Foveated rendering in virtual reality

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Outline

- Background
  - Human Vision
  - Virtual Reality Headsets
  - Gaze Tracking
- Foveated Renderer Design
  - Rendering Components
  - Desktop Implementation
  - Virtual Reality Implementation
- Results
- Conclusion

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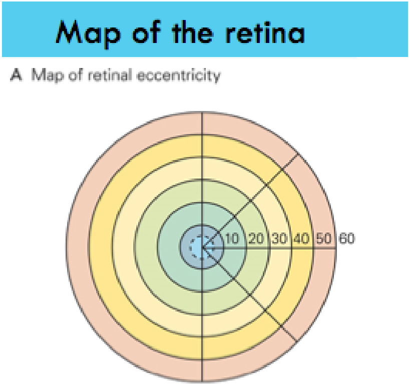
Visual Regions

- Fovea
  - center of vision
  - high spatial density of photoreceptors



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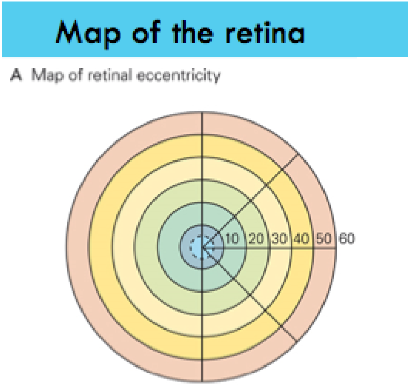
Visual Regions Continued

- Periphery
  - distal region surrounding the fovea
  - progressively lower spatial density of photoreceptors



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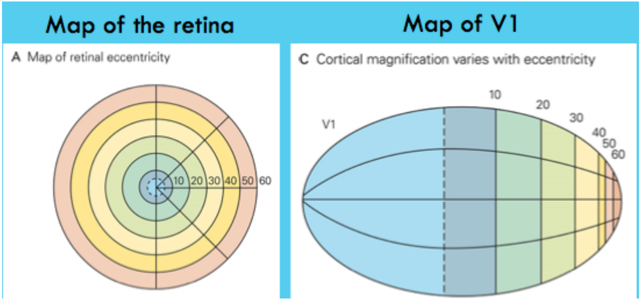
Visual Acuity

- Retinal eccentricity
  - fovea approximately 5 degrees in diameter
- Cortical Magnification Factor (CMF)
- Spatial acuity is lower in periphery, however motion detection is the same



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Virtual Reality Expansion

- Increased corporate and commercial presence in Virtual Reality (VR)
- Options available for a variety of markets
    - casual options like the Samsung Gear VR and Google Carboard
    - enthusiast options like Oculus Rift and the HTC Vive

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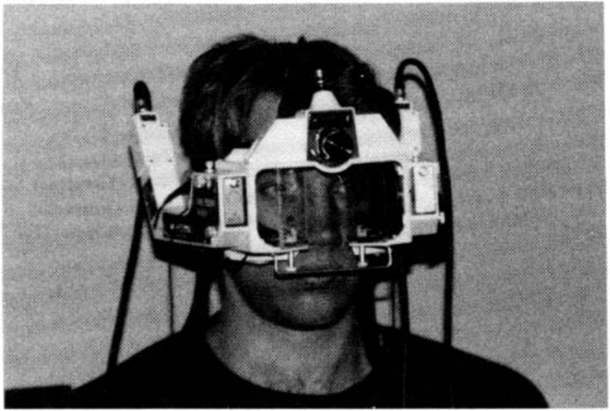
VR Technical Demand

- VR applications typically involve complex scenes with large field of view
- Renderers need to maintain high resolutions and fast refresh rates
- Good fit for Foveated Rendering due to the need for resource optimization

Gaze Tracking

- Technology dedicated to tracking the user's eye to determine point of gaze
- Has a wide variety of applications
- Effective in combination with Virtual Reality Headsets
    - additional method of input
    - gives real-time information on where user's visual regions are located

Previous Gaze Trackers



NAC Eye Mark Eye Tracker from the 1980's [1]

