DEAMP: Dominant-Eye-Aware Foveated Rendering with Multi-Parameter Optimization

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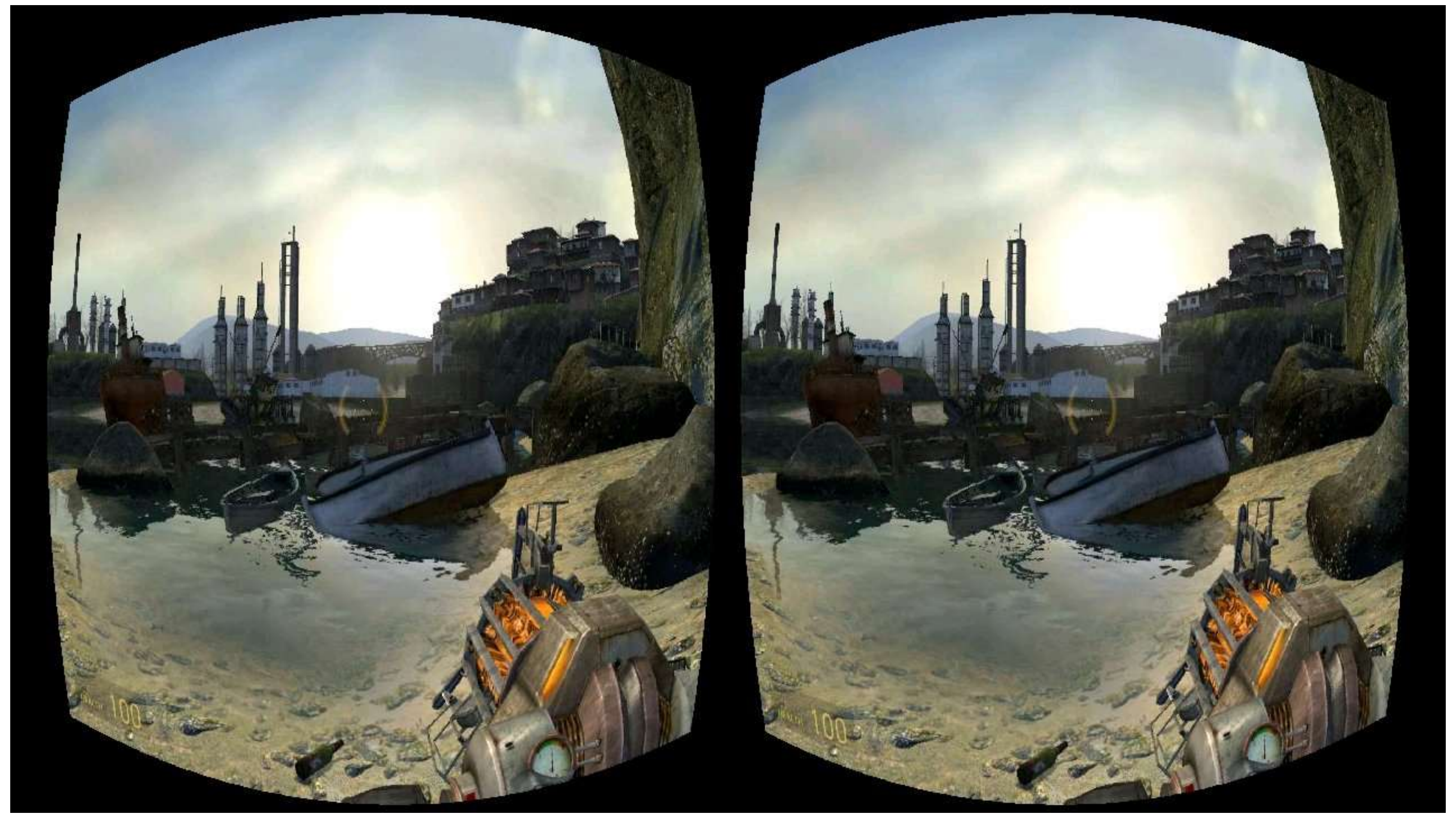
Outline

- Background
- Related Work
- Our Method
- Experiment
- Demo
- Limitations and Future Work

