Fast rendering of foveated volumes in wavelet-based representation

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Overview

- Goal
- Background
- Proposed method
- Experimental results
- Conclusions

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Goal

Our work is to design an algorithm to efficiently render foveated volumes represented by a small number of wavelet coefficients

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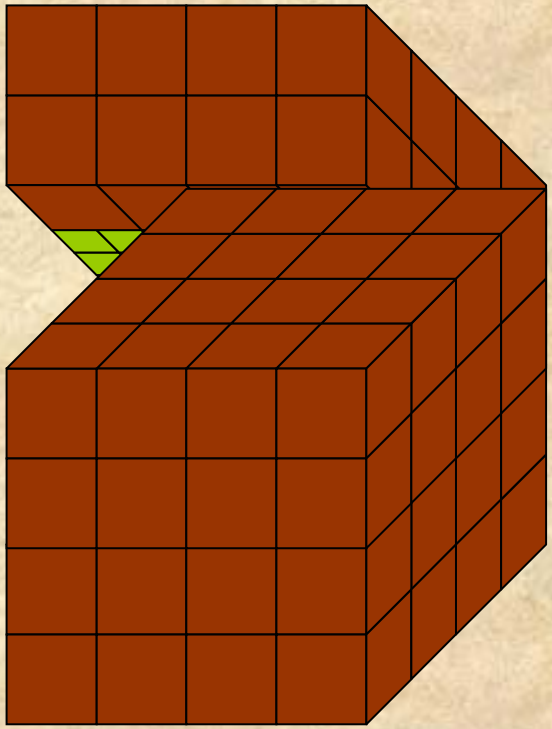
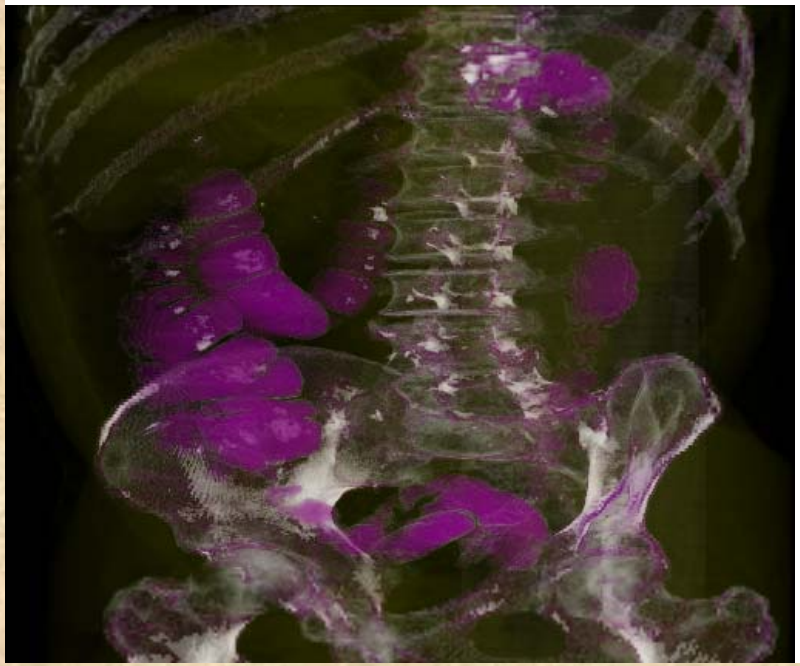
What is a foveated volume?

