Volumetric Medical Data Visualization for Collaborative VR Environments

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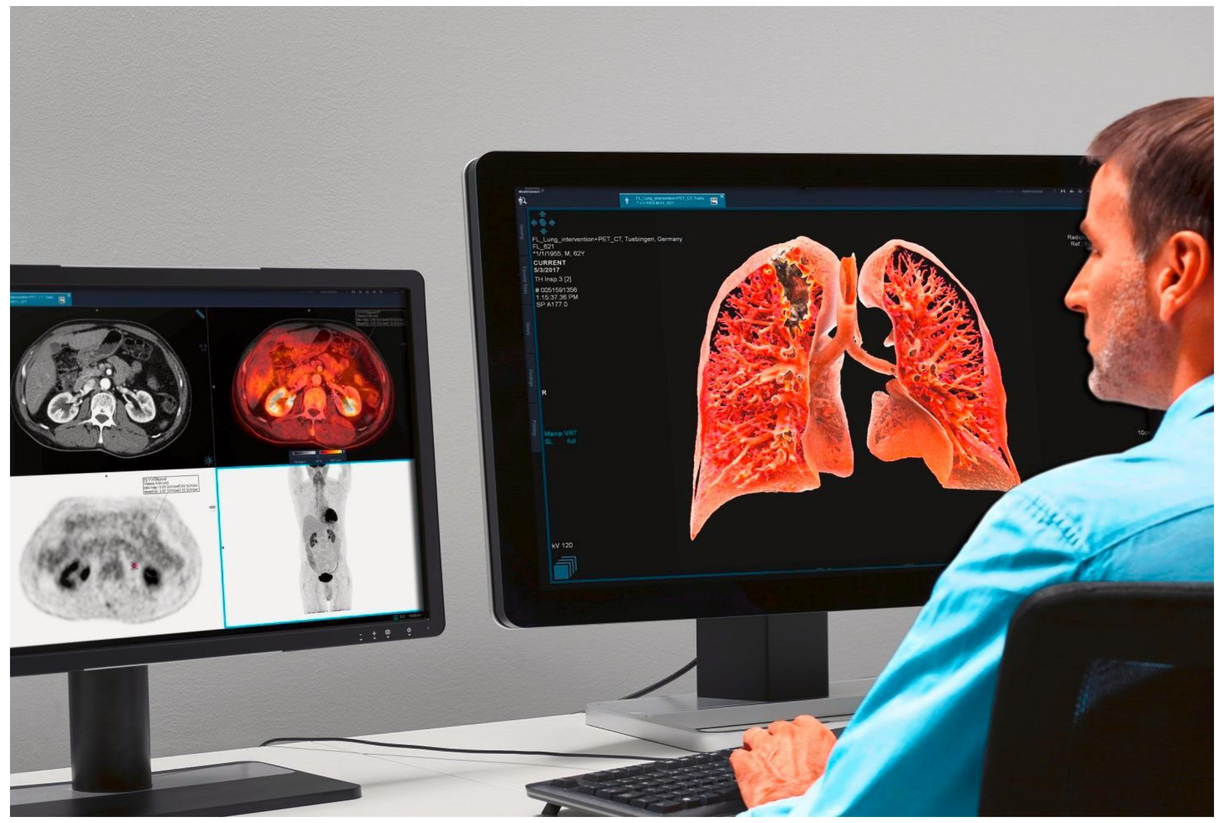
EuroVR 2020 – Scientific Track

25-27 November, Valencia, Spain

Motivation

- In medicine, CT images and 3D visualizations mostly viewed in 2D, alone/co-located



Medical Visualization [Siemens Healthineers]

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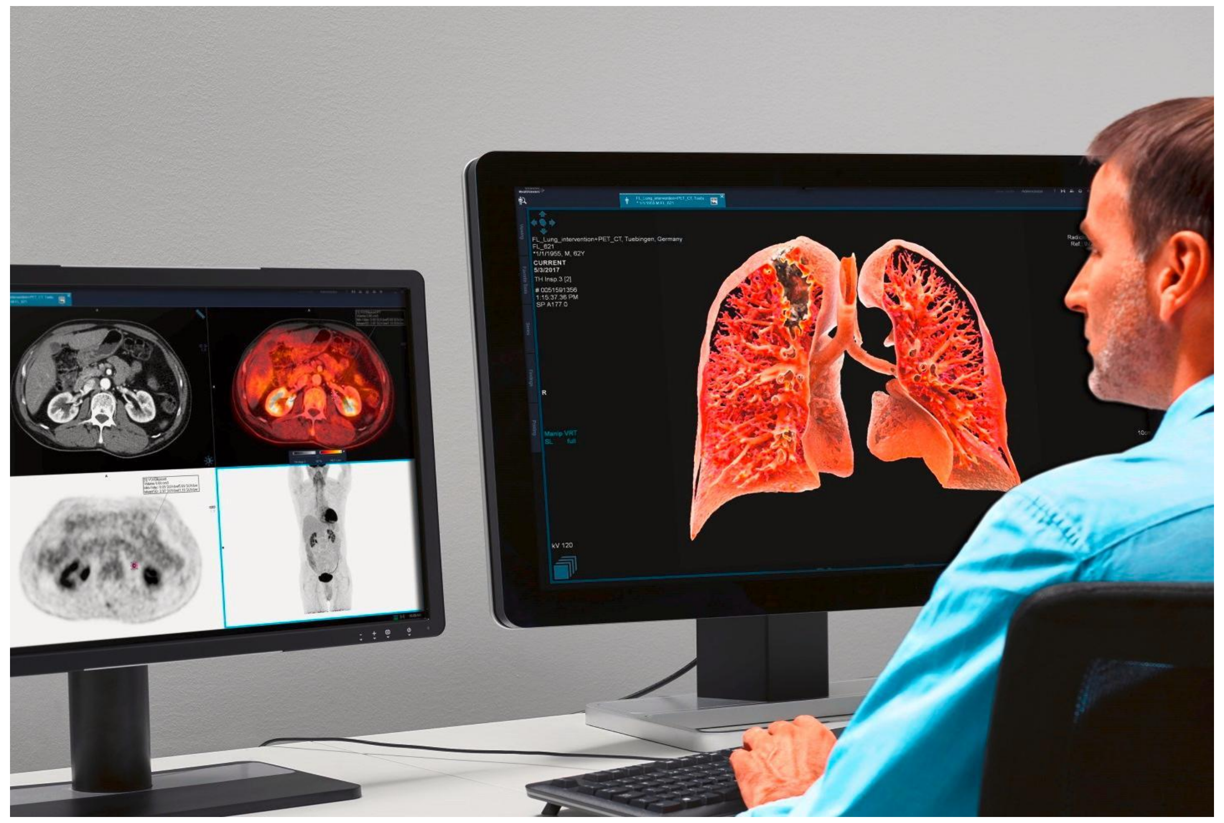
- Future: general trend to use VR and telepresence



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VR in Medicine [Arch Virtual]

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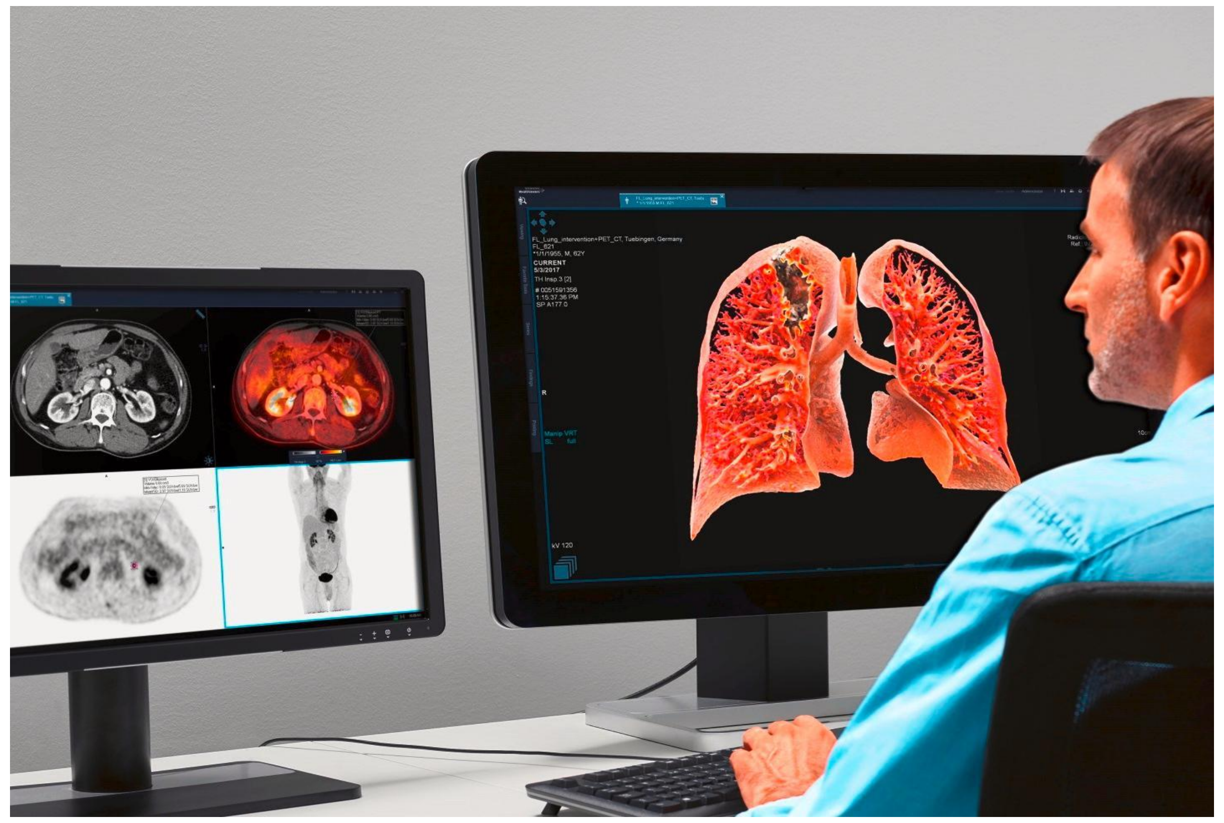
- Future: general trend to use VR and telepresence
- Goal: integrate volume rendering into game engine to view 3D visualizations in VR with remote colleagues



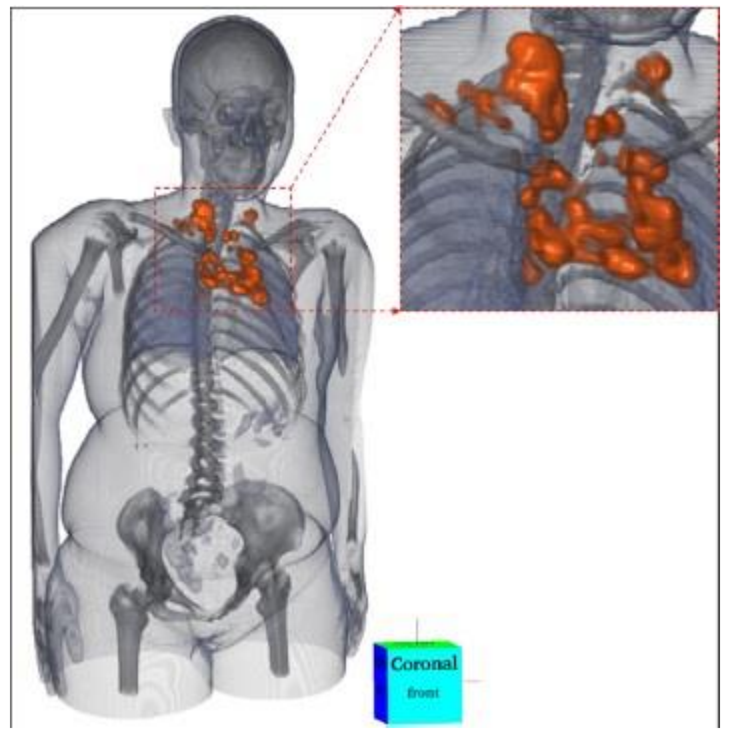
Medical Visualization [Siemens Healthineers]

Vision: Volume Rendering in collaborative VR [shutterstock/Gorodenkoff]

VR in Medicine [Arch Virtual]

Related Work

- Volume rendering for medical visualization: lacks VR/multi-user support [Berger18, Jung19]



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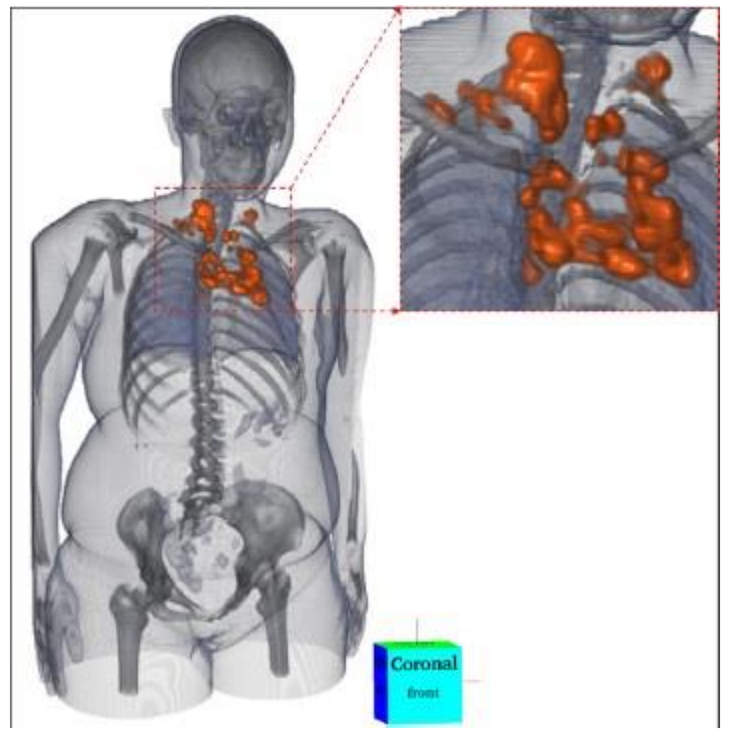

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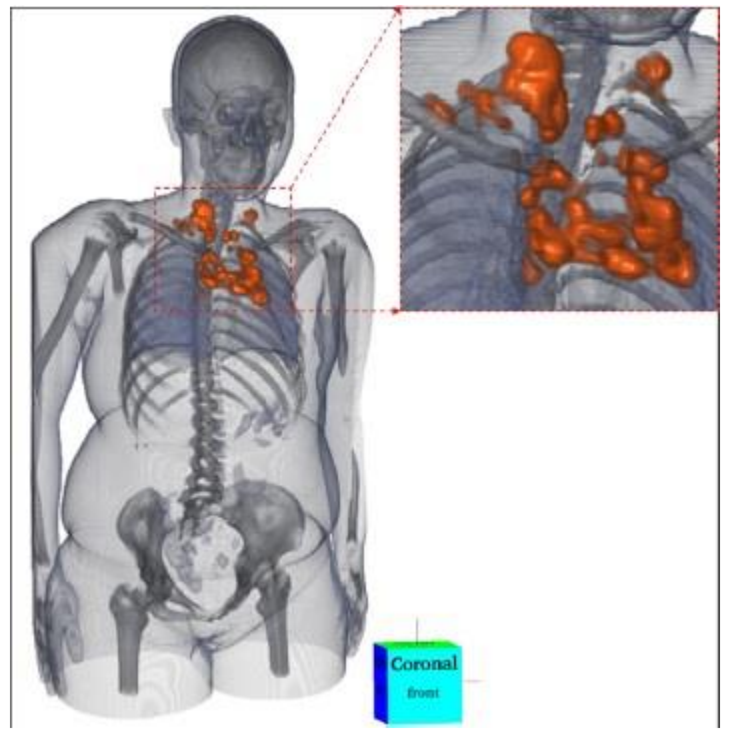

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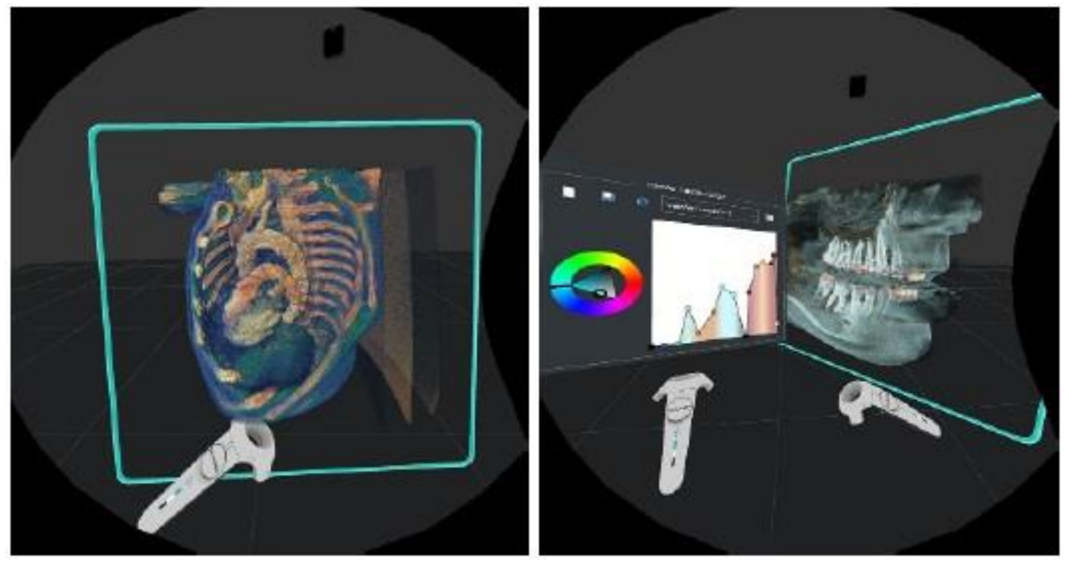

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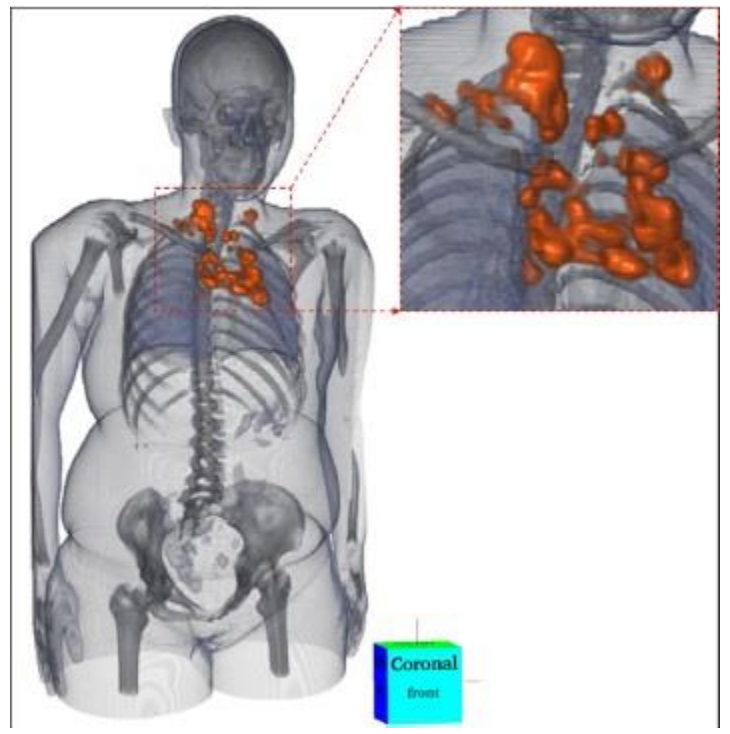
  - Collaboration-focused: no volume rendering [Paiva18, Christensen18, Chheang19]



