Interactive Visualization Techniques for Illustrative Depiction

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An illustration is a picture with a communicative intent

Conveys complex structures or procedures in an easily understandable way

Illustrations use abstraction to prevent visual overload

Abstraction allows the viewer to focus on essential aspects without losing context
Traditional Illustration (2)

- Application of abstraction techniques
  → artistic skills
- Selection of abstraction techniques
  → domain knowledge
Direct Volume Illustration (1)

- Detailed volume data is readily available (medicine, biology, etc.)
- Illustrator’s research process is significantly shortened
- Possibility to easily explore different stylistic choices
- Customized illustrations depicting particular pathologies
- Static illustrations, animations, interactive illustrations
Direct Volume Illustration (2)

- Application of abstraction techniques

- Selection of abstraction techniques

- Data → Illustration System → Viewer

- Illustrator

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Outline

- **Low-level abstraction**
  - “Emphasize, highlight”

- **High-level abstraction**
  - “Reveal, uncover”

- **Composition**
  - “Combine, blend”
Low-Level Abstraction

- Concerned with **how** different objects are presented
- Examples
  - Silhouettes and contours, pen and ink, stippling, hatching, airbrush, ...
Low-Level Abstraction

Stylized Shading
A good representation for visual styles has to fulfill certain requirements

- **Flexibility** – ability to represent many different rendering styles
- **Compactness** – simple and intuitive representation
- **Transferability** – easy extraction from existing artwork
- **Efficiency** – little overhead during rendering to allow interactivity
Lit Sphere Maps (1)

- Use a sphere map indexed by the eye-space normal to determine the color of a point [Sloan et al. 1998]
Lit Sphere Maps (2)

- Easy to obtain – lighting studies are frequently performed using spheres
- Sloan et al. describe simple extraction process from existing works of art
- Intuitive representation, can be directly displayed to the user as a preview
A style representation allows us to shade one object in a given style.

For volume data, we rarely have discrete objects.

We need a continuous parameterization of style space.

A style transfer function maps volumetric attributes to visual styles.
Style Transfer Functions (2)
Style Transfer Functions (3)

- Regular Transfer Function:
  - Data value: (0.4)
  - Opacity: normal
  - Shading: regular shading

- Style Transfer Function:
  - Data value: (0.4)
  - Opacity: normal
  - Shading: lit sphere lookup
Style transfer functions allow for a flexible combination of different visual styles
Low-Level Abstraction

Volumetric Halos
Halos (1)

- Halos are a common technique in art and illustration.
- Frequently used to enhance depth-perception by increasing local contrast.
- Can be employed to guide the viewer’s focus to certain regions.

Medical Illustration Source Book
http://www.medillsb.com
Changes in color and/or luminance around the edges of an object

Frequently approximations of natural lighting phenomena

Not necessarily consistent with global lighting situation

Applied locally to only enhance particular features
Approach

- Full control over halo location, appearance, and extent
- Interactive adjustment of all halo parameters (no pre-computation)
- Multiple halos, each with its own set of parameters
Volumetric Halo Pipeline

- Halo Seeding
- Halo Generation
- Compositing
- Halo Mapping

view-aligned slices

accumulated image
Volumetric Halo Pipeline

- Halo Seeding
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view-aligned slices
accumulated image
Halo Seeding (1)

- Halo seeding stage generates image of halo seed intensities
- Seed intensities determine amount of haloing for each point on the slice based on …
  - … gradient direction and magnitude (halos only appear around contours)
  - … halo transfer function (user-controlled specification of structures of interest)
Halo Seeding (3)

Halo transfer function based on multiple separable components

- **Data value**
  usually linked to opacity transfer function, i.e. only visible structures emit halos

- **Direction**
  based on eye-space normal direction, for directional halos such as drop shadows

- **Position**
  function of distance from a focus point, for localized feature enhancement
Volumetric Halo Pipeline

- view-aligned slices
- accumulated image

Halo Seeding

Halo Generation

Compositing

Halo Mapping
Halo Generation (1)

- Per definition halos are located outside the visible volume
- Seed intensities need to be spread to neighboring locations
- Generate a controllably smooth halo, but don’t filter away contributions of fine structures
- Large halo extents should be possible while still providing good performance
Example of varying halo extent
Halo Mapping

- Translation of halo intensity values to appearance properties
- Halo profile function maps nonzero halo intensities to colors and opacities
Volumetric Halo Pipeline

- view-aligned slices
- accumulated image
- Halo Seeding
- Compositing
- Halo Generation
- Halo Mapping
Compositing (1)

- Mapped halo contributions need to be combined with the normal volume contributions
- Two halo types based on different compositing strategies
  - Occlusive halos
  - Emissive halos
Compositing (2)

- **Occlusive halos** behave similar to shadows
- Only visible if they occlude other structures
- Accumulate in occlusion buffer, mix with sample color
Emissive halos produce a volumetric glow. Always visible, even if no occlusion occurs. For each slice, blend after normal volume contributions.
Results

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High-Level Abstraction

- Deal with **what** should be visible and recognizable
- Examples
  - Cutaways, breakaways, ghosting, exploded views, ...
High-Level Abstraction

Ghosted Views
Illustrators commonly use **ghosting** to simultaneously depict interior and exterior of an object.
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Conventional Direct Volume Rendering

- Transfer functions with high opacity for clear shape cues
- Many internal details are occluded
Gradient-Magnitude Opacity-Modulation

- High transparency displays the whole data set
- Cluttered image, many overlapping transparent structures
Direct Volume Rendering with Clipping

- Clipping reveals internal structures
- Parts of the context information are lost
A new model for direct volume rendering which ...

