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# Foveated Ray Tracing for VR Headsets


Authors :

Adam Siekawa
Michał Chwesiuk
Radosław Mantiuk
Rafał Piórkowski

West Pomeranian University of Technology, Szczecin, Poland

Faculty of Computer Science and Information Technology


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# Rendering

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Foveated Rendering
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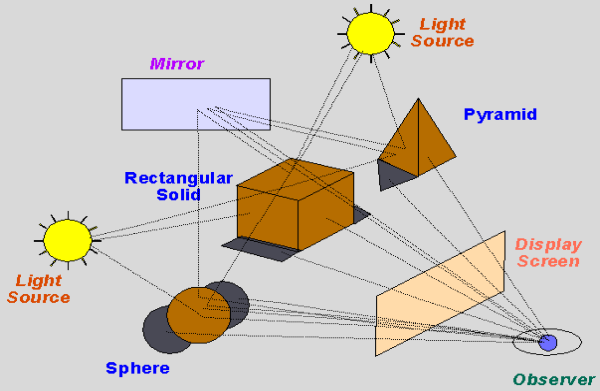
Performance
Rendering Quality
Conclusion




- **Rendering** - image generation based on a virtual scene data.
- **Ray Tracing** - important rendering technique very complex due to large number of computations.
- Rendering technique not limited to .synthesizing whole image.
- **CHALLENGE:** real time ray tracing (60 and more FPS).
- **Less rays -> better performance**

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# Target VR HMD Resolution

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- **VR** - virtual reality, **HMD** - head mounted display
- Current resolution of VR system ~ **6 cpds** (cycles per degree)
- Human visual system resolution - **60cpds**
- **90 FPS required!**

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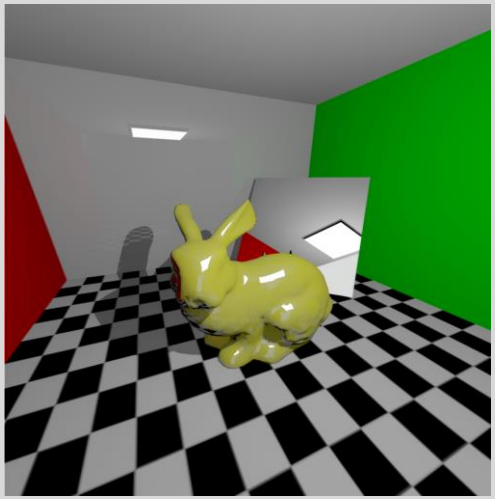
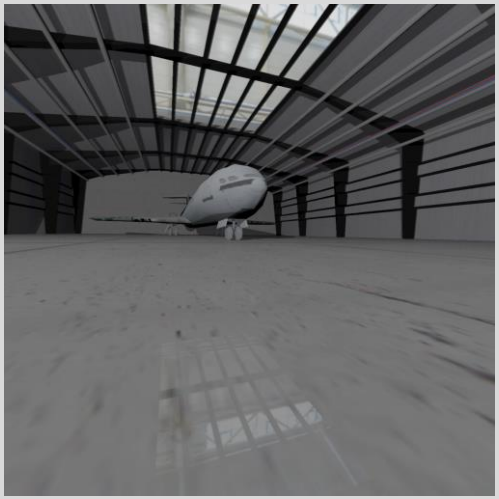
# Rendering without eye tracking



**Rendering time : 49.5 ms**



**Rendering time : 66 ms**

90 FPS -> ~11 ms

- Rendering examples of **HTC Vive VR headset**.
- Two frames for left and right eyes, resolution of 1512x1680 pixels.
- NVIDIA Geforce GTX 1080 GPU.

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# Foveated Rendering


- Information of gaze of the observer can be used in rendering system.
- In fovea area image is rendered in full resolution.
- **In peripheral area quality of rendering can be simplified.**
- It shouldn’t be possible to perceptually detect the reduction of rendering quality.