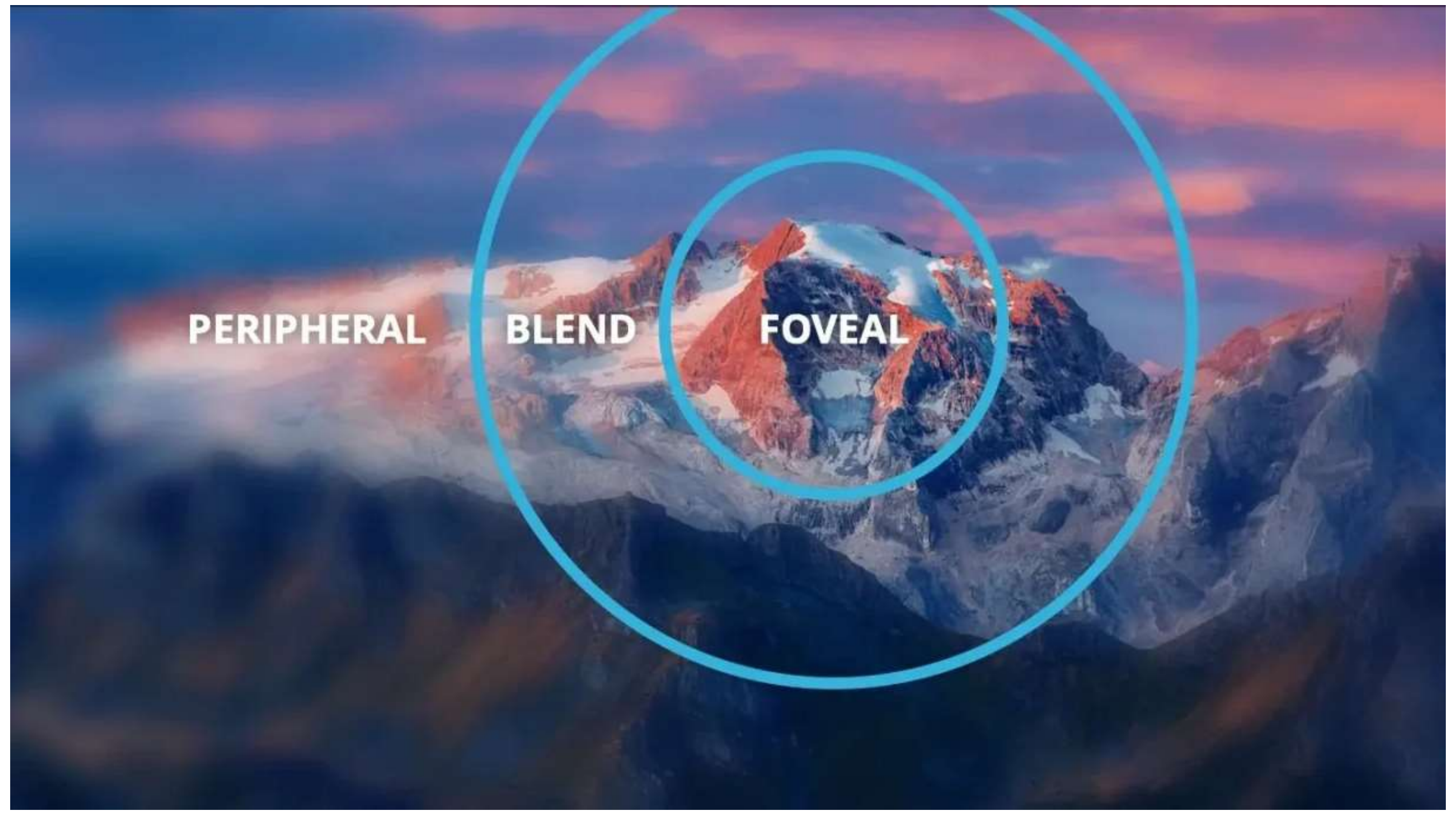
Background

- Virtual Reality generates immersive virtual environments.
- High demand for resolution and interactive frame rates presents a major challenge to widespread adoption of virtual reality.
- Foveated Rendering address this issue by lowering pixel sampling rate at the periphery of the display.

Virtual Reality



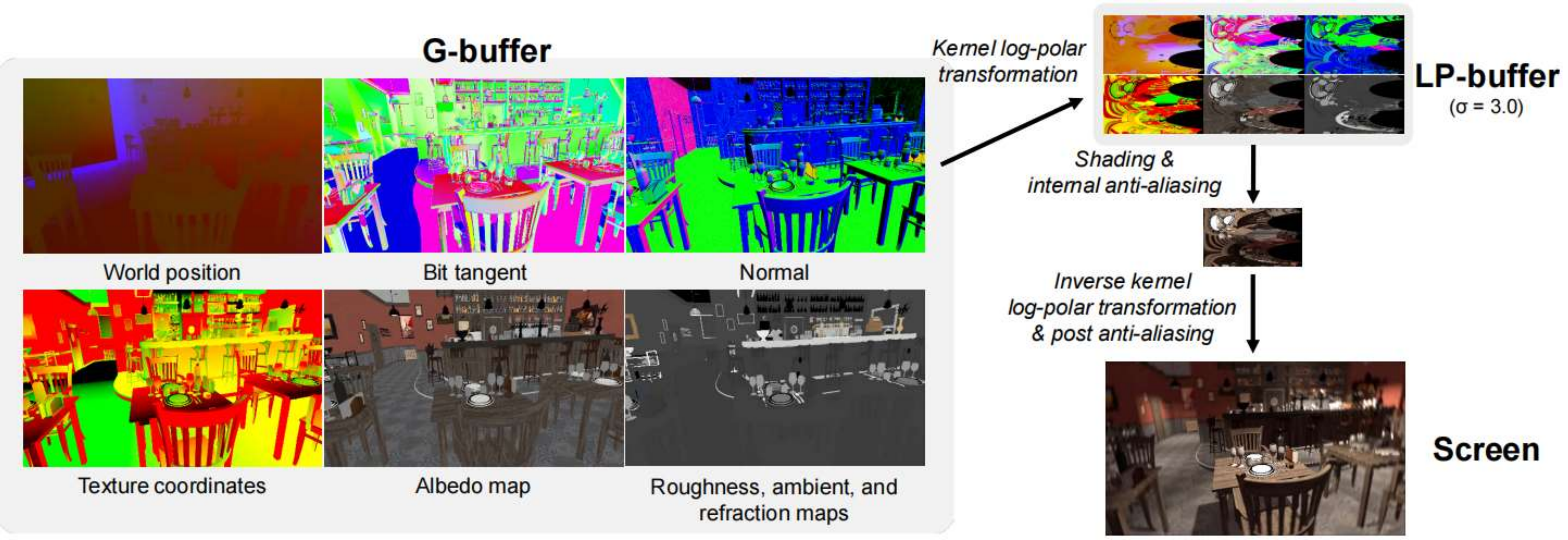
High demand for resolution and frame rate



