Depth Buffer Compression for Stochastic Motion Blur Rasterization

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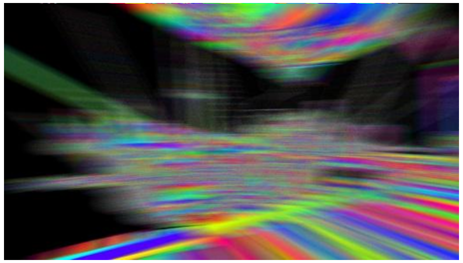
Motivation

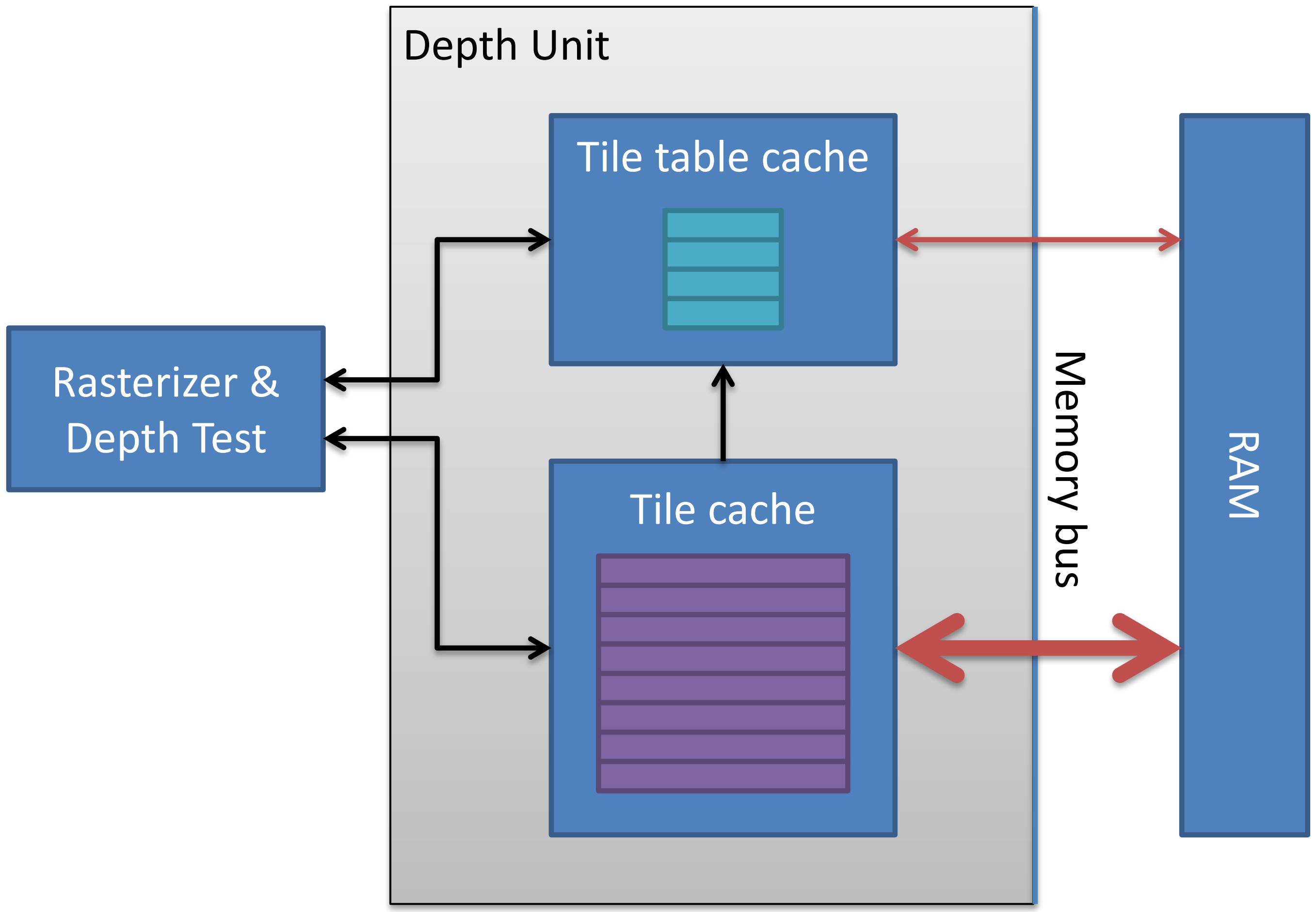
- Depth buffer memory transactions require a significant amount of BW
- Reduced with caching…
- …and with compression
- **Adding stochastically sampled motion blur to the mix**
  - *Doesn't work well with existing algorithms*