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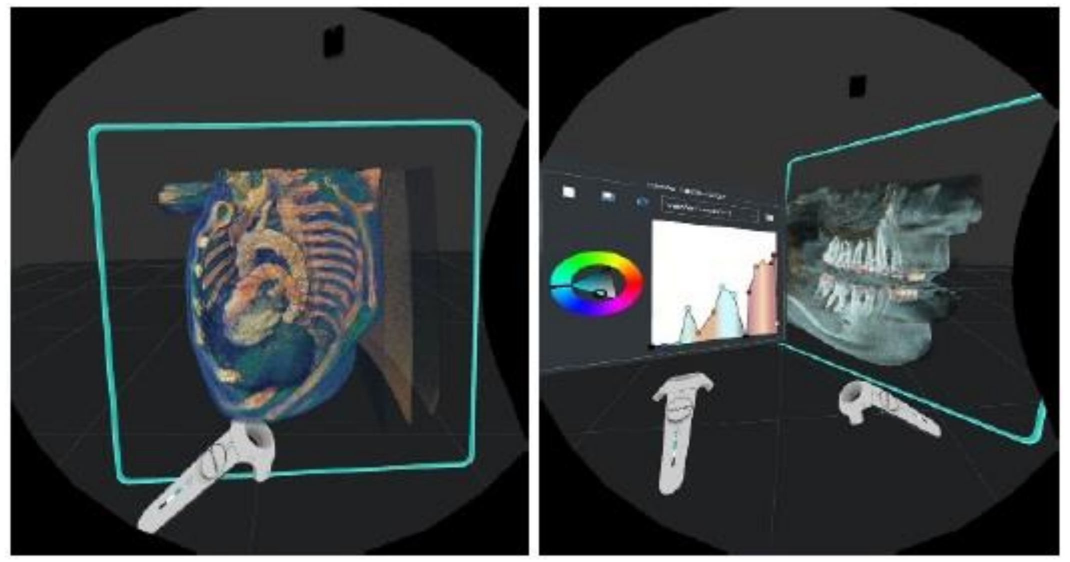
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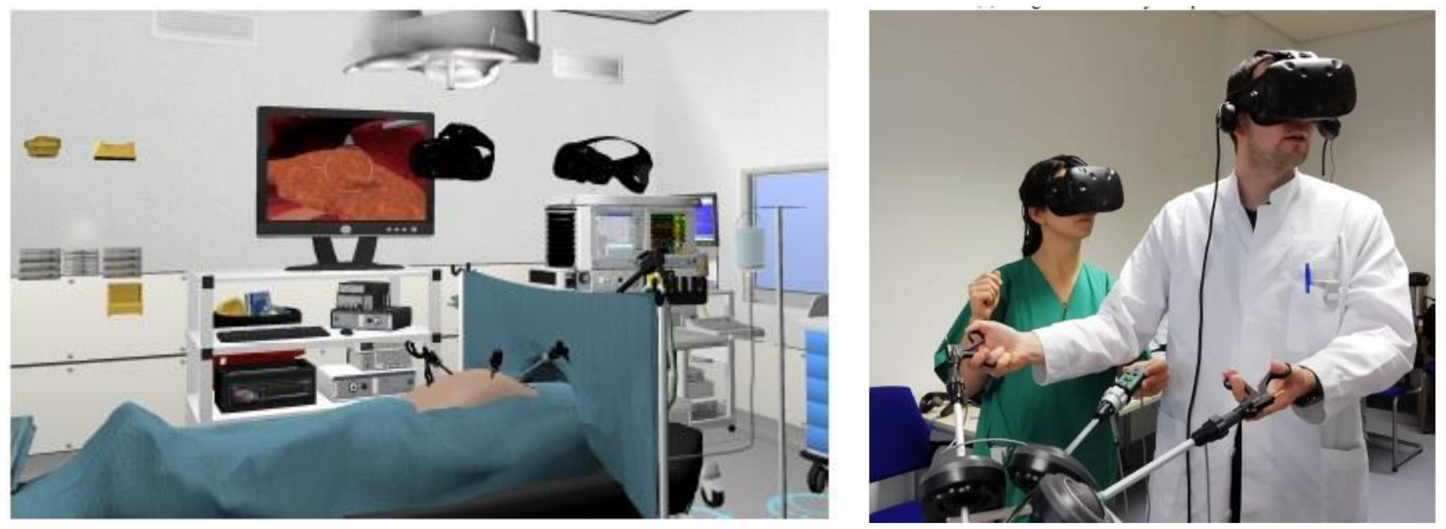
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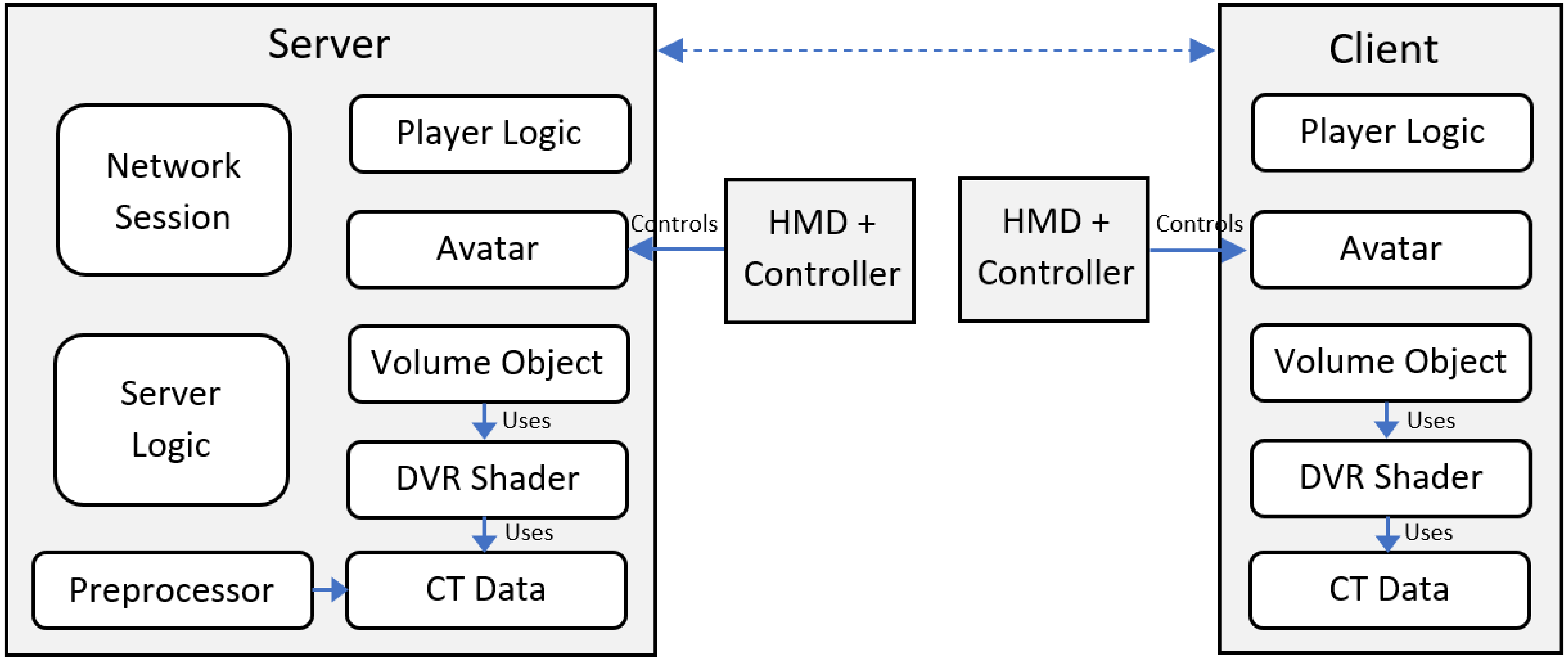
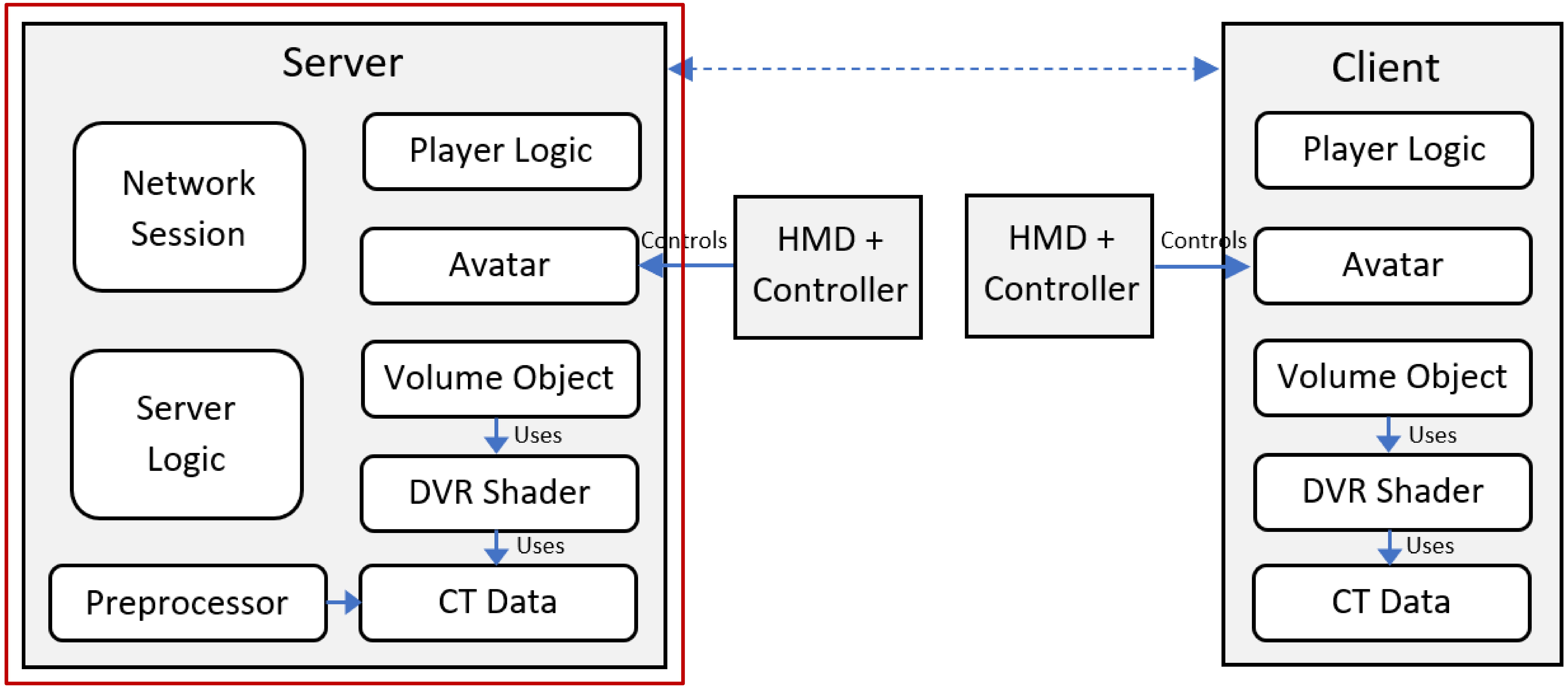
- Shared virtual environment, collaborative inspection & interaction

System Overview



System Overview



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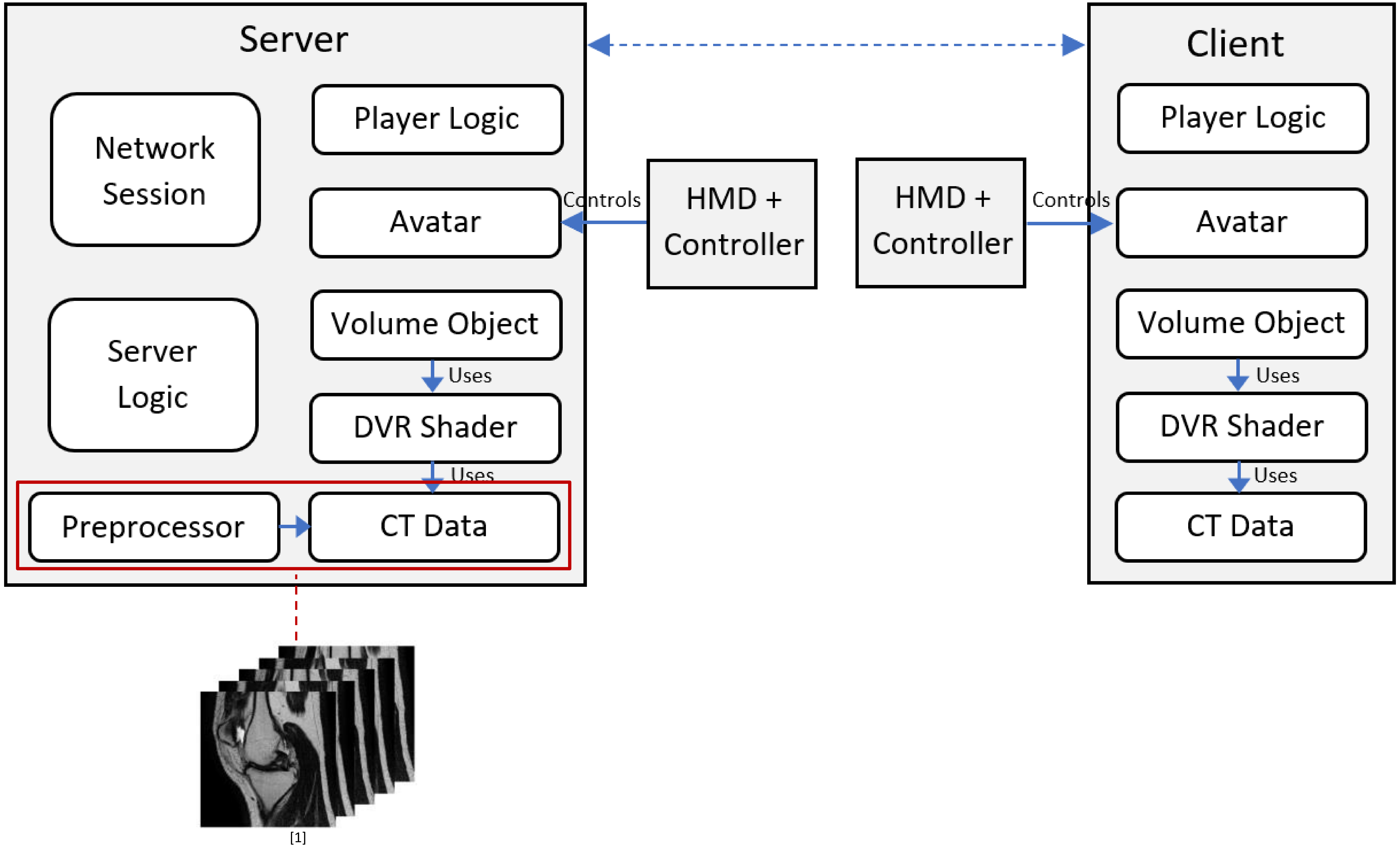

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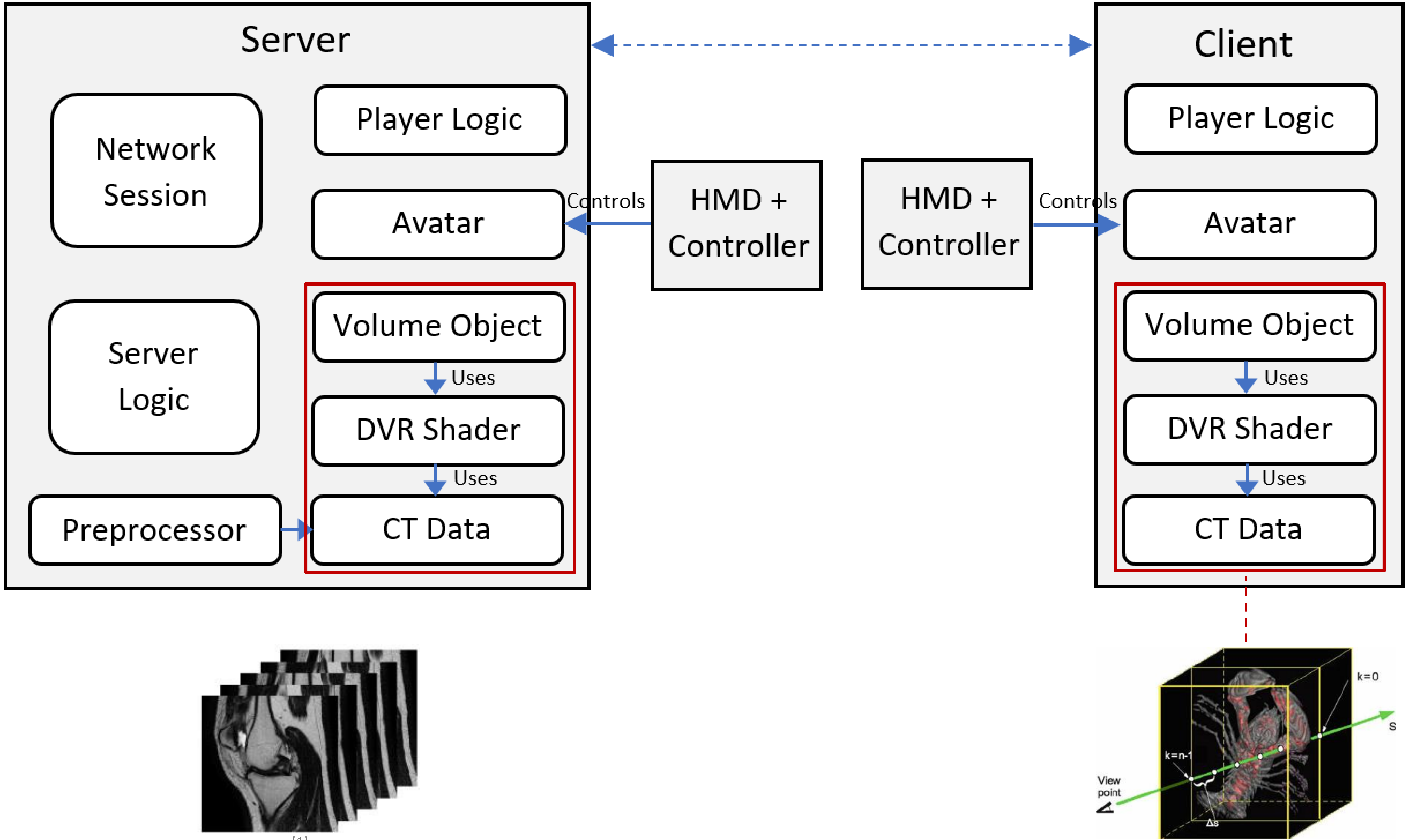

[1] [2]

