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Real-time volumetric shadows for dynamic rendering

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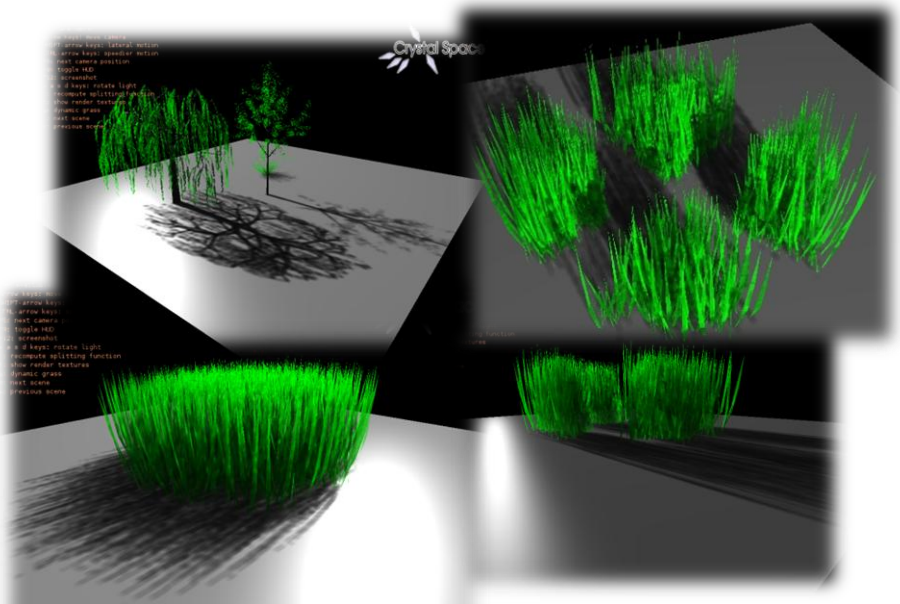

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Why do we need volumetric shadows ?

No shadows

Volumetric shadows

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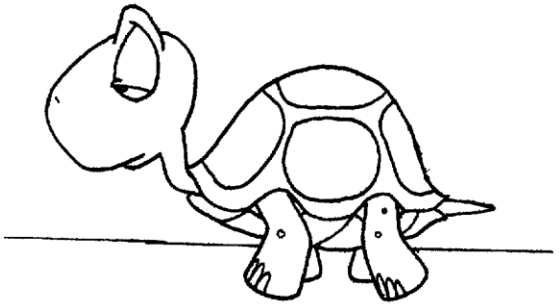
Same story in real-life

No shadows
(dyed blonder hair)

Volumetric shadows
(natural blonde hair)

Offline implementation

- Successfully done by the film industry
  - ray tracing
  - photon mapping
- Not real-time
  - 3DS Max
  - Maya
  - Blender
  - Pixar's RenderMan®



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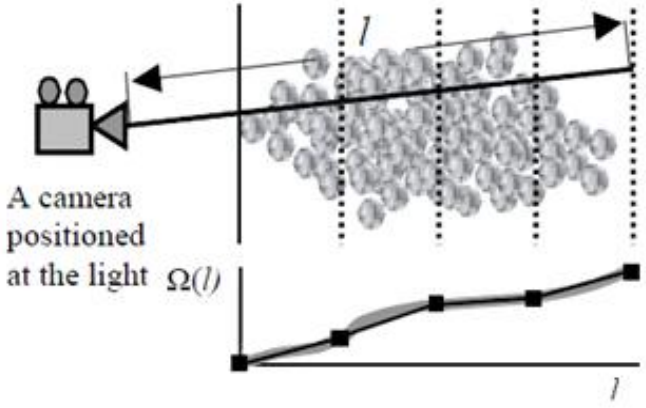
Algorithm (Kim et al.) '01

- Geometry is rendered to texture for a predefined number of times
  - along the light's direction
  - setting the *near* and *far* clip planes