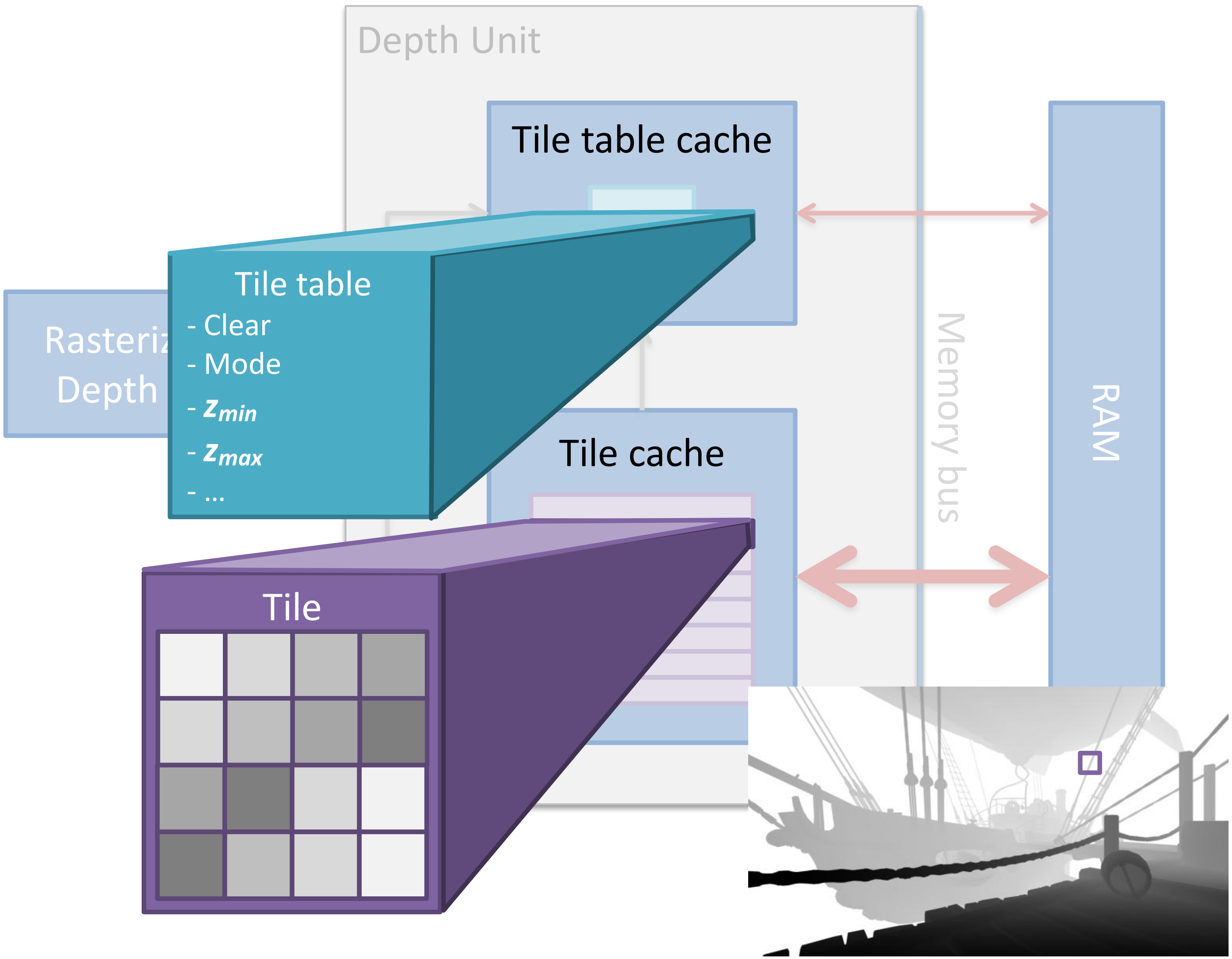
Overview

- Architectural/Compression Frameworks
- Previous Work
- Our Algorithm
- Results
- Conclusions

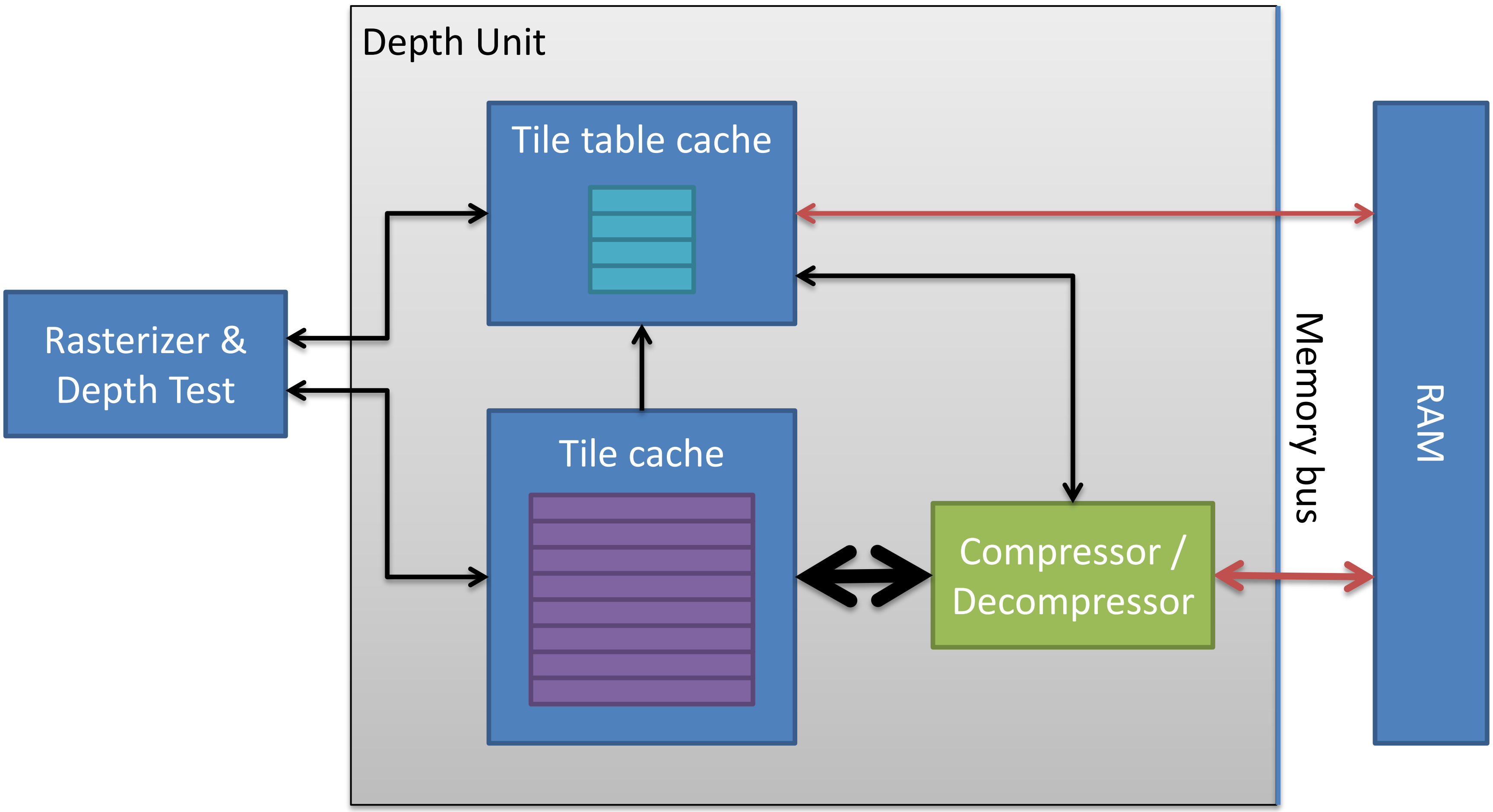
Architectural Framework



Architectural Framework



Architectural Framework



[Morein 2000, Hasselgren and Akenine-Möller 2006]

Compression Framework

Existing compression schemes can be described with the three following steps:

1 *Clustering*

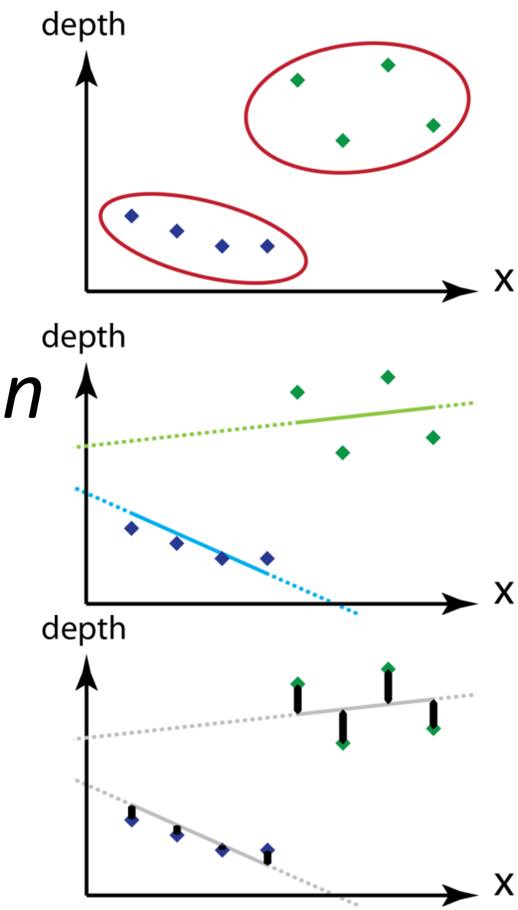
- *Group samples with similar characteristics*