Modern Gaze Trackers

7invensun's aGlass

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Hardware Advances

Comparison of NAC Eye tracker [1] and Tobii VR pro Vive

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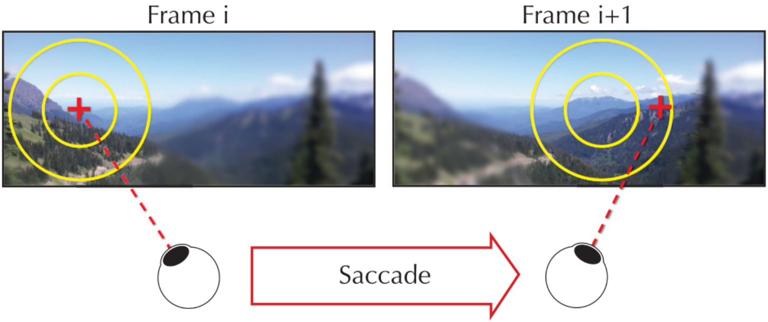
Saccadic Eye Movements

- Disjunct leaping motion of the eyes to look at a new focal point
- Significant hurdle for Gaze Tracking and subsequently Foveated Rendering

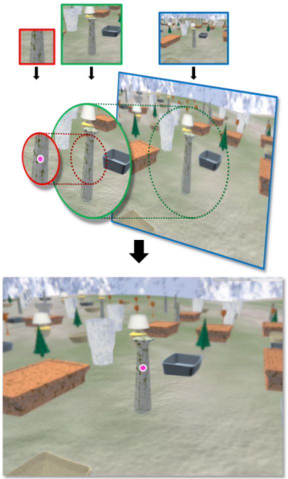


[2]

Outline

Foveal Layers

- Foveal layers are rendered based on retinal eccentricity
  - progessively lower levels of detail for larger layers
  - varying resolutions and refresh rates



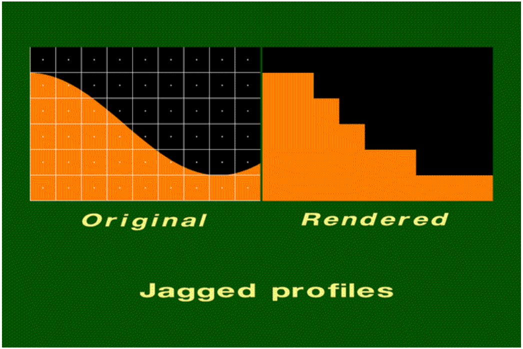
[3]

Aliasing in Foveation

Scene render before and after foveation method [2]

Problems to address

- Aliasing: imperfections generated due the digitization of analogue source material
- Immersion can be broken by motion in peripheral regions of the screen
- Sampling factor can magnify or reduce these issues



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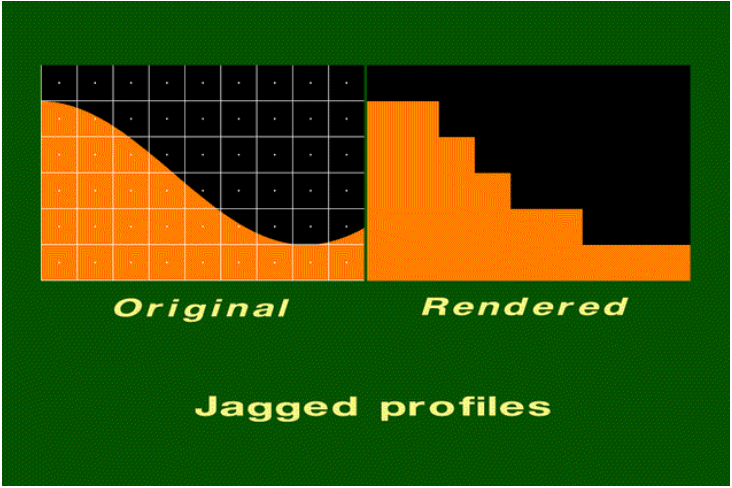
Rendering Tools

- Anti-Aliasing (AA): method of reducing aliasing, smoothing the jagged edges
  - increase sample rate
  - blur the contrasting edges
  - many types of AA that use different combinations of methods
- Temporal jitter of the spatial sampling grid
- Temporal reverse reprojection

Rendering Tools Continued



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Desktop Implementation

- Developed by Guenter et al. in 2012 [3]
- Produced results indistinguishable from non-foveated scenes
- Utilized AA methods such as temporal reverse reprojection, and sample jittering to combat aliasing