- Real-time due to hardware acceleration

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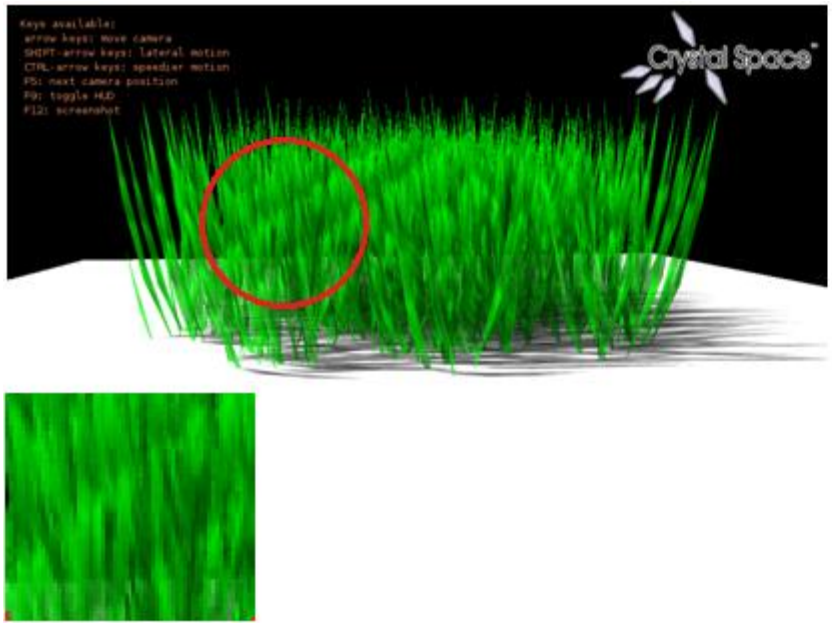
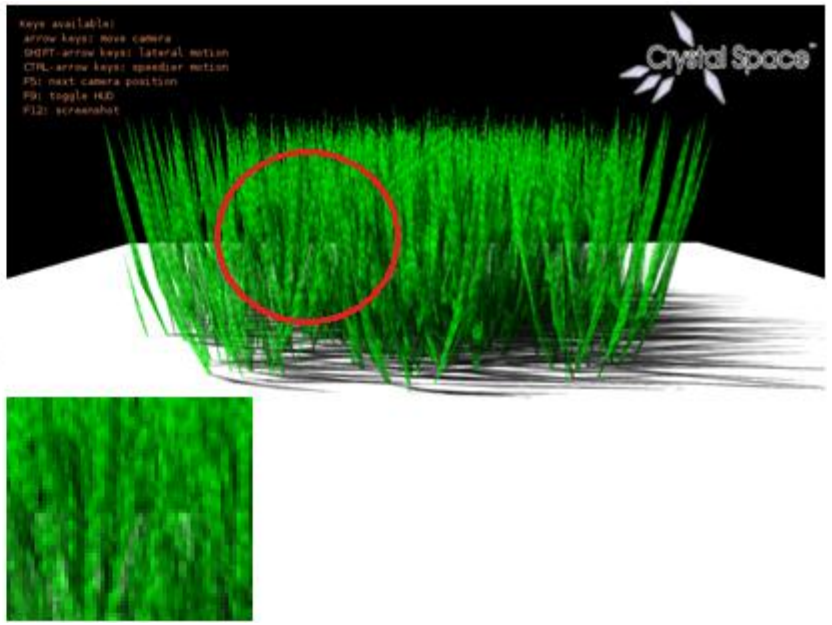
Severe visual artifacts



16 layers



64 layers

- Points are presented in only one layer

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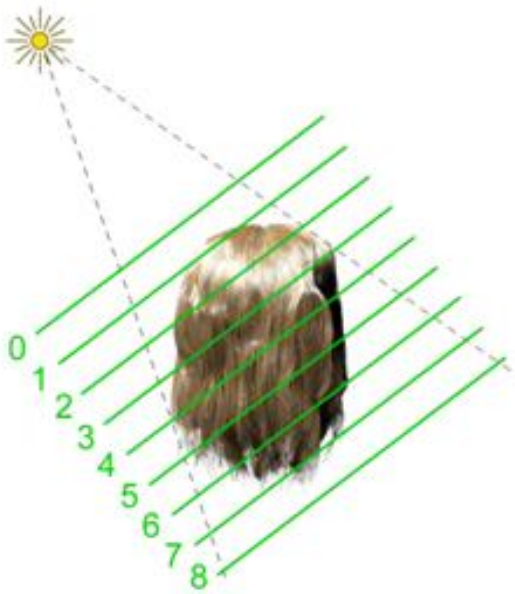
Algorithm (Yuksel et al.) '08