2 *Predictor function generation*

- *Find suitable predictors for each cluster that minimizes the error*

3 *Residual encoding*

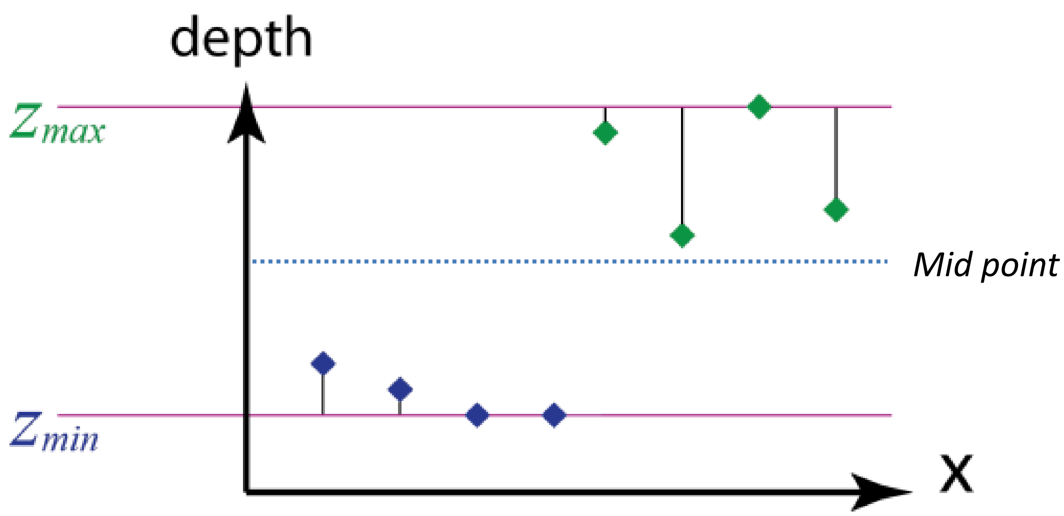
- *Capture the remaining error*



Previous Work

Depth Offset (DO) compression:

- Uses z_{min} and z_{max} of the tile
  - *We assume that these are freely available in the tile table*



Described by Hasselgren & Akenine-Möller [2006]

Previous Work

- Most other compression schemes assumes that $z = z_c / w_c$ is linear over a triangle in screen space;

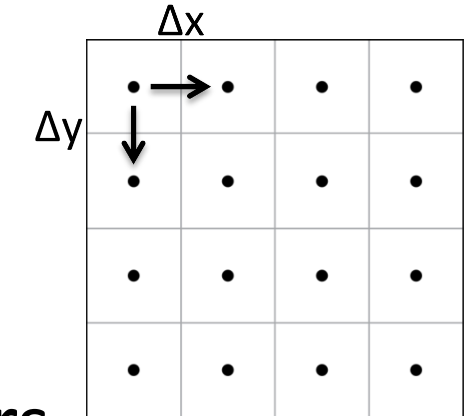
$$z(x, y) = a + bx + cy$$

- Perfectly valid for static scenes

Previous Work

Anchor encoding* / *DDPCM ***(Differential Differential Pulse Code Modulation)***

- Create a predictor plane from three neighboring pixels
- Store residuals in few bits
- DDPCM can handle two planes originating from different corners
  - *Clustering*



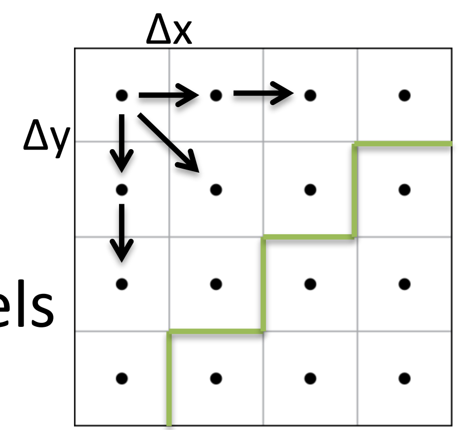
Described by Hasselgren & Akenine-Möller [2006]

Previous Work

Improvements on Anchor encoding / DDPCM:

[Hasselgren and Akenine-Möller 2006]

- Smarter bit distribution
- Better clustering



[Ström et al. 2008]

- Predicts from a larger number of pixels
- Handles floating point buffers
- Variable rate residuals with Rice coding

[Lloyd et al. 2007]

- Targets logarithmic shadow maps

Previous Work

Plane encoding

- Communicates with the rasterizer
  - *Input: coverage mask and plane equation*
  - *Can store many planes in one tile*
  - *Store compressed in cache*

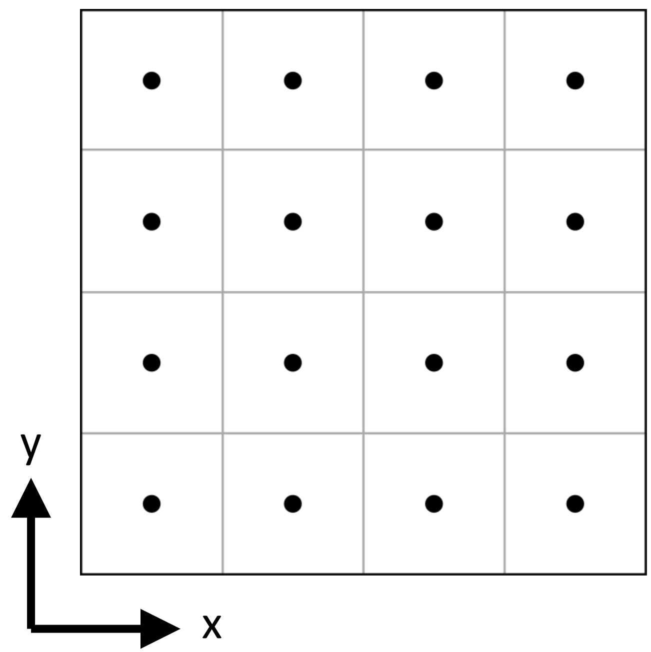
0	0	1	1
0	1	1	2
1	1	1	2
1	1	2	2

0: $a_0x + b_0y + c_0$
1: $a_1x + b_1y + c_1$
2: $a_2x + b_2y + c_2$

Described by Hasselgren & Akenine-Möller [2006]

Motion Blur Challenges

- Assumptions made by previous work:
  - *z is linear over a triangle in screen space*
  - *Samples are arranged in a grid*



(Note:** Neither of these assumptions is made by DO**)