- features the simple user-control of clipping planes → few parameters with intuitive interpretation
- preserves context information based on intrinsic features of the data set → no explicit feature definition (segmentation)
$m(p) = |g|^{(k_t \cdot s(p) \cdot (1 - |p - e|) \cdot (1 - \alpha_{i-1}))^{k_s}}$
- Opacity is only selectively reduced
- Strongly defined features persist
User-Defined Parameters (1)

- $\kappa_t$ controls "depth of cut"
  - Higher values $\rightarrow$ remove more occluding structures
  - Zero $\rightarrow$ results in conventional direct volume rendering

- $\kappa_s$ controls "sharpness of cut"
  - Higher values $\rightarrow$ less smooth transition in opacity
  - Zero $\rightarrow$ pure gradient-magnitude opacity modulation
User-Defined Parameters (2)

- Effect of $\kappa_t$
User-Defined Parameters (3)

- Effect of $\kappa_S$
User-Defined Parameters (4)

\( \kappa_t = 1.5 \)

\( \kappa_t = 3.0 \)

\( \kappa_t = 4.5 \)

\( \kappa_t = 6.0 \)
Results (1)
Results (2)

medical illustration

context-preserving volume rendering
Results (3)
High-Level Abstraction

Exploded Views
Exploded Views (1)

- Common in technical illustrations (e.g., assembly instructions)
- Displace occluding structures to reveal the focus object
- Human perception does a good job at putting objects back together
Exploded Views (2)

- Frequently focus objects are occluded by other structures
- Reveal the focus without completely removing the context
- Rely on human perception to reconstruct information
- In contrast to static illustrations, we need to take into account interaction
Exploded View Pipeline

Focus Selection → Part Definition → Layout Generation → Rendering
Focus Selection

- Approximate specification of focus structure in dataset
- Via transfer function, segmentation, volume painting
- Degree-of-interest function specifies importance of each voxel
- Can be interactively refined during visualization
- All voxels with nonzero degree-of-interest are called selection, rest is background
Part Definition

- Partition of the background object into several non-overlapping regions
- Could be done automatically (curve skeleton, symmetry detection)
- Simple interactive approach: user can split volume along arbitrary planes
- Different tools: axis splitter, depth splitter, line splitter
- Splitting can be refined/modified once the view is exploded
Layout Generation

- Displacing each part manually is cumbersome and time-consuming
- Would have to be adjusted whenever the viewpoint changes
- Several potentially conflicting layout requirements
- We use a three-dimensional force-directed layout approach for part arrangement
- Different forces represent our layout requirements
Explosion Force

- Explosion force moves the parts away from the selection object
- Set of points within the selection object is generated which exhibit a repulsive force on all parts
Viewing Force

- Moves parts away from the line of sight to prevent occlusions of the selection
- Modeled after distortion viewing technique for 3D graphs [Carpendale et al. 1996]
Spacing Force

- Parts should move apart in order to prevent clustering
- Each part exhibits a repulsive spacing force on all other parts
To reach an equilibrium, we need a force which works opposite to the other ones.
The return force pulls parts back to their initial location.
Results (1)

unconstrained explosion

parts connected by slider joint, left part is static
Results (2)

plastinated anatomic sculpture (G. von Hagens, “Bodyworlds”)

interactive exploded-view illustration
Results (3)

Degree-of-Explosion
Explosion Factor
Viewing Factor
Spacing Factor
Composition

- Focuses on the **combination** of different pictorial elements

- Examples
  - Gradual transitions & fading, blending, masking, …
Composition

2.5D Layers
2.5D Layers (1)

- 2D image editing software (e.g. Photoshop) employ conventionally use layered editing
- Useful extension of 2D layers to an interactive 3D environment is required
- Provide the flexibility of 2D layers, but allow them to use 3D information
- In addition to color and opacity, layers have a depth value
Main challenge: layer content is generated dynamically
Hybrid Visibility

- Manual illustration
- Implicit visibility
- Individual layers

Explicit visibility

Hybrid visibility
Blending

- Visibility-based operator
  - Combine a group of layers with correct implicit visibility

- Occlusion-based operators
  - Have a blending weight based on occlusion relationships
Layer masks should be valid for more than one viewpoint

Modulate stroke influence with distance to original location
Hybrid Visibility Compositing and Masking for Illustrative Rendering

paper1070
Composition
Semantic Layers
Semantic Layers (1)

domain semantics

curvature:
  negative – zero – positive

vessel diameter:
  thin – normal – thick

brain activity:
  low – high

etc.

visual abstraction semantics

contour style

exaggeration

flatness

visualization rule:

if ... is ... then ... is ...
Semantic Layers (2)

- Membership functions
- Data semantics
- Visual abstraction semantics
- Fuzzy logic
- Data attributes
- Parameters for visual abstractions
- Visualization rules
  - Rule 1: ...
  - ...
  - Rule n: ...

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Data attributes

Fuzzy Logic (1)

Visual abstractions

if principal curvature is negative
then contour style is blue
Example for two rules

rule 1

if \ldots then \ldots

rule 2

if \ldots then \ldots
if distance to plane is low then skin-style is transparent blueish
if distance to plane is high then skin-style is opaque pink
if distance to plane is very low then flatness is subtle
if distance to plane is low then flatness is medium
if distance to plane is middle then flatness is dominant
if distance to plane is high then flatness is subtle
Conclusions

- Visualization techniques inspired by/adapted from traditional illustration
- Different aspects of illustrative visualization techniques
  - Low-level abstraction
  - High-level abstraction
  - Composition
- Interactive setups require additional considerations
http://www.volumeshop.org

Thank you for your attention!
Questions?