Computer Assisted Radiology and Surgery (CARS) - Tutorial

Medical Augmented Reality: Improving Depth Perception

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Some slides made by **Prof. Nassir Navab, Prof. Gudrun Klinker**, and **Alejandro Martin Gomez**

Technische Universität München + Johns Hopkins Whiting School of Engineering

Overview. Visual System and Perception

- Visual Perception
- Medical AR: Challenges and Examples
- Depth Cues
- Focus and Context

Perceptual Issues in AR. Visual Perception

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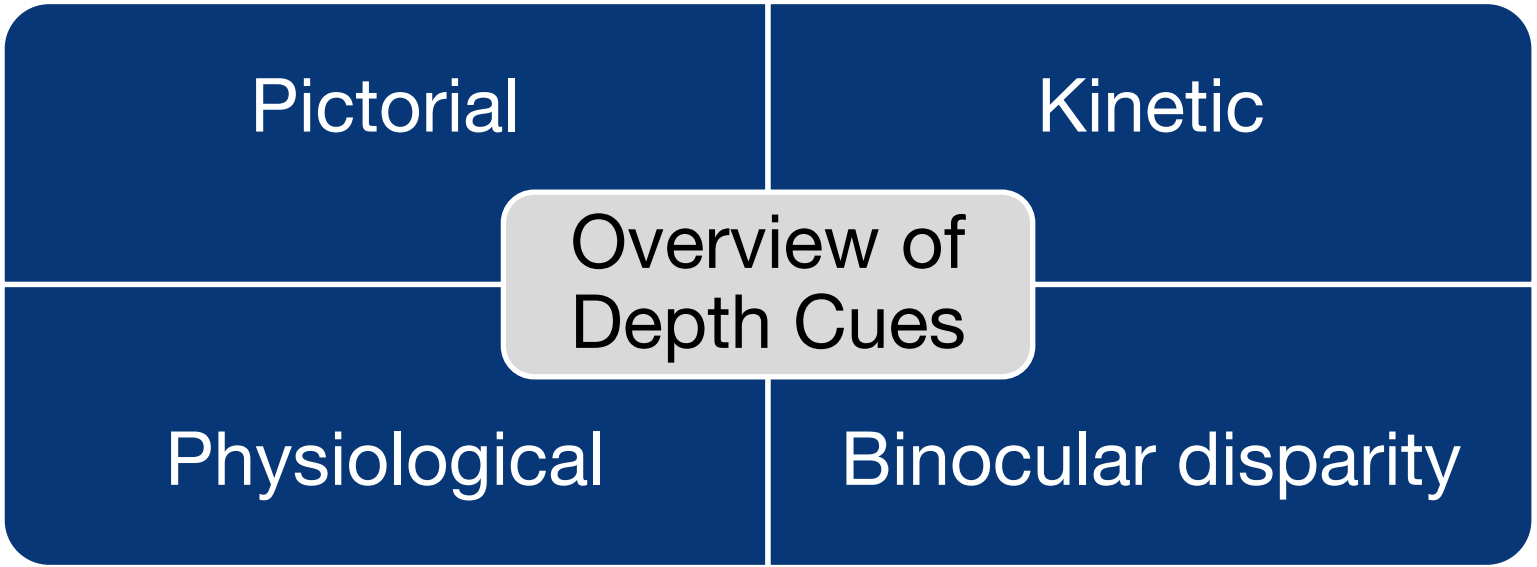
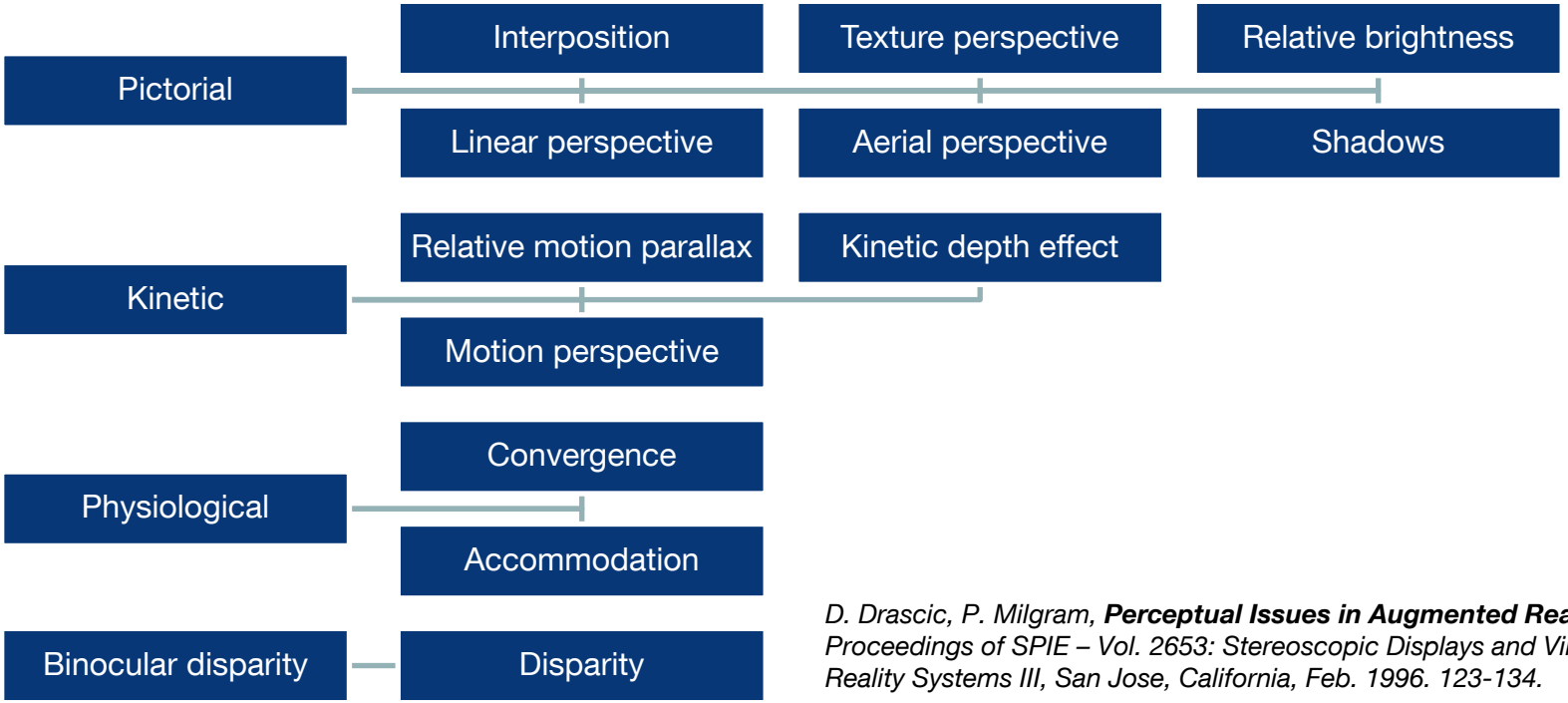
Perceptual Issues in Augmented Reality