Motion Blur Challenges

- Assumptions made by previous work:
  - *z is linear over a triangle in screen space*
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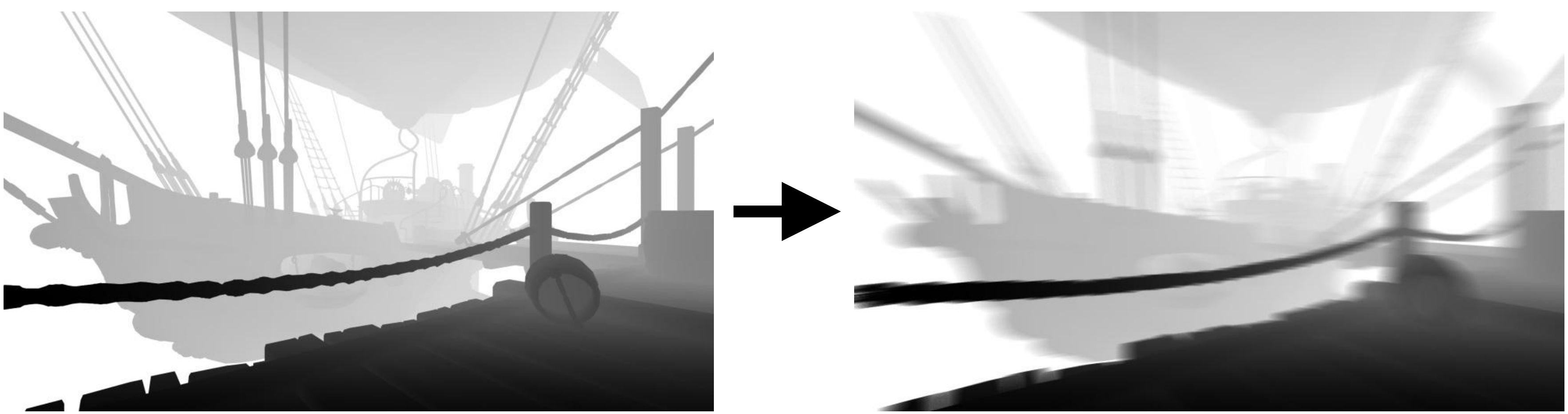
Introducing ***motion blur***

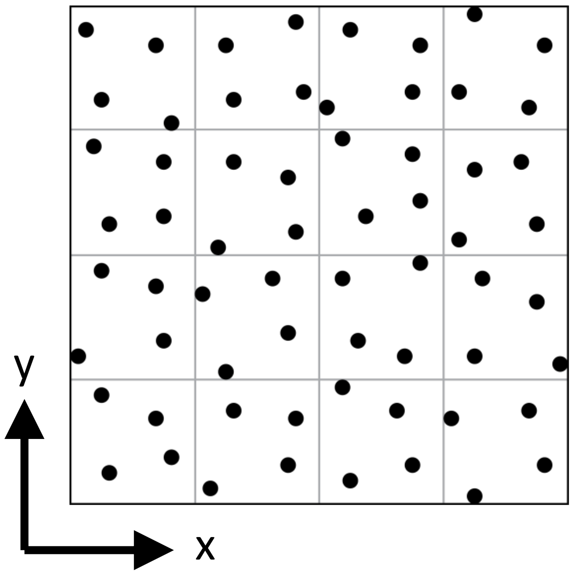


Motion Blur Challenges

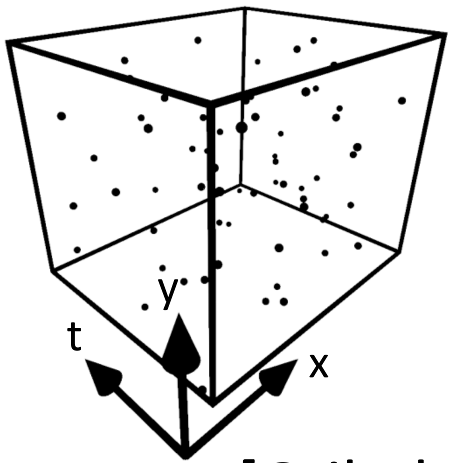
- Assumptions made by previous work:
  - ~~z is linear over a triangle in screen space~~
  - ~~Samples are arranged in a grid~~

Introducing ***motion blur***

MSAA



Time dependence



[Gribel et al. 2010]

Our Algorithm

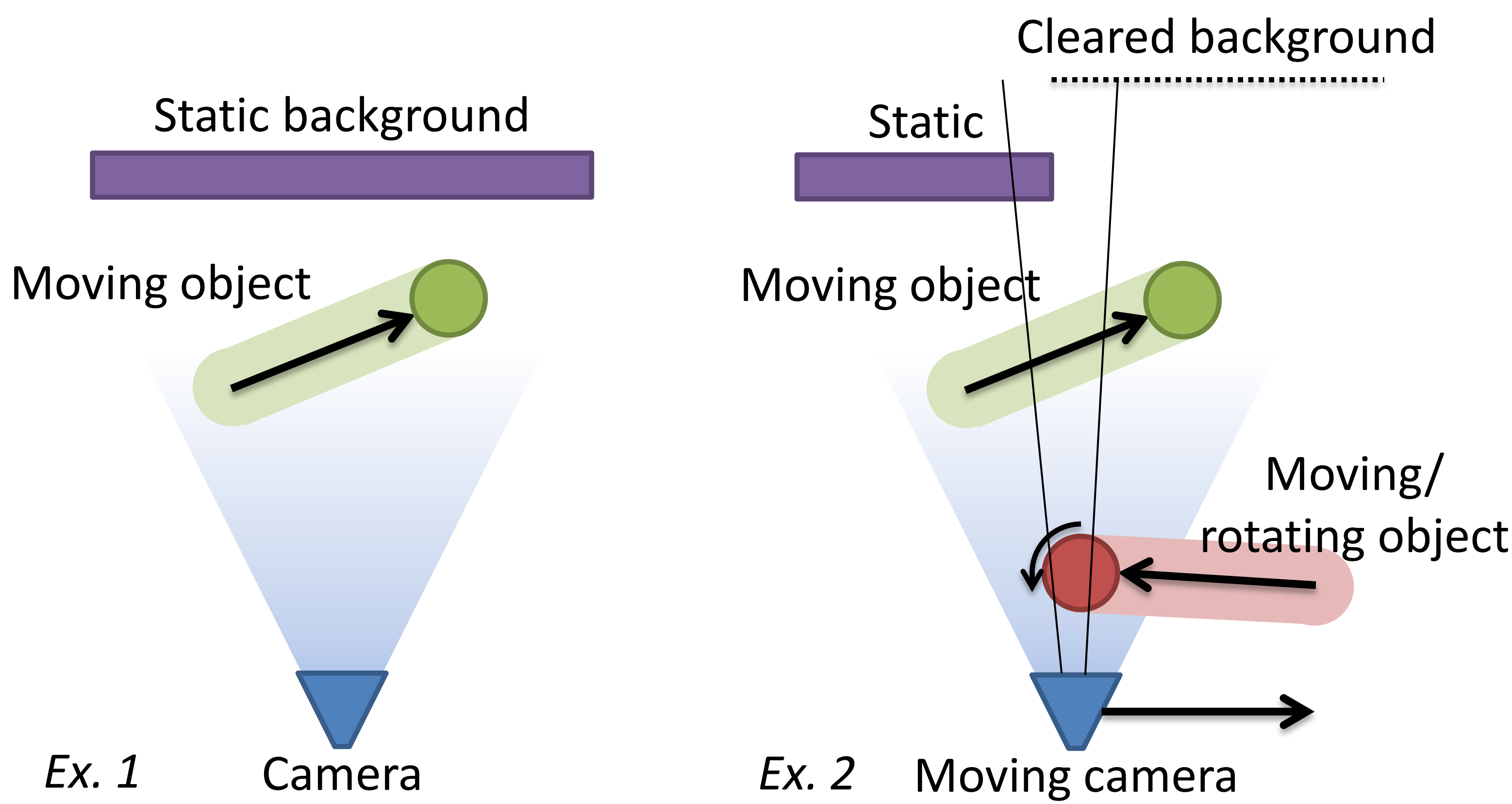
Algorithm steps:

1. *Clustering*
2. *Predictor function generation*
3. *Residual encoding*

Our Algorithm

1 *Clustering*

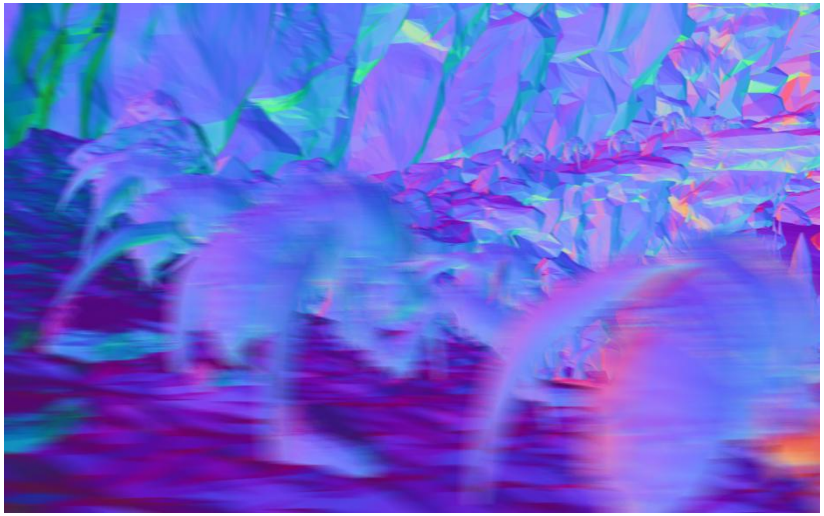
- Different depth layers often have different characteristics



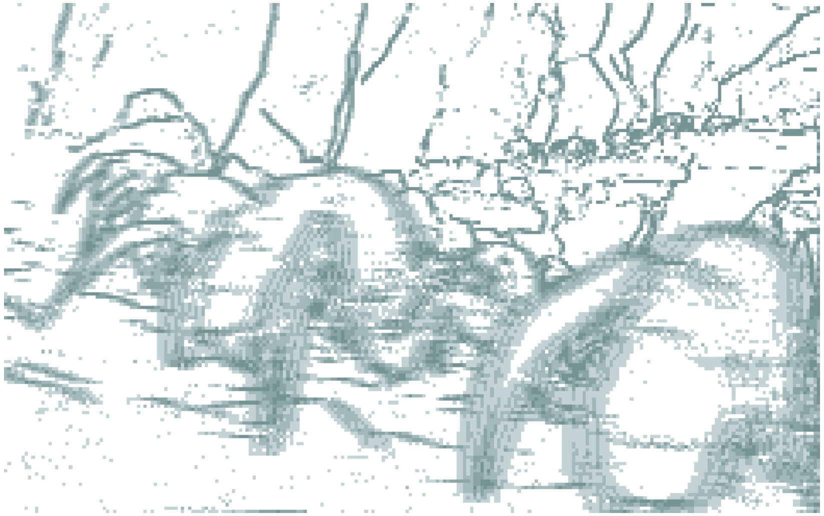
Our Algorithm

1 *Clustering*

Clustering is very useful around moving silhouettes



Normal shaded

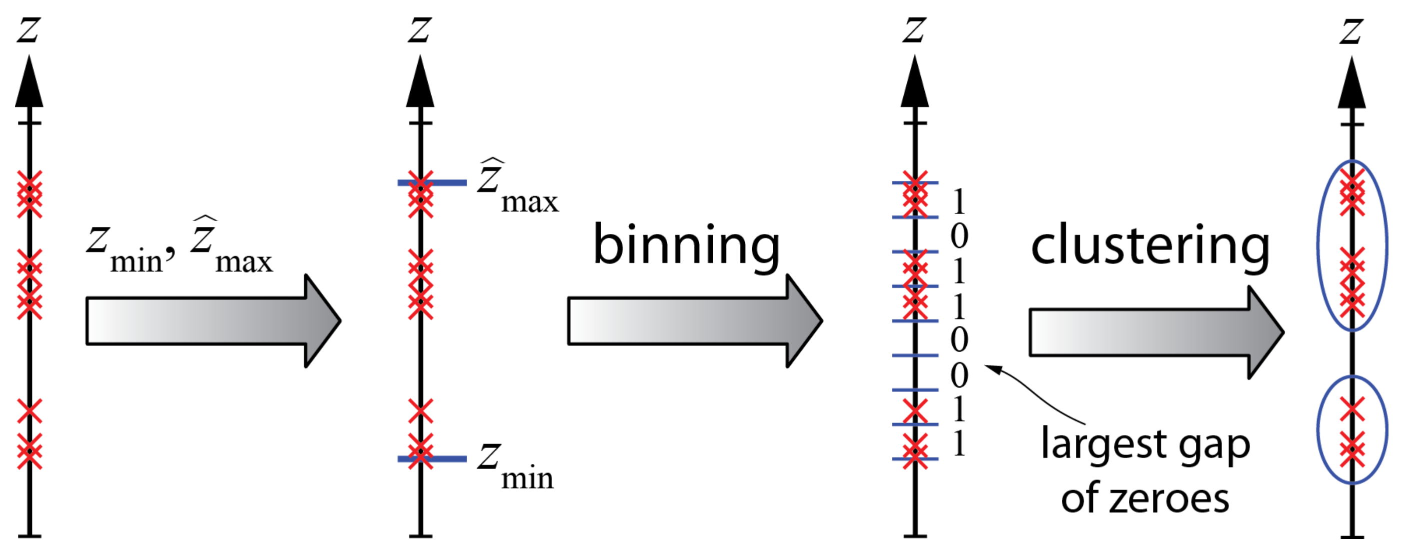


= Two layers

Our Algorithm

1 *Clustering*

Assume that there is at least *some* separation in depth between layers

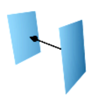


Our Algorithm

2 *Predictor function generation*

For each layer we use one of 3 different predictors:

 **Static patch:** Patch(x, y)

 **Moving plane:** Plane(x, y, t)

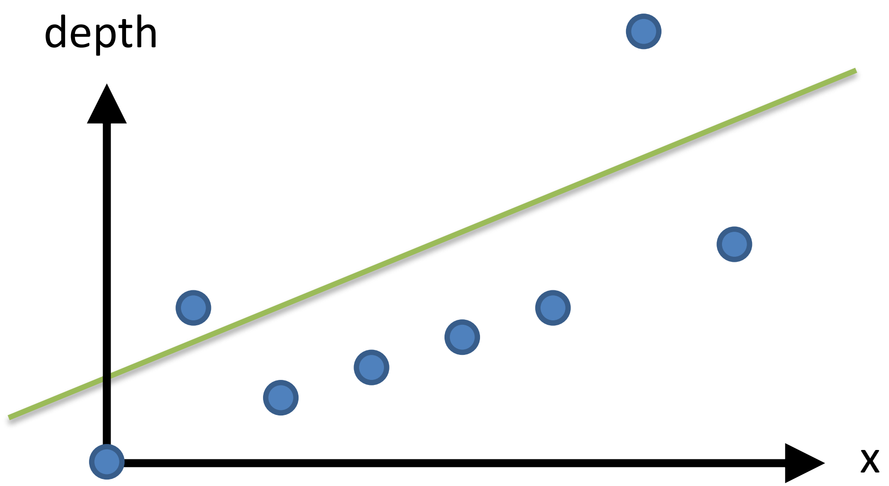
 **Moving patch:** Patch(x, y, t)

Goal: Minimizing error => fewer residual bits

But *which* error do we wish to minimize?