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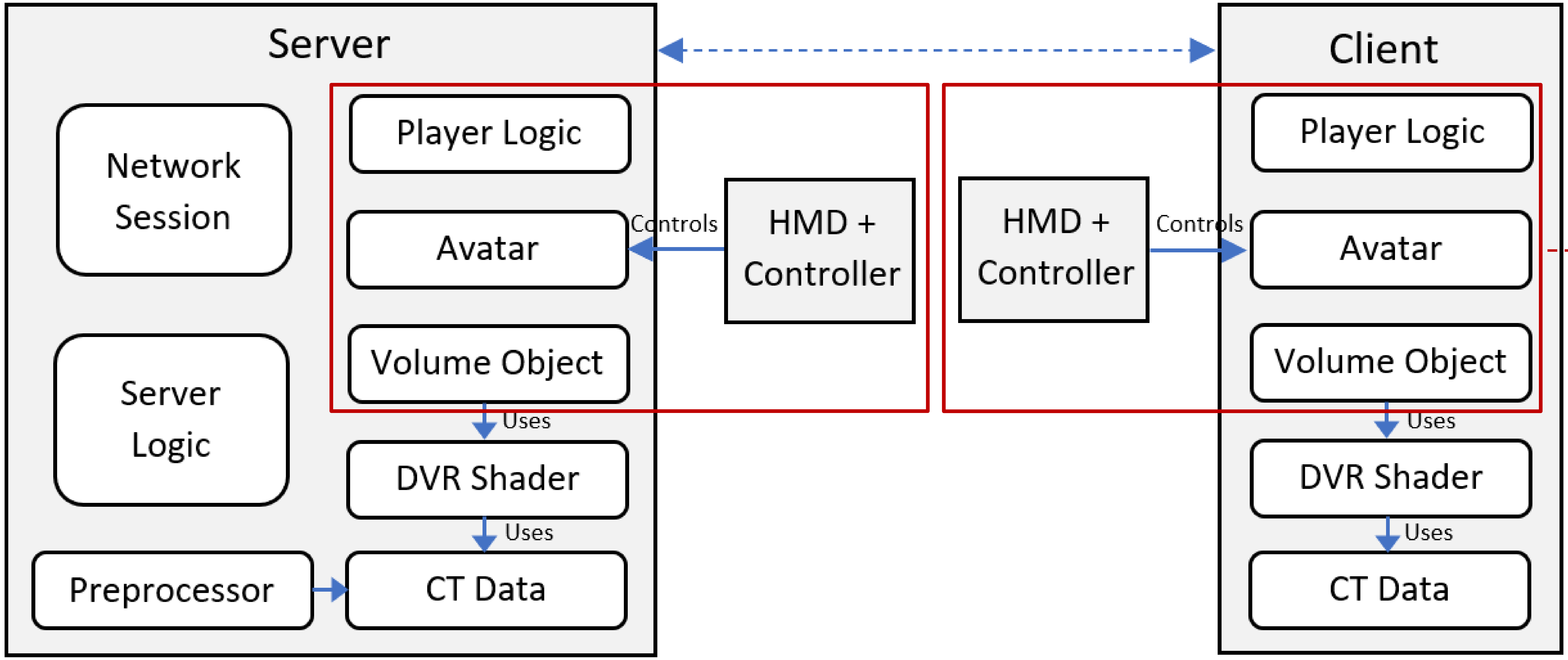
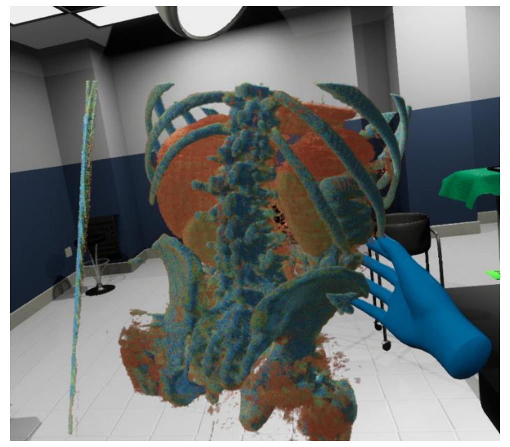
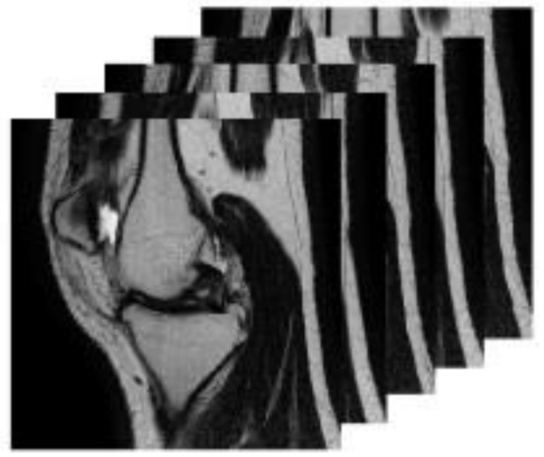
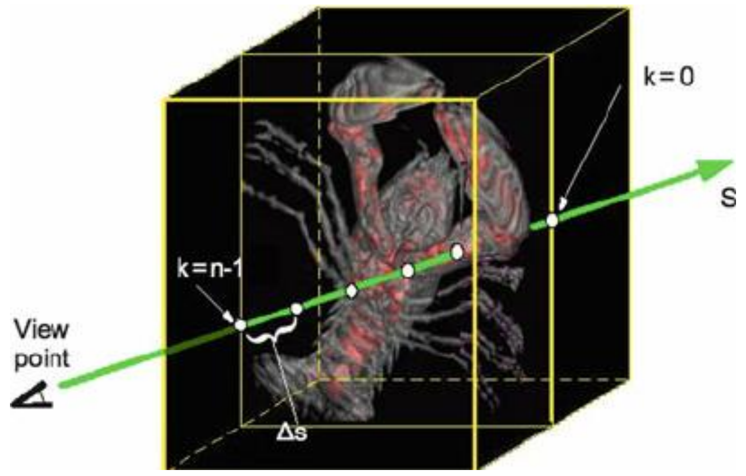






[1]



[2]

Direct Volume Rendering

- Preprocessing of CT data

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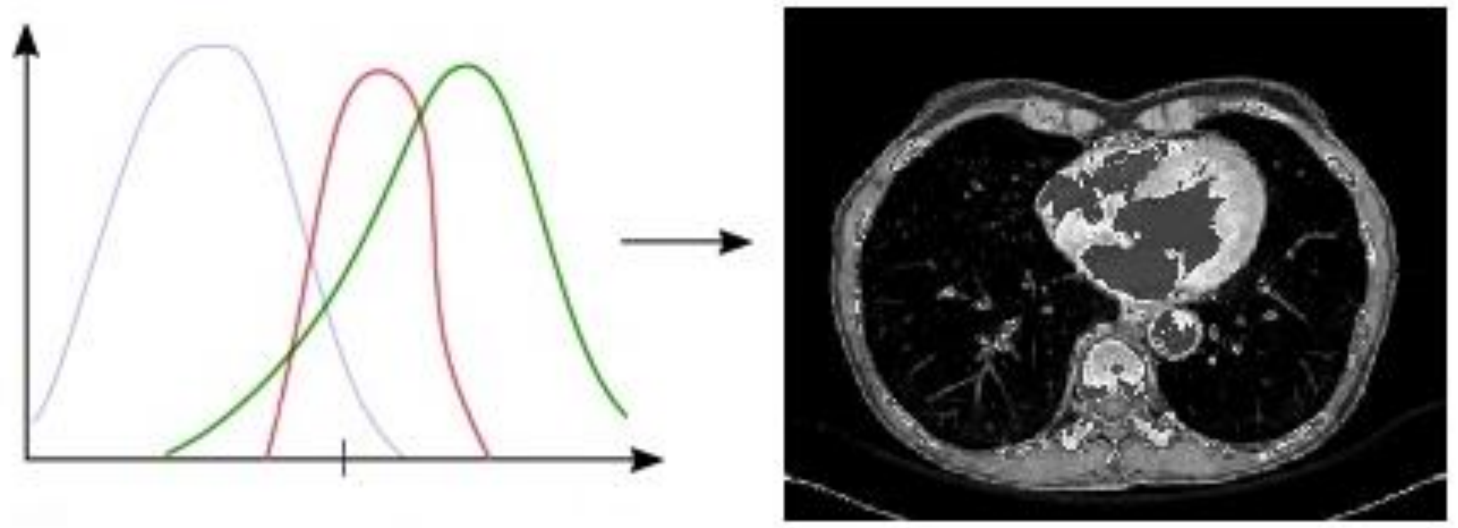
  - Window blending similar to [Mandell17] enables combination of transfer functions



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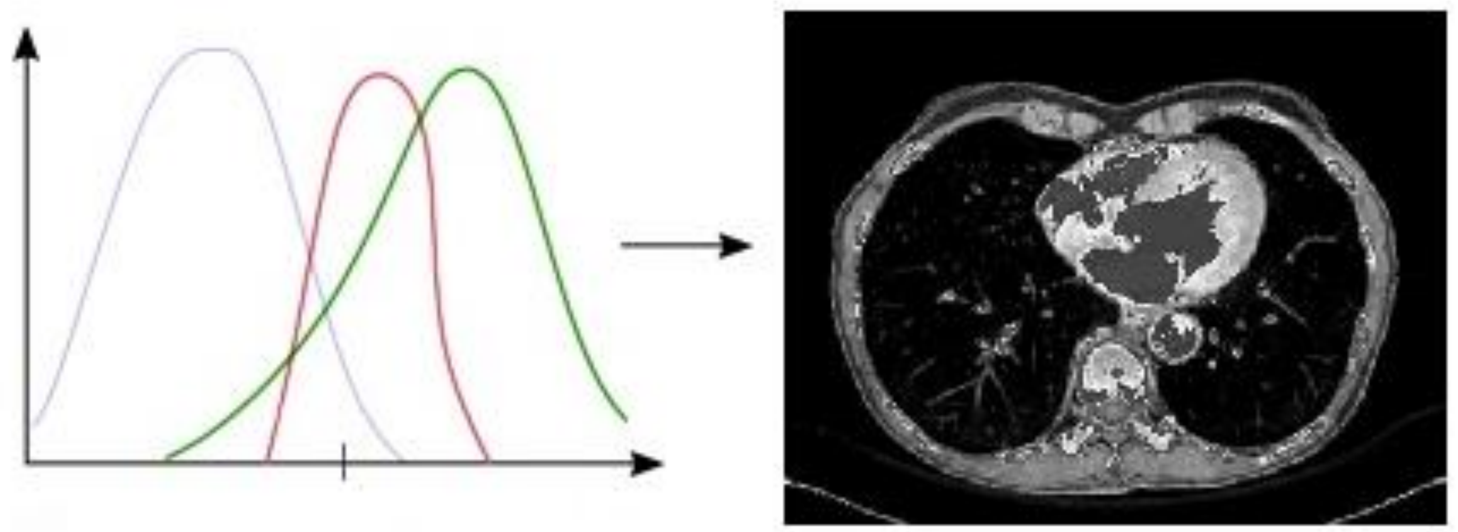

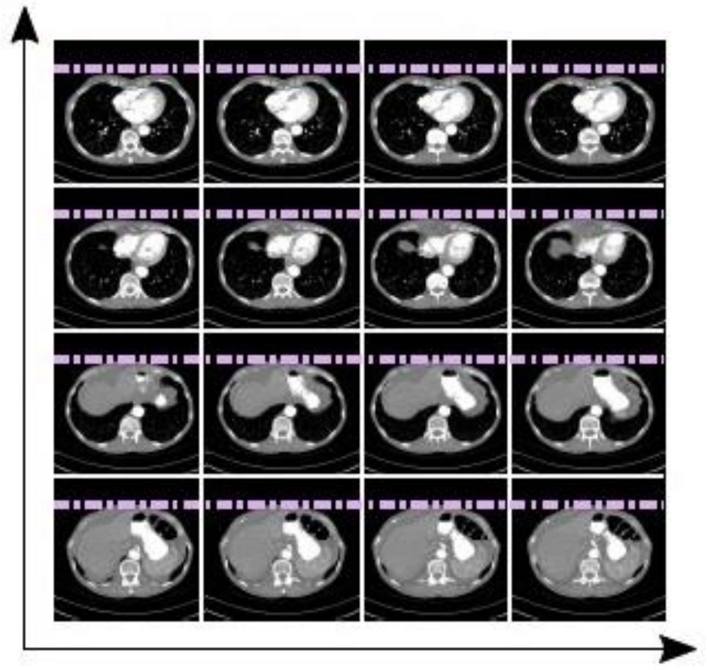

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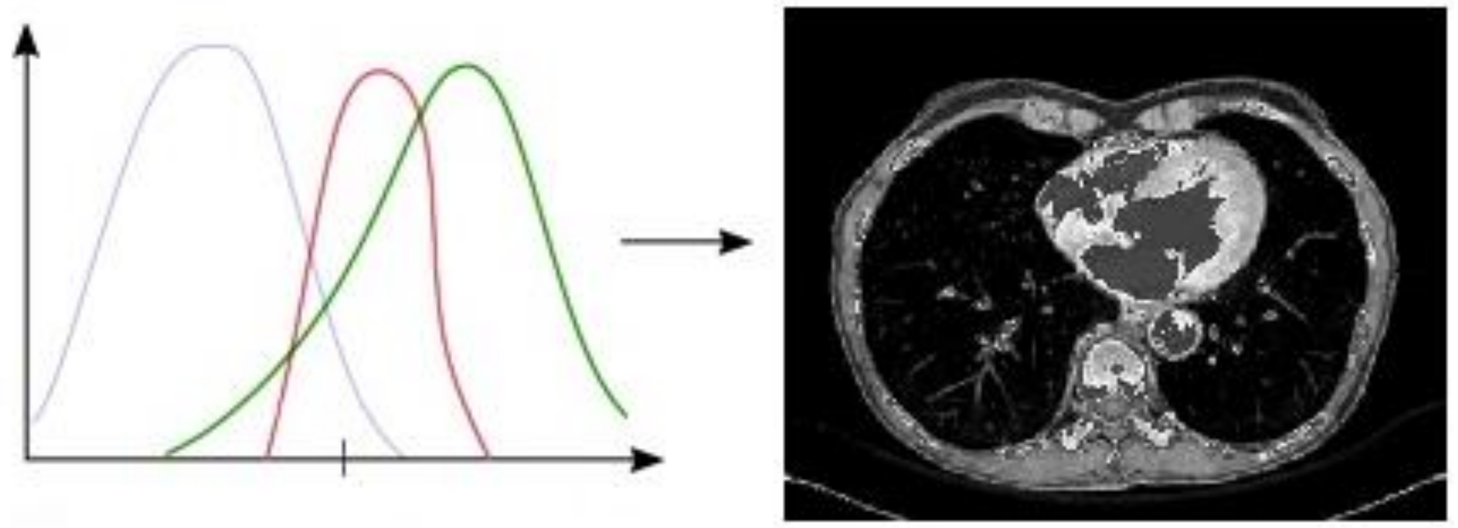

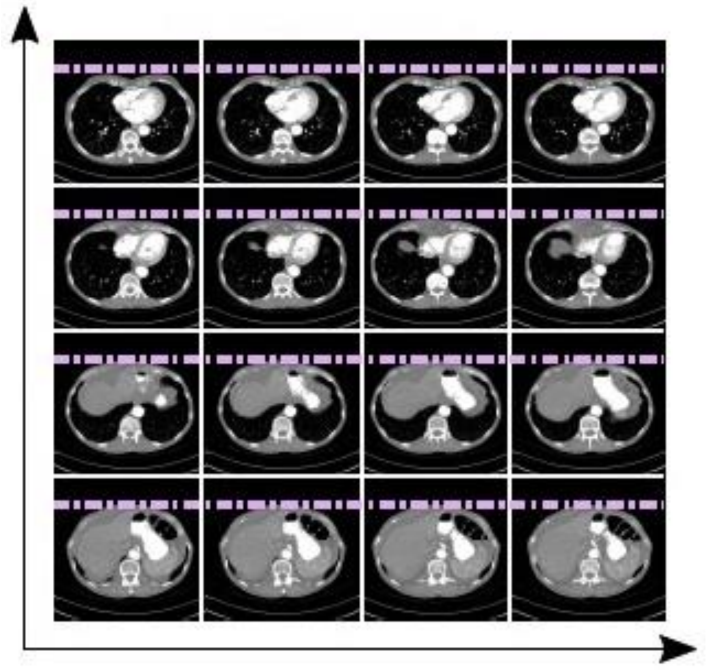

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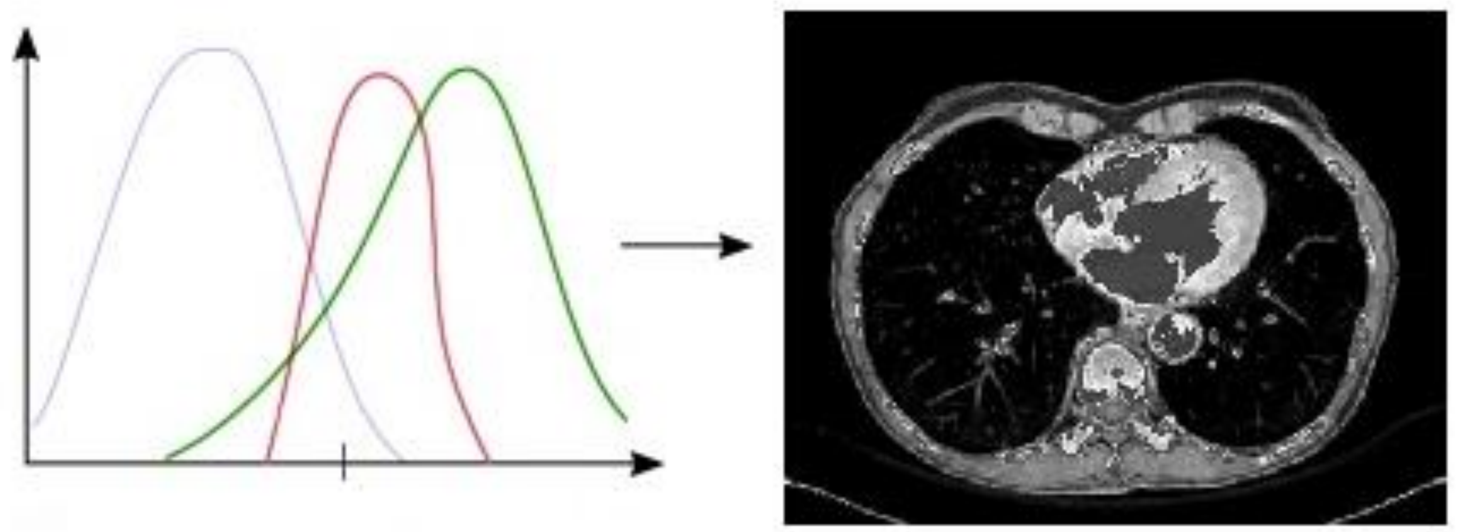