- A foveated volume can be viewed as a blending of multi-resolution regions

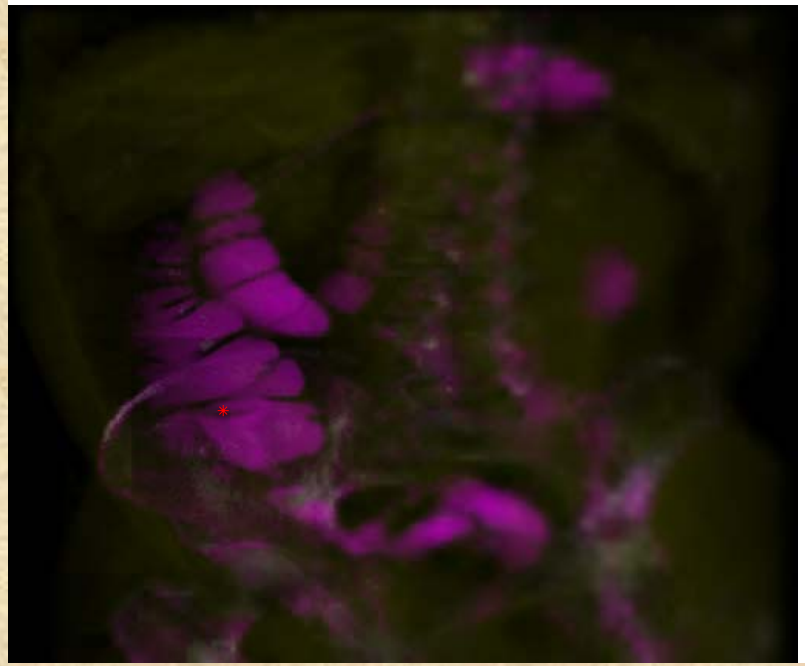


Foveated volume rendering

- Volume rendering using ray tracing
- Variable resolution with high image quality in region of interest