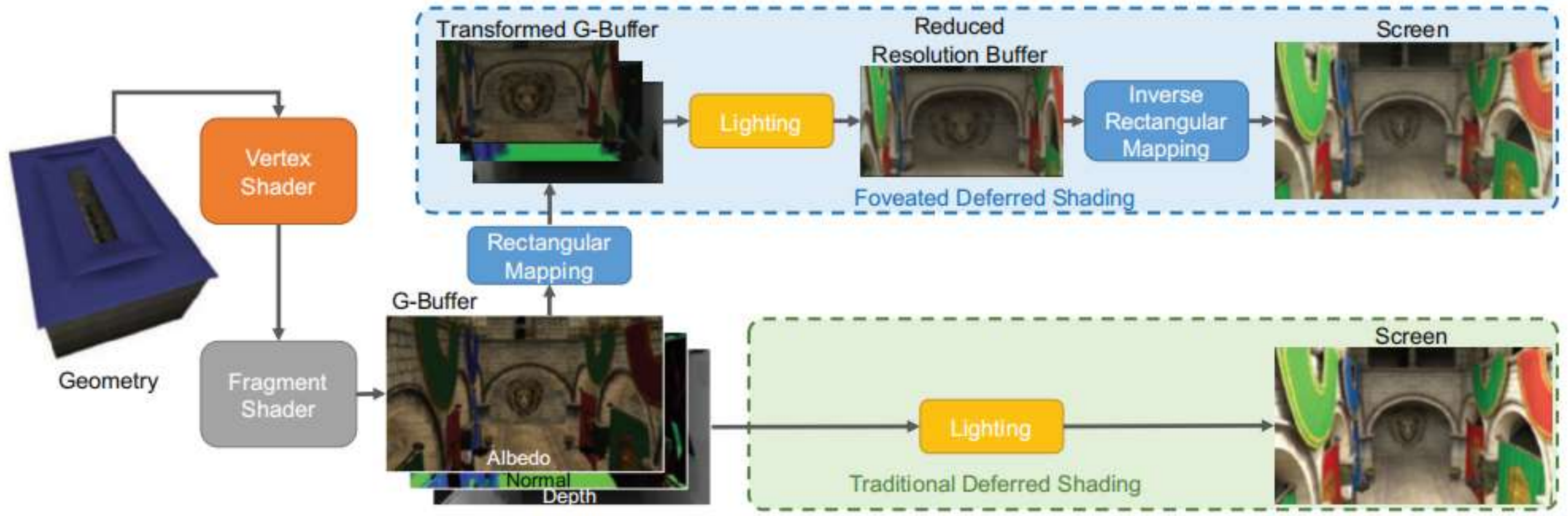
Foveated Rendering

Related Work

- Recent studies mainly focus on exhaustive algorithmic optimizations.
- The feature of human binocular vision is not fully exploited.



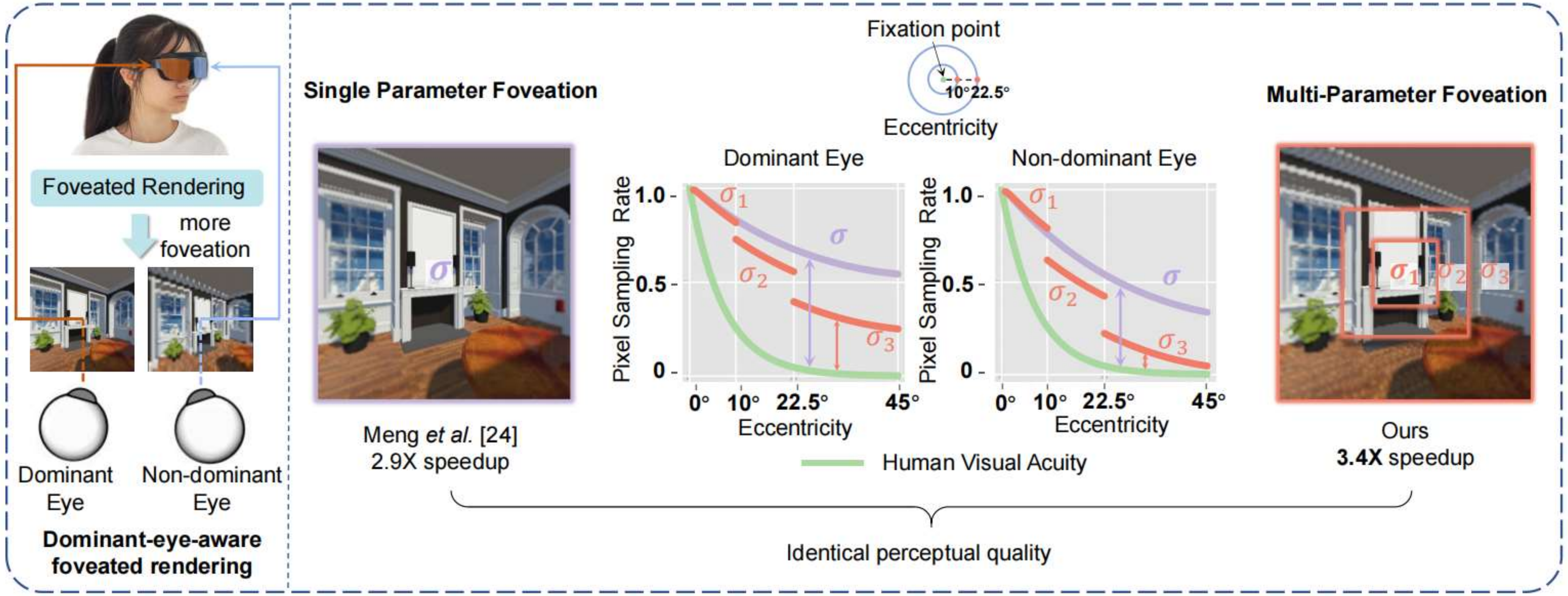
Kernel Foveated Rendering
[Meng *et al.* 2018]



Rectangular Mapping-based Foveated Rendering
[Ye *et al.* 2022]

Our Method - Motivation

- Existing method causes a significant gap between the pixel sampling rate and the visual acuity fall-off model at the periphery of the visual field.
- It results in an increased number of rendered pixels, leading to unnecessary rendering costs.
- We proposed a more optimized method which sampling rate approached the visual acuity fall-off model more closely and accelerated foveated rendering.