- Layers are aligned with the object's shape via a depth map
  - less layers produce better renderings



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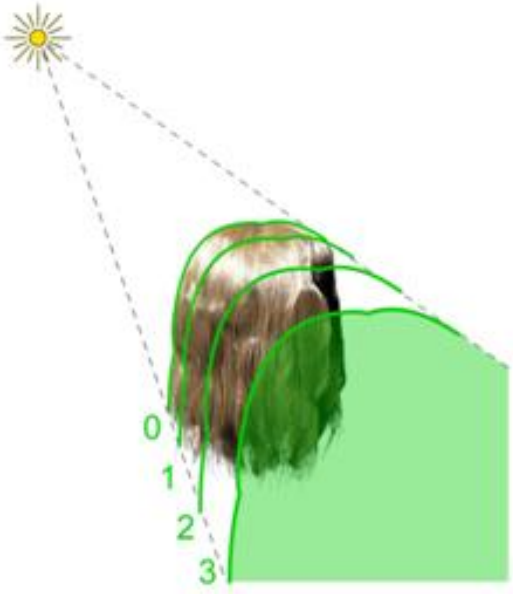

Deep Opacity Maps

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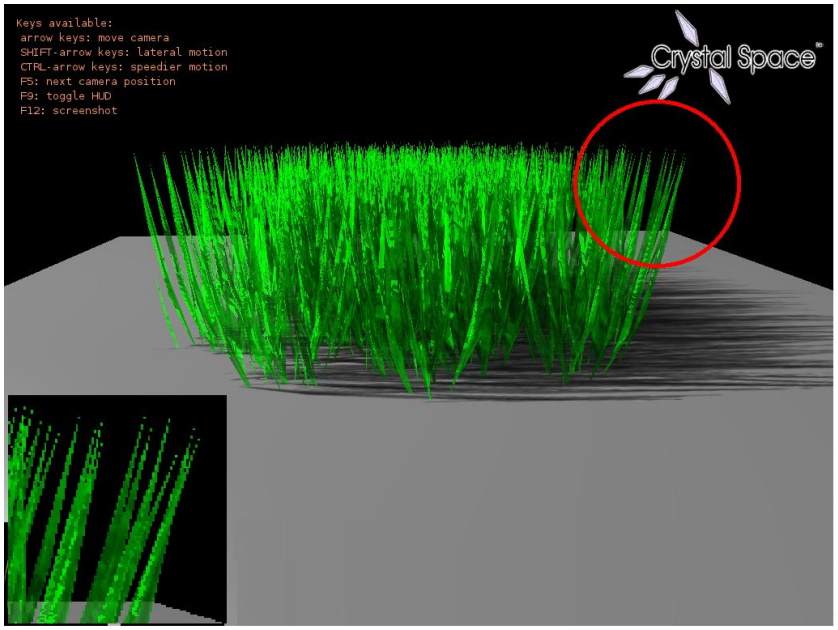
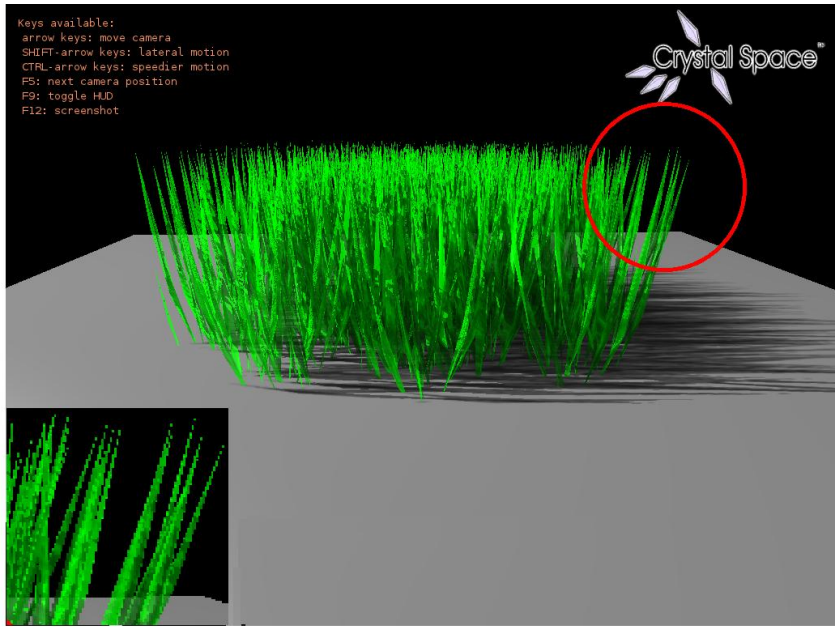
Still some visual artifacts