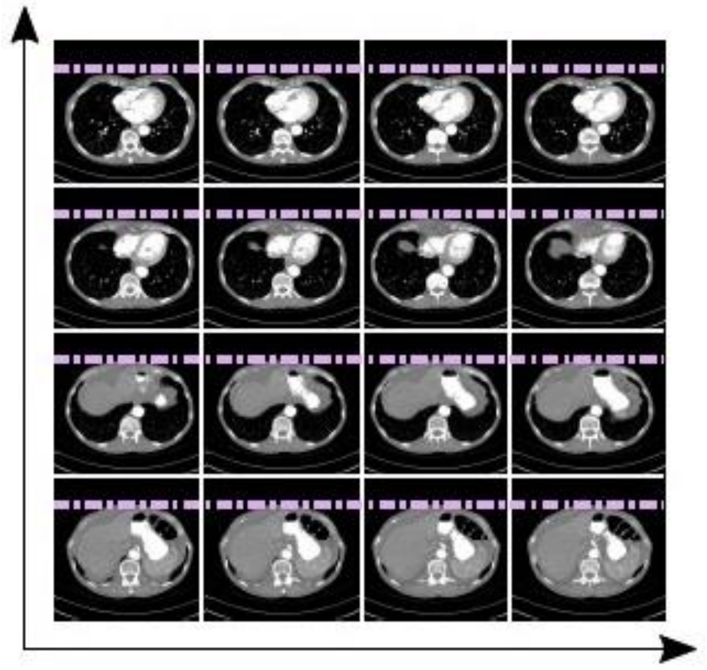

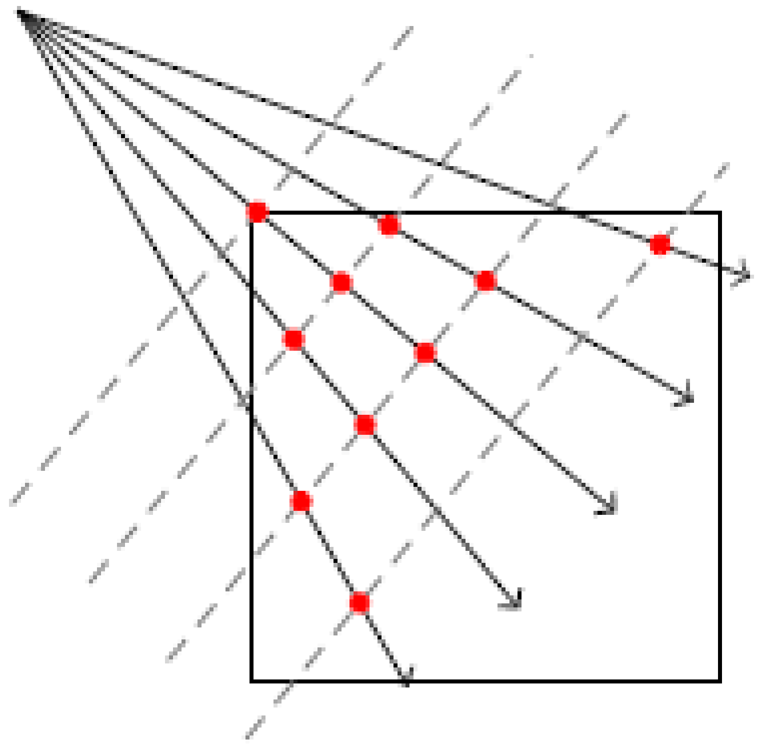

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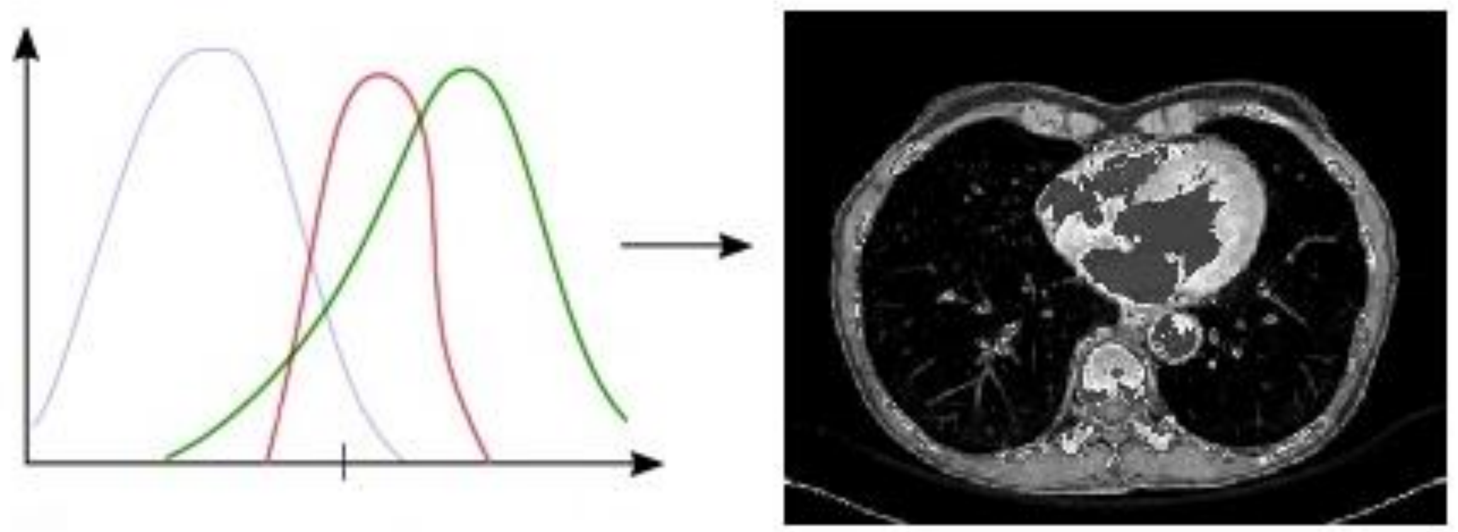
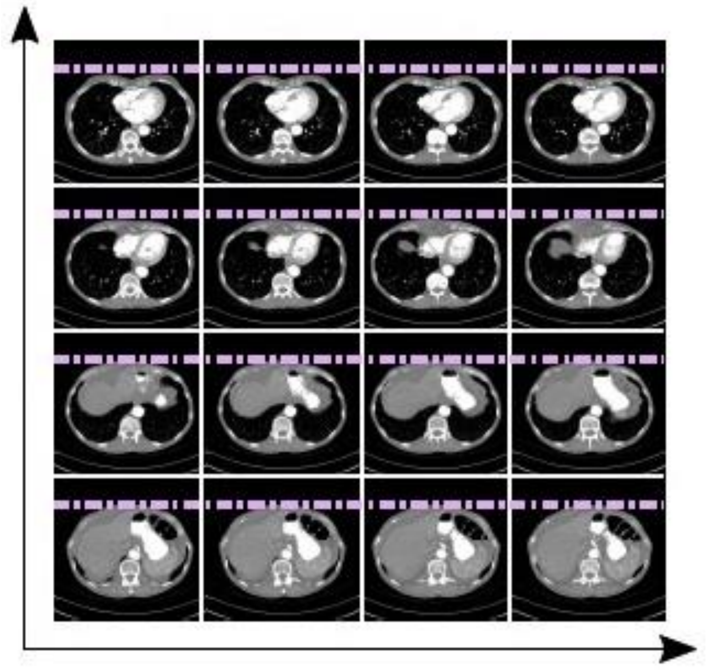
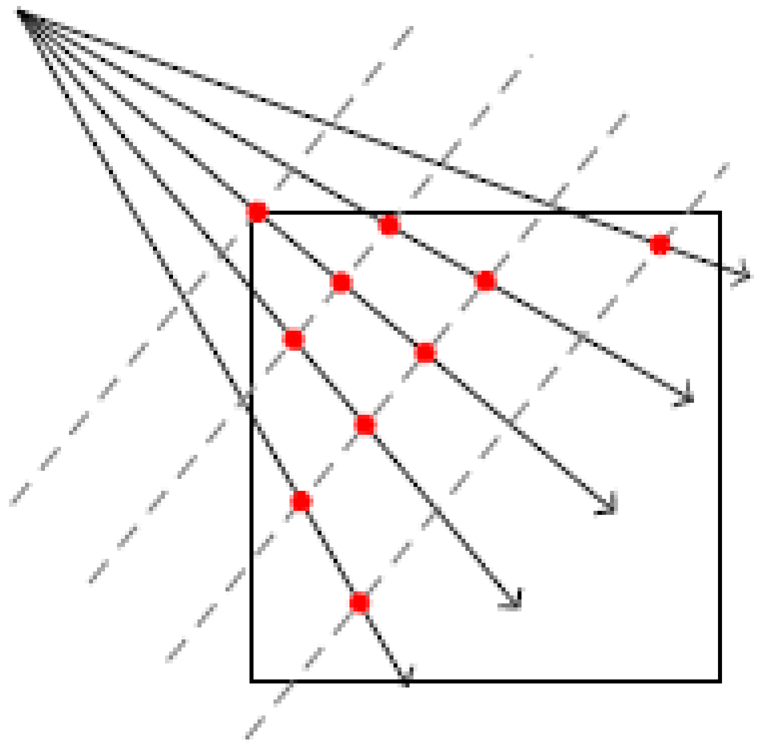
  - Supports multiple dynamic light sources

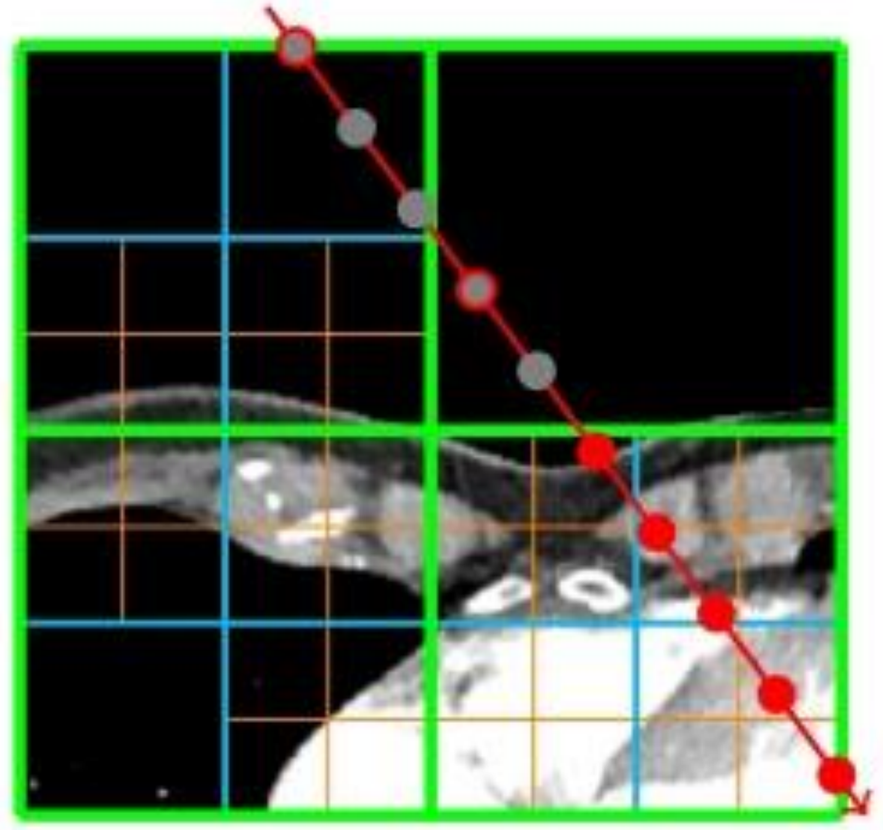






Direct Volume Rendering

- Optimizations:
  - Empty space skipping via octree increases performance



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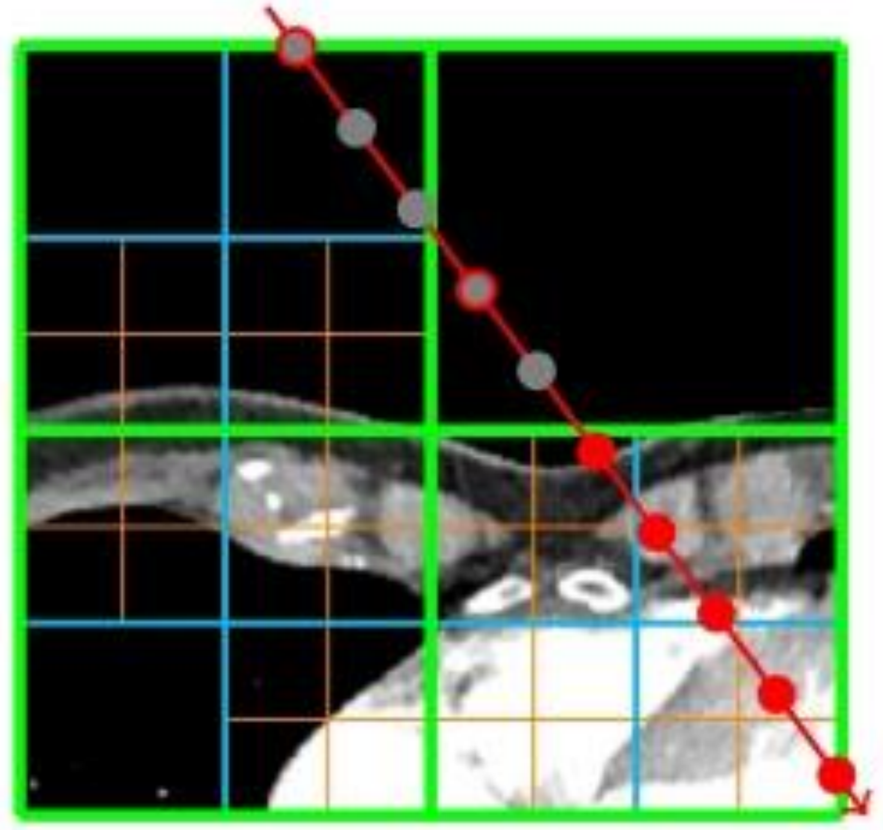

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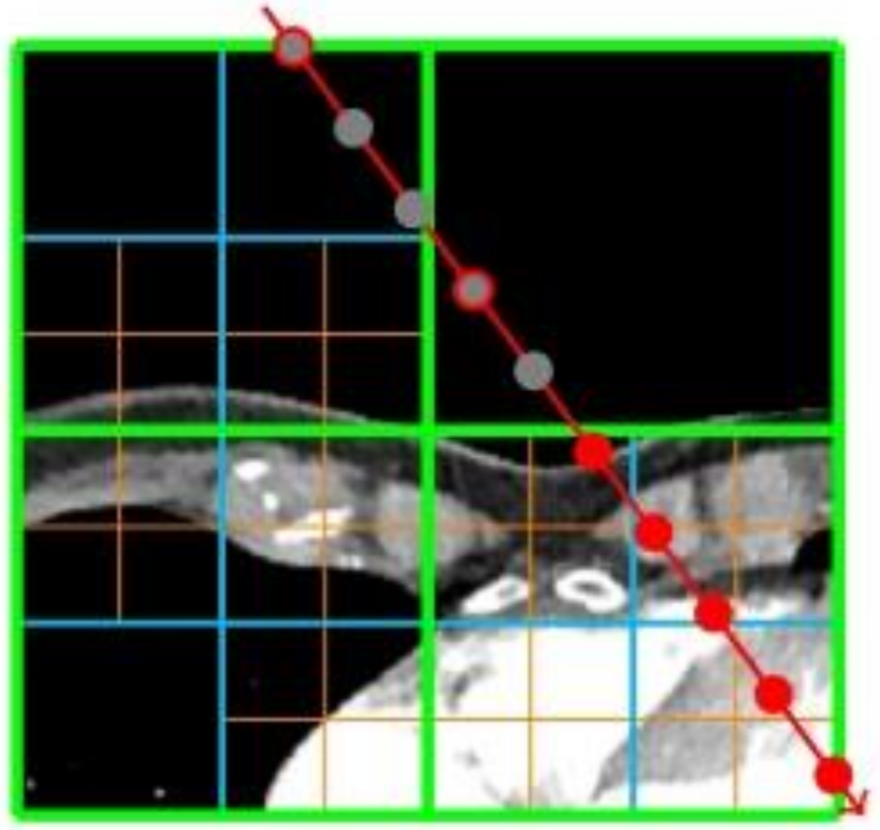

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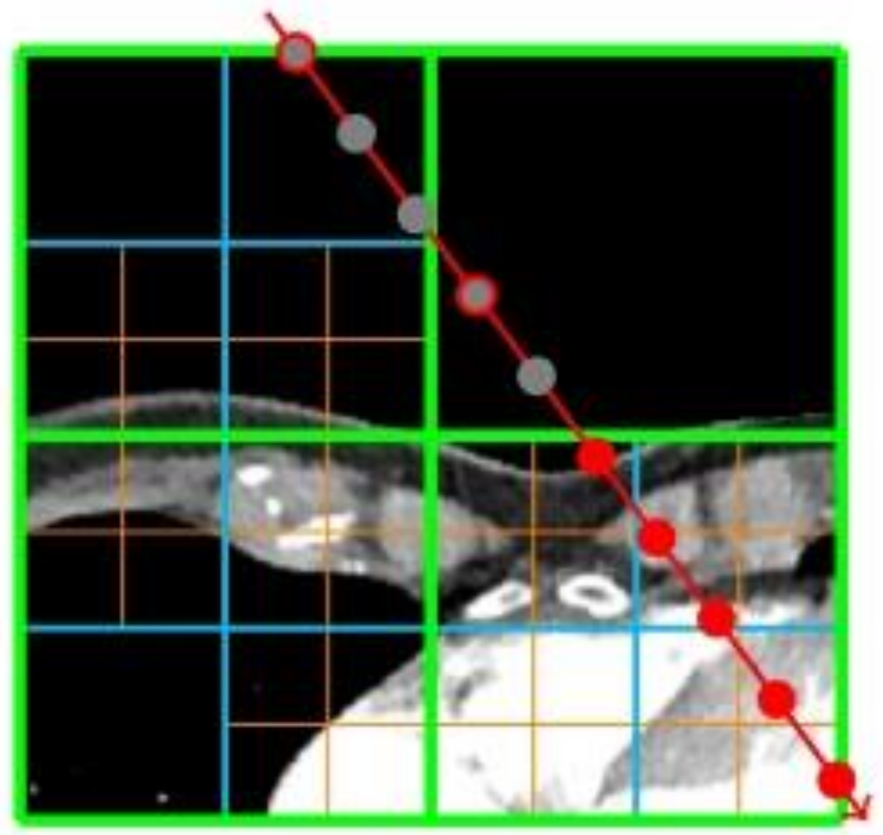

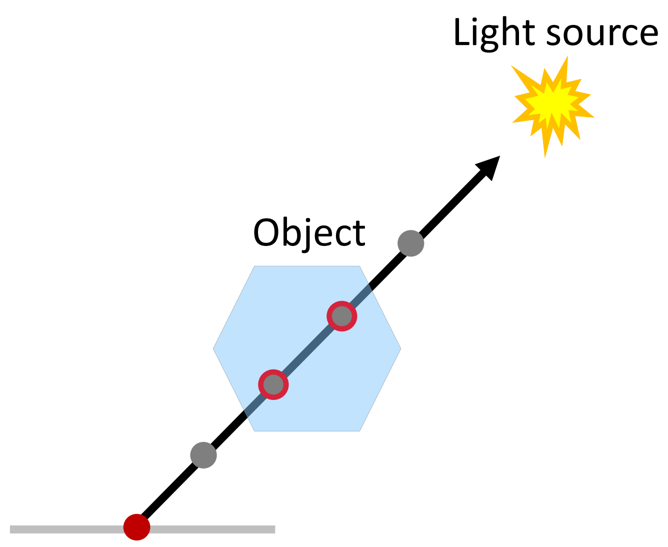

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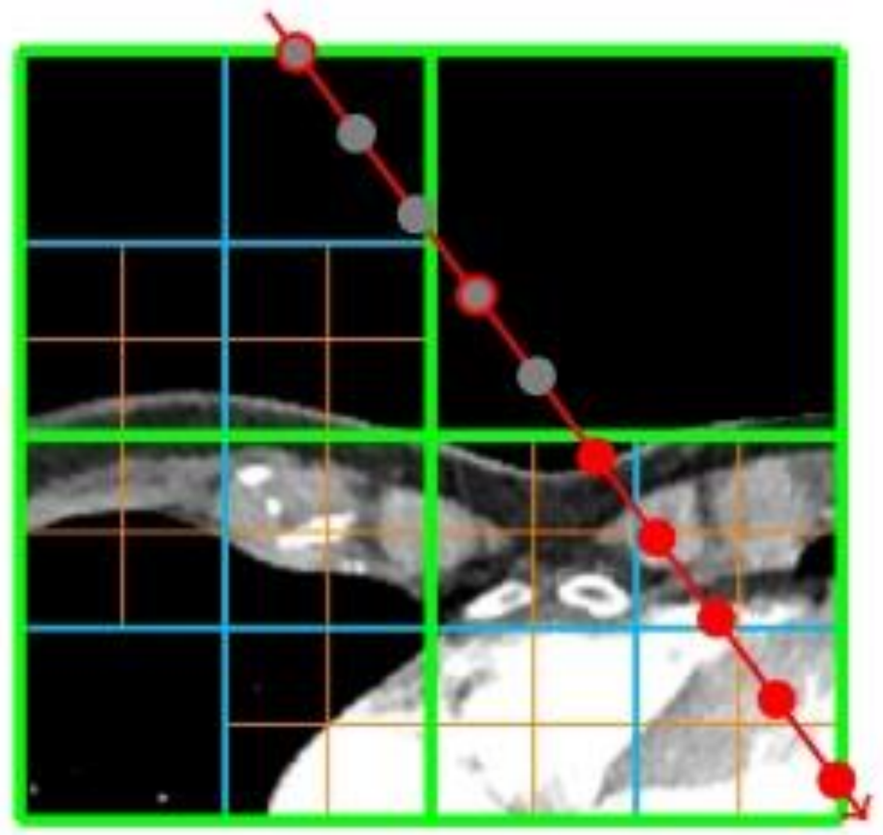