Desktop Implementation Continued

- Rendered scenes with three different foveal layers
- Reduced the number of pixels shaded by a factor of 10-15
- Limited by hardware that is outdated by modern standards

Virtual Reality Implementation

- Developed by Patney et al. [4]
- Directly references the design of Guenter et al. [3]
- Applies the technique of foveated rendering to scenes in Virtual Reality
- Developed using a *Perceptual Visual Target* to guide design choices

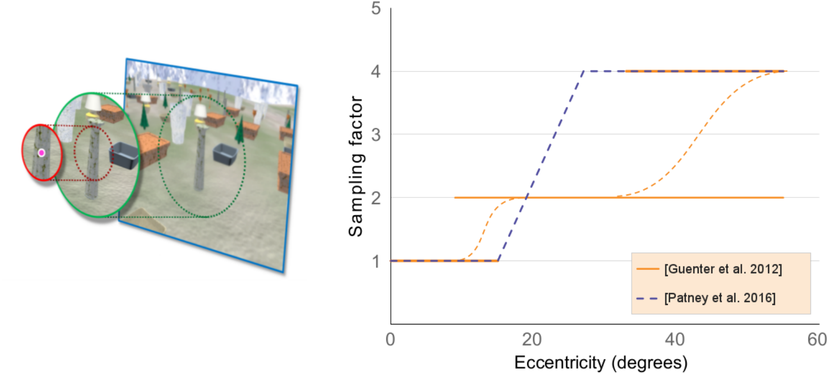
Perceptual Visual Target

- Created an emulated foveated renderer VR application
  - scenes rendered at full-resolution and level of detail
  - foveation performed as a post-process
  - not meant to improve performance
- Allowed variation of parameters without implementing new methods
- Conducted a user study to determine effectiveness of different foveation methods
  - study used a gaze-tracked VR Headset
  - participants asked to maintain viewing direction to normalize results

Virtual Reality Implementation Continued

- Due to results of their prototype user study:
  - prioritized temporal stability and contrast preservation
- Created their own version of a Temporal Anti-Aliasing algorithm to eliminate temporal inconsistency
- Utilized a piecewise linear variation of sampling factor instead of foveal layers

Sampling Factors



Comparison of the change in sample factor rate [3]

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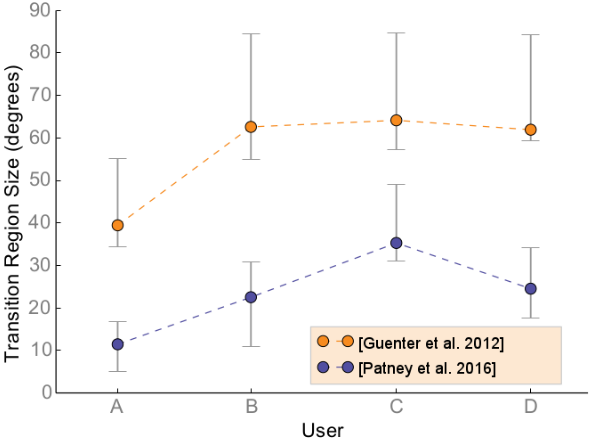
Patney et al. User Study

- Patney et al. [4] conducted a user study of both their system and that of Guenter et al. [3]
- Both systems were applied to a VR Head Mounted Display setup to be effectively compared

User Study Setup

- Four subjects
- Two-alternative forced choice test
  - two scenes presented in sequence
  - subjects had to pick which scene looked better
- 200 trials
- Scenes used in trials were varied by transition region size
- Successful trials were defined as those with the smallest transition region sizes

User Study Transition Thresholds



Comparison of Transition Region Size used in Patney et al.'s user study [4]

User Study Results

- Users tolerated higher rates of foveation by Patney et al.'s system
- Validates the approach of minimizing temporal aliasing and preserving contrast
- Patney et al. were able to shade 70 percent less pixels than the non-foveated scene. [4]
- Able to use lower quality shading up to 30 degrees closer to the fovea than Guenter et al.

Outline

Looking Forward

- The hardware required for foveated rendering is becoming more common
- Contrast-preserving temporally-stable foveation implementations have been proven to work
- As scene complexity increases, optimization methods suchs as foveated rendering will become more in demand

Thanks for listening

Questions?

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