Bad ending position



Good ending position

- No information about where objects end
  - doesn't really work with multiple objects

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Bounding Opacity Maps

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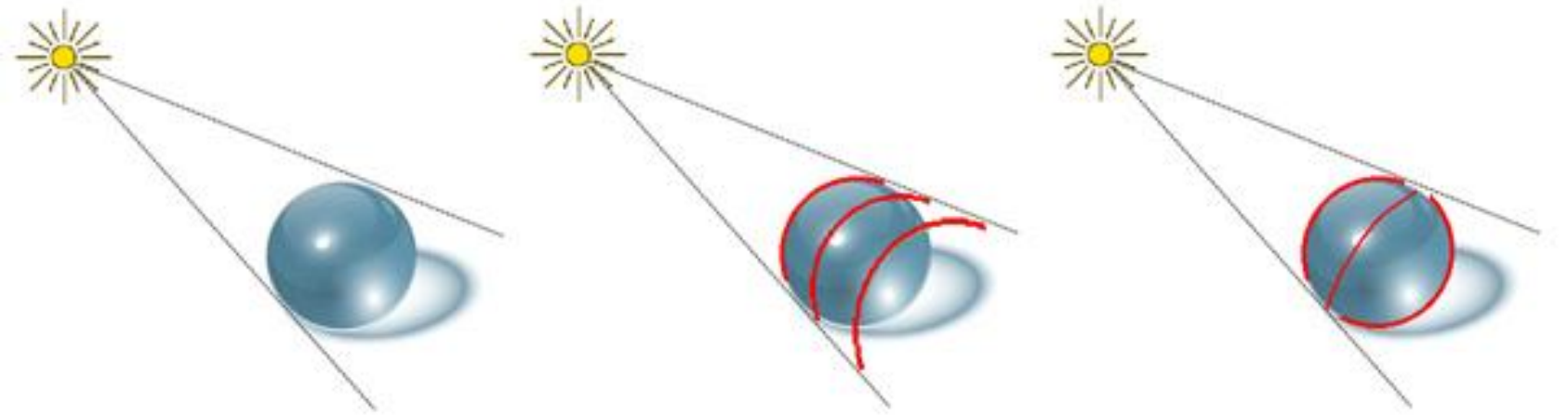
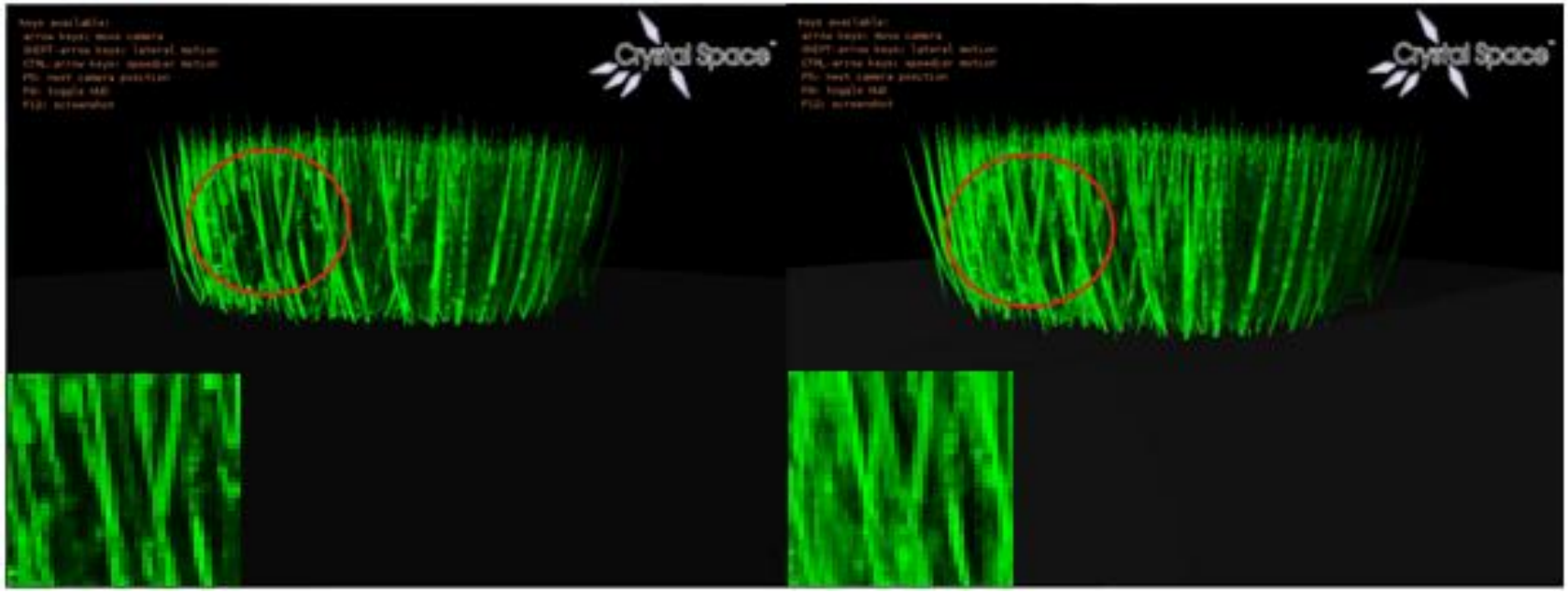
Algorithm (me) '11