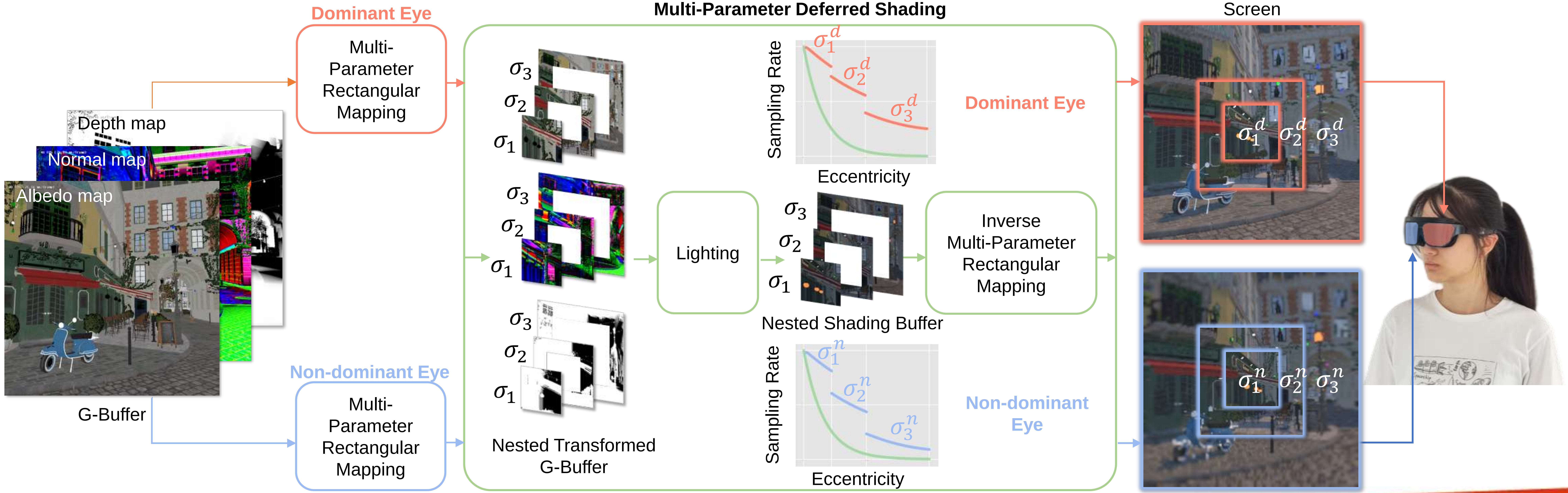


Our Method - Overview

1. We implement the Multi-Parameter rectangular mapping for the G-buffer.

2. During the lighting pass, we shade each pixel by utilizing the information from the transformed G-buffer.

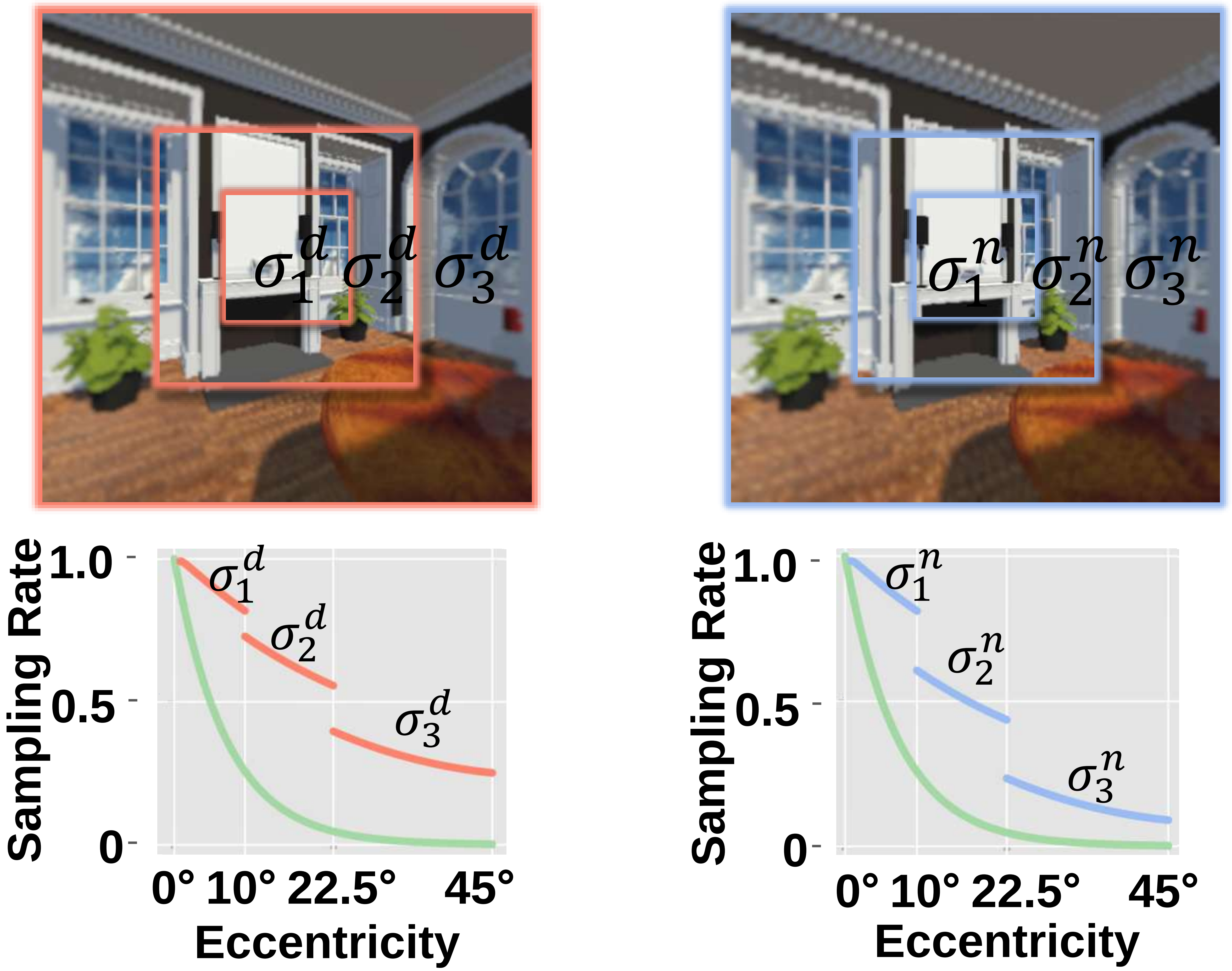
3. Finally, we apply the inverse M-P rectangular mapping of the nested shading buffer to the full-resolution screen.