D. Drascic, P. Milgram, ***Perceptual Issues in Augmented Reality,*** *Proceedings of SPIE – Vol. 2653: Stereoscopic Displays and Virtual Reality Systems III, San Jose, California, Feb. 1996. 123-134.*

Overview of Depth Cues



D. Drascic, P. Milgram, ***Perceptual Issues in Augmented Reality,*** *Proceedings of SPIE – Vol. 2653: Stereoscopic Displays and Virtual Reality Systems III, San Jose, California, Feb. 1996. 123-134.*

Medical AR:
Challenges faced through decades

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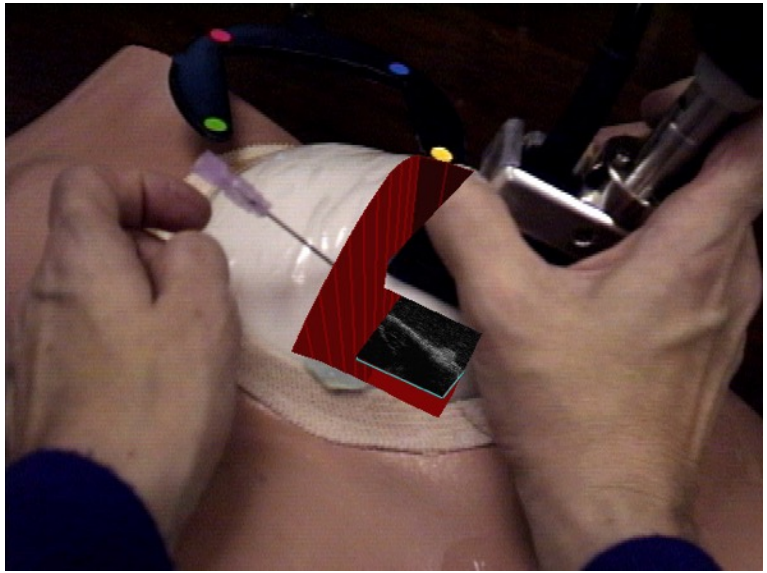
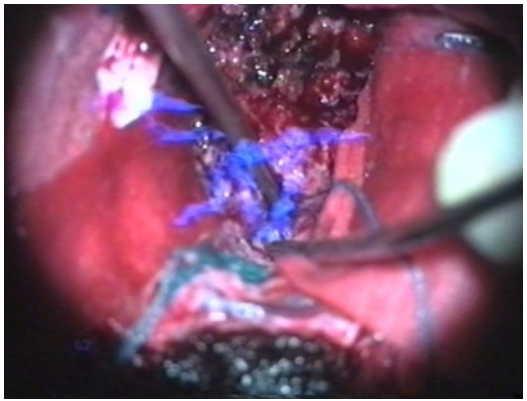
Medical AR: Challenges faced through decades

- Fuchs et al. 1993
  - Main challenges:
    - Computational power!
    - Tracking and synchronization



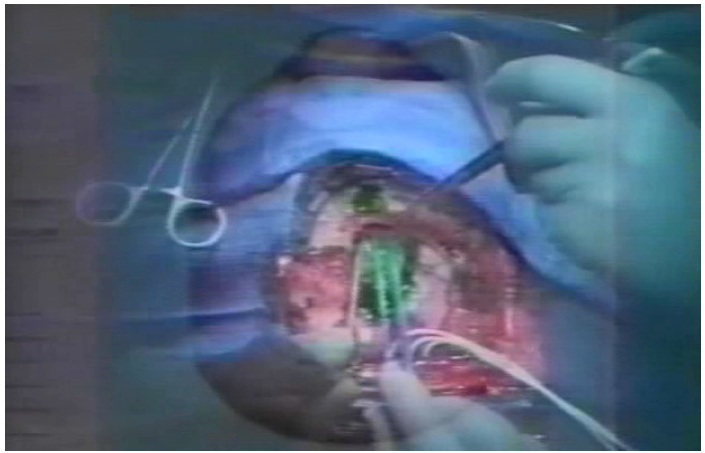
Medical AR: Challenges faced through decades

- Edwards et al. 1995:
  - Main Challenges:
    - Depth Perception
    - Workflow Integration



Medical AR: Challenges faced through decades

- Kikinis et al. 1996:
  - Main Challenges:
    - Depth Perception
    - Workflow Integration



Medical AR: Challenges faced through decades

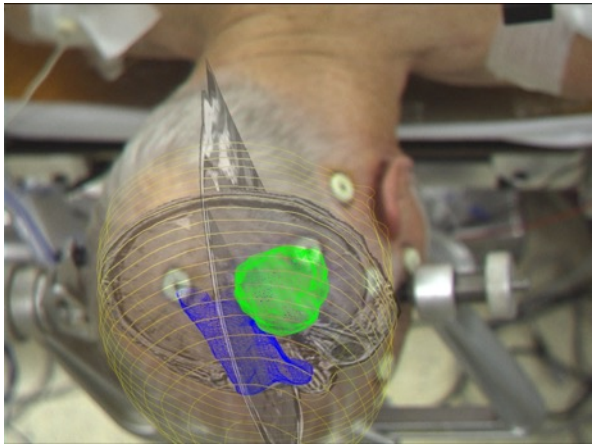
- Dii Gioia et al. 1998:
  - Main Challenges:
    - Tracking
    - Workflow Integration

Medical AR: Challenges faced through decades

- Birkfellner et al. 2000:
  - Main Challenges:
    - Tracking
    - Workflow Integration