- Layers are aligned with the object's shape via **two** depth maps
- Follows the distribution of light in real-life
  - even less layers produce even better renderings



Light distribution | Deep Opacity Maps | Bounding Opacity Maps

Visual artifacts



Linear split

Logarithmic split

- Too few layers and bad splitting scheme

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Linear splitting

- Good for sparse objects / bad for dense ones
  - lighting changes throughout the entire object's length

Real-life photographs of sparse objects

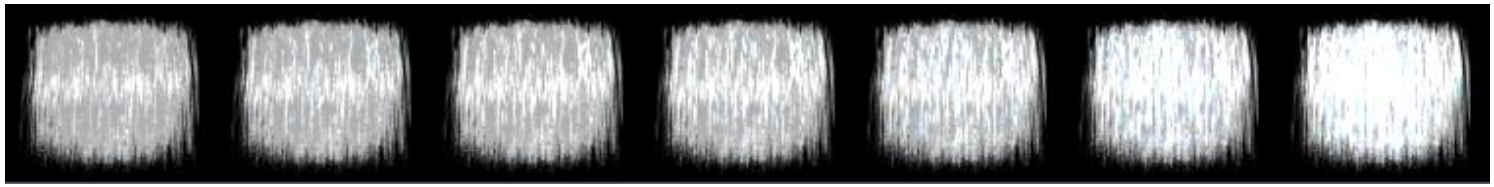
Logarithmic splitting

- Good for dense objects / bad for sparse ones
  - lighting changes only at the beginning


Real-life photographs of dense objects

Hybrid splitting

- Linear interpolation between linear and logarithmic splitting
- Automatically choose the best ratio
  - consecutive layers are different
  - every new layer brings new information
- The layers are gray **images**
  - image processing problem
  - mutual information



Mutual information

- Two methods were tested
  - Sum of absolute differences
  - Cross-correlation coefficient

$$C = \frac{\sum_{x,y}\left(I_1(x,y) - \bar{I_1}(x,y)\right)\left(I_2\left(T(x,y)\right) - \bar{I_2}\left(T(x,y)\right)\right)}{\sqrt{\sum_{x,y}\left(I_1(x,y) - \bar{I_1}(x,y)\right)^2 \sum_{x,y}\left(I_2\left(T(x,y)\right) - \bar{I_2}\left(T(x,y)\right)\right)^2}}$$

- Cross-correlation gives better results
  - takes standard deviation into account
  - normalized between [-1, 1]