Full resolution volume rendering

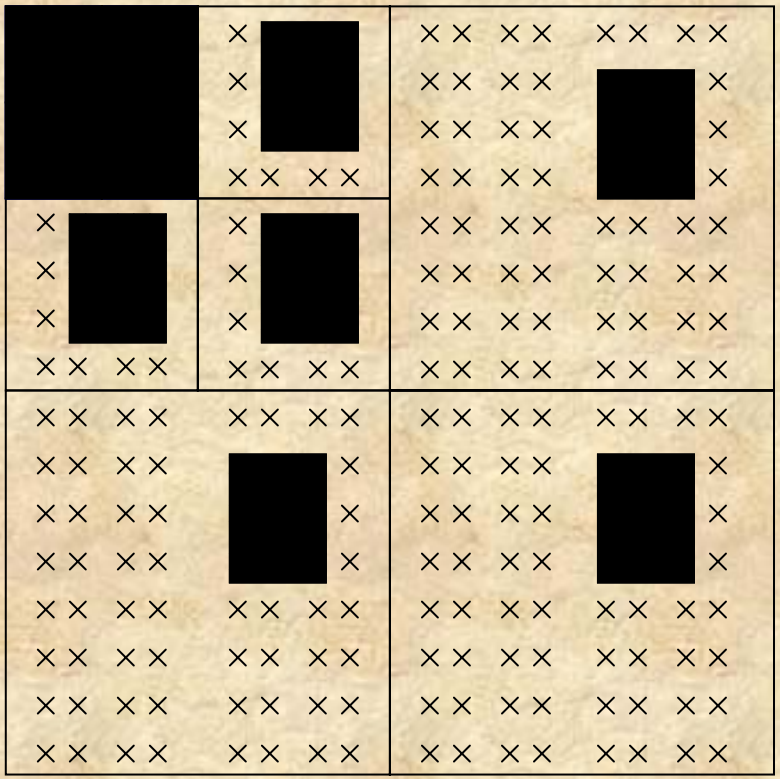


Foveated volume rendering

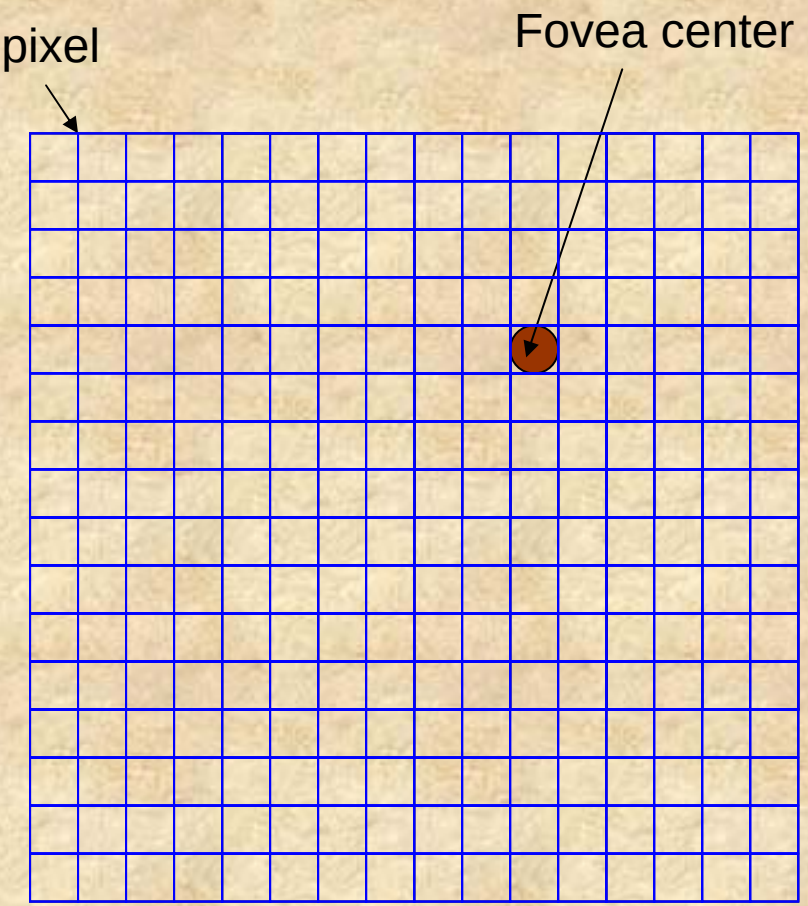
How to represent foveated volumes?

- Wavelet foveation
  - Ideal formulation of wavelet foveation [Chang et al. 2000]
  - Approximation by retaining relevant wavelets with parameters (fovea rate r_0, location x_0)

Wavelet foveation



(a) Wavelet coefficients



(b) Foveation parameters ($r_0 = 3$, $x_0 = (10,4)$)

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Main Idea and Contributions

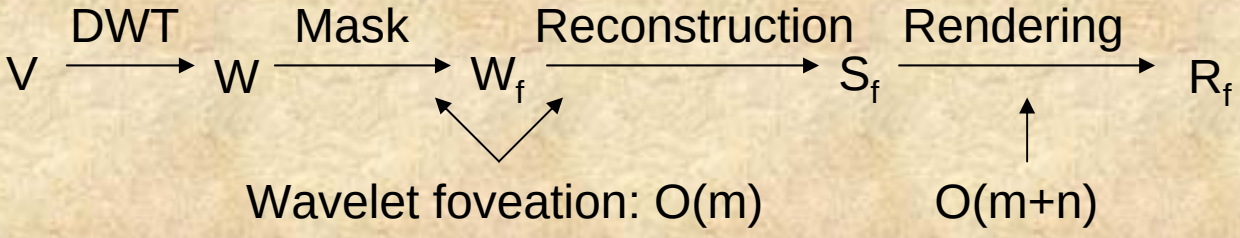
- The method
  - Render a foveated volume only from relevant wavelet coefficients
- Advantages
  - No expensive preprocessing
  - No special data structure (e.g. octree)
  - Allowing interactively rendering with changing viewing parameters (e.g. transfer function) at run time

Algorithm

- How to render foveated volume?
  - Direct way: Reconstruct foveated volume and render
  - Our method: Thick ray rendering from a small number of wavelet coefficients