Our Method

We divide each eye’s visual field into three nested layers (6L). Multiple foveation parameters control the level of foveation of each layer, respectively.

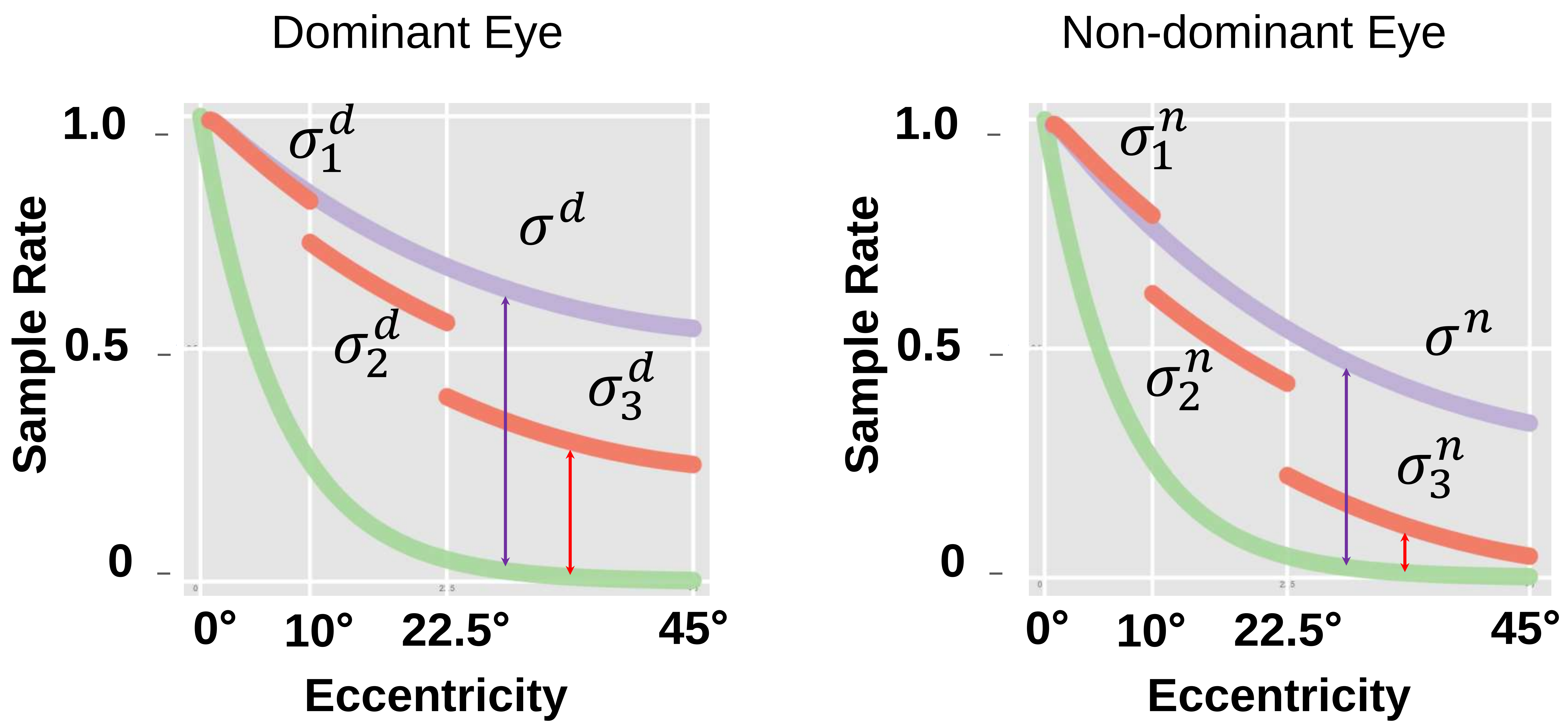
Dominant Eye



Non-Dominant Eye

Our Method

Our method with multiple parameters narrowed the gap between the pixel sampling rate and the visual acuity fall-off model while maintaining consistent perceptual quality.