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# Human Retina

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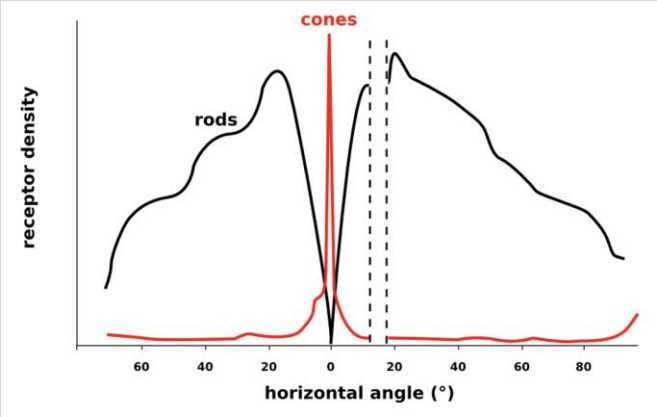


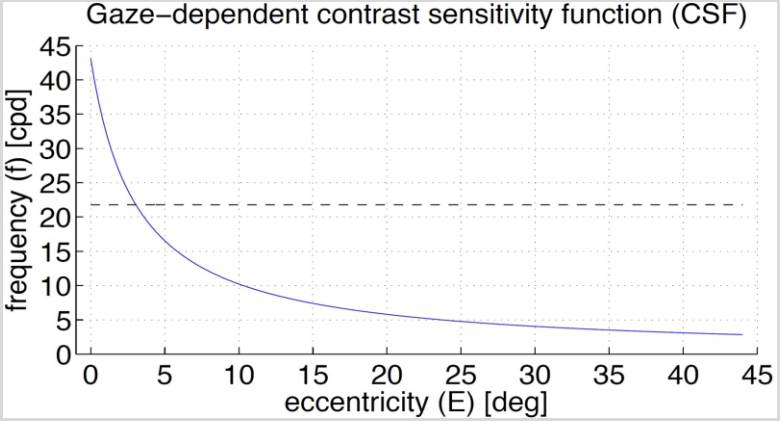


- **Peripheral region contains less cones.**
- Gaze-dependent CSF describes resolution of human vision for different eccentricities.
- Details of observed scene are **imperceptible in peripheral region**.

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# Foveated Rendering System

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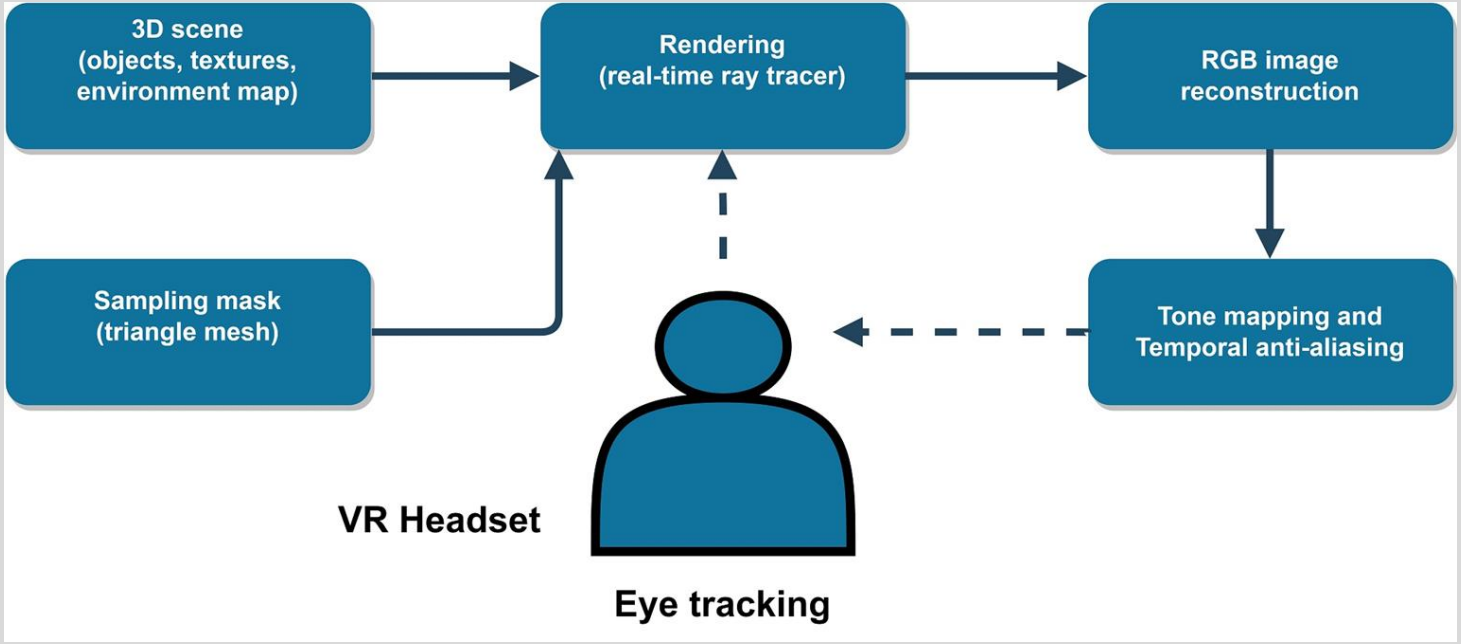