Our method

- Step **I**: Reconstruct super-pixels
- Step **II**: Thick ray rendering



V: image data

DWT: Discrete Wavelet Transform

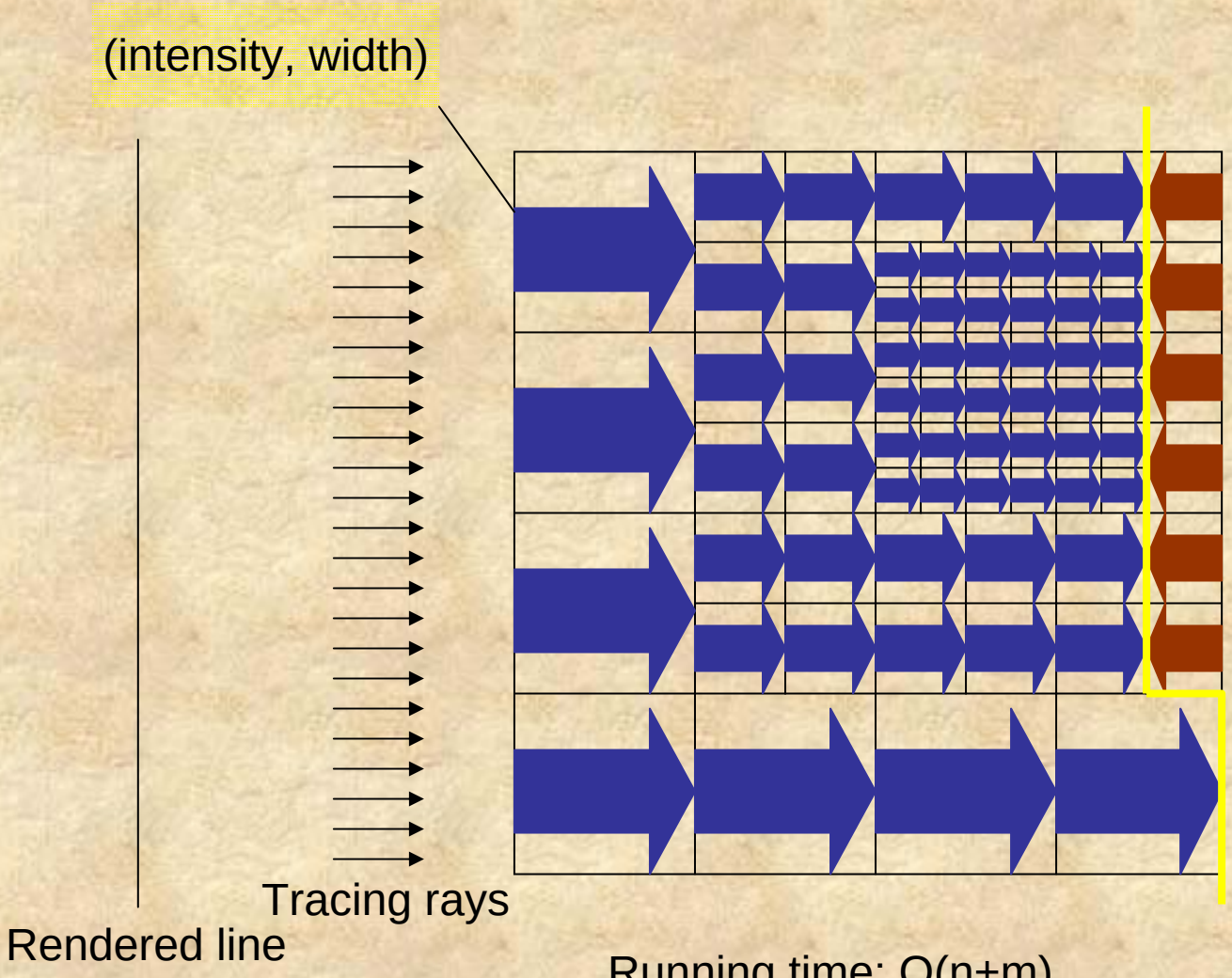
V_f: Foveated image

W_f: Wavelet coefficients of V_f

R_f: Rendered result of V_f

S_f: Super-pixels of V_f

Thick ray rendering



Running time: O(n+m)