Our Algorithm

2 *Predictor function generation*



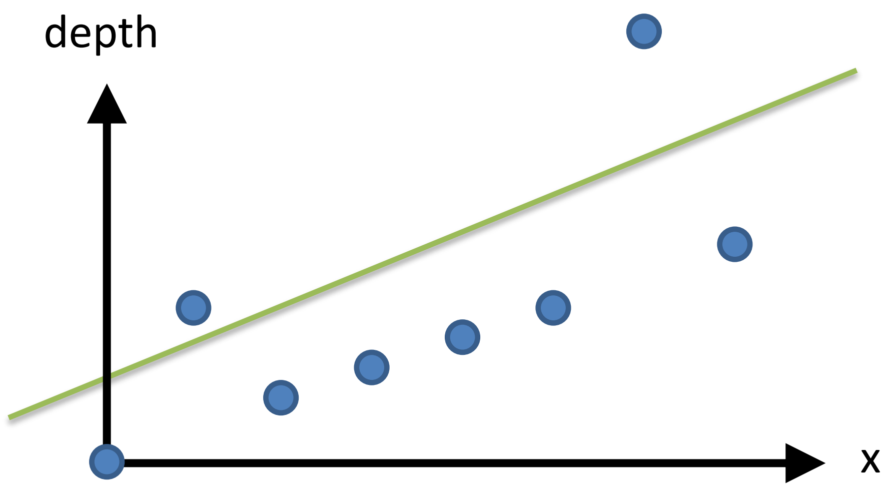
Minimize the *maximum* error of any sample

- Use *minimax* (related to the convex hull)
  - *Very expensive*

[Houle and Toussaint 1988]

Our Algorithm

2 *Predictor function generation*

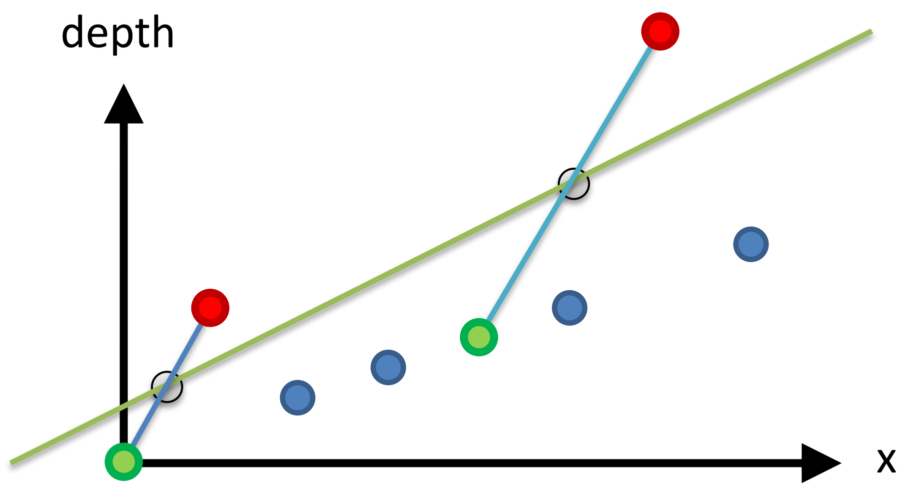


We use an approximation of *minimax*

- Simplify the problem by reducing the number of points to a few representatives
- A similar approach is used as a first step in all of our compression modes

Our Algorithm

2 *Predictor function generation*



1. Split the samples into two sub-tiles. Then for each sub-tile:
   A. Find samples with minimum and maximum *z* values
   B. Use the mid-points as representative points
2. Use the representative points to solve for the predictor

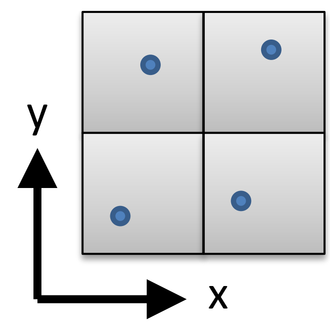
More details in paper…

Our Algorithm

2 *Predictor function generation*

Static patch: $z = a + bx + cy + dxy$

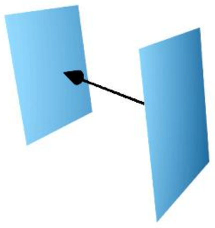
- Not time dependent
- Select 2x2 sub-tiles in xy



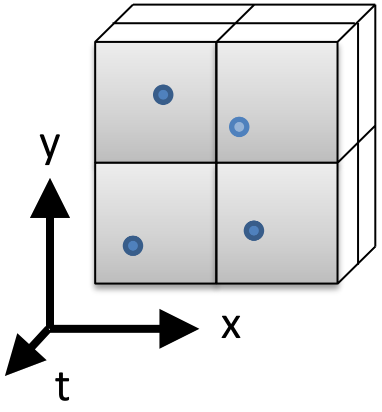
Our Algorithm

2 *Predictor function generation*

Moving plane: $z = a + bx + cy + dt$



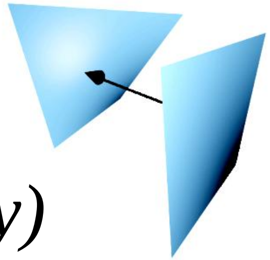
- Time dependent plane
- Select 2x2x2 sub-tiles in xyt
  - Select 4 points that are not coplanar



Our Algorithm

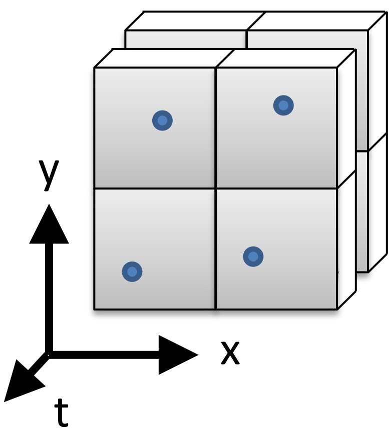
2 *Predictor function generation*

Moving patch:



$$z = (1 - t)\,(a_0 + b_0 x + c_0 y + d_0 xy) + t\,(a_1 + b_1 x + c_1 y + d_1 xy)$$

- Interpolate two patches
- Select 2x2x2 sub-tiles in xyt
  - Create one patch in each 2x2x1-slice
  - Extrapolate to t = 0 and t = 1
  - Predict by interpolating between the two



Our Algorithm

3 *Residual encoding*

- Calculate the offset coefficient, ***a***, so that all errors are positive
- Each sample is given the same number of residual bits
  - I.e. that of the largest remaining error
- We "steal" one bit combination to signal clear instead
  - Use the maximum representable error given residual bit count