Medical AR: Challenges faced through decades

- Sauer et al. 2000
  - Main challenges:
    - Depth Perception
    - Workflow Integration



Medical AR:
CAMP Examples

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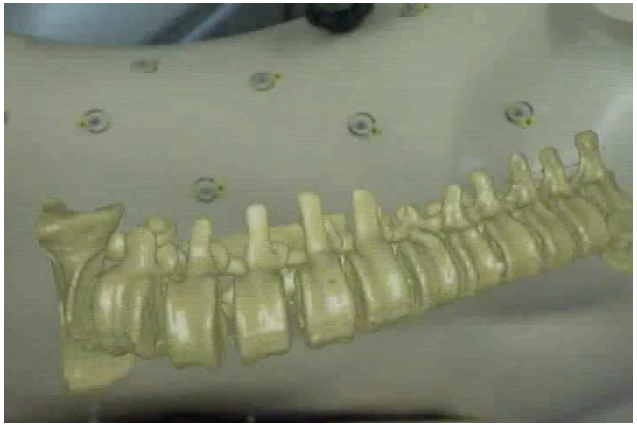
Examples. Medical AR

Motivation:
Misleading Depth Perception of Augmented Anatomy

Medical Imaging Data can be registered accurately
BUT
anatomy seems to be located outside the "patient"!

Virtual objects can **only** be presented **superimposed** onto the real objects.
Visualized anatomy occludes skin → **Misleading Depth Perception**

Improved Depth Perception Using the Virtual Window



Is a virtual window into the patient or a Semi-transparent skin the ultimate solution?

T. Sielhorst, C. Bichlmeier, S.M. Heining, N. Navab ***Depth perception a major issue in medical AR: Evaluation study by twenty surgeons,*** *Proceedings of Medical Image Computing and Computer-Assisted Intervention (MICCAI 2006), Copenhagen, Denmark, October 2006, pp. 364-372*

C. Bichlmeier, N. Navab ***Virtual Window for Improved Depth Perception in Medical AR*** *International Workshop on Augmented Reality environments for Medical Imaging and Computer-aided Surgery (AMI-ARCS 2006), Copenhagen, Denmark, October 2006*

Depth Cues

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Depth Perception. Definition

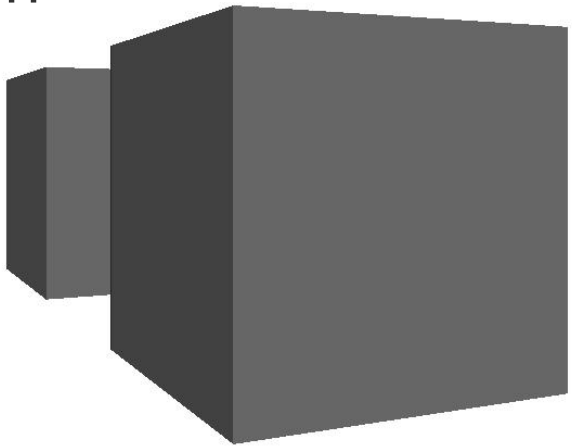
AMERICAN ACADEMY™
OF OPHTHALMOLOGY

Depth perception is the ability to see things in three dimensions (including length, width and depth), and to judge how far away an object is.

https://www.aao.org/eye-health/anatomy/depth-perception

Top 4 Visual Depth Cues in personal space

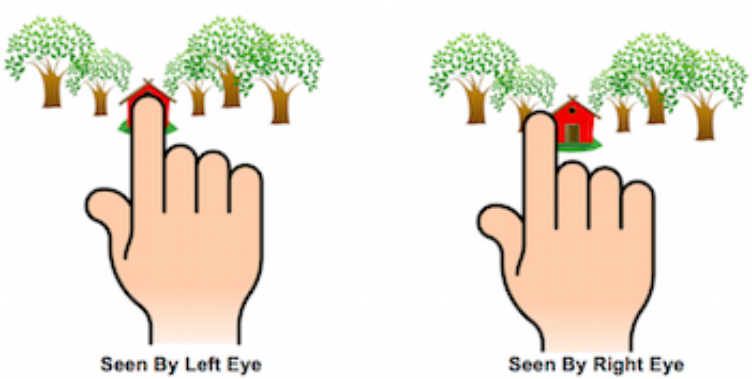
1. Occlusion/Interposition



Cutting, J. E. & Vishton, P. M. Perceiving layout and knowing distances: The integration, relative potency, and contextual use of different information about depth *W. Epstein & S. Rogers (Eds.), Perception of Space and Motion,* **1995**, 69-117

Top 4 Visual Depth Cues in personal space

2. Binocular Disparity / Stereopsis



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Top 4 Visual Depth Cues in personal space

3. Motion Perspective & Motion Parallax

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4. Relative Size & Familiar Size