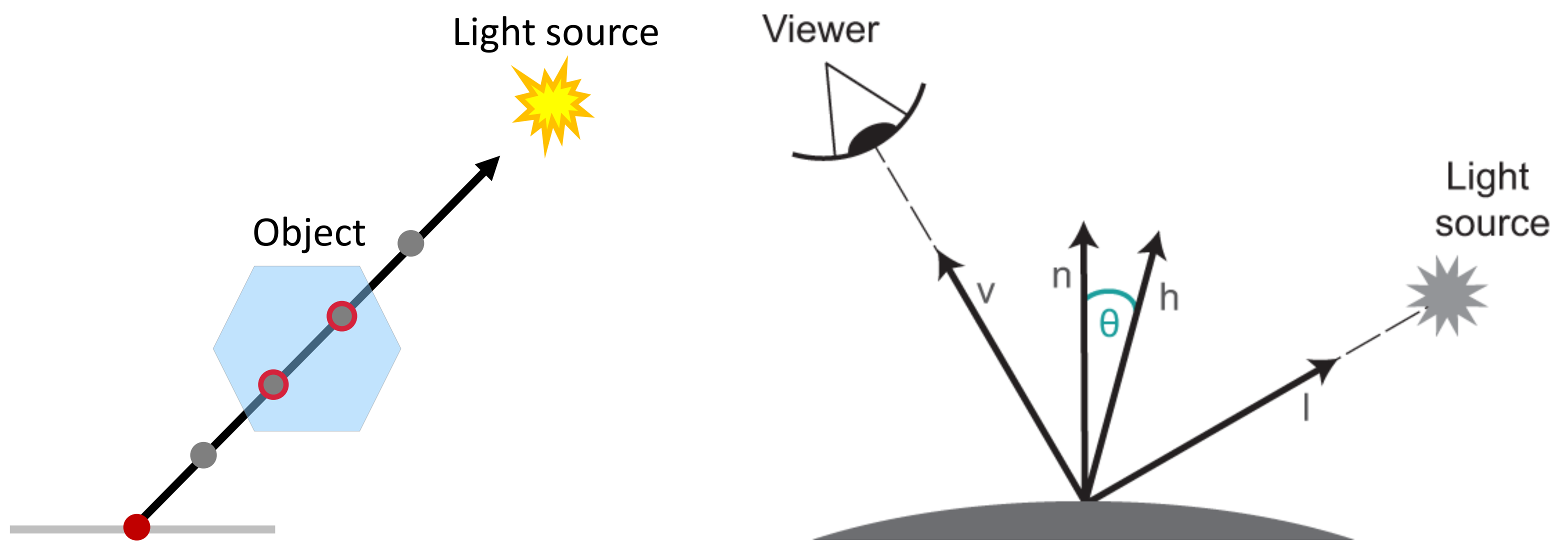

[3]

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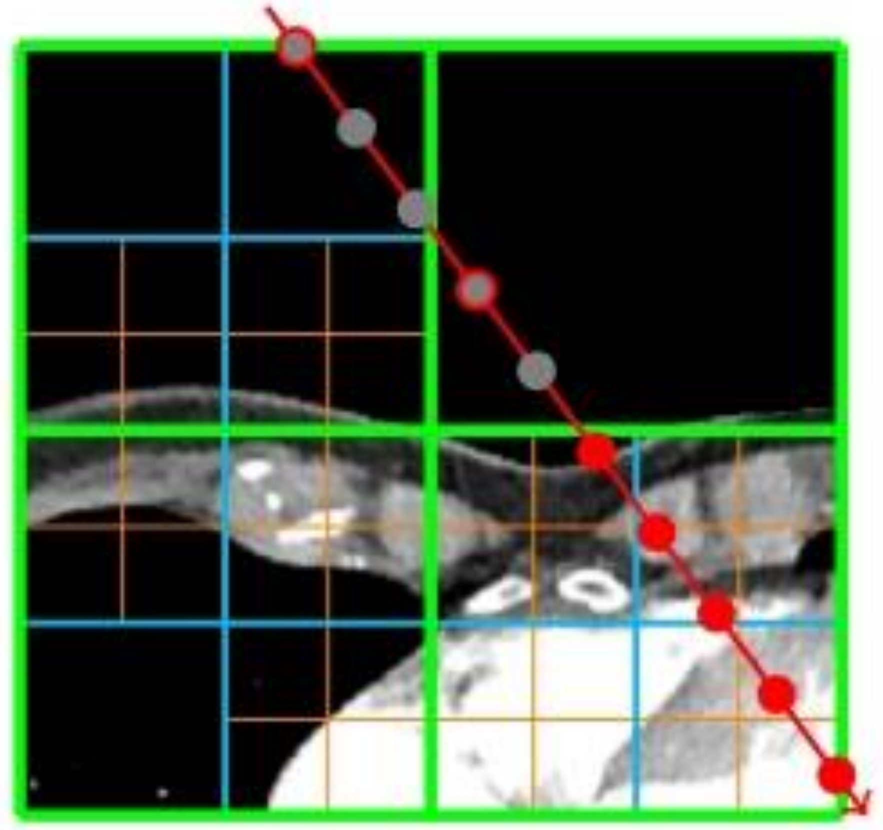
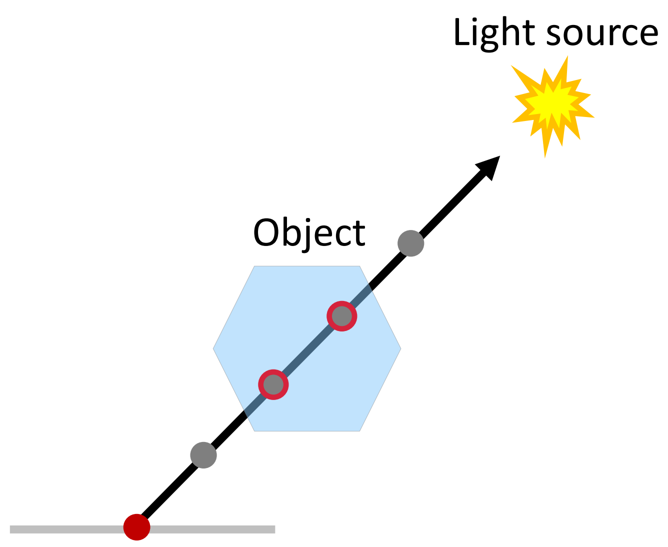
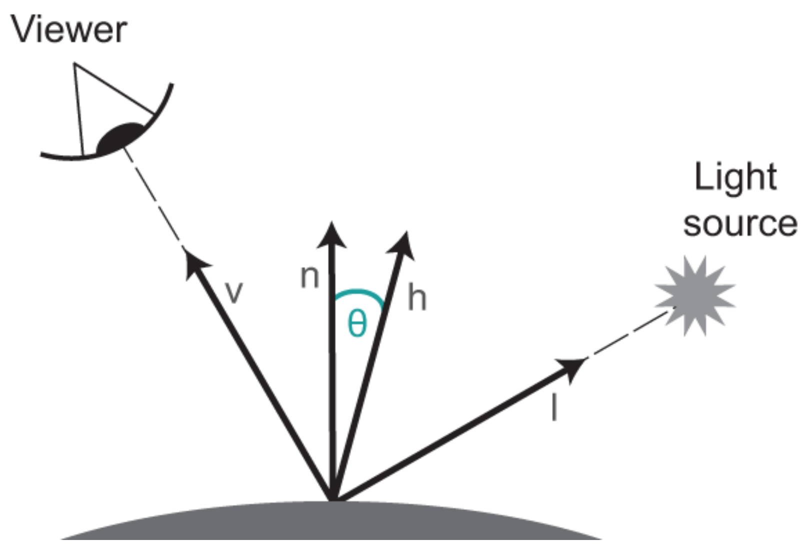


- Multiple local lighting techniques
  - Shadow rays
  - Blinn-Phong
  - Volumetric local ambient occlusion





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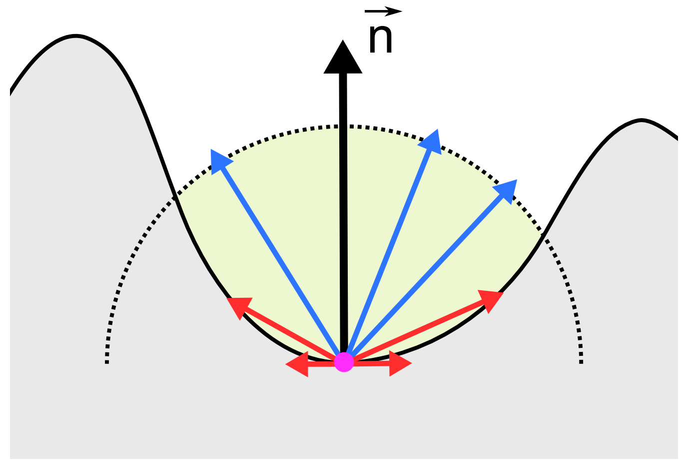
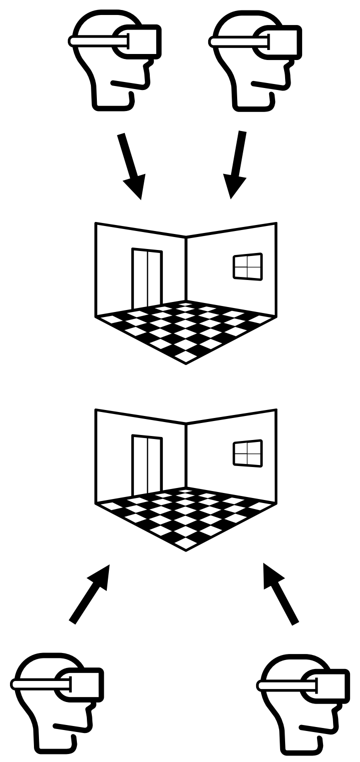


[4]

Collaborative VR

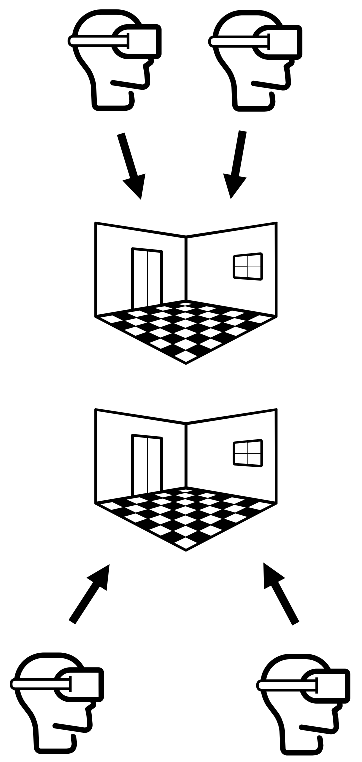
- Lobby system for multiple parallel rooms



[5]

Collaborative VR

- Lobby system for multiple parallel rooms
- Immersive shared environment
  - High quality virtual OP



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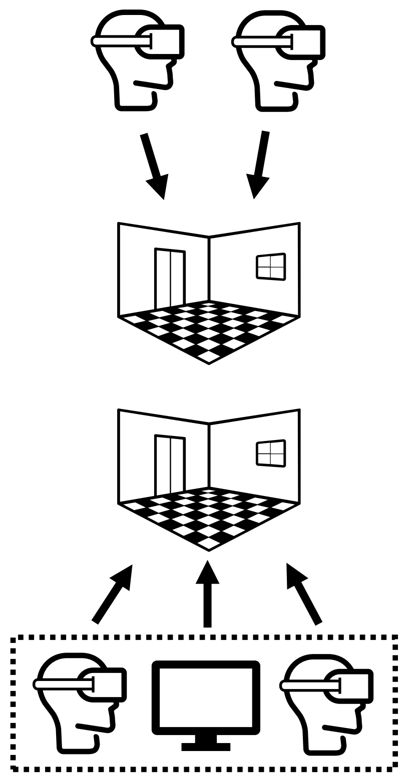

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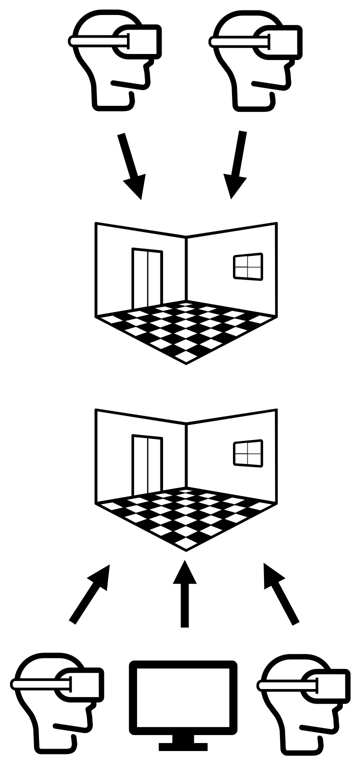

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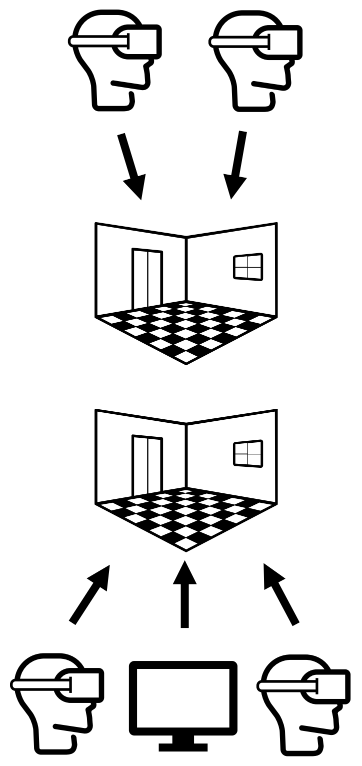

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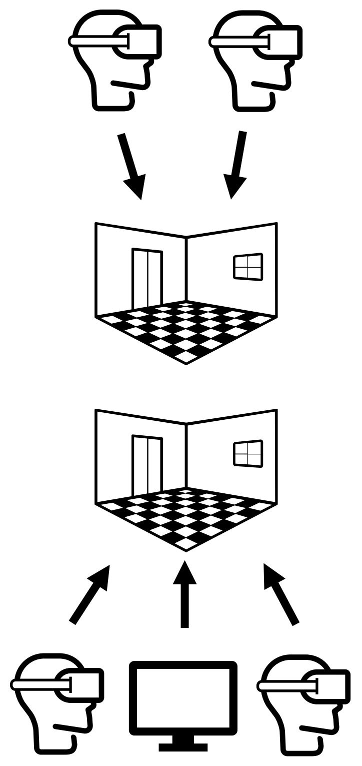
- Locomotion via teleport + room-scale
  - Visual teleportation effect reduces confusion



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  - Motion controller/mouse + keyboard

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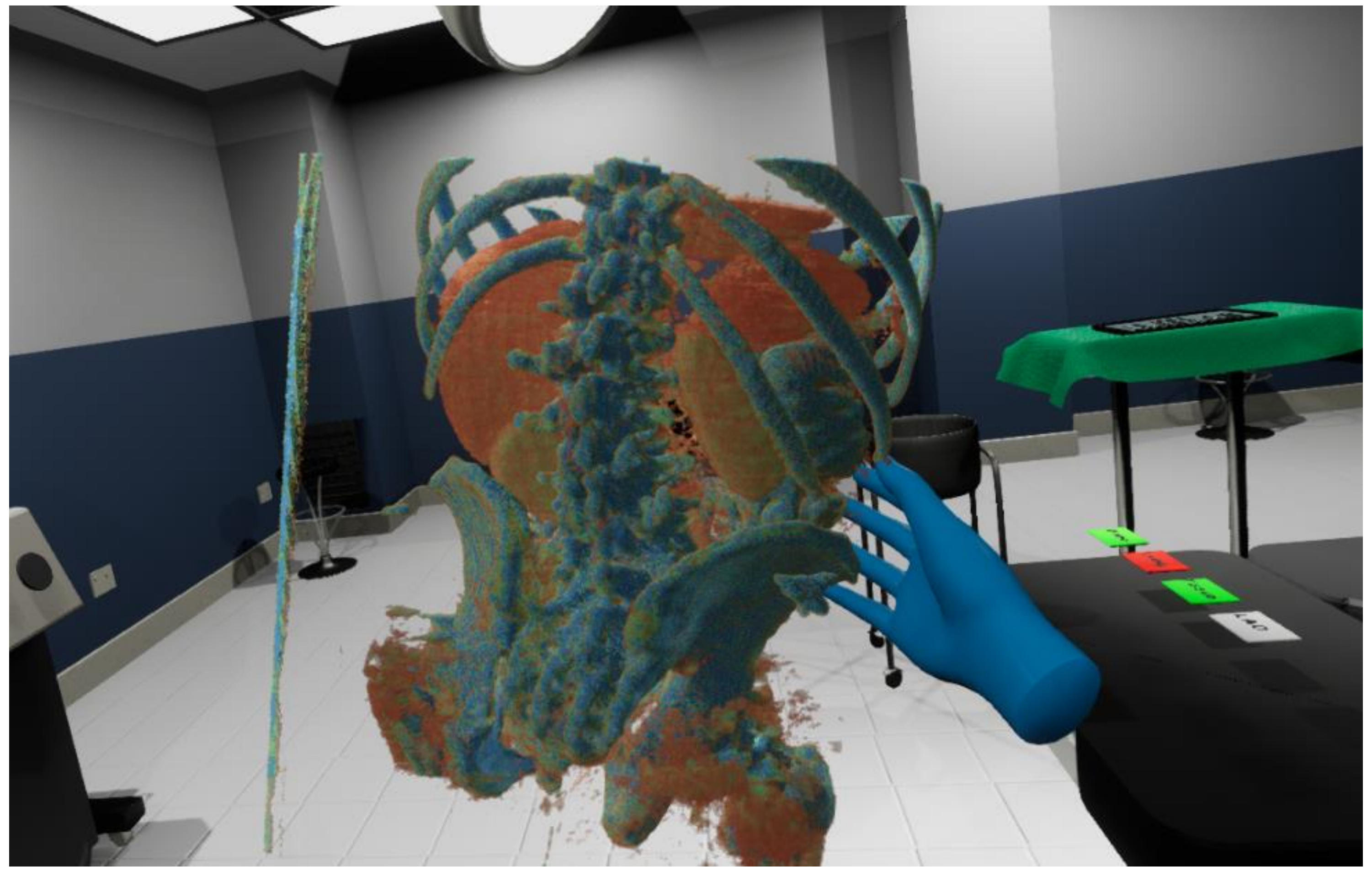