- **HTC Vive** virtual reality headset.
- **Pupil Labs** eye tracker.
- **Ray Tracer** implemented with **OpenCL** and **Radeon Rays**.

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# Sampling Mask

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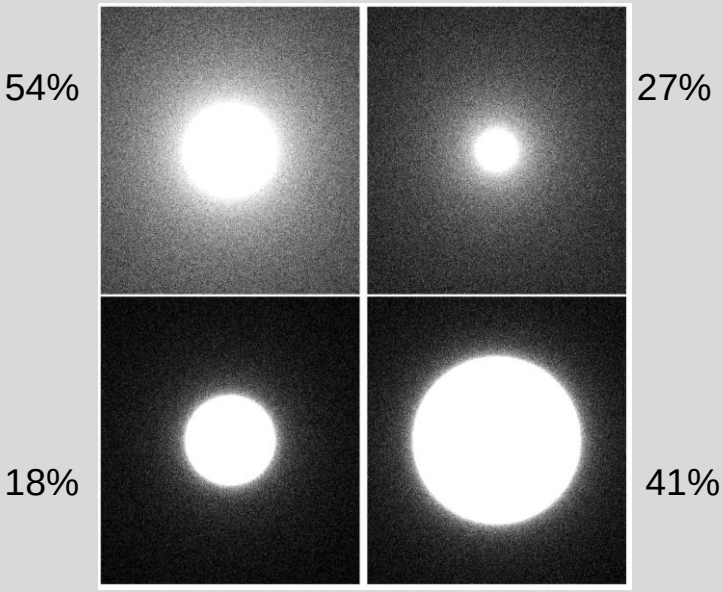


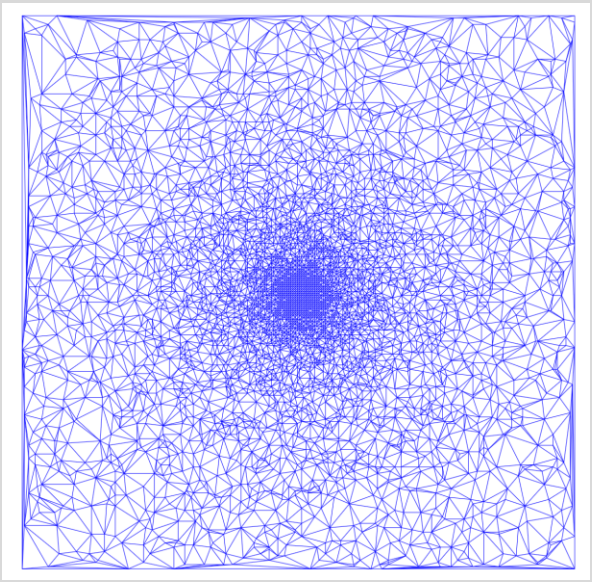

- Four sampling mask.
- **Mask containg 54% is consistent with human visual system.**
- Other three mask are used to measure different distribution.
- Blank pixels will be interpolated using **triangulation**.