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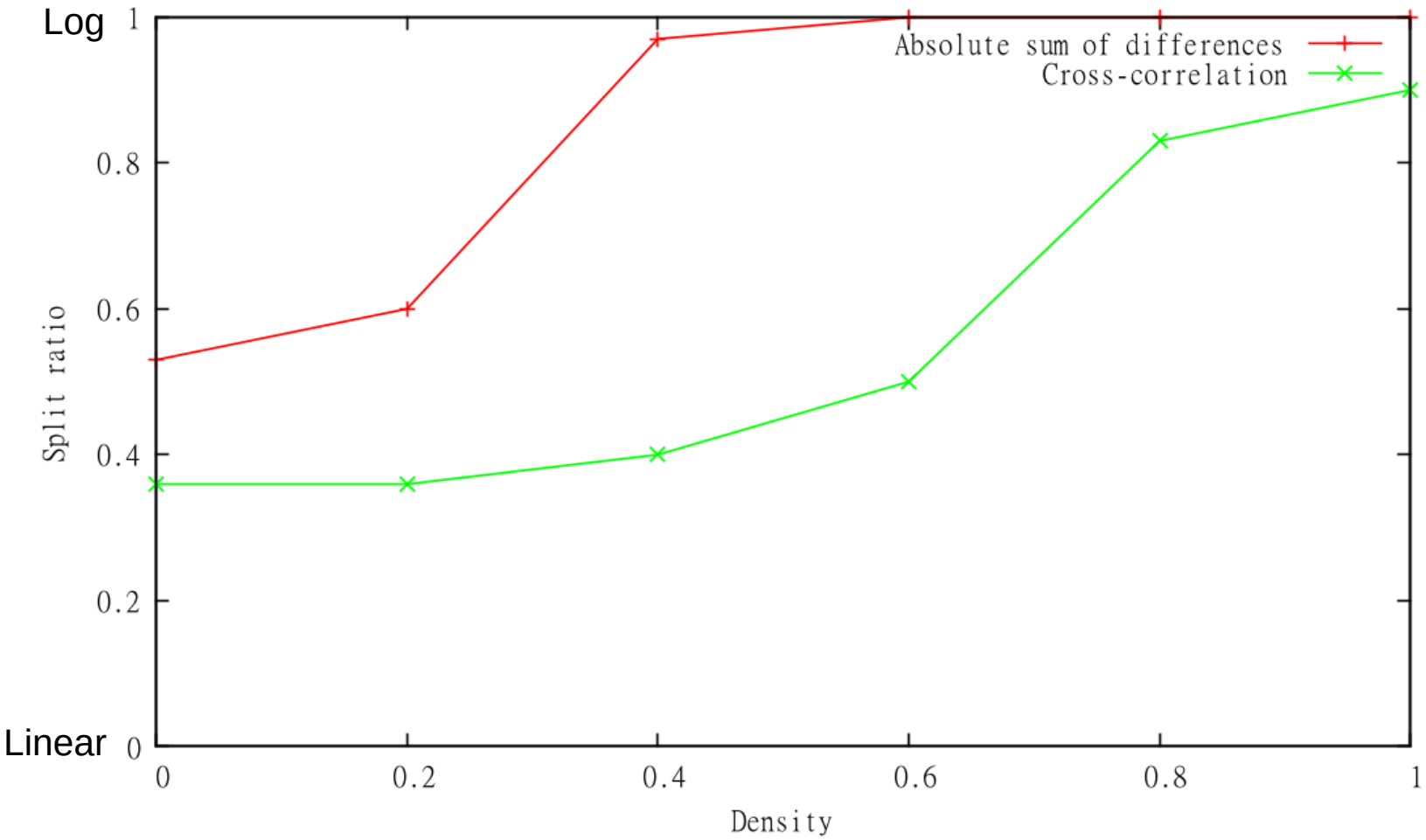
Split ratio vs. Density