Visualization of foveated volume

- Space variant weighting function
  - Varying across the 3D space

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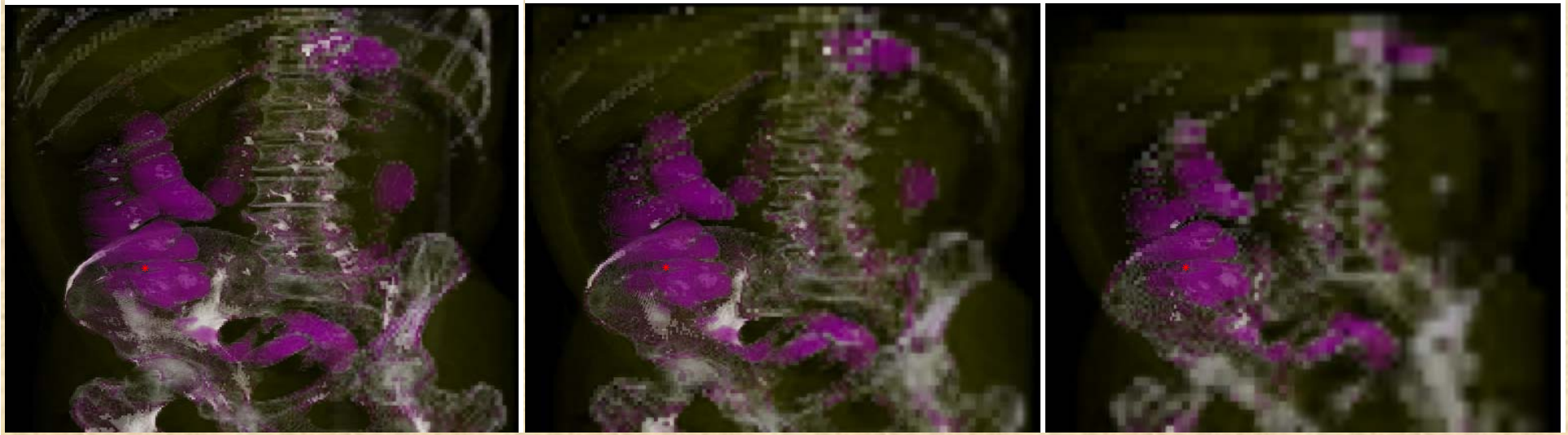
Experimental results