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# Sampling Example

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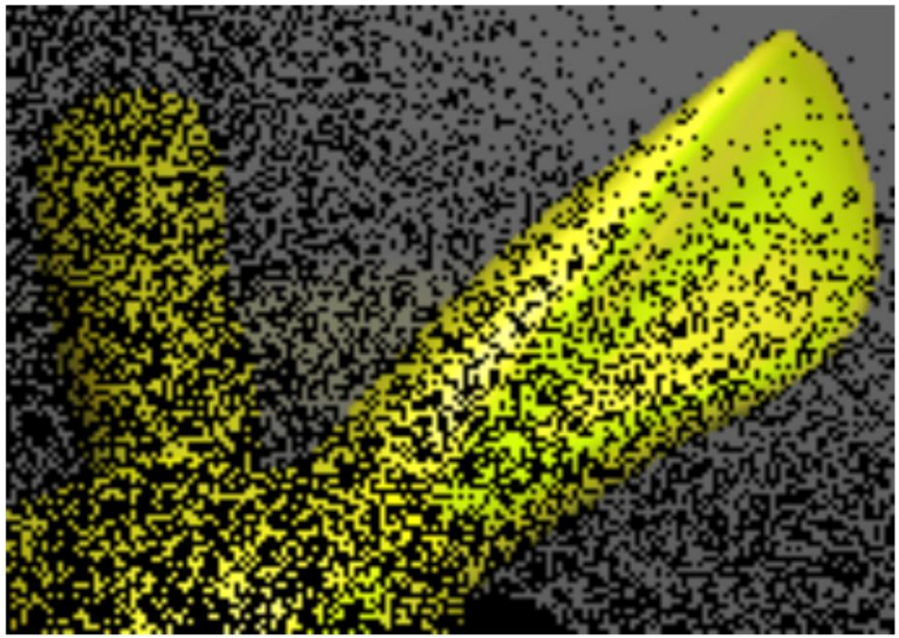

- Example of **rendering using sampling mask**.
- Interpolation of blank pixels not yet applied.

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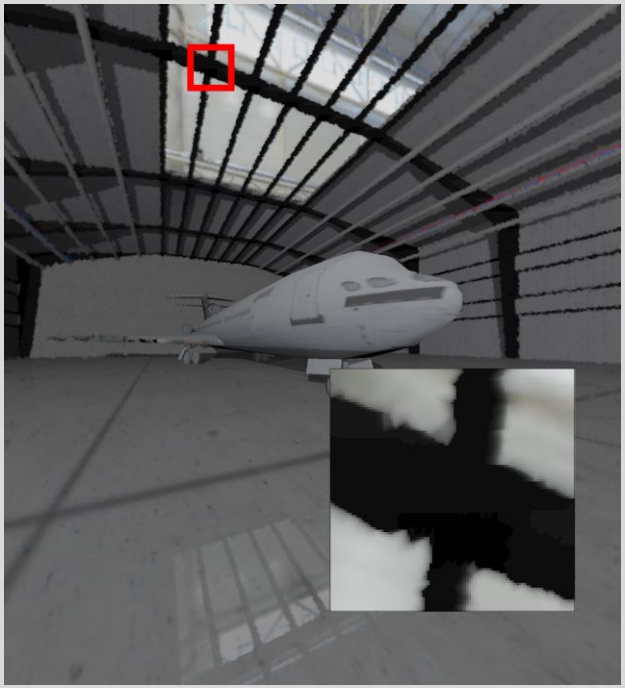
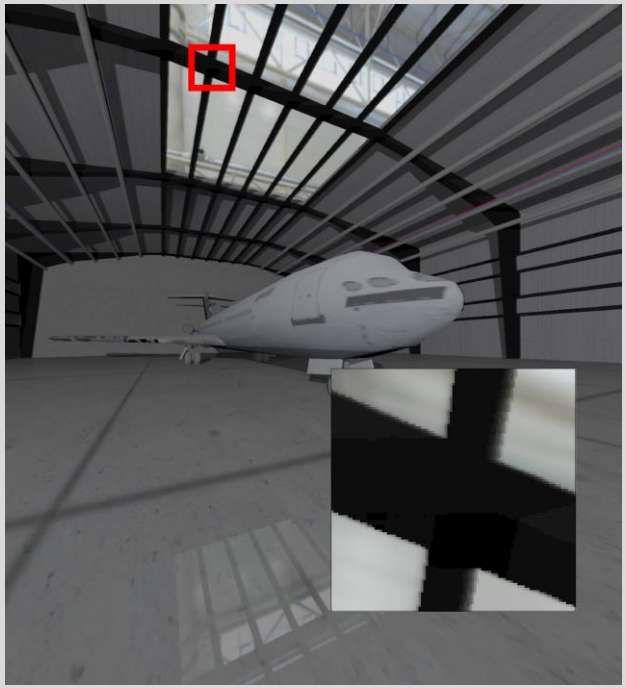
# Rendering using sampling mask



Foveated rendering



Full resolution rendering

- Left image : rendering using 18% sampling mask.
- Right image : reference render.
- Fragment bordered with red square zoomed.