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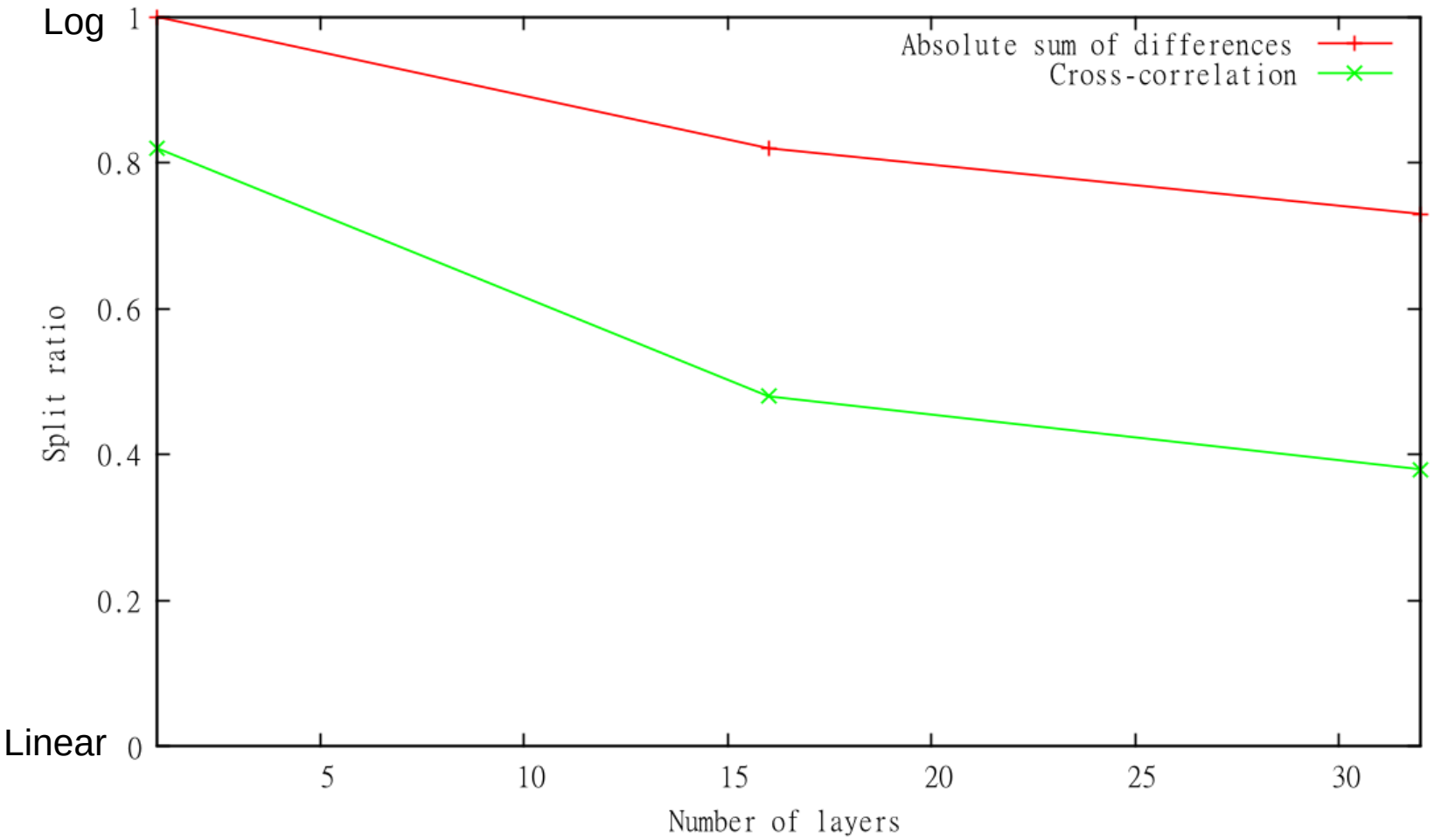
Split ratio vs. Number of layers