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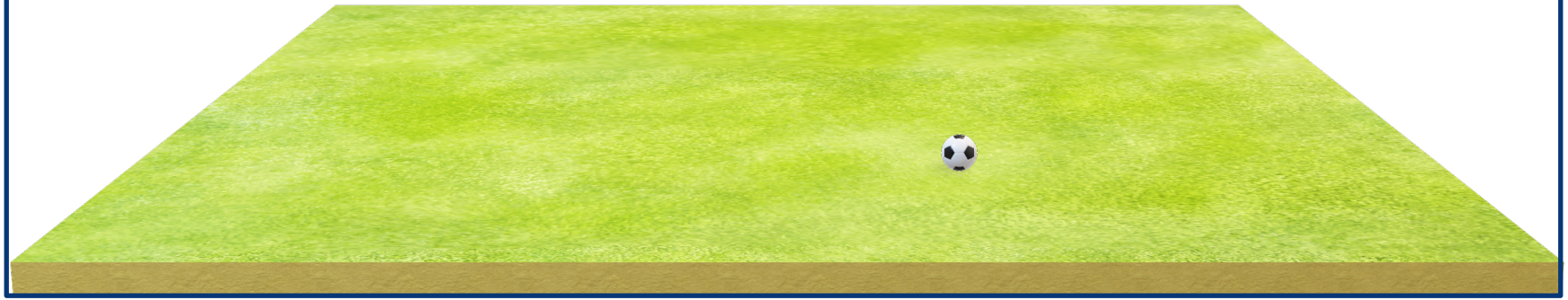
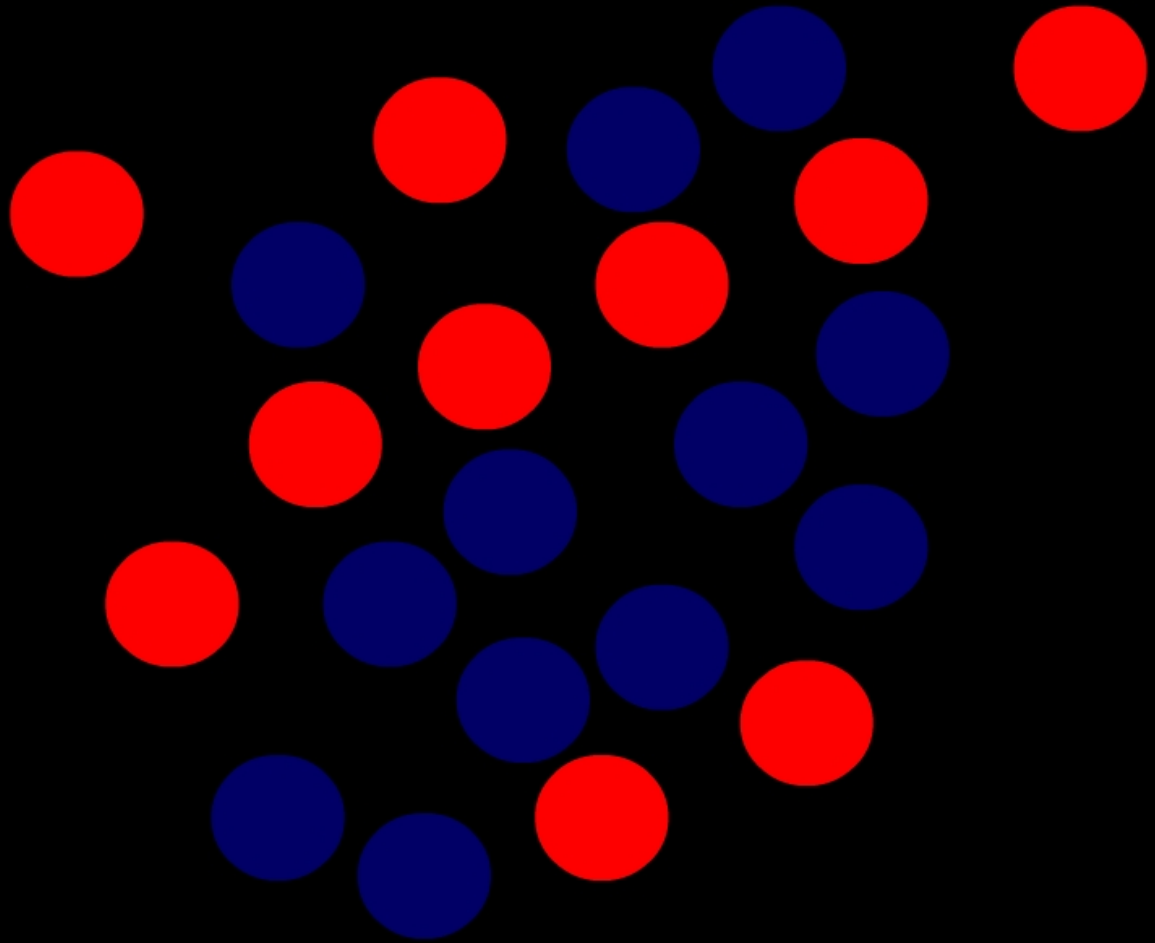


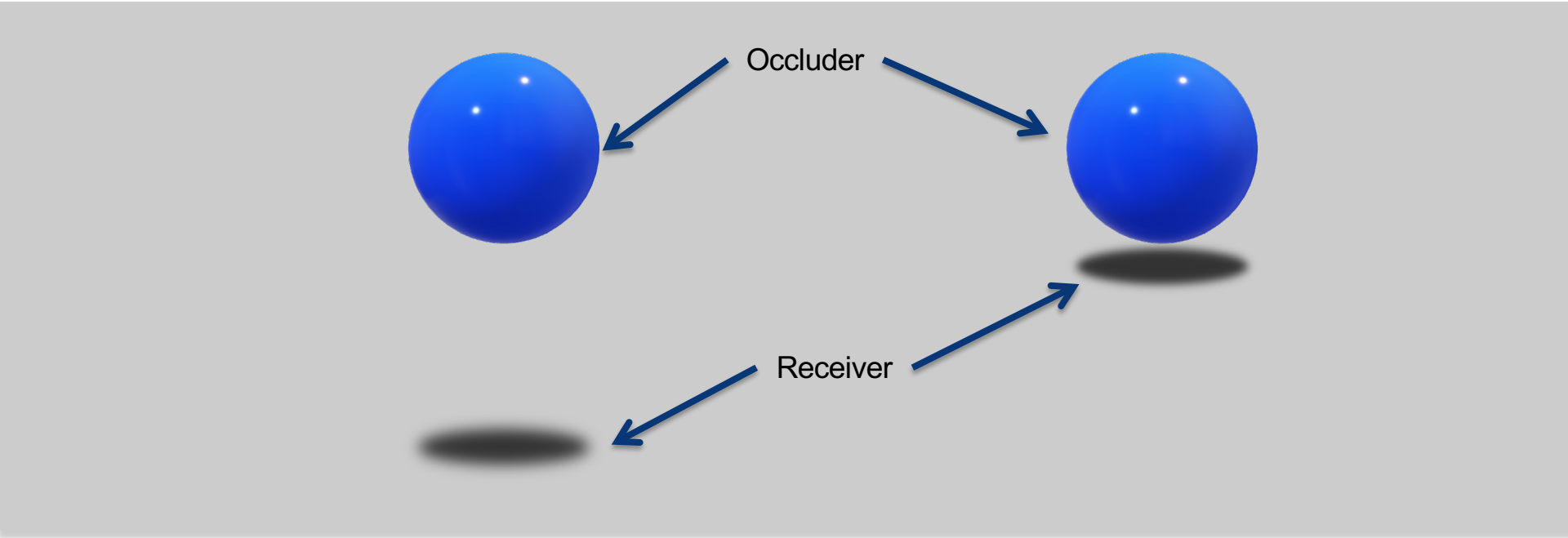
Cutting, J. E. & Vishton, P. M. Perceiving layout and knowing distances: The integration, relative potency, and contextual use of different information about depth *W. Epstein & S. Rogers (Eds.), Perception of Space and Motion,* **1995**, 69-117