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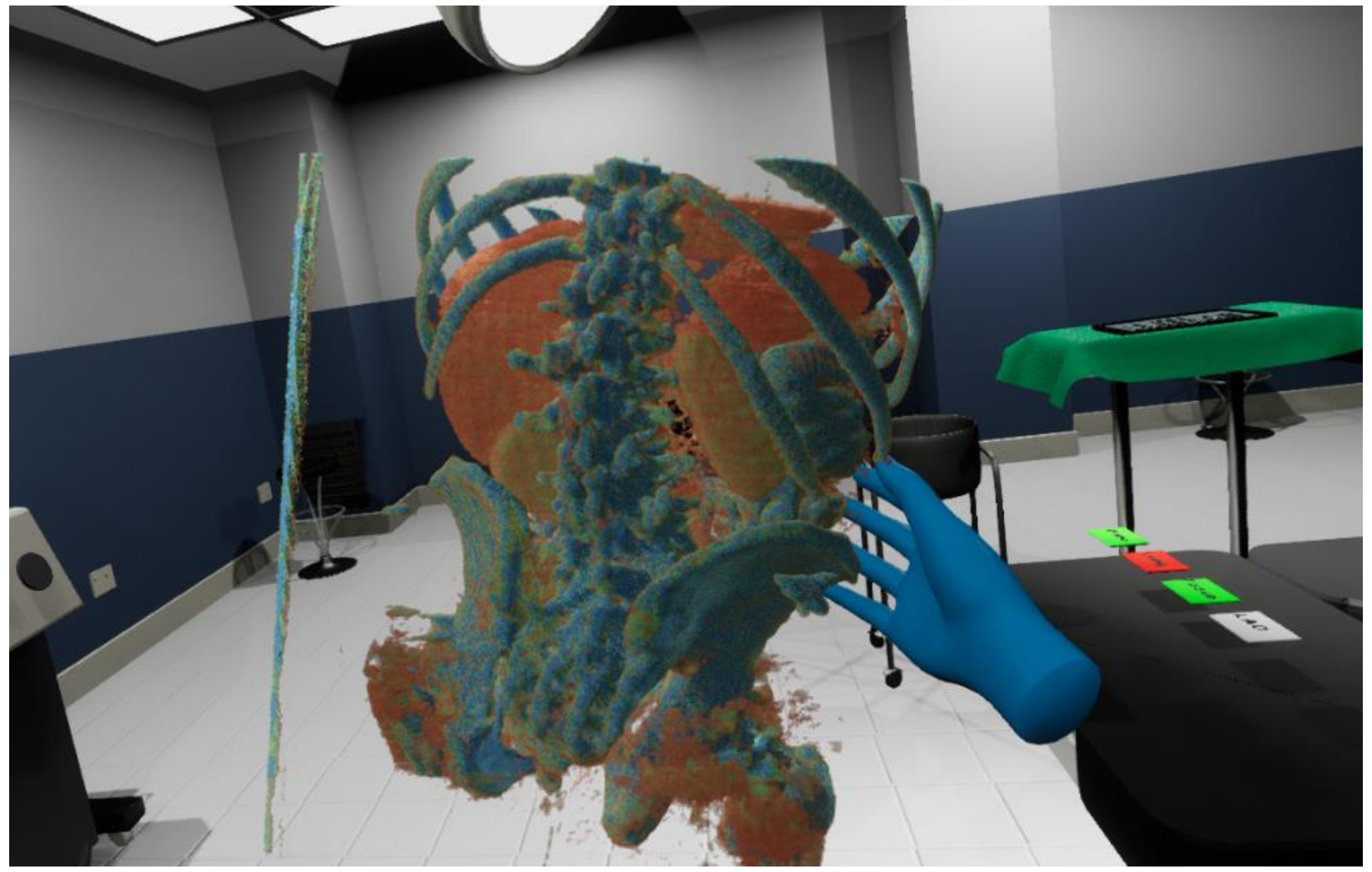
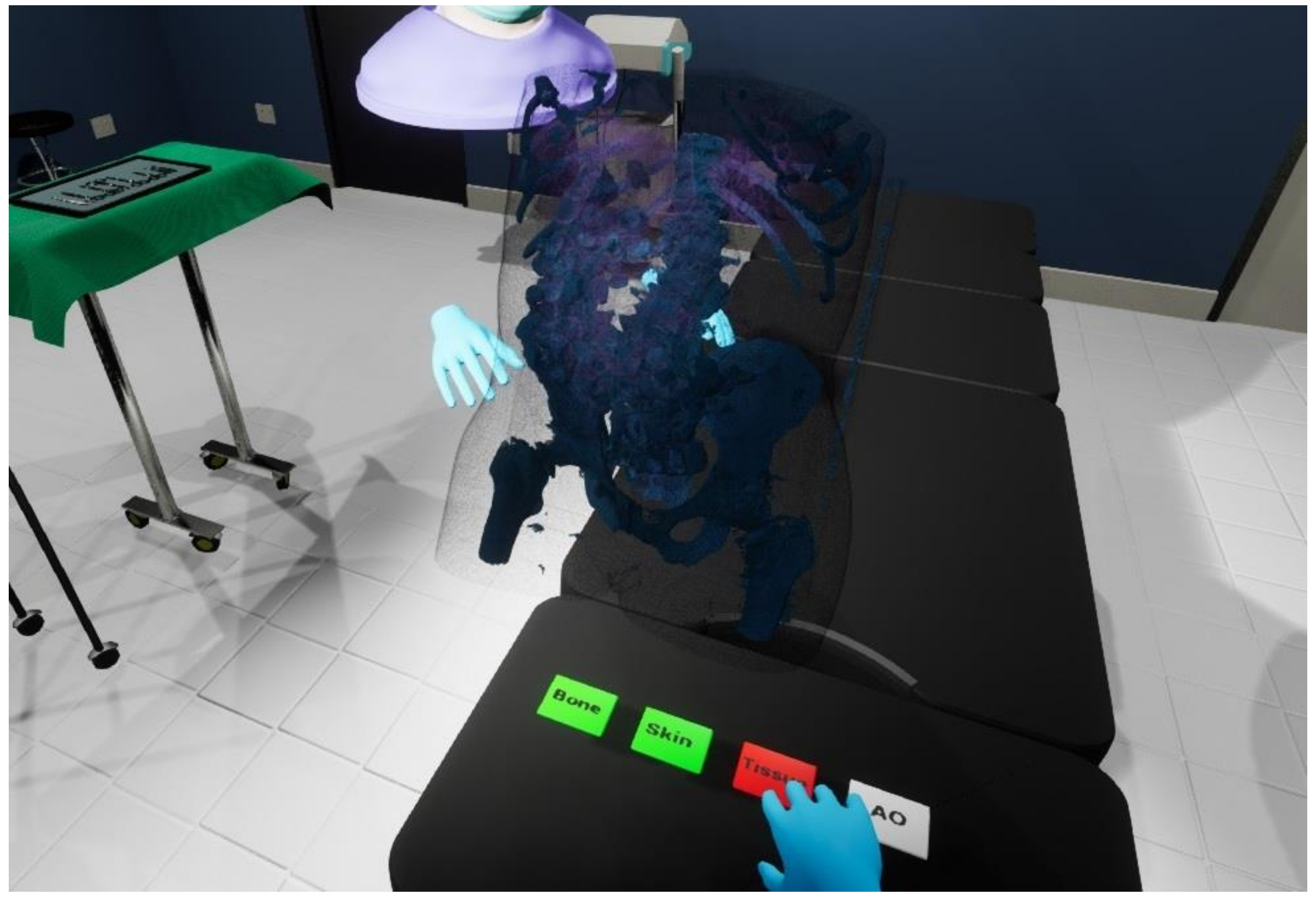
- Dynamic switching of lighting modes and selected transfer functions





Interaction

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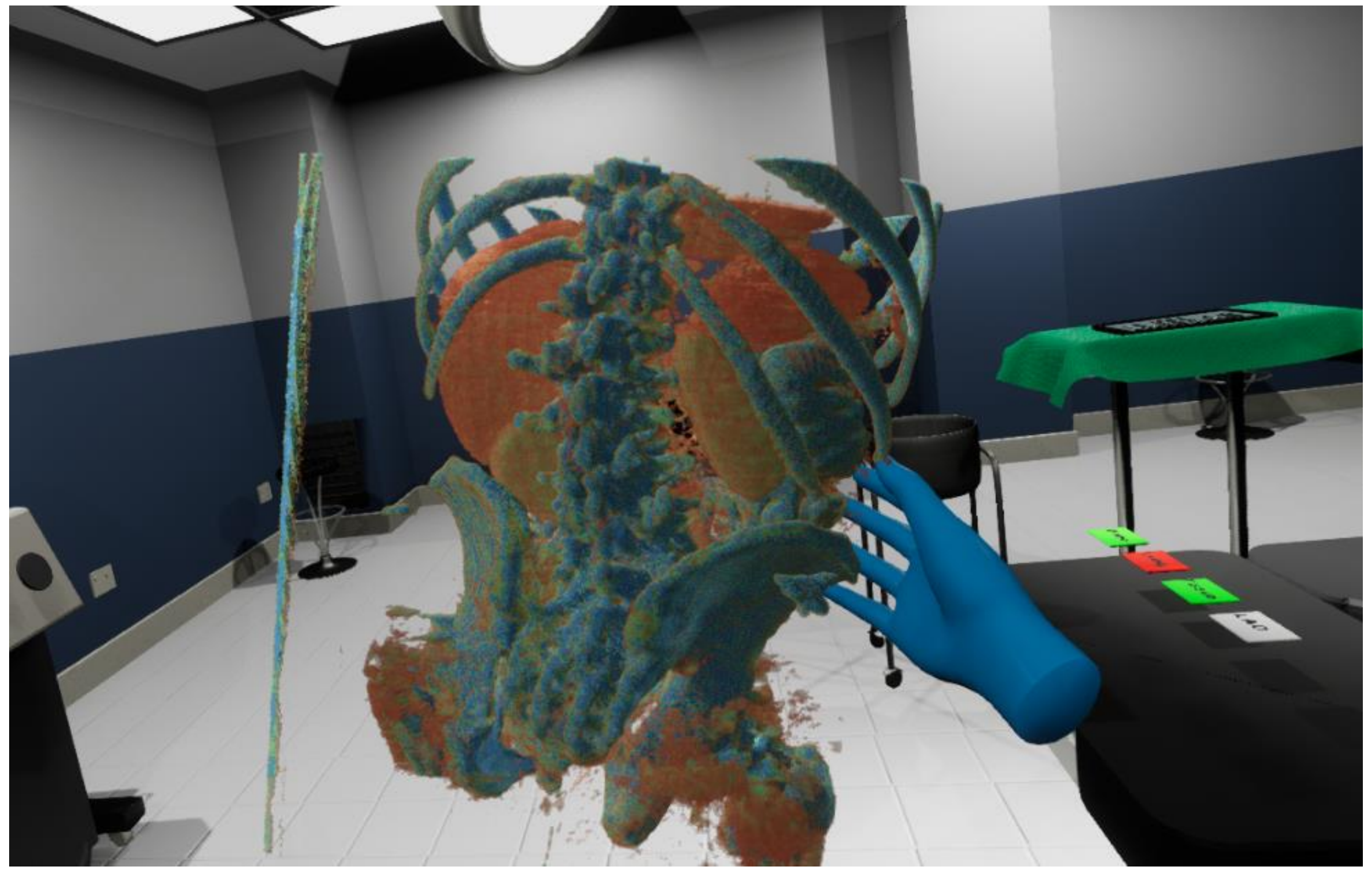
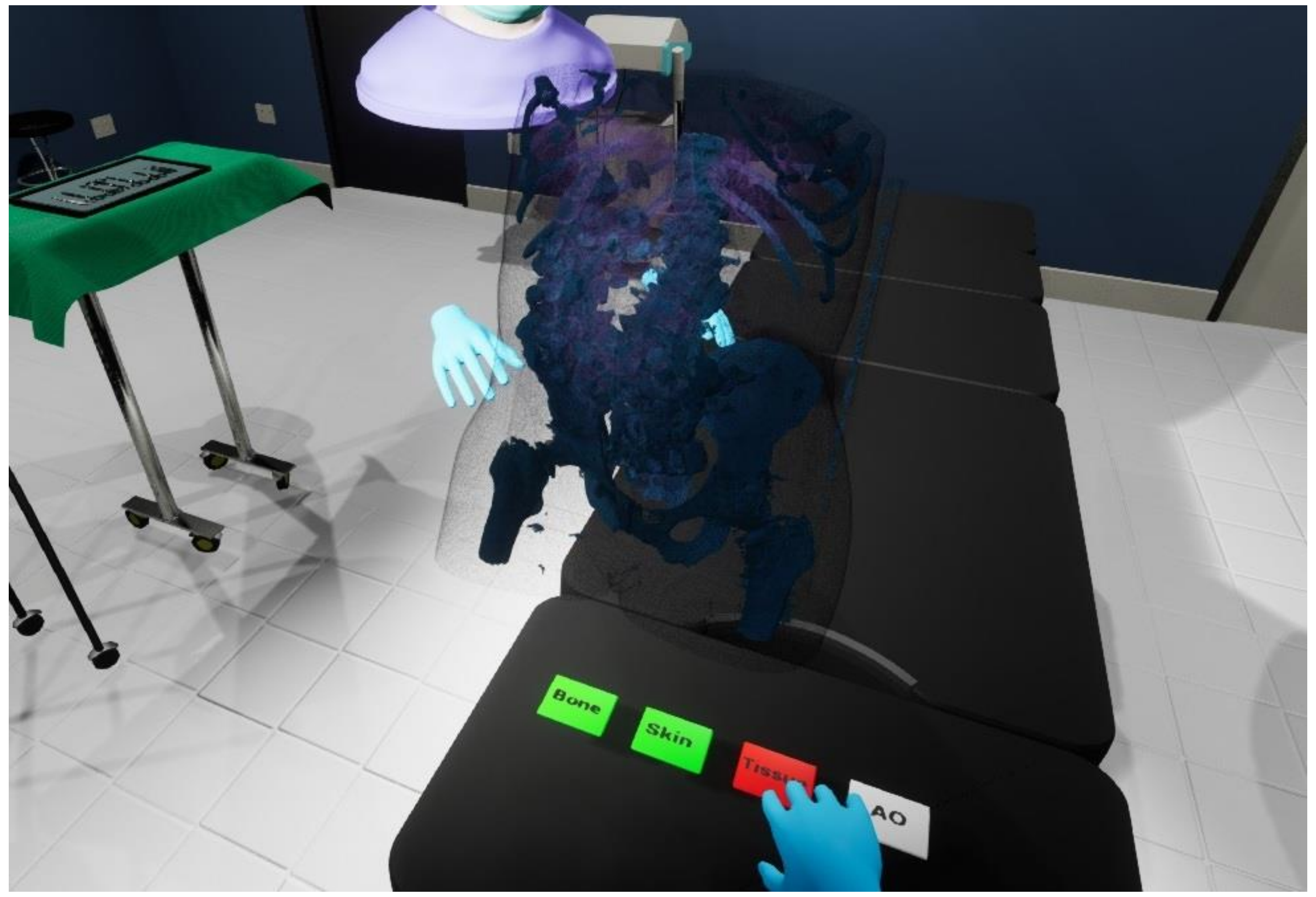
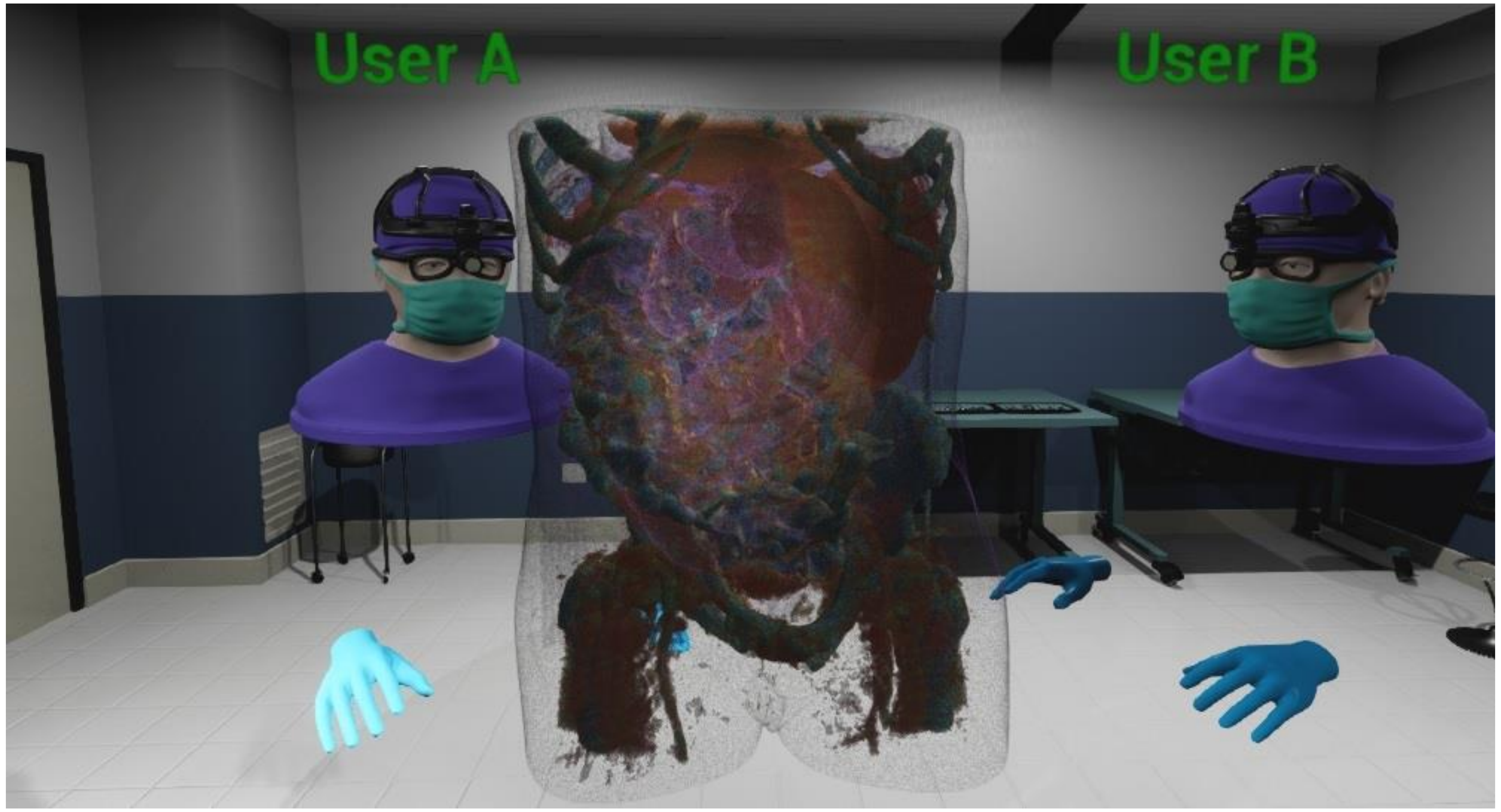
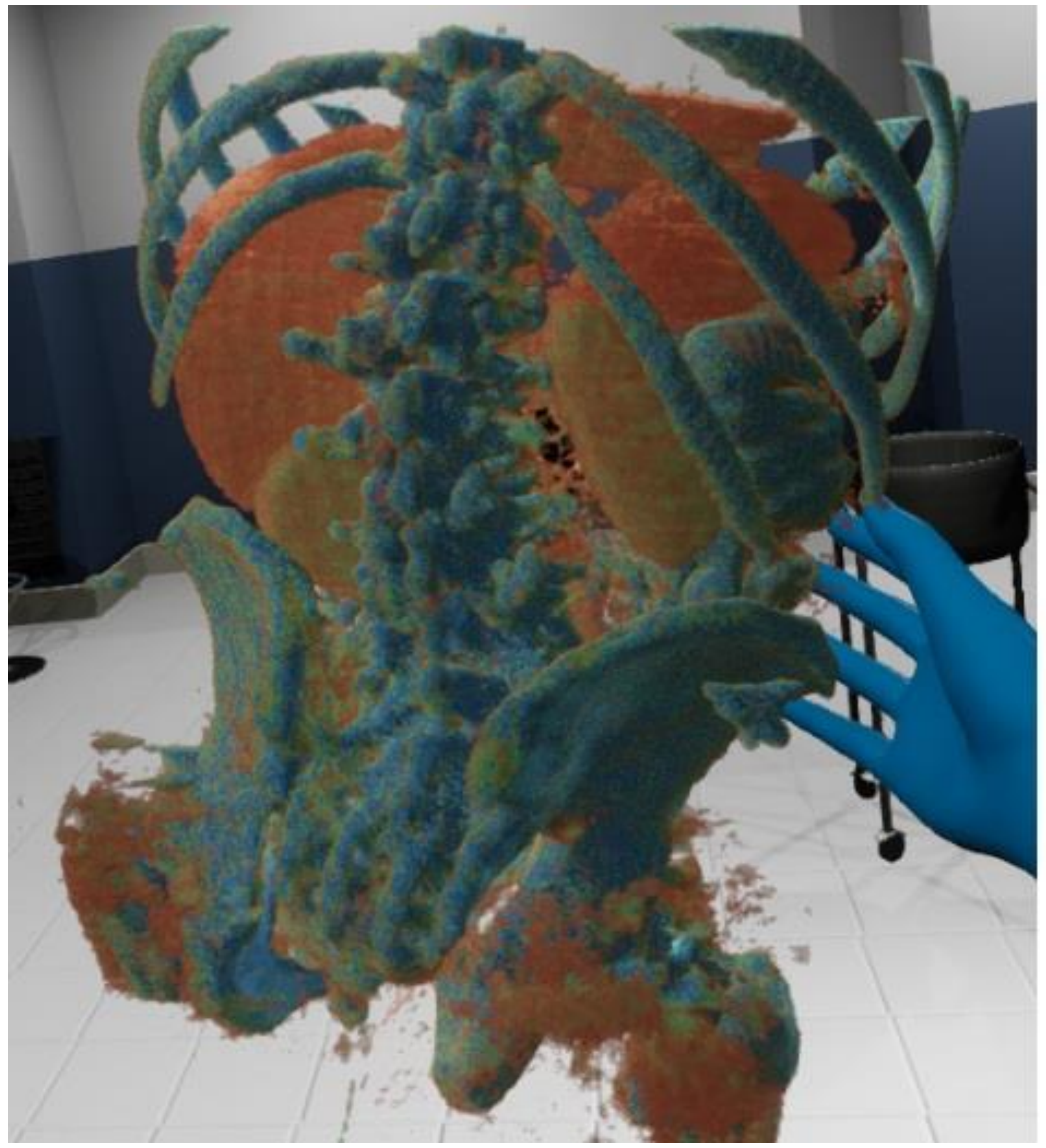
- Shared 3D CT visualization
    - Grab, rotate, move
- Dynamic switching of lighting modes and selected transfer functions
- 2D CT images on virtual monitor