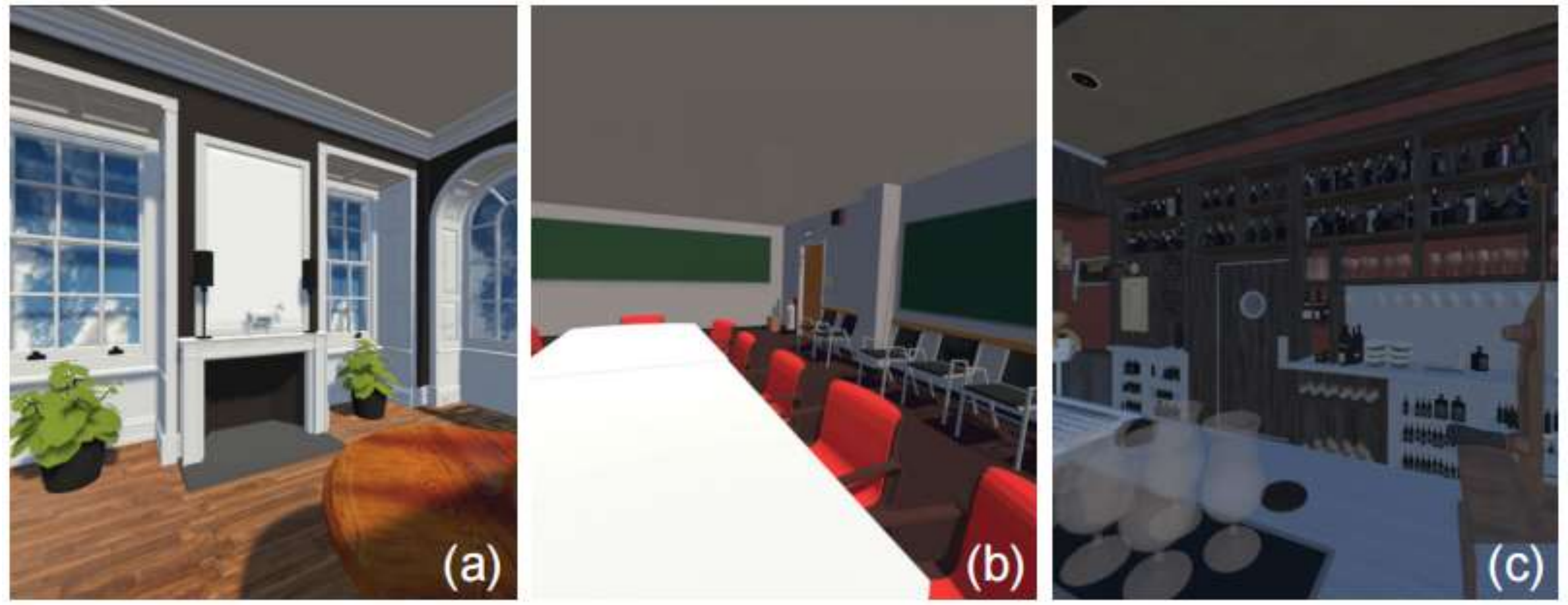


Experiment - Comparison of Random Test and Slider Test

Random Test: participants score the quality of foveated rendering based on different values of σ presented in a random order.

Slider Test: participants monotonously adjust the level of foveation by themselves.

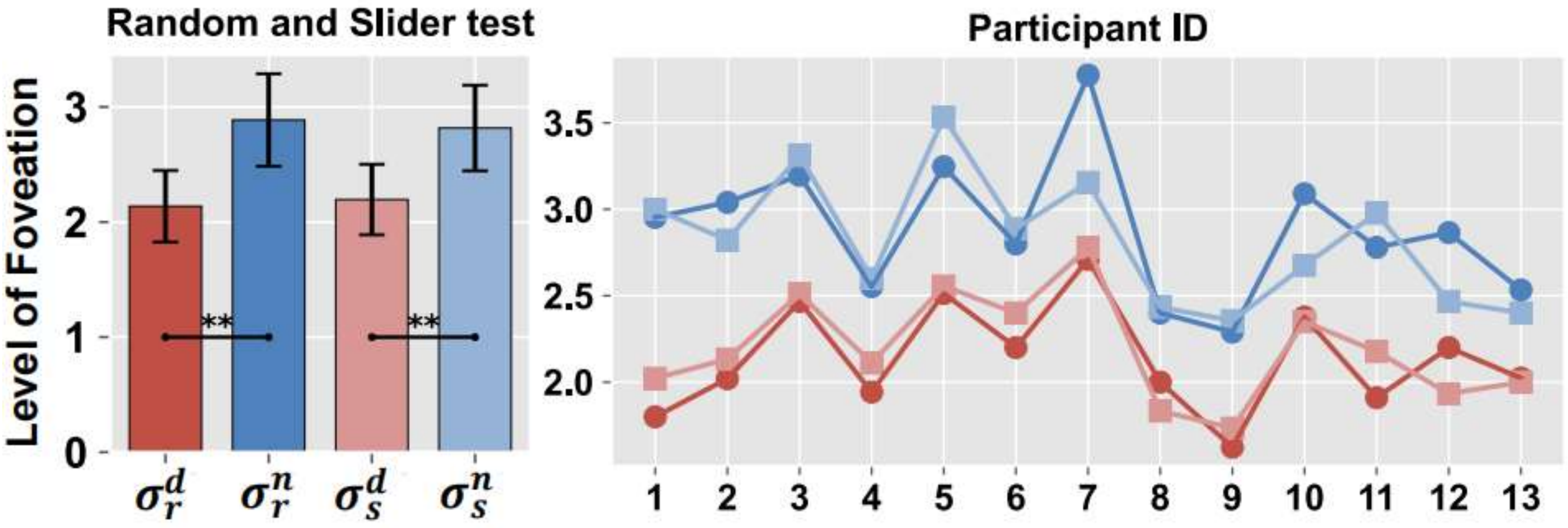
To ascertain whether there is significant difference between the results of the random test and the slider test. We conduct a pilot study.