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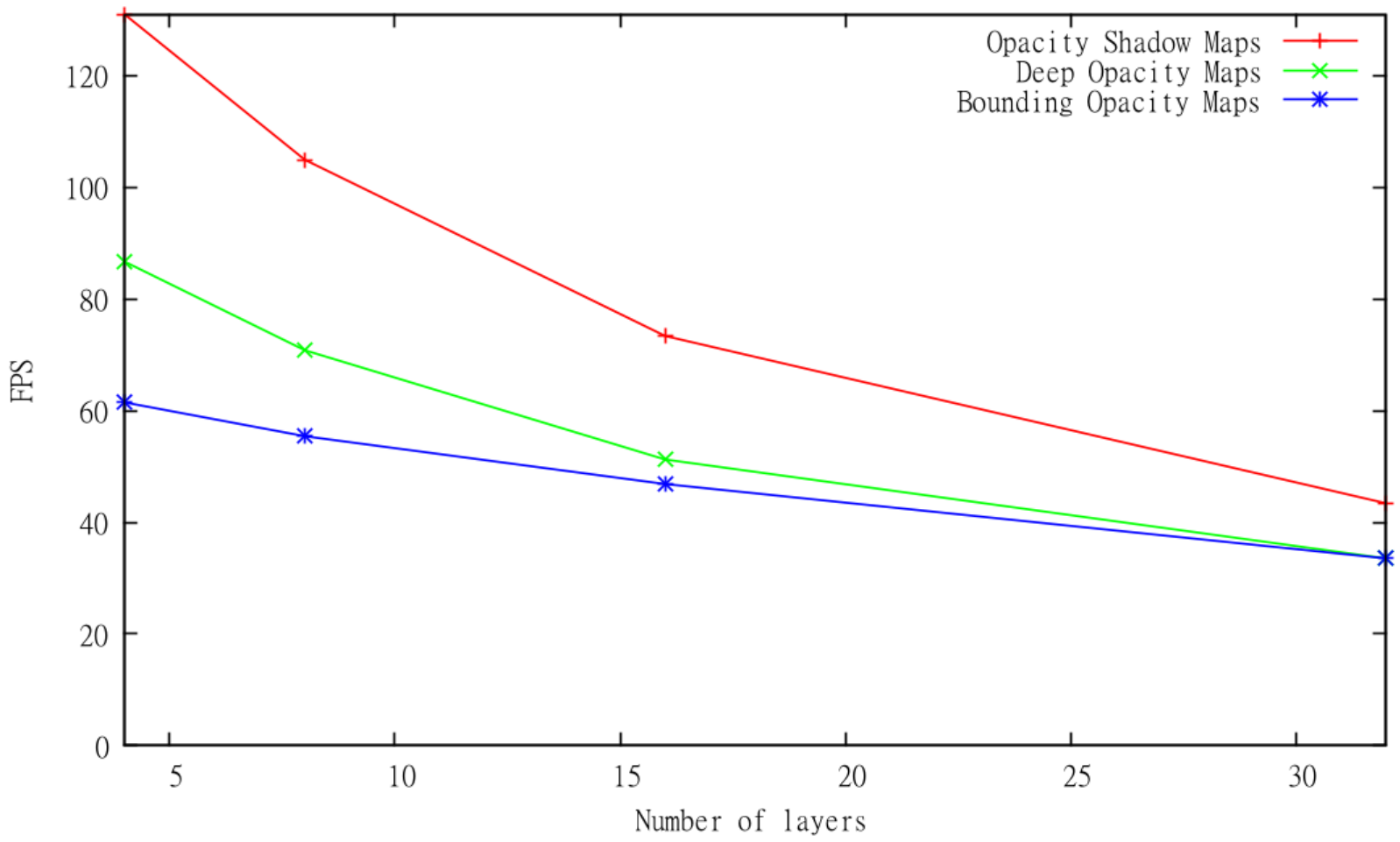
FPS vs. Number of layers



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To Do

- Different splitting function for each ray / region
  - splitting texture (another render pass)
- Compute split ratio in real-time (CPU bound now)
  - solved by using the GPU
- Find the optimal number of layers
  - easier to find the biggest number of layers that keeps the application real-time
- Extend to clouds and smoke
  - add support for volumetric rendering

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Conclusions

- Self-shadows needed for realistic rendering
- Previous method do this in real-time, but suffer from visual artifacts
  - don’t follow the light distribution from real-life
- New methods for approximating the light distribution are proposed
  - Bounding Opacity Maps
  - Hybrid Splitting
- Dyed blonde hair looks unnatural
  - doesn’t cast volumetric shadows!

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Q & A

- Thank you for your attention
  - http://www.youtube.com/watch?v=JUrC7yv26eA
- Full source code
  - https://crystal.svn.sourceforge.net/svnroot/crystal/CS/branches/soc2011/selfshadow/
- More about this project
  - http://volumetricshadows.wordpress.com/
- Contact details
  - alexandru.voicu10@imperial.ac.uk
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