Color – Perception of Relative Depth

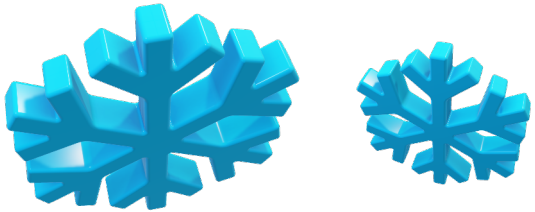


Shadow – Perception of Depth

Shadow – Perception of Depth



Perceptive Advantage of Mirror Reflection



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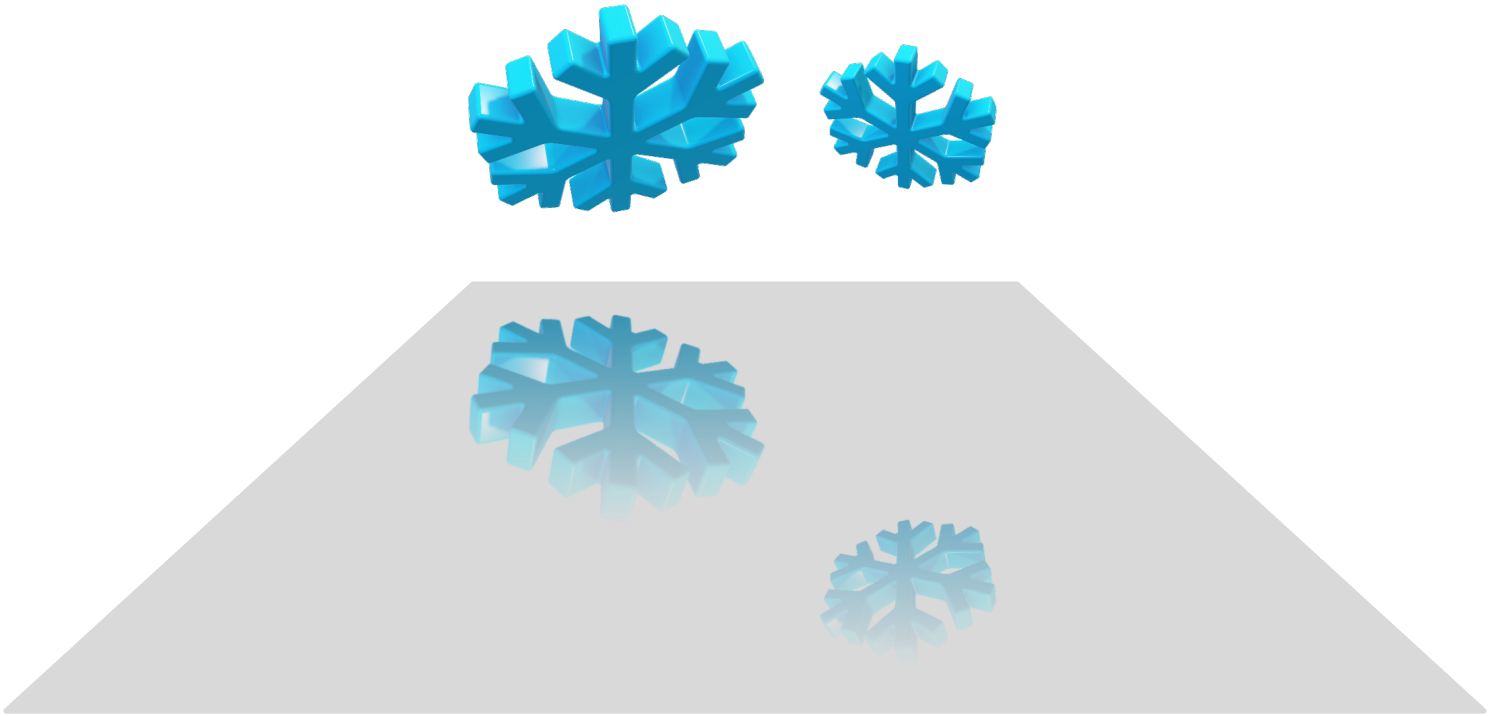

Why are Visual Cues Important?

Clockwise or Anticlockwise?

What visual cues are missing?

Original sequence by:
Nobuyuki Kayahara's
http://www.procreo.jp/labo/labo13.html

GIF available at:
https://en.wikipedia.org/wiki/Spinning_Dancer

Focus and Context

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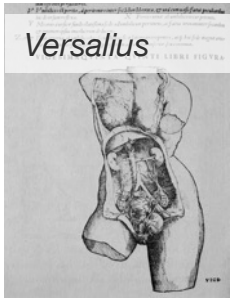
Focus and Context Visualization

Objective:
Using given cues for communicating relative & absolute distances of objects within the scene.

Focus (region of interest):
- Should be uncovered and directly visible
- Should be emphasized and displayed in detail
- Should be perceived at the right location

Additional **Context** information:
- Should provide visual cues for the perception of layout and distances
- Should enable understanding complex anatomic structures

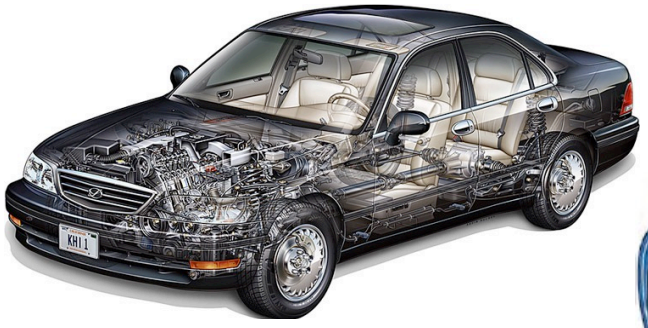

Alexander Tsiaras


Versalius


Da Vinci

Focus & Context Visualization: Definition

1. **Extraction**
   - of a **focus** layer
   - of **context** layers
2. **Shading** of the layers
3. **Modulation** of transparency or position of **context Layers**
   - Cut-away
   - Exploded views
   - Ghosting
4. **Composition** of the layers



Previous VR Work:
- *J. Krueger et al.; IEEE Transactions on Visualization and Computer Graphics, 2006.*
- *S. Bruckner et al.; IEEE Transactions on Visualization and Computer Graphics, 2006*

Related (parallel) AR work:
- *M. Lerotic et al.; MICCAI 2007*
- *D. Kalkhofen et al.; ISMAR 2007*

Ghosting for AR: Fusion of Real and Virtual Anatomy

Objective:
Improved Depth Perception for Medical Augmented Reality using video see-through HMDs

Basic Idea:
Using the geometry of the skin and observer position for manipulating the transparency of video images.