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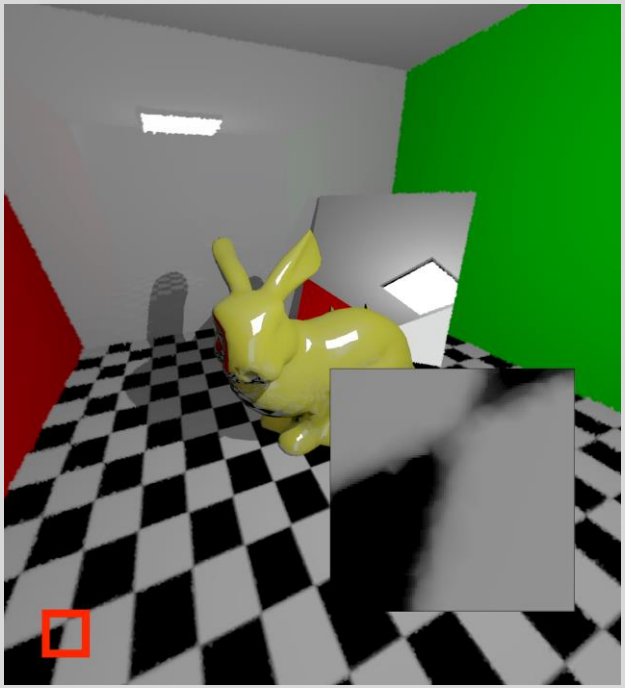
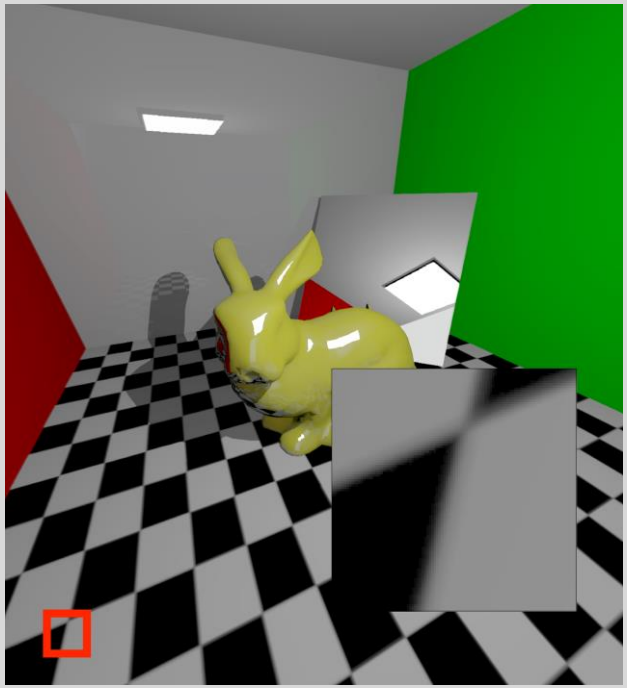
# Rendering using sampling mask



Foveated rendering



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# Rendering performance

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| Scene | Sampling mask | Rendering time [ms] | Speed-up |
|---|---|---|---|
| Air Shed | 18% | 18.1 | 3.7x |
| | 27% | 23.7 | 2.8x |
| | 41% | 37.5 | 1.8x |
| | 54% | 29.8 | 2.2x |
| Bunny Box | 18% | 15.0 | 3.3x |
| | 27% | 17.9 | 2.8x |
| | 41% | 27.6 | 1.8x |
| | 54% | 24.1 | 2.1x |

- Reducing number of samples increase rendering speed.
- **For mask 51% (correct with HVS) : two times faster rendering**.
- For mask 18%: 3.7 times faster rendering.
- **Higher accelerations for higher resolution of VR systems**.