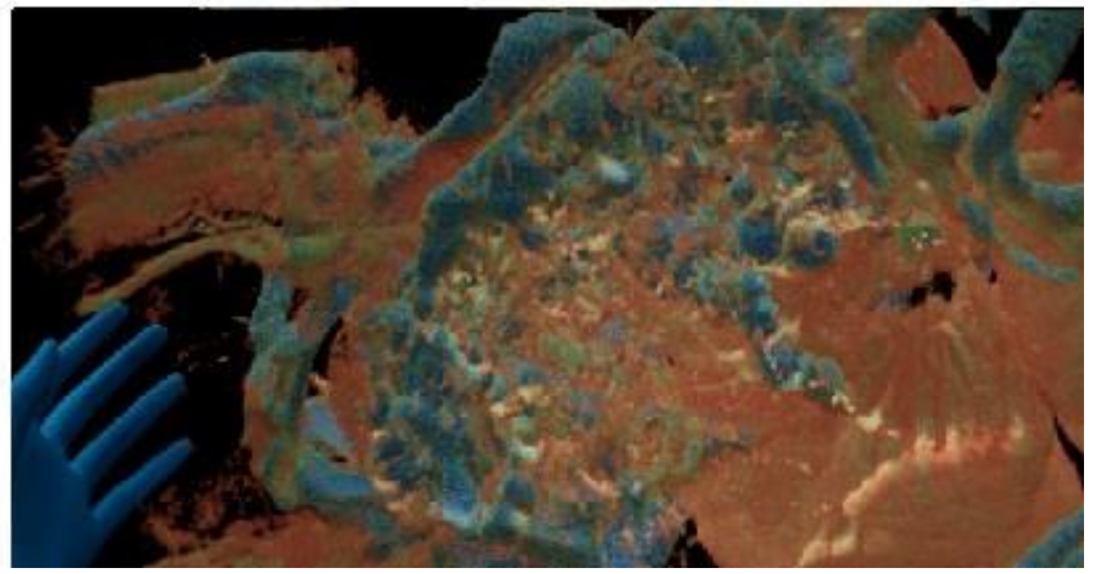




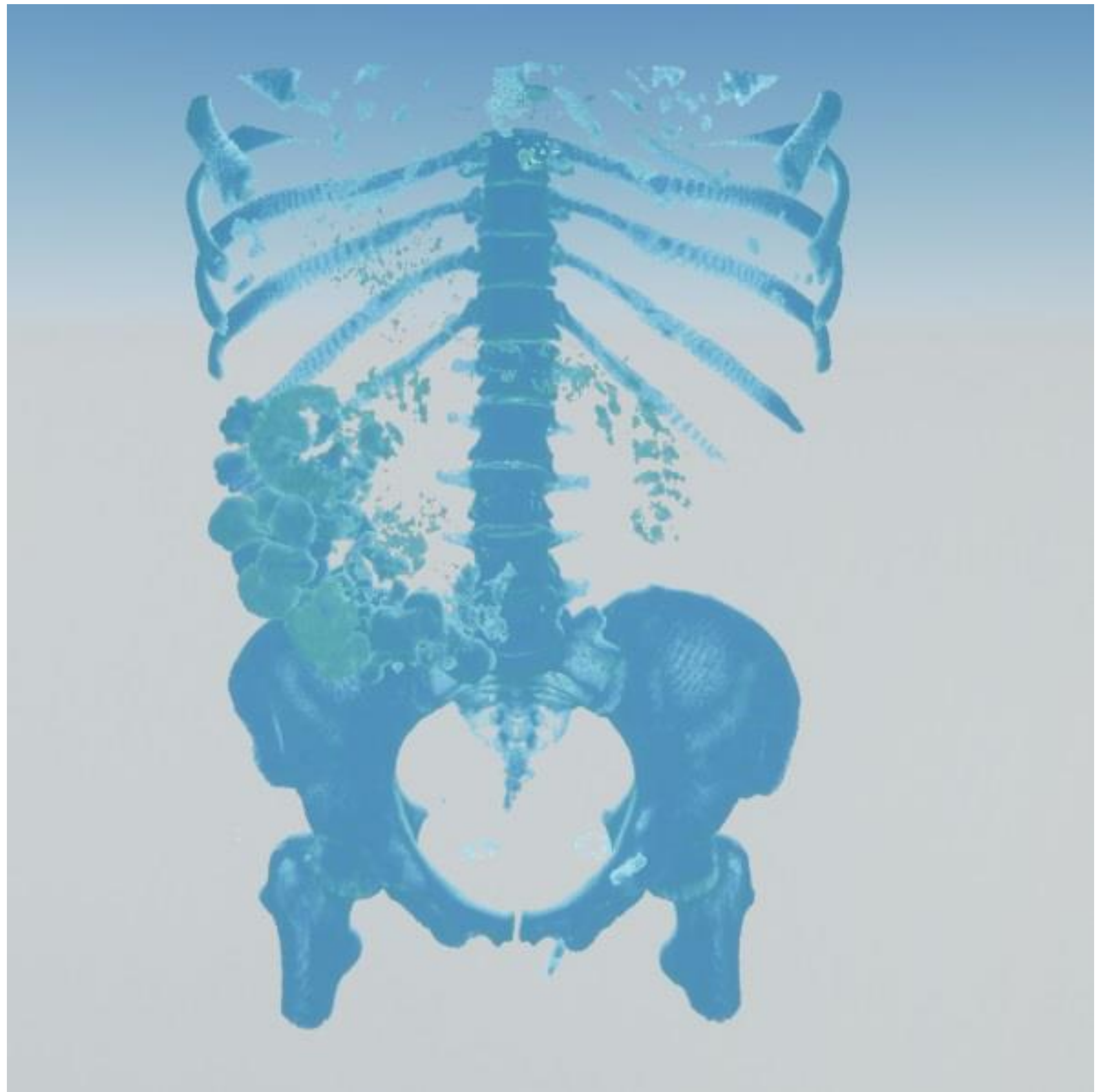
Results: VR Environment with 3D Visualization