First Version is Based on **Ghosting**:

- Skin is the only context layer
- Anatomy is in the focus

Focus & Context Visualization: Designing the X-Ray View

Distance falloff:
Radius around the intersection point of line of sight & skin

Angle of incidence:
Comparing view vector & normals of skin surface

Curvature:
Profile of skin within the region of interest

Input: Observer

Input: Skin Properties

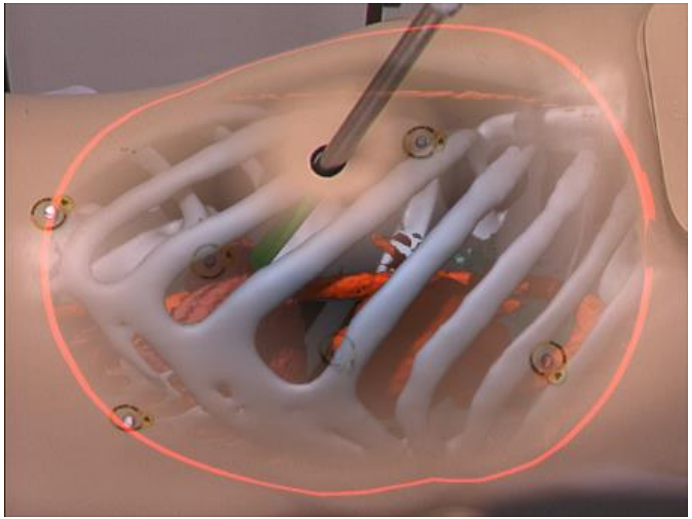
Reactive transparency adjustment of the skin region within video images.

Results: Reactive Vision Channel

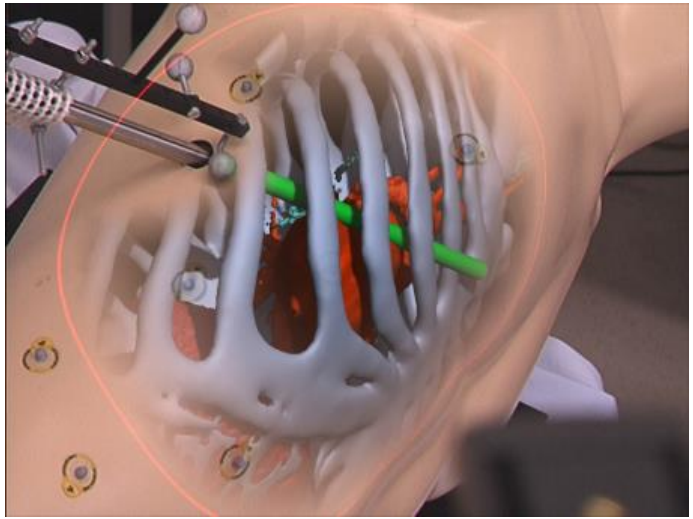
- Vision channel follows the line of sight of the observer.
- Red border around the vision channel highlights the region of interest.
- The three parameters for transparency definition can be adjusted and weighted according to the region of interest.

Focus & Context Visualization: Surgical Instruments

Objective: Using the in-situ visualization for keyhole surgery.
Requirement: Integration of augmented endoscopic instruments.



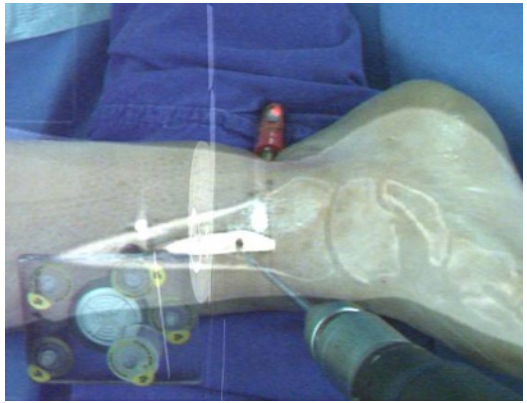
Skin gets opaque where the surgical instrument enters the port.



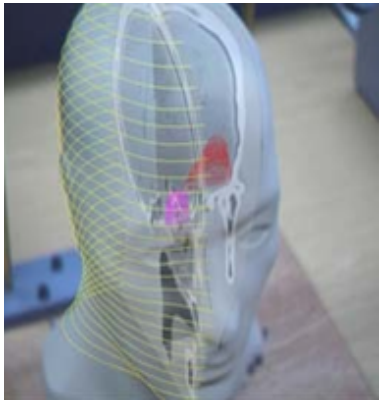
Surgical instrument is augmented only inside the body.

