original



Selective Illustration (6)

- Labels are arranged along the silhouette, overlaps and intersecting lines are resolved

Demonstration: www.cg.tuwien.ac.at/volumeshop/



Conclusions (1)

- Illustration uses different degrees of abstraction at different levels
  - Low-level techniques: stylized depiction
  - High-level techniques: smart visibilty
- VolumeShop: prototype system for creating illustrations directly from volume data
- Abstraction selection is still performed manually
- Application of abstraction techniques is done automatically

Conclusions (2)

- Visual arts are a great source of inspiration
- Illustrations are more aesthetic than synthetic images
- Visualization can be interactive, illustration not
- Smart visibility makes visualization expressive
  - Local modification of visual properties
  - Modification in spatial arrangement
- Illustrative Visualization: computer supported interactive and expressive visualizations through abstractions as in traditional illustrations

Thank you for your attention!

Abstraction Techniques for Illustrative Visualization

- Illustrations play a major role in the education process. Whether used to teach a surgical or radiologic procedure, to illustrate normal or aberrant anatomy, or to explain the functioning of a technical device, illustration significantly impacts learning. One of the key concepts for creating an expressive illustration is abstraction. Abstraction introduces a distortion between the visualization and the underlying model according to the communicative intent of the illustration. Inspired by observations from hand-made illustrations, similar techniques for the generation of rendered images have been developed. These techniques work on different levels: low level abstraction techniques (stylized depiction methods) deal with how objects should be presented, while high level abstraction techniques (smart visibility approaches) are concerned with what should be visible and recognizable. We review several existing approaches from both categories and describe important concepts used in the design of a system for creating interactive illustrations directly from volumetric data. A fully dynamic three-dimensional illustration environment is discussed which directly operates on volume data. Single images have the aesthetic appeal of traditional illustrations, but can be interactively altered and explored. The system combines artistic visual styles and expressive visualization techniques. Direct multi-object volume visualization allows to control the appearance of inter-penetrating objects via two-dimensional transfer functions. Furthermore, a unifying approach to efficiently integrate many non-photorealistic rendering models is presented. We discuss several illustrative concepts which can be realized by combining cutaways, ghosting, and selective deformation. Finally, we describe a simple interface to specify objects of interest through three-dimensional volumetric painting. The presented methods are integrated into VolumeShop, an interactive hardware-accelerated application for direct volume illustration. Further information on the presented techniques is available at http://www.cg.tuwien.ac.at/research/vis/.

- References:

- Ivan Viola, Armin Kanitsar, Eduard Gröller: Importance-Driven Feature Enhancement in Volume Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 11(4):408-418, 2005.
- Stefan Bruckner, Sören Grimm, Armin Kanitsar, Eduard Gröller: Illustrative Context-Preserving Volume Rendering. In *Proceedings of EuroVis 2005*, pages 69-76. May 2005.
- Stefan Bruckner, Eduard Gröller: VolumeShop: An Interactive System for Direct Volume Illustration. In *Proceedings of IEEE Visualization 2005*. October 2005.