Dynamic Visual Dominance in Stereoscopic Foveation - Supplementary

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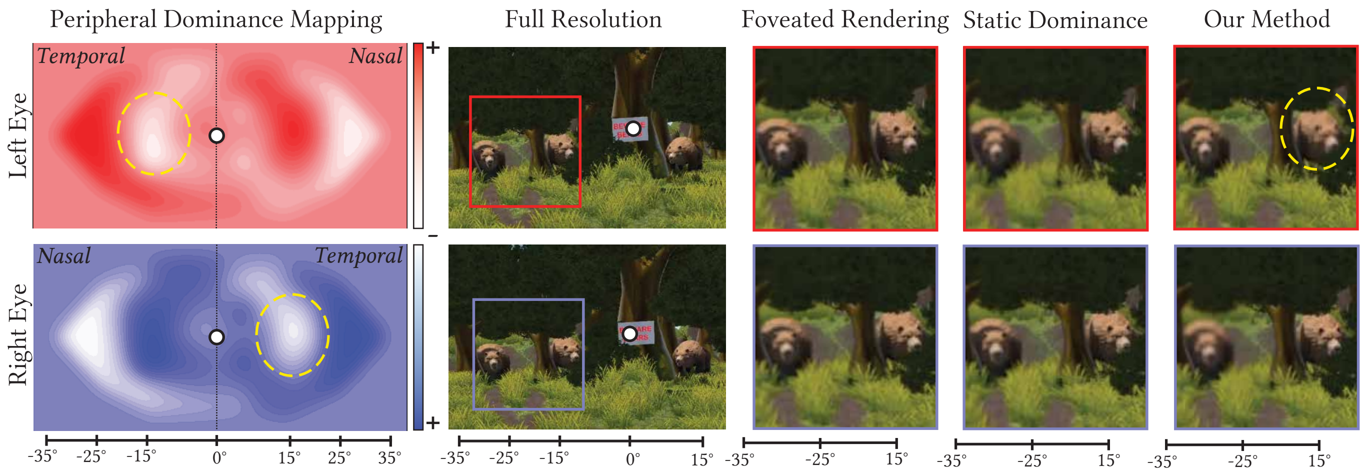

Fig. 1. We show that visual dominance is not a static, eye-fixed percept, but varies dynamically between the eyes as a function of gaze direction and peripheral offset from the fovea. Consequently, different regions of a stereoscopic image are dominated by different eyes depending on the fixation point. **Left:** Our retinal dominance maps for the left and right eyes obtained from our psychophysical experiments. The central white markers indicate the fixation point, and the bottom scale denotes retinal eccentricity. Red and blue colors indicate the level of dominance toward the left and right eyes, respectively. As can be observed, the temporal viewing hemifield (corresponding to the nasal retinal region) consistently dominates over the nasal viewing hemifield (corresponding to the temporal retinal region), particularly at larger eccentricities, with the exception of the blind spots (dashed circles). **Right:** We leverage the map to introduce asymmetric blur for foveated rendering. With standard foveated rendering as reference, the first approach applies a static dominance, introducing additional blur in the left eye only, assuming right-eye dominance. Our method, shown in the last column, accounts for dynamic dominance changes by applying additional blur according to the dynamic dominance maps of each eye. Please refer to the difference in blurriness between the two bears for better visualization. While the static approach applies a stronger blur to the nominally non-dominant left eye, the dominance maps reveal a local dominance switch in this region, which can lead to visible artifacts. In contrast, our method adapts to this switch, shifting additional blur between eyes where it is perceptually less noticeable. By leveraging gaze-dependent, dynamically varying visual dominance, our approach enables stronger localized blur with reduced artifacts.