- Users: 13 participants
- Techniques: 2L
- Scenes: (a) Fireplace Room

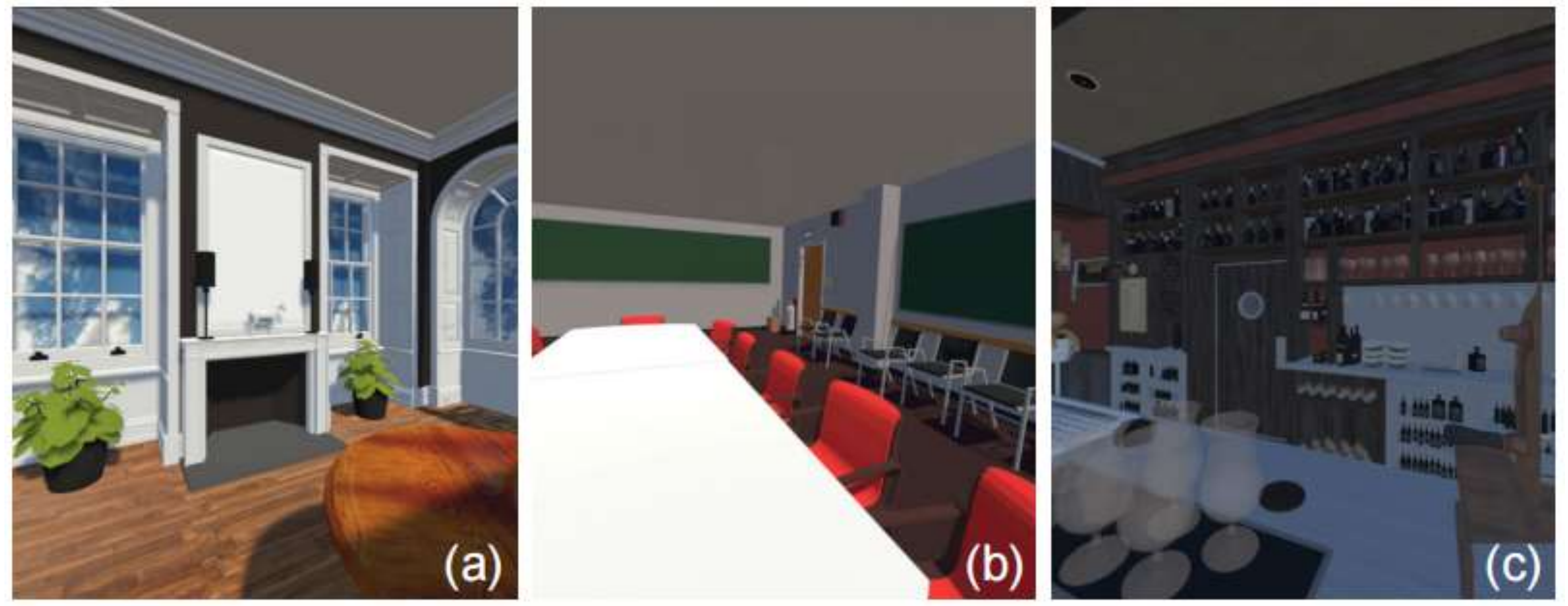
Experiment - Comparison of Random Test and Slider Test

- There is no significant difference in the foveation parameters measured from the random test and the slider test.
- To reduce the total duration of the experiment, we only apply the slider test to each layer in the subsequent 4L and 6L tests.



Experiment - Estimation of Foveation Parameters

We conduct this user study to estimate the foveation parameters of our proposed methods (4L and 6L).



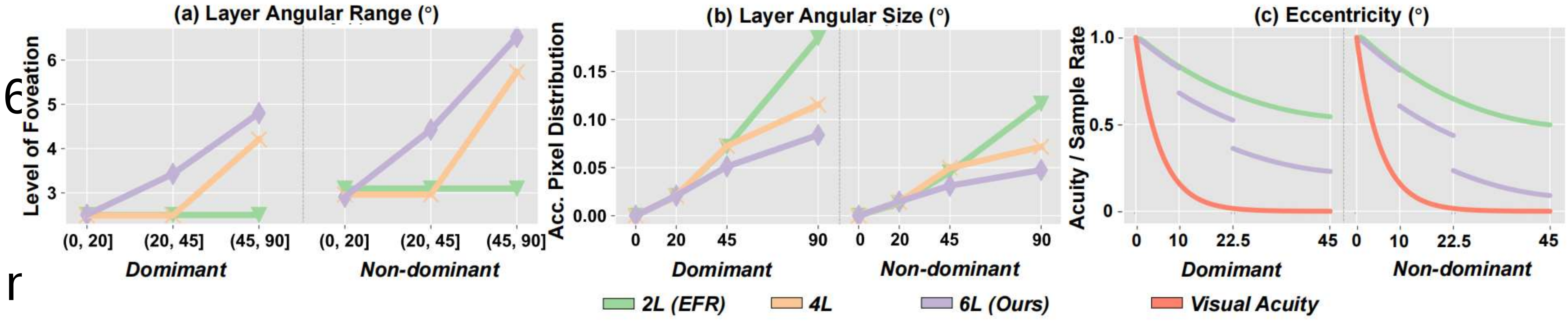
- ➢ Users: 16 participants
- ➢ Techniques: 2L, 4L, 6L
- ➢ Metrics (Compare with 2L):
  - Level of Foveation
  - Total Rendered Pixels Count