Improving Depth Perception

Bajura et al. 1994

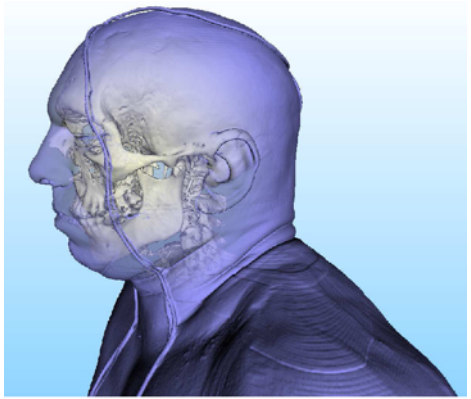


Traub et al. 2004

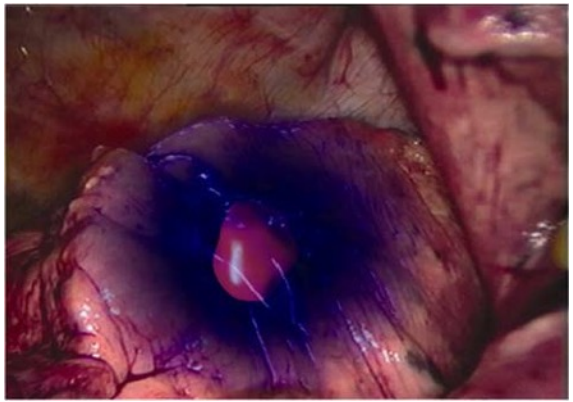


Vogt et al. 2006

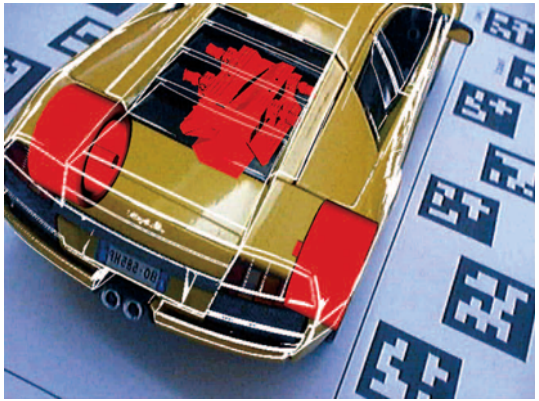
Improving Depth Perception



Krüger, et al. 2006

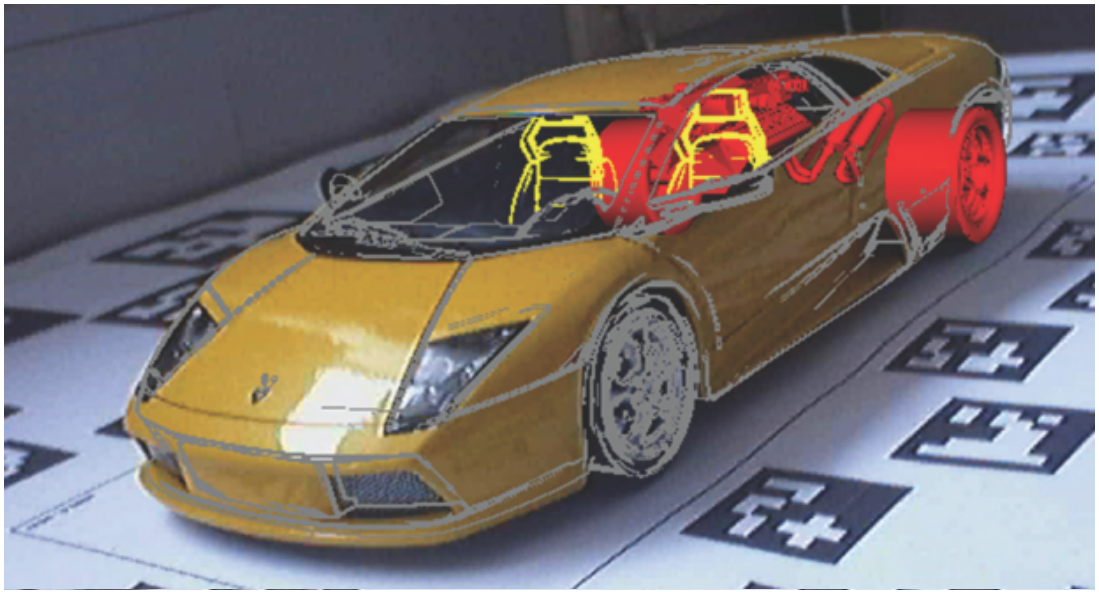


M. Lerotic et al. 2007



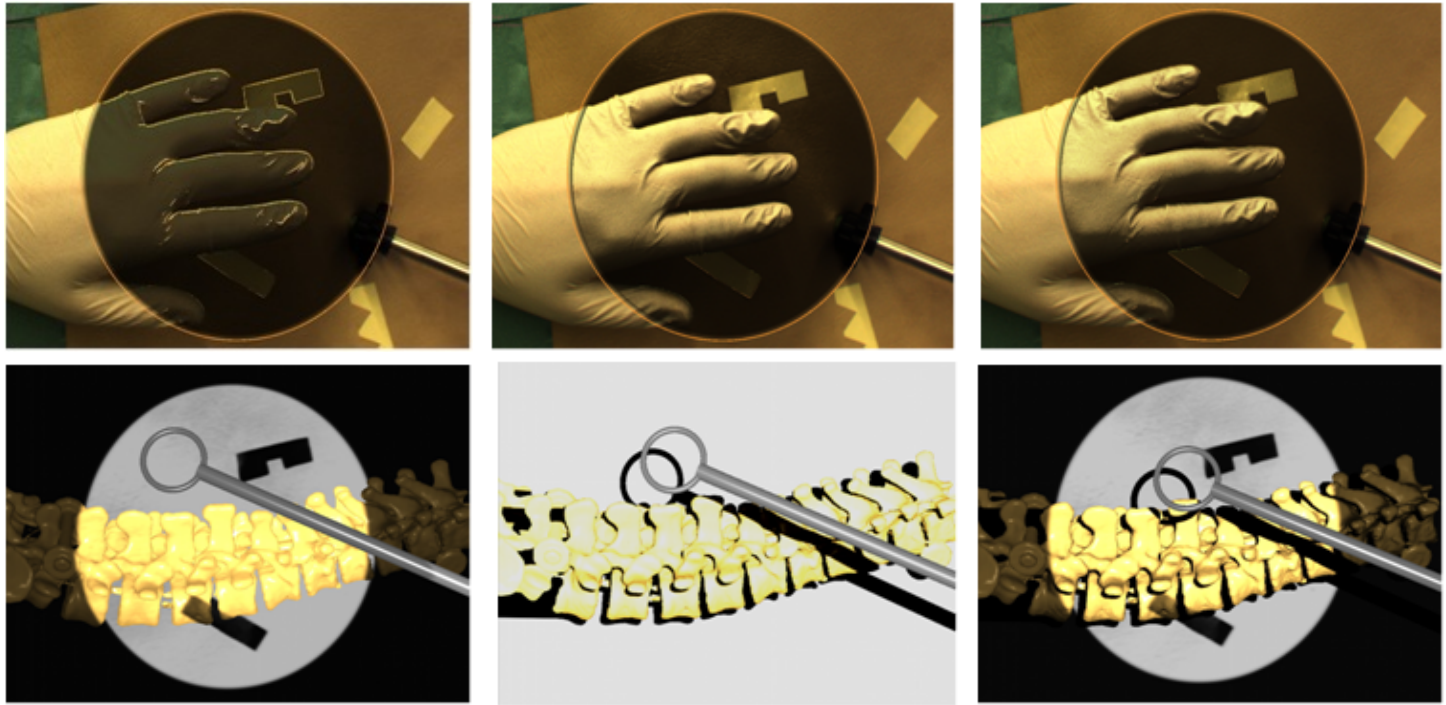
D. Kalkofen et al. 2007

Improving Depth Perception

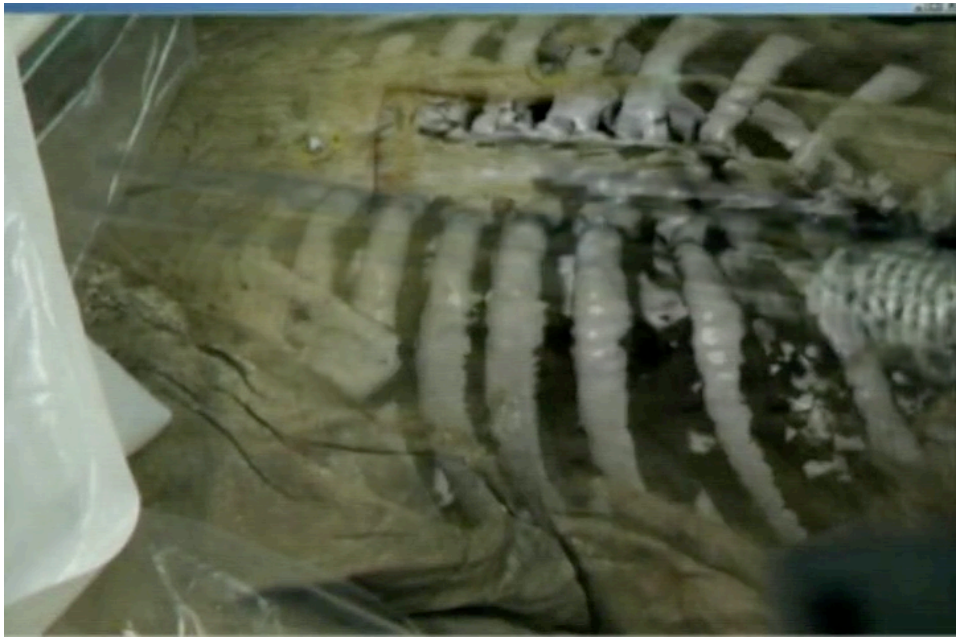


D. Kalkofen et al. 2007

Contextual In-Situ Visualization – Lighting & Shadows



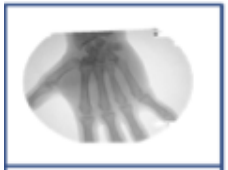
Results: Instruments Cast Shadow on Anatomy



- Visual feedback about relative position of instrument and operation site due to user interaction.