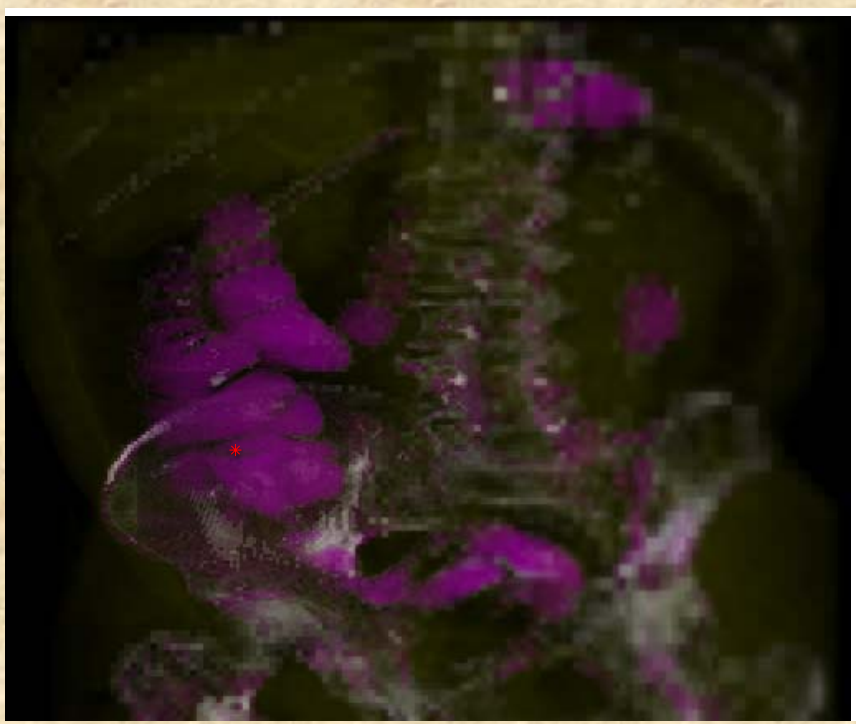


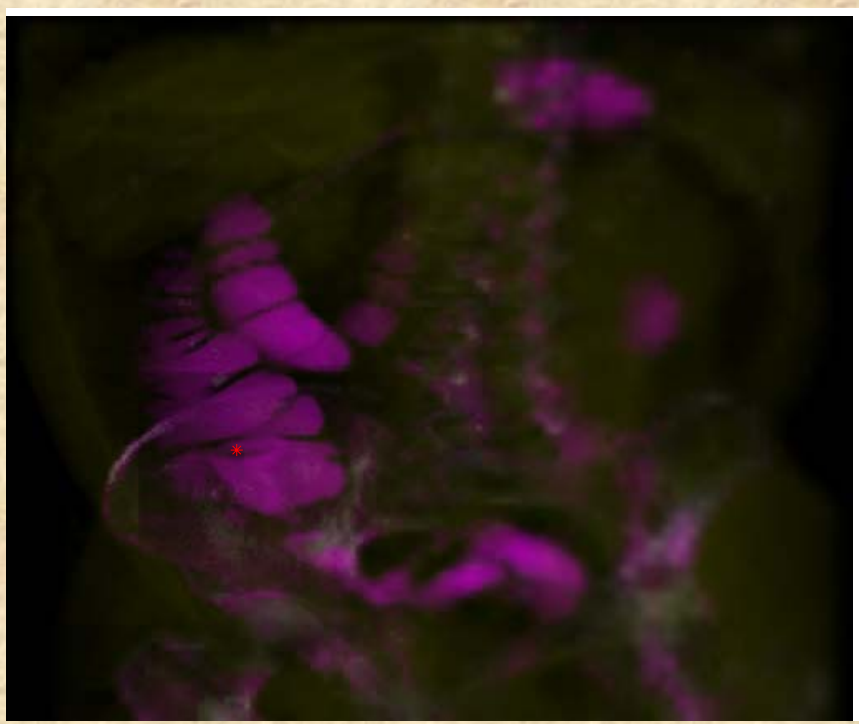
(a) Fovea rate $r_0 = 100$ (b) Fovea rate $r_0 = 50$ (c) Fovea rate $r_0 = 25$

A reduction to 21.3% (a), 5% (b) and 1% (c) of the original volume.

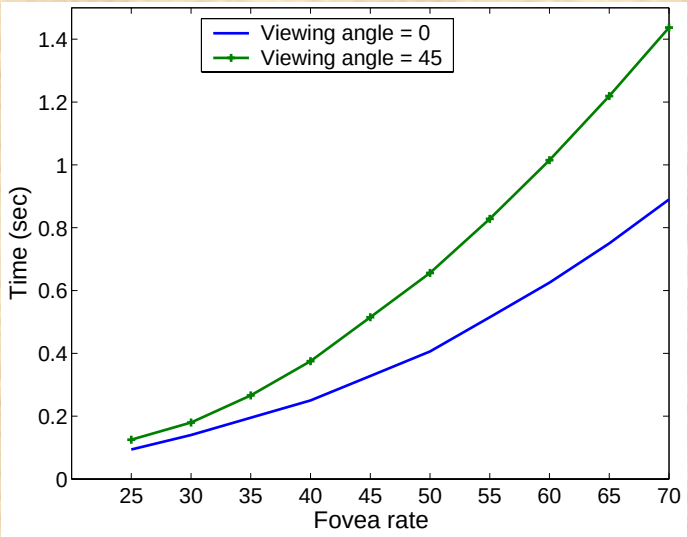
Rendering time: 1.23sec, 0.55sec, 0.15sec on PC with 3GHz P IV, 1GB DDR RAM