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# Rendering quality - experiment

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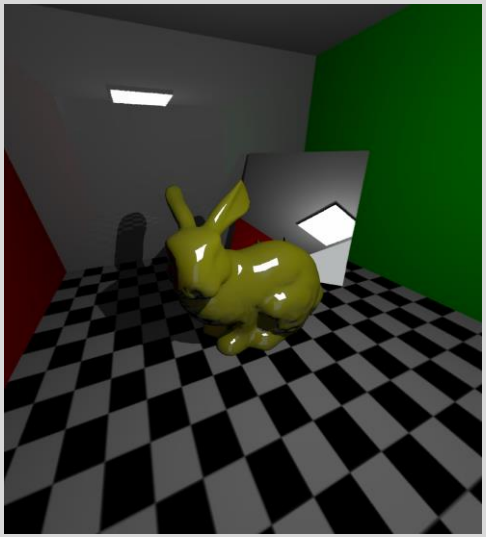
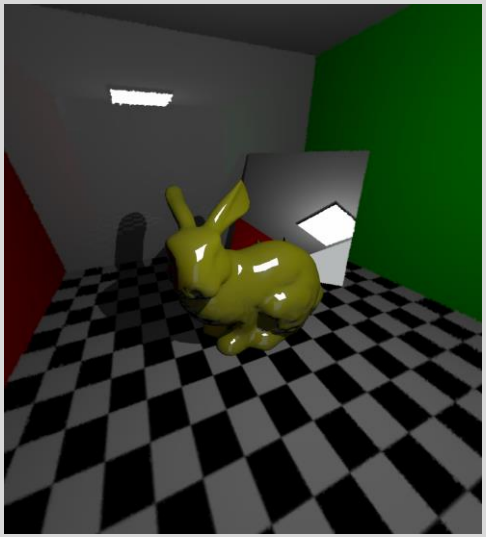
Perceptual experiment:

- Scene rendered in VR environment.
- Dynamic switch between masks at random moments, separated by few seconds.
- Observer informs when he/she see change of used sampling mask.
- Experiment performed on 6 volunteer in age between 20 and 24.





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# Rendering quality - results

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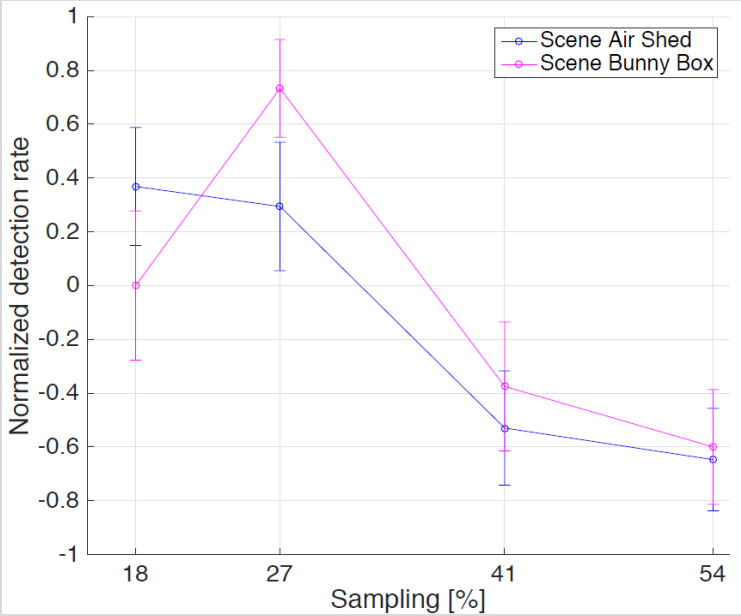


- Presented result decribe number of observed changes of rendering quality after applying sampling mask in normalized scale.
- Quality reduction is visible for all sampling mask.
- For sampling masks  41% and 54% visibility is acceptable.

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# Conclusion and Future Work

- Foveal rendering can be used in VR environment using reduced spatial sampling with the mask, which follows CSF.
- Rendering performance is twice higher for reduced sampling. Even better results will be achieved for future HMDs.
- Temporal aliasing is a problem magnified by the reduced spatial frequency. Better filtering is required.
- Accuracy of eye tracking was not studied. Further studies are required.

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# Foveated Ray Tracing for VR Headsets


- Michał Chwesiuk
  - mail : mchwesiuk@zut.edu.pl
  - www : https://mchwesiuk.pl/
- Radosław Mantiuk
  - mail : rmantiuk@zut.edu.pl




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