Our Algorithm

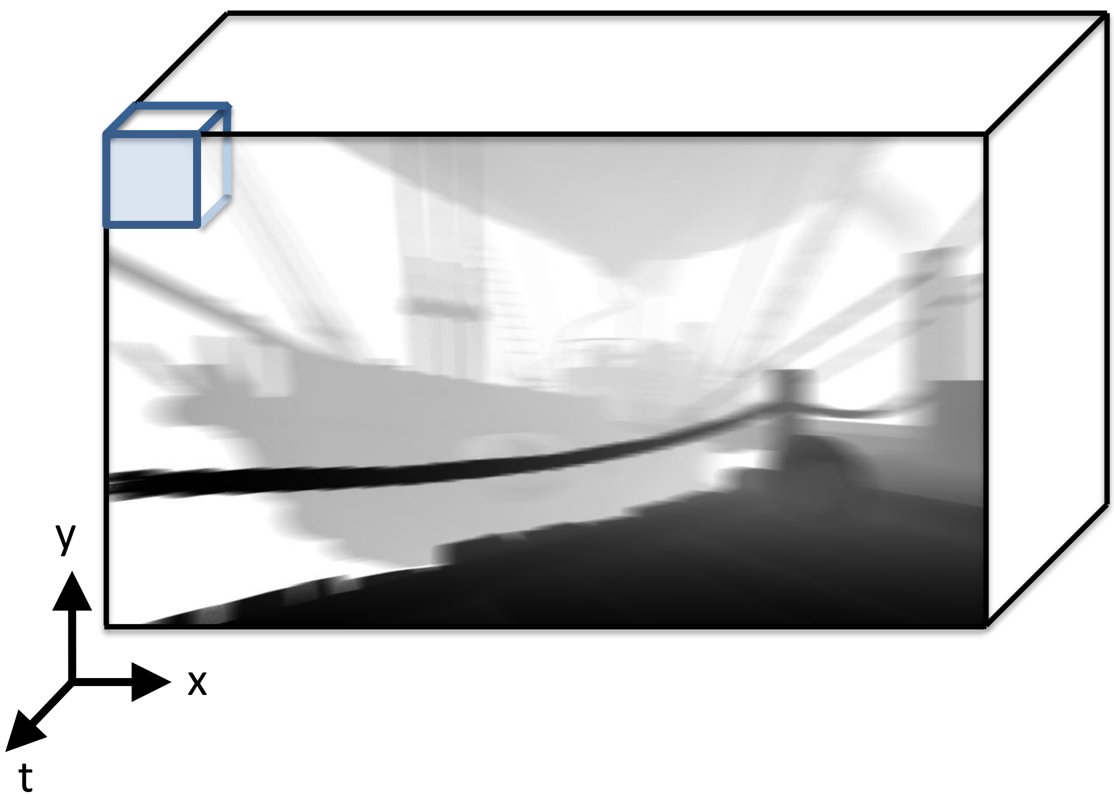
Selecting the best combination

- Try all predictor combinations and select the one with the lowest total bit count
- We also try to compress with *DO*
  - *Will present results from our algorithm alone, and in combination with DO*