Varying across the 3D space

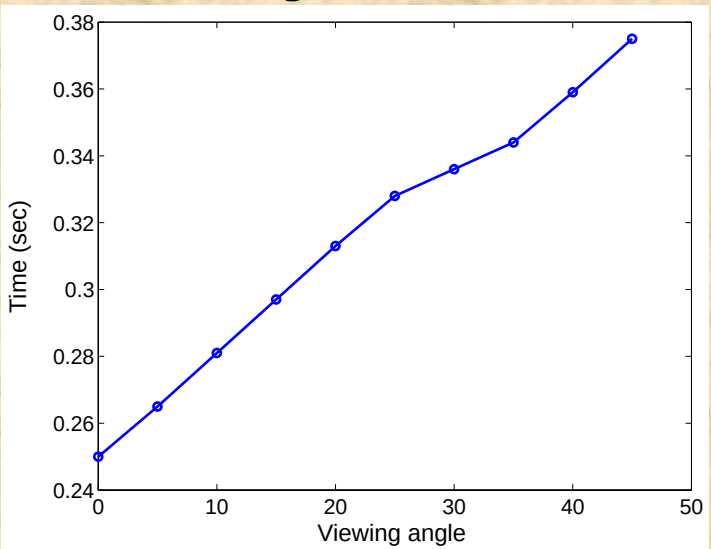




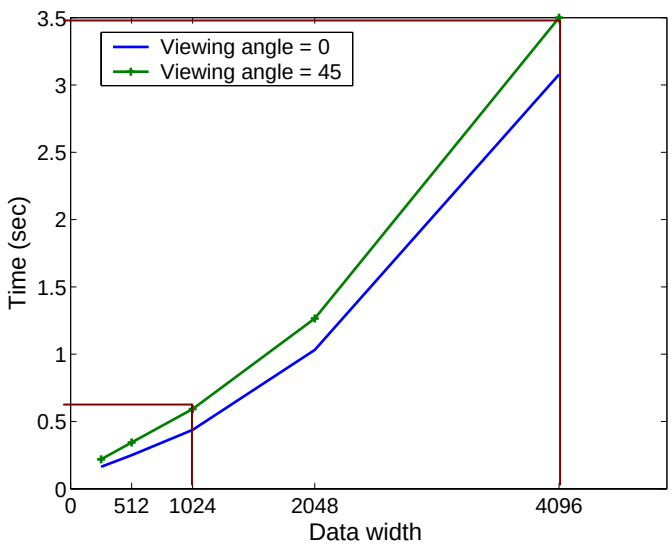
Performance analysis



(a) Rendering time versus fovea rate



(b) Rendering time versus viewing angle



(c) Rendering time versus data width

Conclusions

- Method of efficiently rendering of foveated volume in wavelet-based representation ($O(n^2+m)$)
- A good tradeoff between rendering resolution and rendering rate
- Suitable to apply in low computing resources and/or real time requirement

Related work

- Gaze-directed volume rendering [Levoy et al. 1990]
- Distance based enhancement for focal region based volume rendering [Zhou et al. 2004]
- Importance-driven volume rendering [Viola et al. 2004]
- Efficient visualization of volume data sets with region of interest and wavelets [Piccand et al. 2005]