X-Ray Visualization in Augmented Reality Environments
Visual Augmented Reality

• Combine real and virtual imagery
• Tracking & Registration data is used to align virtual objects within real imagery
Visual Augmented Reality
X-Ray Visualization

- Augmentation of hidden objects
Careless Visual Augmentation

- Overrides important landmarks
- Override important depth cues
Careless Visual Augmentation

- Override important depth cues (occlusions)
Perception of Spatial Arrangements - Depth Cues -

- Occlusion
- Relative size
- Perspective
- Texture Details

- Motion Parallax
  - Far distant objects appear to move slower than near objects

...
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...
Occlusion Handling
- Phantom Rendering -

- Init depth buffer by rendering the virtual counterpart of a real object, registered in 3D
Correct Occlusion Rendering
Uniform Transparency Modulation

- Blend foreground pixel where object is hidden (via stencil masking & pixel blending)
Illustrative X-Ray Visualization

- Preserve occlusion cues
- Perception of spatial relationships
  - Ghosting (non-linear transparency modulation => sparse representation)
  - Cutaway
  - Explosion

http://www.cutaway-illustration.com
Illustrative X-Ray Visualization in AR
- Ghosting, Cut-away & Explosion Views -
Ghosted Reality

Stylized phantom controls opacity of video pixel
Shading occluding structures in AR
- Video vs. Virtual Preservation -

- To ‘understand’ the occluder, we need to perceive its ghosting as one object
- Very sparse video preservings are difficult to identify

=> Enhance preserving to perceive ghosting <=
Ghosting in AR

Augment stylized phantom
Virtualized Ghosting

Where to use virtual and where to preserve real information?
Mixed Ghosting

- Mix virtual and real information based on weighted opacity of stylized phantom
Registration Error

- Phantom does not perfectly fit to real object!
  - Modeling error
  - Tracking error
  - Offset data synchronization
  - ...
Ghosting Erroneous Phantoms

- "Regular" ghosting is difficult to understand
Error Compensation

• Virtualized ghostings are able to communicate the error
Error Compensation

- Phantom and hidden object should use the same registration data!
  - Tracking
  - Modeling
  - …
Missing Phantom

- Stylize video directly
- Object order has to be known!
Image Space Ghosting

- Feature Distribution!
  - Video feed
  - Feature detection
  - Feature distribution
  - Derived transparency
  - Blend VR
  - Blend video
Ghosting from Video

• Indendent from tracking error => NO error communication!
• Virtualized ghostings may produce clutter (need information filter: mask)
• Depth order must be known
Hybrid Ghosting from Video
Rendering Ghostings

G-Buffer Extraction → G-Buffer Processing → Scene Compositing

Apply Object based feature extractor

Apply Image based feature extractor
GBuffer Rendering: Object Grouping

- G-Buffer’s content spread over scene graph
- Context sensitive scene graph traversal
  [Reitmayr05]
Rendering Algorithm II/III
- GBuffer Processing -

- 2D image operators on different 2-1/2d layer
Rendering Algorithm III/III
- Scene Compositing -

- Can’t simply blend!
- ‘Raycast’ into G-Buffer volume
  1) Sort G-Buffer per pixel
  2) Blend fragments per pixel
Multiple Object Occlusion

- Which object to preserve?
- Amount of preserving?
- Need information filter
Filtering by Object Discrimination
- during gbuffer processing -

• Limited to a few objects
Fragment Reduction
- during gbuffer extraction -

- Use only visible fragments
- ... by regrouping G-Buffer
Fragment Reduction
- during gbuffer extraction -

- **Pros:**
  - Fast (in hardware)
  - First step of the algorithm

- **Cons:**
  - Expensive to apply
different object groupings
  in different areas of
Framebuffer = different
filter strategies

G-Buffer 1

G-Buffer 2
Fragment Reduction - during scene compositing -

- Pro:
  - Compositing strategy changeable at runtime (easily applicable per region)

- Con:
  - Last step of rendering

[Diagram showing G-Buffer 1, G-Buffer 2, G-Buffer 3, and G-Buffer 4]
Cutaway

- Mentally interpolate occlusions
- Loose information!!
- Cut-out might become as big as occluder
  - No occluder = mental occlusion cue will remain
  - Mentally ‘uncutting’ becomes difficult for big cuts
Explosion Diagrams in AR

- Keeps hidden AND occluding structure visible
- Also works for multi-layered occlusions
Explosion of Multi-Layer X-Ray

- Multi-layer explosions
- Bad layouts are not able to communicate the assembly
  => mental occlusion interpolation is impossible
- NEED to present a clear explosion sequence
Explosion Layout

- **Symmetry**
  - Similar parts explode similar

- **Limited number of explosion directions**
Grouped Layouts
- Focus & Context Layout -

- Groups reduce complexity
- X-Ray visualization => Focus and Context visualization => Focus and Context explosions = minimal number of groups related to focus
Partitioning

- Recursively find **ALL** valid partitions
  - Partitions do not collide on their path
  - To be able to further explode a partition:
    - All parts have to be connected
  - Test only directions of main axis
Grouping
- Focus and Context -

- AND/OR
  Graph=Sequences of ALL valid Partitions

- Layout => Search for a single sequence

- F+C Group => Recursively search for the biggest partition not containing the focus

- Biggest=number of parts
Rendering Explosions in AR

- Transfer of real world information
Video Textured Phantoms

1) Texture virtual model with real world information
2) Explode video textured model
Problem 1 of Video Textured Phantoms

- Problem 1/2: video textured phantoms need a complete virtual representation of hidden structure
Dual Phantom Rendering

- Use a 2. phantom (next to the exploded one) to declare video information void

1) Render textured phantoms  
2) Void video  
3) Combine masked video, textured phantoms and hidden VR
Problem 2 of Video Textured Phantoms

- Problem 2/2: occluded phantoms will transfer visible real world information
Synchronized Dual Phantom Rendering

- Instead of simply declaring the video void, we write the object’s id and let OpenGL’s depth resolve the problem.
- During texture transfer, we check the phantom’s id with the value in the id-buffer (which represents the visible phantom).
Visualization

• Simple transfer of video easily results in a visual mess of mixed information
• Identify a part as one object
Restauration

- Restorate **parts** and **background**
  If (#vrInfo > 50%) shade all VR
  Else ‘guess real world information’
Part Discrimination

- New contextual information around relocated objects may be confusing
- Visually discriminate exploded parts
- Background vs. part neighbors)
Connection Lines in AR

- Help communicate transformations
- Thin and unconnected information over real background
  - May result in clutter
  - May be visually lost
Connection Lines in AR

- Motion blur is a stronger visual communicator
Embedded Connection Lines

- Motion blur is less cluttered
  - Embed connection lines in motion blur
Error Compensation
Error Compensation

- ... by virtualization (adding virtual context)
Illustrative X-Ray Visualization in AR
- Ghosting, Cut-away & Explosion Views -
Shading X-Ray Vision

- Hidden objects visually ‘stand out’ (focus of attention)

http://www.cutaway-illustration.com
Control of Attention

- General problem in AR
- Frames and arrows are impractical in x-ray visualization
- Need F+C shading/colorization
Focus and Context

• Binary F+C classification
  – Object relations are lost
Context Preserved Attention

- Non-Binary, Non-Uniform F+C classification
  - ... by cascading F+C classifications

- Emphasizing real focus:
  - Add virtual context (halo, de-emphasize mask)
  - Substitute with more salient VR

- Deemphasizing real context
  - Image operators (desaturation, blur)
Visual Communication in AR
https://www.icg.tugraz.at/~denis/visualAR