Machine Learning for Relevance based Imaging

Surgeon, tools



Xray anatomy

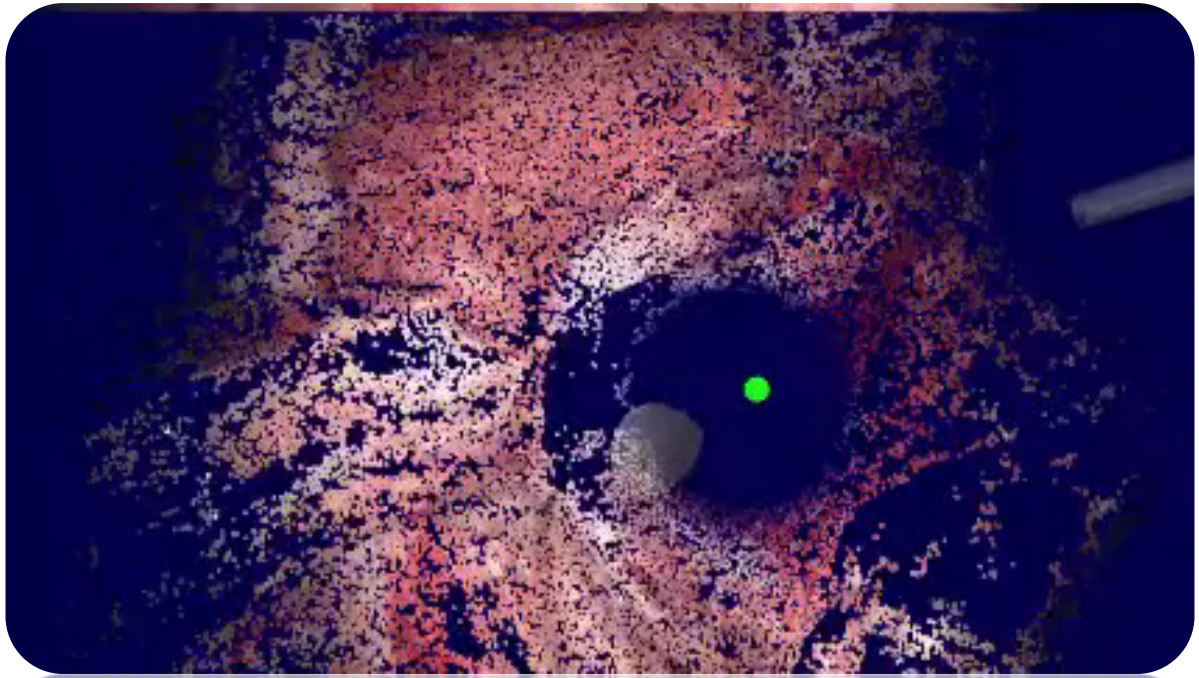
Patient

Background

Results: Instruments Segmentation

- X-Ray image overlaid between the patient hand and the surgeon hand, and tools, providing useful depth cues.

Adding Motion Parallax with Static Viewpoints



A Method to Introduce & Evaluate Motion Parallax with Stereo for Medical AR/MR, Megha Kalia

Open Questions

- Depth Perception vs. Occlusion
  - Co-registered visualization:
    - Lowers cognitive load, no mental transform needed
    - Requires focus & context to provide correct depth cues
    - Occludes important areas => surgical action area
  - Alternatives?
    - Virtual Window
    - Line-based Visualization
    - ...?