In human vision, the inputs perceived by each eye do not contribute equally to the final percept. Instead, visual dominance influences how these inputs are fused, giving more weight to one eye view over the other. While eye dominance has been traditionally treated as a static, eye-fixed property, recent evidence suggests that dominance can vary with viewing conditions. In this work, we systematically characterize dynamic visual dominance across the visual field, with a particular focus on peripheral vision, where perceptual asymmetries are most relevant for stereoscopic rendering. Through two complementary psychophysical experiments, we first show that tolerance to eye-asymmetric blur at the fovea under binocular viewing depends on gaze direction, confirming that eye dominance is not spatially invariant. We then show that peripheral dominance is primarily governed by retinal eccentricity, with consistent naso-temporal asymmetries and dominance reversals around the blind spots. We leverage our insights in a dominance-contingent rendering application, where additional blur is selectively applied to the perceptually non-dominant eye regions under binocular viewing. Compared to static dominance approaches, our method enables stronger localized quality reductions, illustrating the practical relevance of dynamic peripheral

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dominance for stereoscopic foveated rendering. Thus, our goal through this work is to show how visual dominance behaves dynamically in both the fovea and the periphery, indicating how foveation techniques could benefit from it.

CCS Concepts: • **Computing methodologies → Virtual reality**; **Perception**.

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This supplementary document contains the following sections:

- S1. Hardware details
- S2. Gaussian blur filter computation
- S3. Details on the results obtained in the foveal experiment
- S4. Details on the gaze-contingent application proposed
- S5. Implementation details of the VRS prototype
- S6. User Study Questionnaire

S1. Hardware details

Tab. 1 shows details of the HMD used in the experiments.

Table 1. Specifications of the Varjo XR-4 HMD.

Display Resolution	3840 × 3744 pixels per eye
Display Refresh Rate	90 Hz
Passthrough Cameras	2 x 20 Mpx
Eye Tracking Frequency	200 Hz
Eye Tracking Accuracy	Sub-Degree

S2. Gaussian blur filter computation

The bidirectional (vertical and horizontal) Gaussian kernel was implemented by first computing the spatial weight of each pixel as a function of its offset from the kernel center, and then normalizing the weighted sum to obtain the final blurred pixel appearance, as described by the following equations:

$$w(i,j) = \exp\left(-\frac{i^2+j^2}{2\sigma^2}\right) \quad (1)$$

$$\mathrm{G(x,y)} = \frac{1}{\sum_{i=-r}^{r}\sum_{j=-r}^{r} w(i,j)} \sum_{i=-r}^{r}\sum_{j=-r}^{r} \mathrm{F}(x+i, y+j)\cdot w(i,j) \quad (2)$$

where σ denotes the standard deviation of the Gaussian kernel, r is the kernel radius, and $F(x,y)$ and $G(x,y)$ represent the input and blurred images, respectively.

S3. Details on the results obtained in the foveal experiment

In Fig.4, the raw data obtained from all the trials performed in the study about visual dominance in the fovea are displayed.

S4. Details on the gaze-contingent application proposed

The sampling strategy considered to transform dominance blur maps $b_{l,r}\left(s_{x,y}\right)$ into blur kernel levels $\sigma_{l,r}\left(s_{x,y}\right)$ is shown in Fig. 2. This transformation could be optimized in production to increase the non-dominant gains while remaining unperceptible, potentially considering the blur detection threshold in the non-dominant eye.

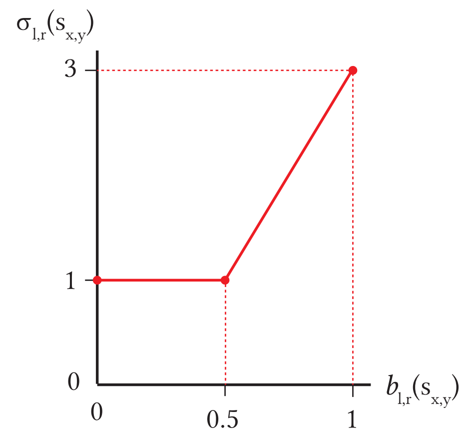

Fig. 2. Visual representation of the transformation between blur maps ($b_{l,r}\left(s_{x,y}\right)$) and the blur kernel ($\sigma_{l,r}\left(s_{x,y}\right)$) performed in the application.

On the other hand, the masks obtained from sampling the dominance maps obtained from our interpolated results are shown in Fig. 3. In the colored areas, additional blur is applied in those regions where the corresponding eye is non-dominant to the final percept, thus not being perceptible.