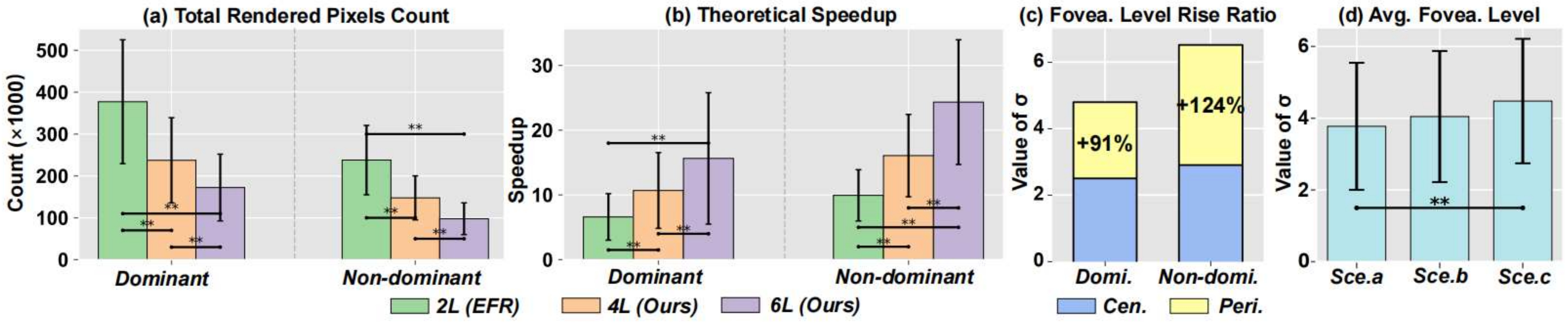
Step	Adjusted σ	Highest fovea. level	Reference	Uniform change of σ
1	σ_1^d	$\hat{\sigma}_1^d$	full-resolution rendering	$\sigma_2^d = \sigma_3^d = \sigma_1^n = \sigma_2^n = \sigma_3^n = \hat{\sigma}_1^d$
2	σ_2^d	$\hat{\sigma}_2^d$	frame rendered from step 1	$\sigma_3^d = \sigma_2^n = \sigma_3^n = \hat{\sigma}_2^d$
3	σ_3^d	$\hat{\sigma}_3^d$	frame rendered from step 2	$\sigma_3^n = \hat{\sigma}_3^d$
4	σ_1^n	$\hat{\sigma}_1^n$	frame rendered from step 3	$\sigma_2^n = \sigma_3^n = \hat{\sigma}_1^n$
5	σ_2^n	$\hat{\sigma}_2^n$	frame rendered from step 4	$\sigma_3^n = \hat{\sigma}_2^n$
6	σ_3^n	$\hat{\sigma}_3^n$	frame rendered from step 5	——

Experiment Procedure (6L)

Experiment - Estimation of Foveation Parameters

- We observe higher acceptable foveation level on the periphery.
- The pixels rendered gradually decreases from 2L to 6L.
- Our 6
- The r … nt eye.





Experiment - Measurement of Rendering Time

The deferred shading pipeline has demonstrated a notable reduction in rendering time when compared to other existing methods.

Procedure (ms)	Full-resolution	KFR [23]	RMFR [45]	EFR (KFR) [22]		2R (EFR) [22]		4R (Ours)		6R (Ours)	
				dom	n-dom	dom	n-dom	dom	n-dom	dom	n-dom
Depth Pass	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Shadow Pass	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.35	0.35
Defer Pass	3.93	4.05	4.11	4.08	4.03	4.13	4.09	3.99	3.94	**3.89**	3.92
Skybox	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Shading/Pass1	19.27	5.49	3.34	4.52	2.19	3.34	2.53	2.94	2.06	2.76	**1.97**
Pass2	/	0.28	0.22	0.25	0.23	0.22	0.23	0.11	0.12	0.13	**0.10**
TAA	0.65	0.43	**0.42**	0.43	0.43	**0.42**	**0.42**	0.48	0.48	0.43	**0.42**
Total GPU Time	24.41	10.81	8.65	9.84	7.44	8.67	7.83	8.07	7.15	7.77	**6.97**
Binocular Time (ms)	48.82	21.62	17.30	17.28		16.50		15.22		**14.74**	
Fps	20	46	58	58		61		66		**68**	

Demo

Non-dominant Eye

$\sigma_1^n = 2.9, \sigma_2^n = 4.0, \sigma_3^n = 5.5$

Dominant Eye

$\sigma_1^d = 2.4, \sigma_2^d = 3.0, \sigma_3^d = 4.0$

Limitations and Future Work

- We found it is difficult to render multiple nested layers in parallel on the GPU pipeline due to the limitation of the Falcor framework. In the future, we will explore the parallel rendering method for multiple nested layers, to further improve the rendering speed.

- The pilot study and main study each lasted approximately 60 minutes. In the future, we plan to design an algorithm to reduce the time for parameter selection.

Thank you!

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