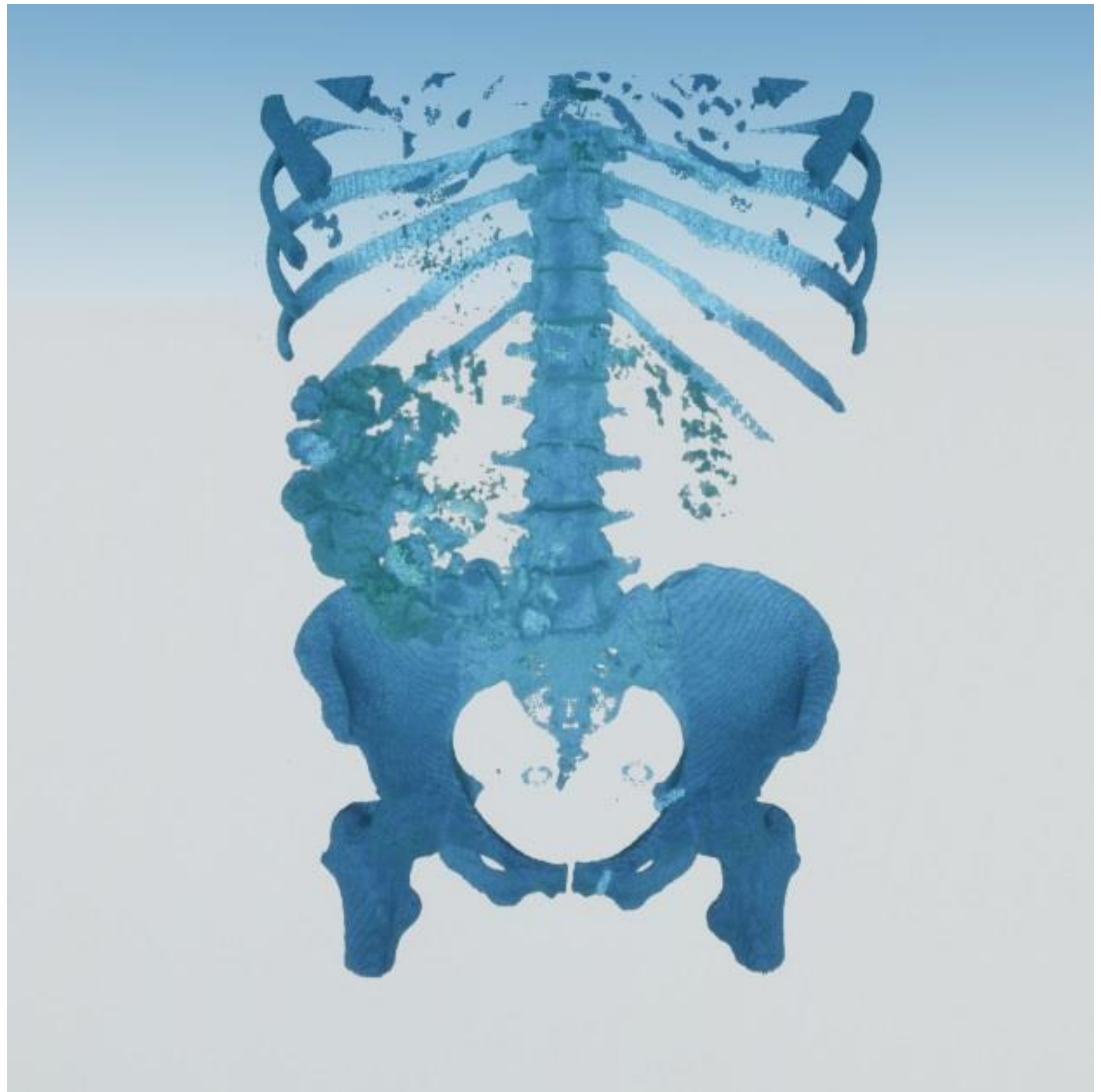




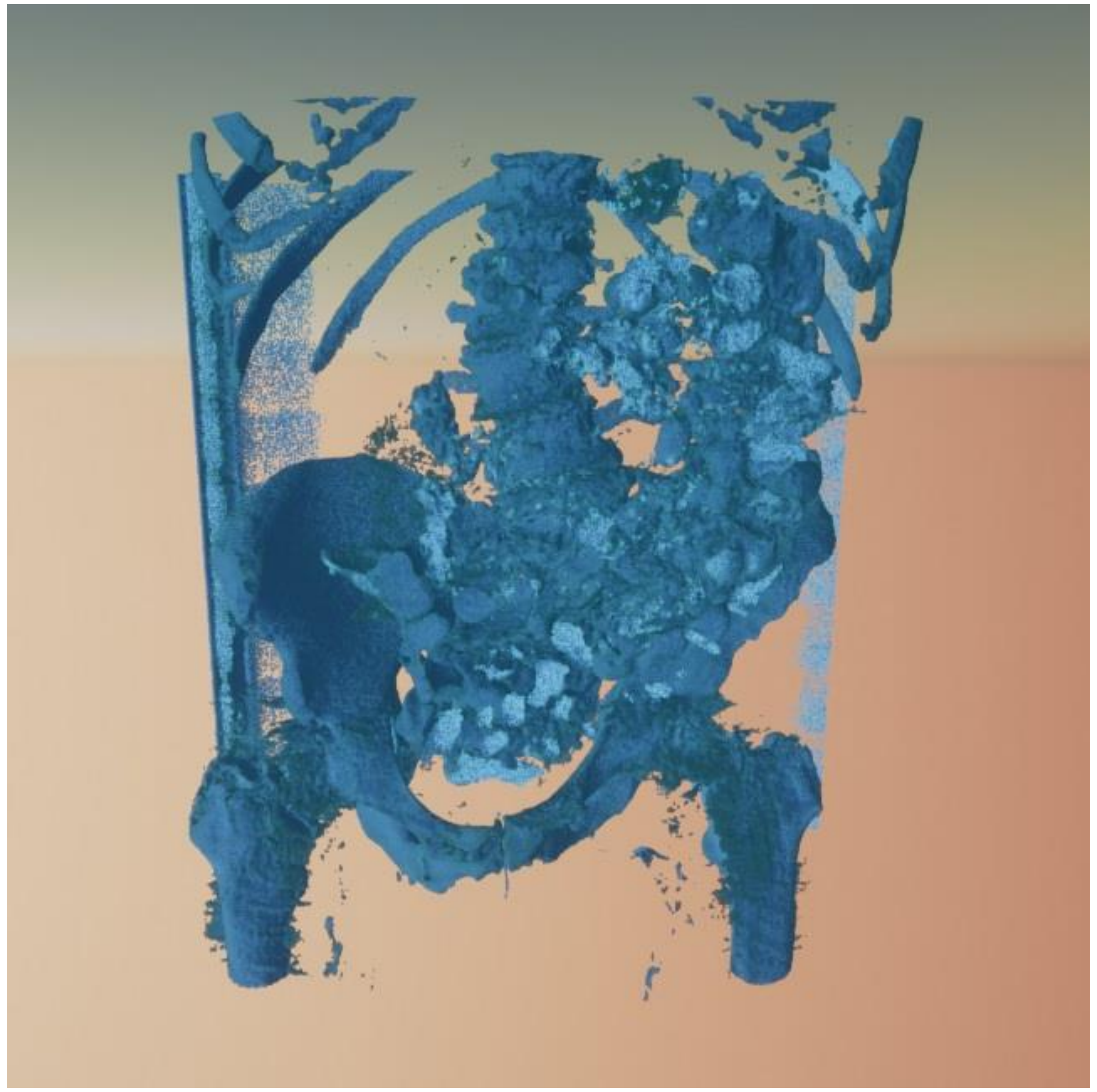
Results: DVR Lighting Techniques


Shadow rays

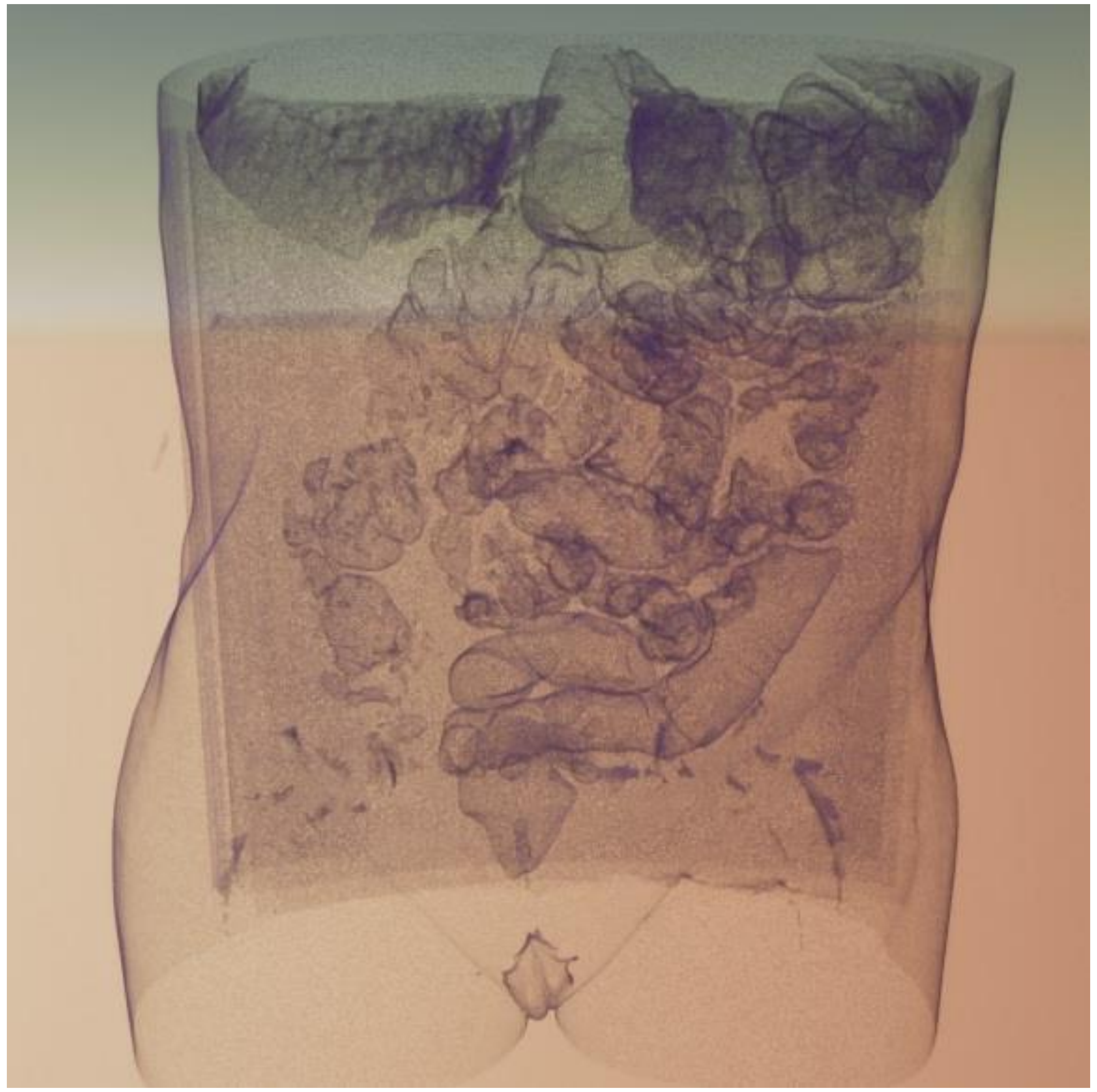

Blinn-Phong


Local ambient occlusion

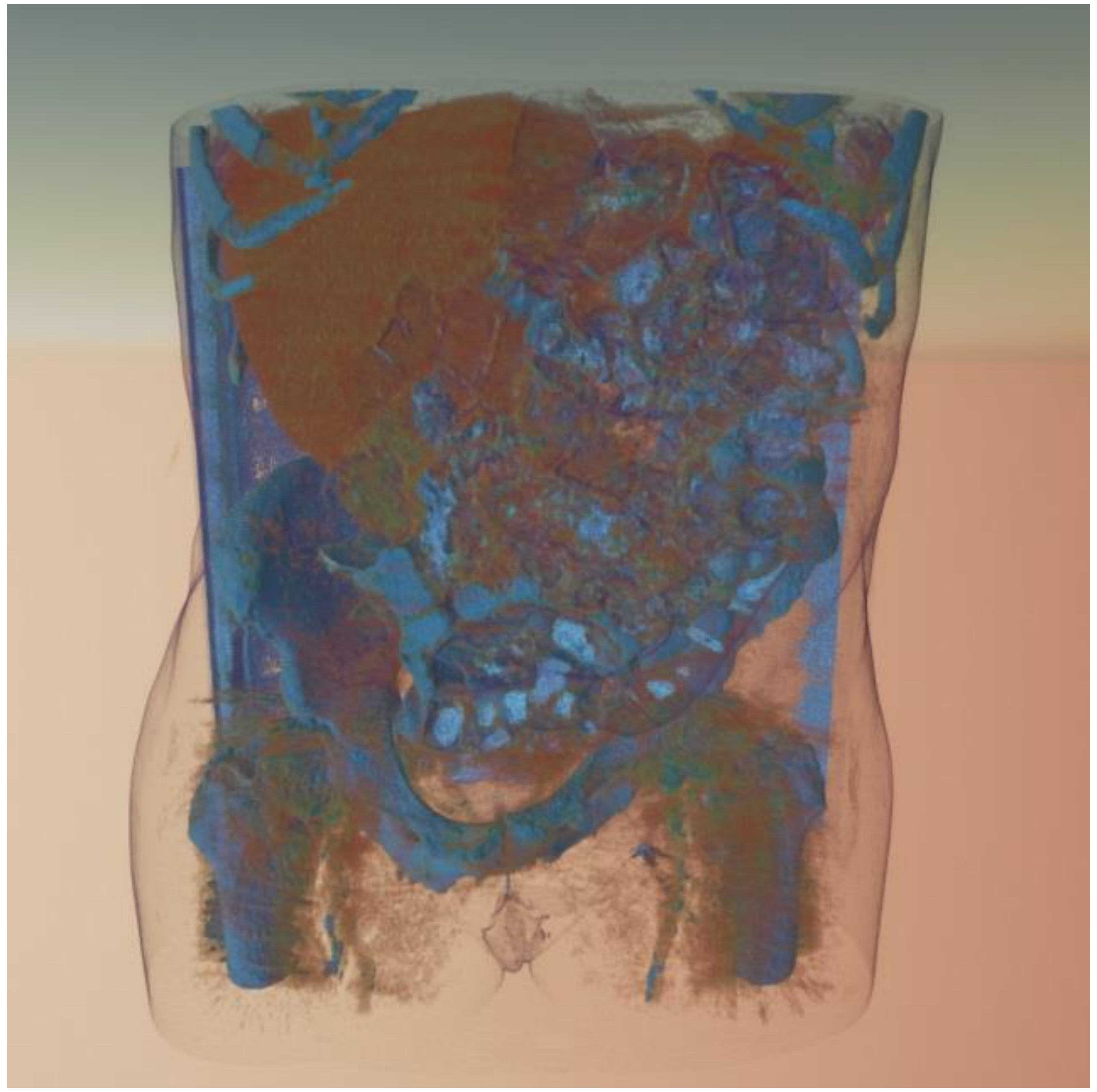
Results: DVR Transfer Functions



Bone

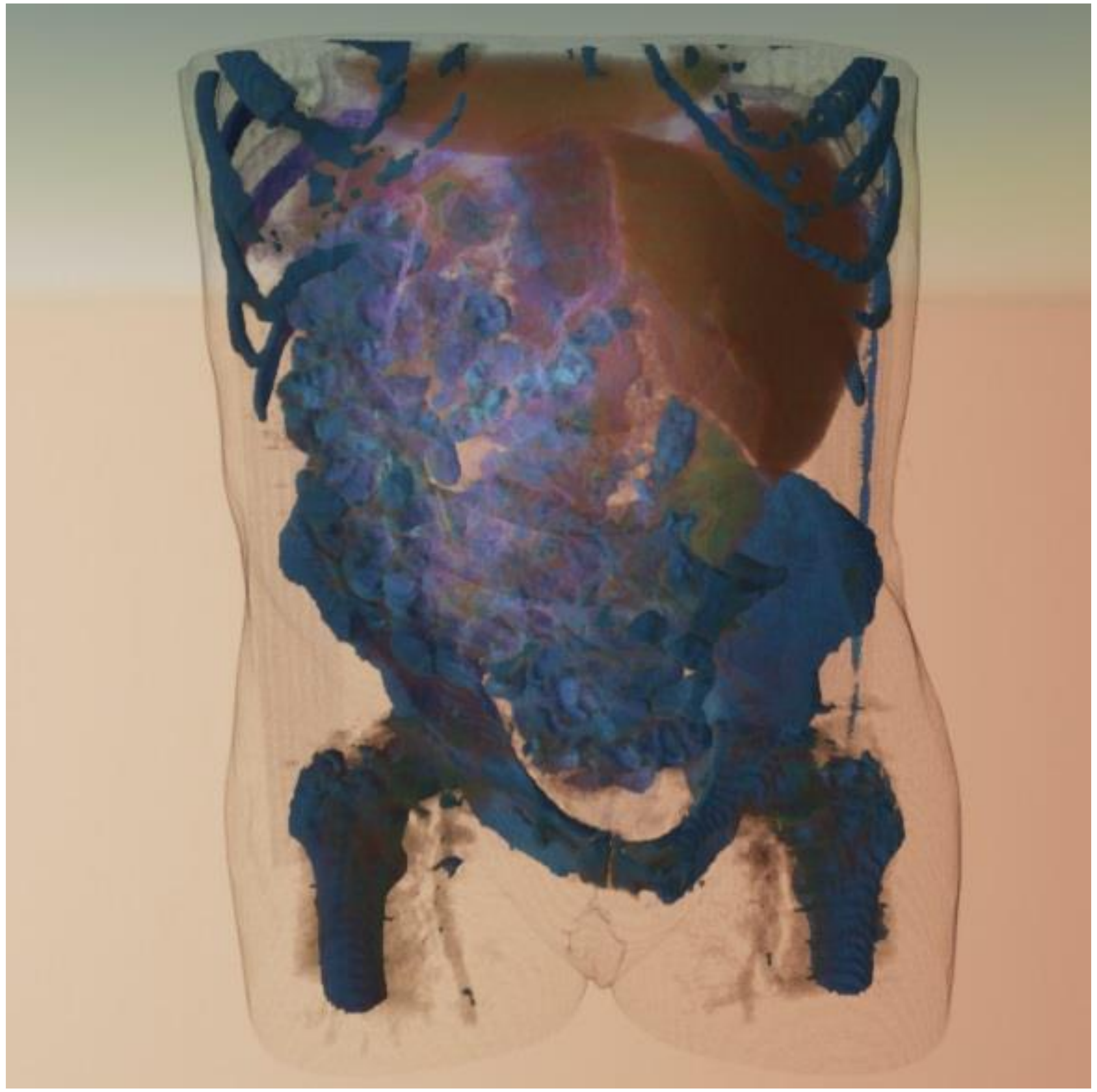


Bowel and skin

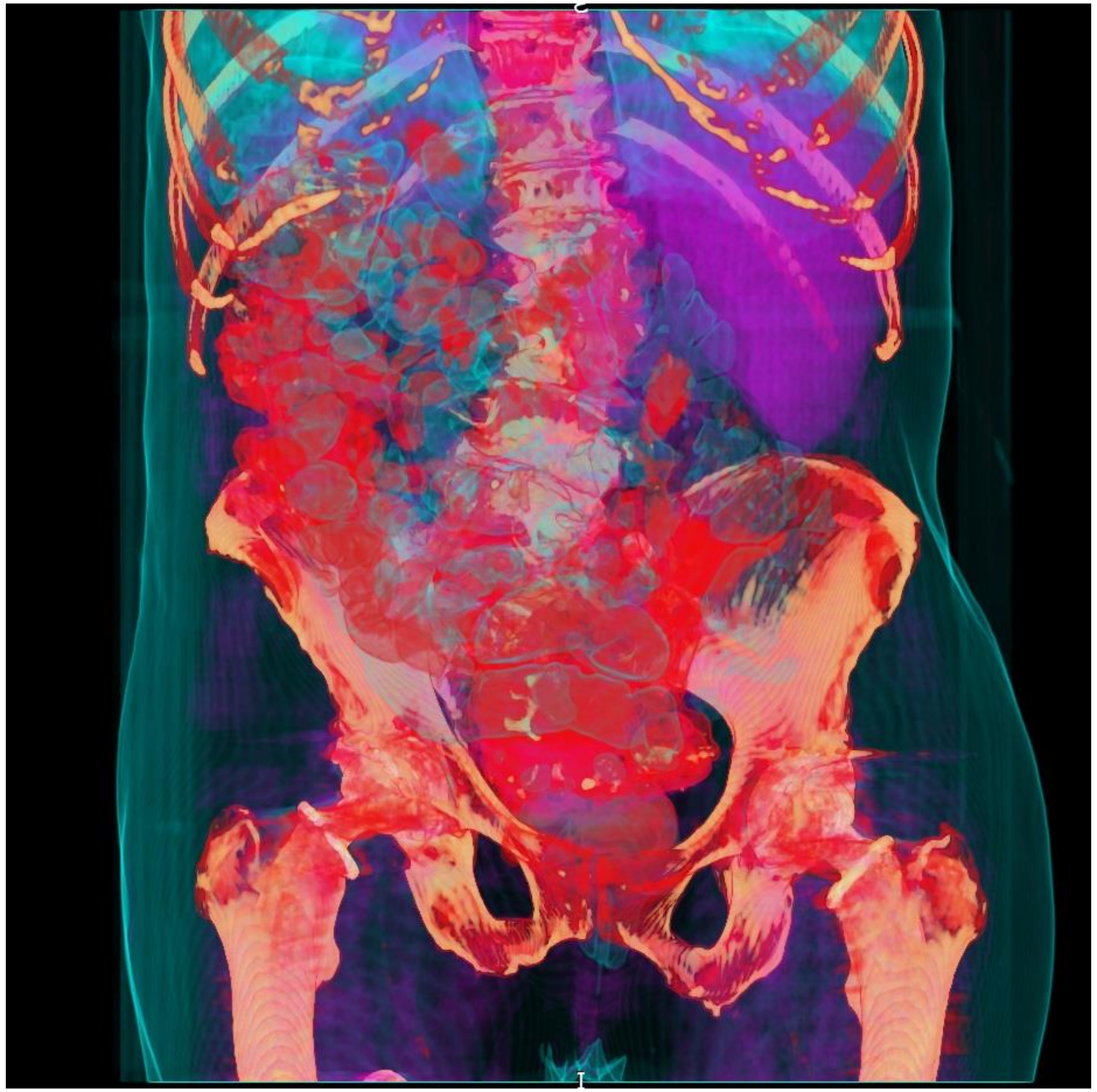


Soft tissue + bone + bowel and skin

Results: Visualization Comparison

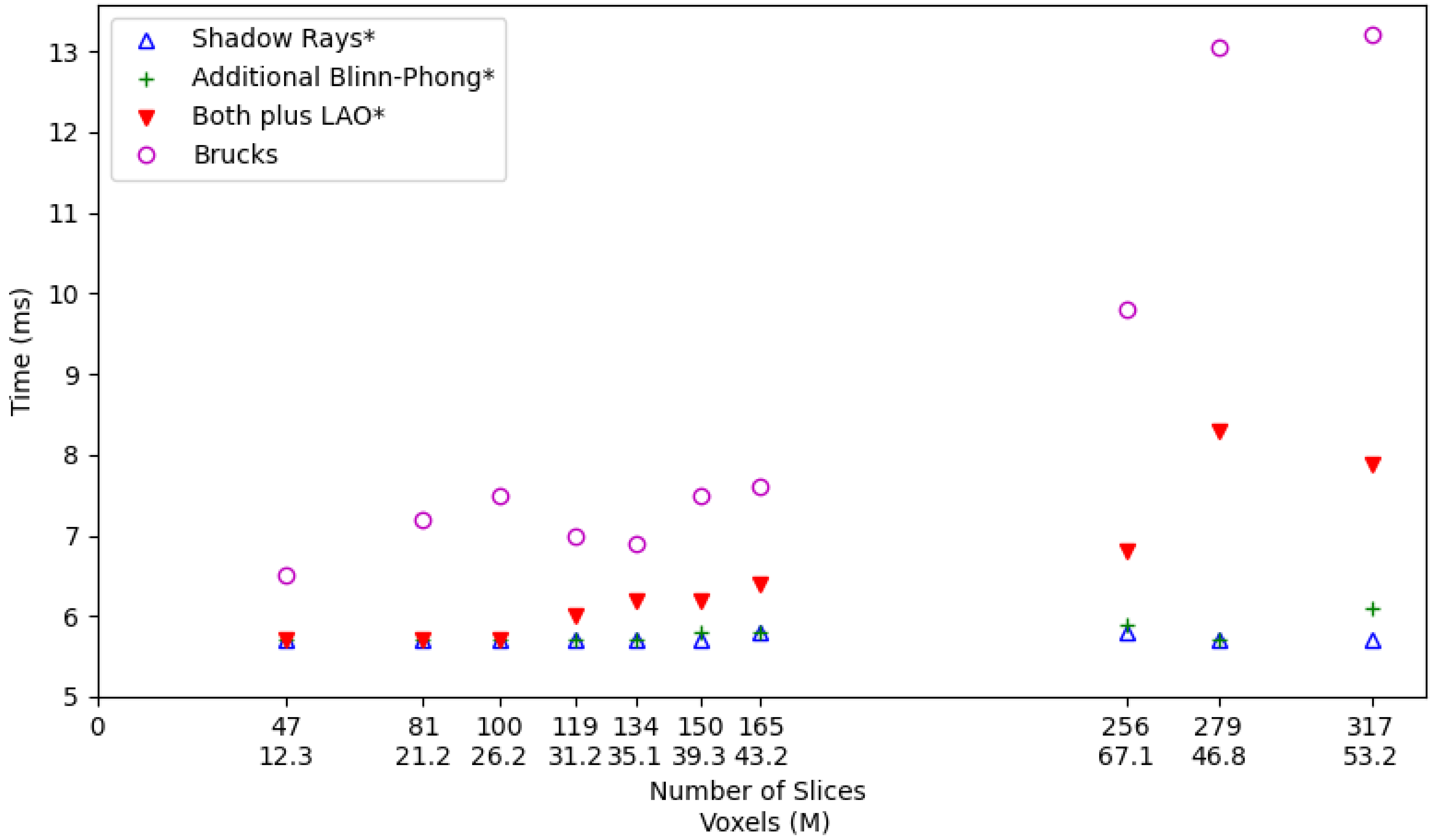


Ours



RadiAnt DVR

Results: Performance



System Specification

Item	Details
Screen Resolution	1920x1080
CPU	Intel Core i7 4790
GPU	Nvidia Titan V
RAM	32 GB
OS	Windows 10
Engine	Unreal Engine 4.22

Conclusion

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- Custom direct volume renderer for Unreal Engine 4
  - High visual quality
  - Real-time performance, > 100 Hz with 317 slices
- Immersive shared 3D environment with interactive volume CT data
- Well suited for collaborative planning and assessment in VR, according to preliminary user feedback

Future Work

- Include dynamic clipping planes

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- Enable dynamic adjustment of transfer functions
- Conduct formal user study

Thank you

Questions?

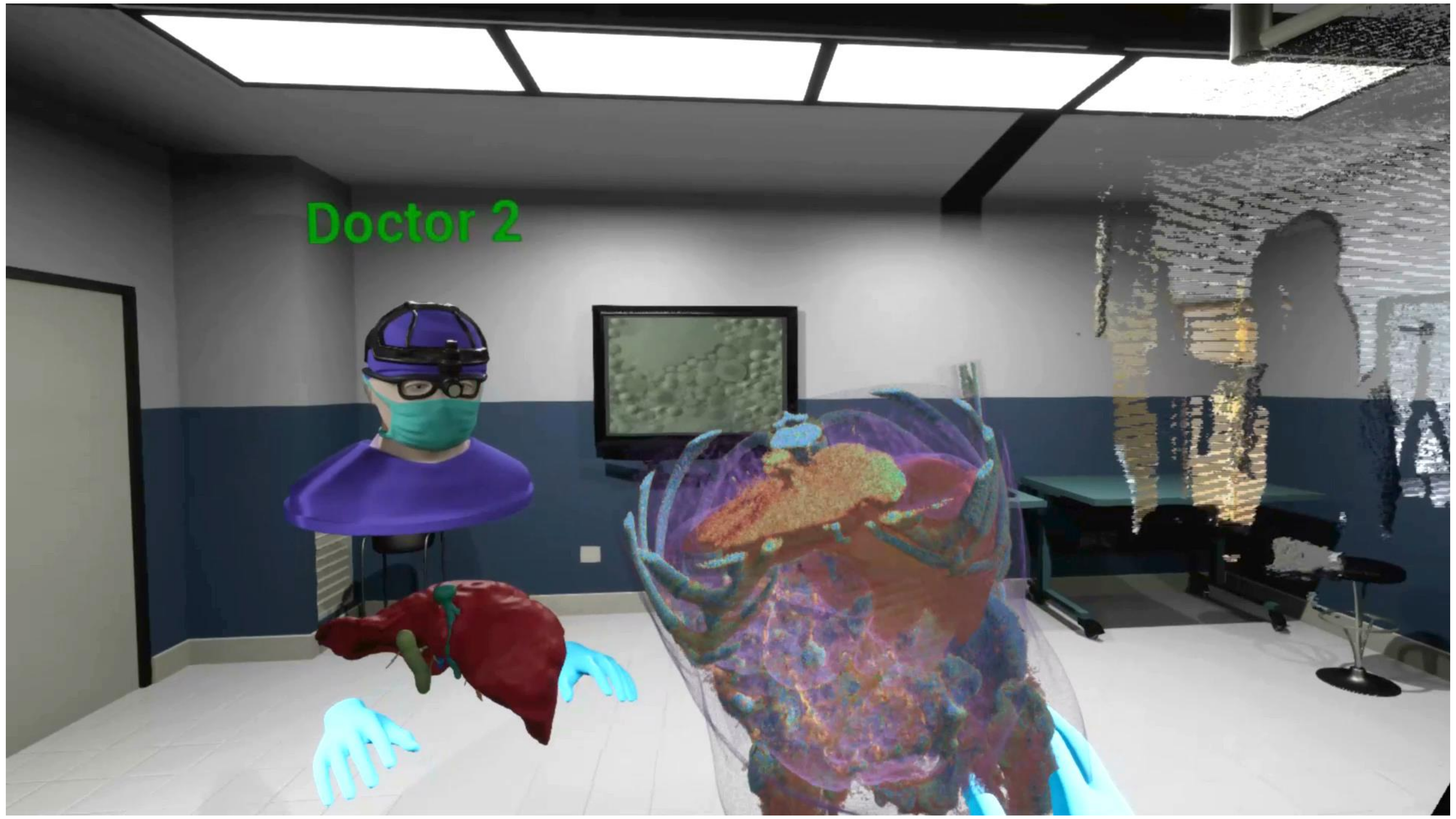

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Image References

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2. Bartz and Preim; 2011; Visualization of Segmented Anatomical Structures

3. Geert Ariën (https://www.geertarien.com/blog/2017/08/30/blinn-phong-shading-using-webgl/)

4. Florian Cassayre (https://cg.cassayre.me/2019/05/09/ambient-occlusion-prototype.html)

5. VR icon by Milan Gladiš from the Noun Project (https://thenounproject.com/search/?q=vr&i=597665)
   Room icon by Batibull from the Noun Project (https://thenounproject.com/term/room/2072696/)