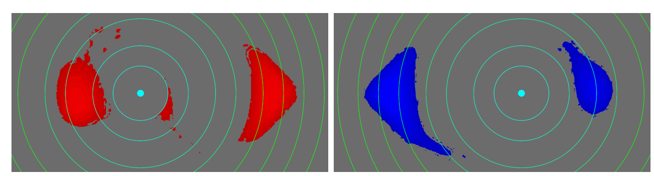

Fig. 3. Our peripheral dominance mask applied as additional blur in foveation. Coloured regions show non-dominance zones for each eye where additional blur is applied. Red regions show non-dominance regions for the left eye, while blue regions show non-dominance regions for the right eye. Each green line represents an increment of 5° from fixation, while the stereoscopic region always spans 25° from the screen center.

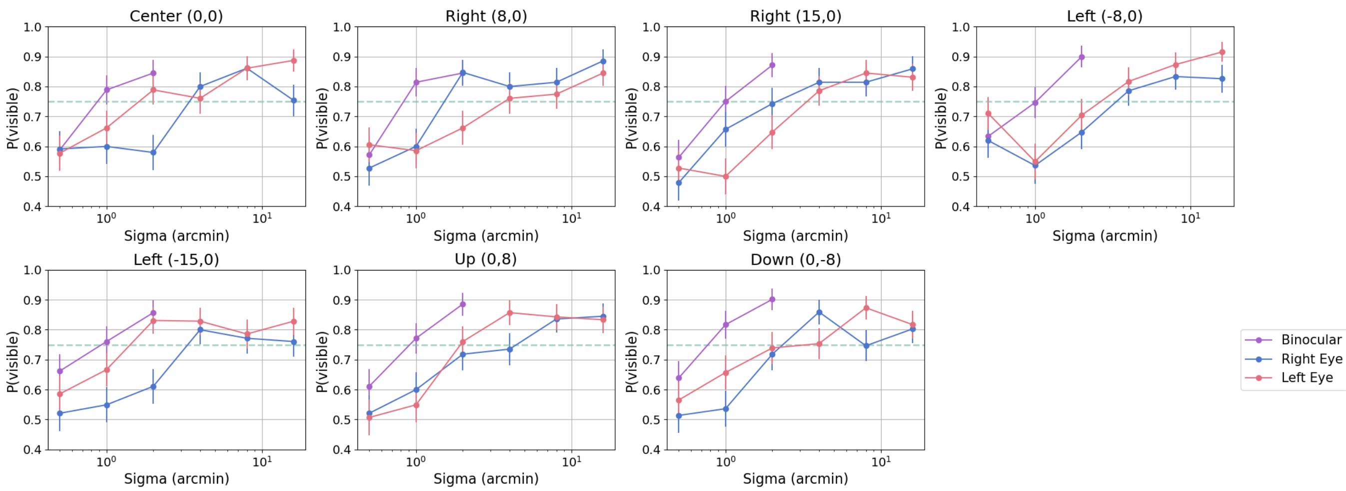

Fig. 4. Raw data used to fit the psychometric functions in the foveal visual dominance experiment (Experiment 1).

S5. Implementation details of the VRS Prototype

The scene employed to evaluate computational savings in the VRS prototype is the one used in the VRS API demo[1]. In this environment, a shading rate image (SRI) is used to encode shading rates in screen space by means of a rendering feature. The peripheral dominance map is provided as SRI and thus converted to dynamic shading rates based on the eccentricity location from the fixation point for the complete non-dominant view. In the tested scene, only a volumetric renderer feature simulating fog takes advantage of VRS. Therefore, increased savings would be expected with more complex shaders implementing additional features or global illumination. The SRI used to estimate the reported savings is displayed in Fig. 5.

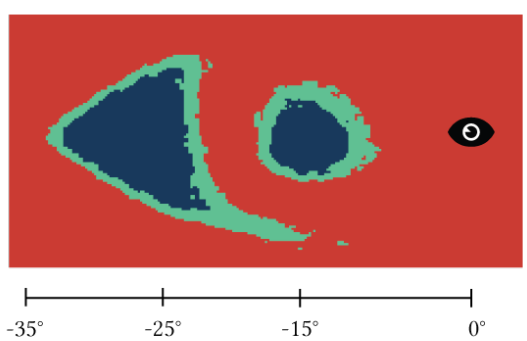

Fig. 5. Shading Rate Image (SRI) used to estimate computational savings. When fixating at $(15, 0)$ expressed in degrees of visual angle relative to the screen center in screen space, the displayed monocularly-dominated areas in the left periphery fall in the stereoscopic region of the headset. Red color corresponds to 1×1 shading rate (SR), while green and blue colors show 2×2 and 4×4 SR, respectively. The horizontal axis shows eccentricities in degrees of visual angle from the fixation location.

S6. User Study Questionnaire

In this section, questions and explanations presented to participants are shown, as well as response options provided in the demographic survey completed before the experiment session.

E1. How does the text work?

Each trial consists on different audiovisual stimuli being presented to you under different conditions and your task is to look at all of them. A traffic cone is used as visual target while the auditory cue is provided by a beep. The trial always starts by pressing the space bar. First of all, one traffic cone will appear at the center of the screen, we refer to it as the fixation point. After some time looking at this central traffic cone, it will disappear and another one appears at one side. As soon as you detect or perceive the visual target, you have to look at it, so perform the saccade from the fixation point to the visual target. After a while, the visual target disappears and the fixation point spawns again, so you look at the fixation point. Then, the second traffic cone appears on the opposite side, making you to saccade towards it as happened with the first one. Finally, this second traffic cone disappears and the central one appears, returning to the initial situation. After this procedure, you need to decide which traffic cone was closer to you in depth considering both visual and auditory information, the one on the right or the one on the left.

To answer this, just press the left or right arrow on the keyboard accordingly. After providing this answer, press the space bar again to start the new trial. Each condition has 30 trials and there are 8 conditions, after which the experiment ends. If you have any questions, please ask the experimenter now.

☐ *Understood*

[1] https://github.com/Unity-Technologies/shading-rate-demo

E2. Consent for participation in the study

I agree to participate in the research study. I understand the purpose and nature of this study and I am participating voluntarily. I understand that I can withdraw from the study at any time, without any penalty or consequences. I grant permission for the data generated from this questionnaire to be used in the researcher's publications on this topic. The generated data will be stored anonymously under a randomly generated unique ID. Any information that is obtained in connection with this study and that may be identified with you will remain confidential and will be disclosed only with your permission.

☐ *I agree*

Q1. Subject anonymous ID

____

Q2. Age

____

Q3. Gender

☐ *Male* ☐ *Female* ☐ *Rather not to say* ☐ *Other*

Q4. Home Country

____

Q5. Do you have any visual impairments?

☐ *Yes* ☐ *No*

Q6. If you answered "Yes" to the previous question, please specify your condition (e.g. poor distance vision):

____

Q7. If you have any visual impairments, do you have it corrected?

☐ *Yes* ☐ *No*

Q8. If you answered "Yes" to the previous question, please specify how you have it corrected (e.g. glasses):

____

Q9. Which is your dominant eye? To quickly test it, do a circle with your hands and frame the webcam (top left corner of the screen) keeping straight arms. Once it is framed in the center of the circle, close each eye sequentially and discover which one dominates.

☐ *Left Eye Dominant* ☐ *Right Eye Dominant*

Q10. Do you play video games?

☐ *No* ☐ *Yes, sporadically* ☐ *Yes, often* ☐ *Yes, everyday*

Q11. Specify your experience with Virtual Reality

☐ *None, I have never used a virtual reality device.*
☐ *Basic, I have used virtual reality devices less than 5 times.*
☐ *Experienced, I have used virtual reality devices several times.*
☐ *Professional, I use virtual reality devices on a daily basis.*

Q12. If you have already tried virtual reality, please specify those that apply

☐ *I have tried desktop-based devices like Oculus, HTC Vive, or Play Station VR.*
☐ *I have tried smartphone-based devices like Google Cardboard*
☐ *I use virtual reality devices everyday*
☐ *I suffered fatigue, dizziness or eyestrain when using virtual reality devices*

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