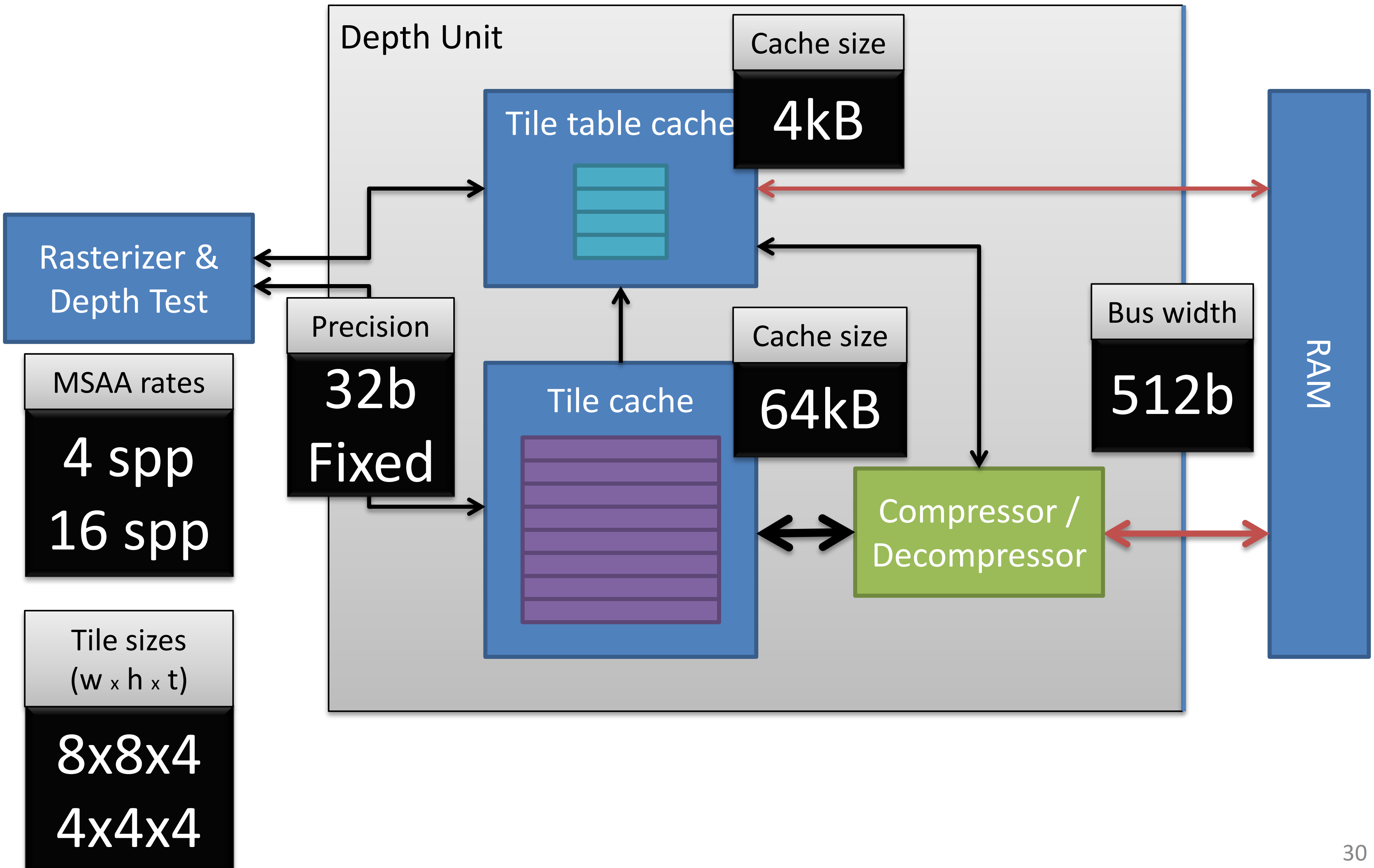
Implementation

Tiles are extended in the t-dimension as well

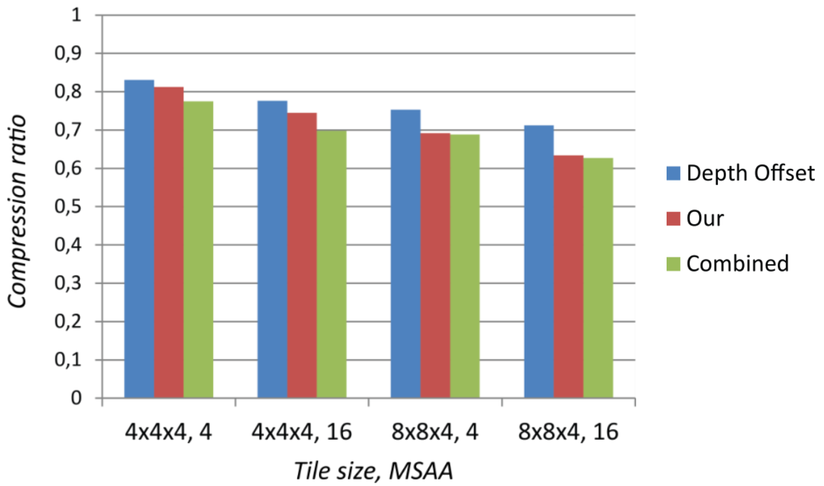
- w *x* h *x* n

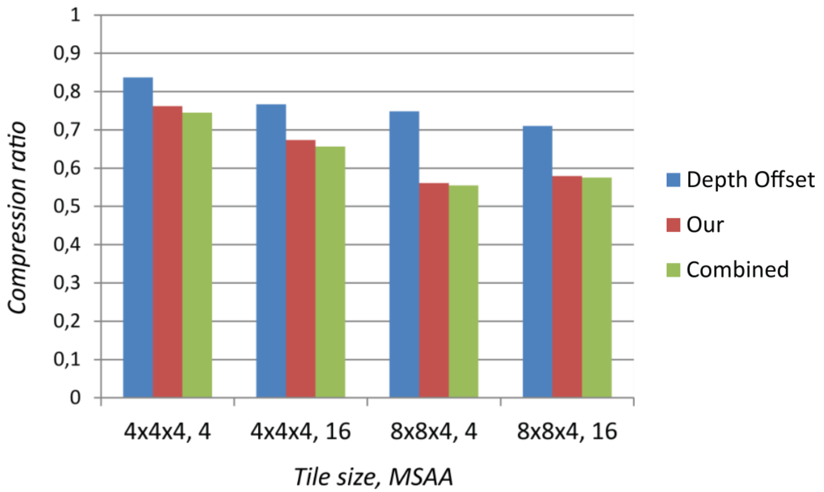


Implementation

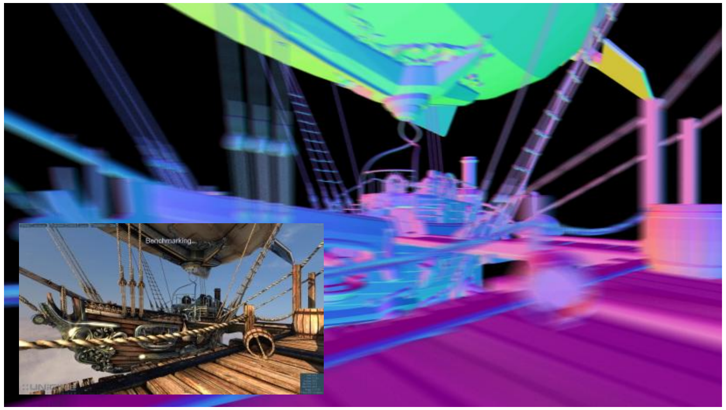


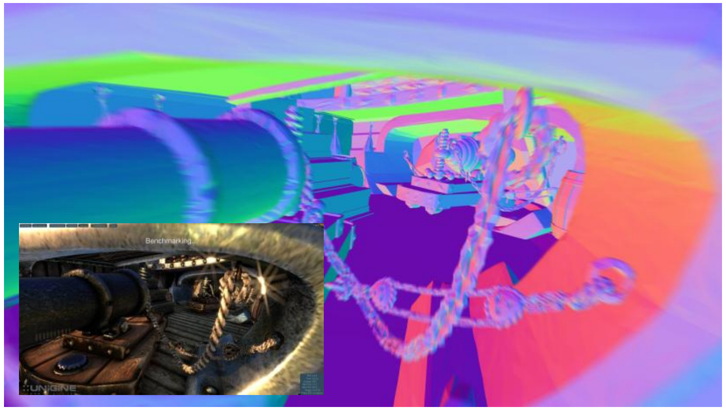
Results
Airship & Cannon





Original images courtesy of Unigine

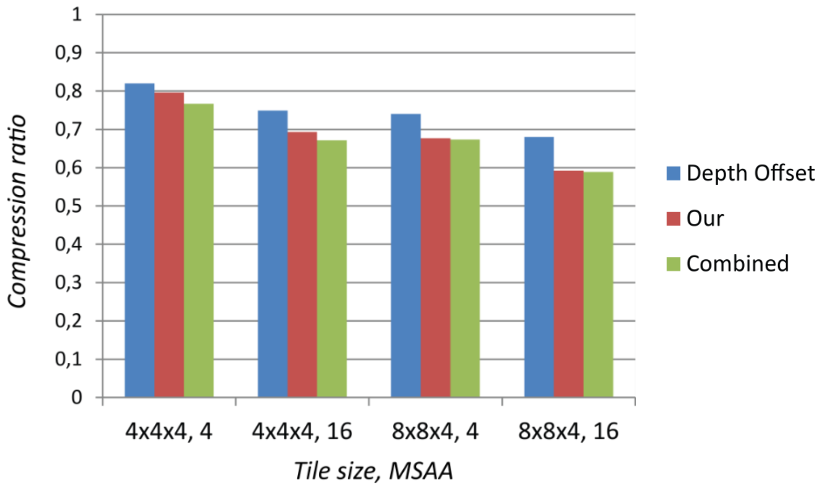


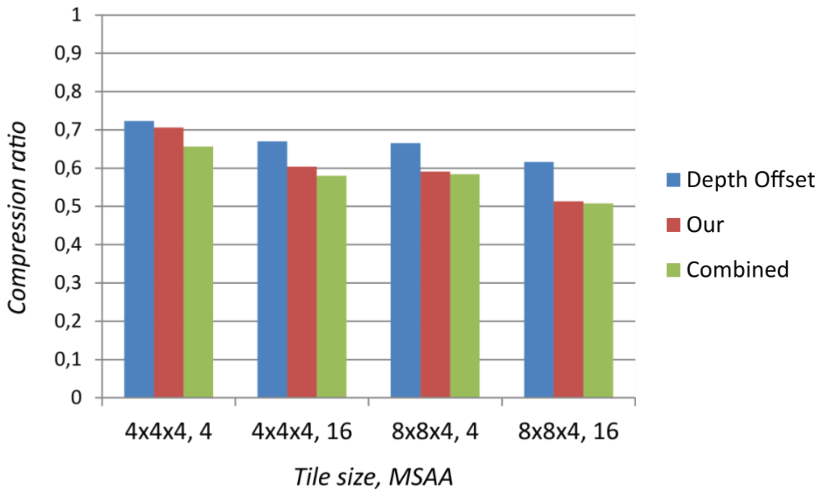


Images are rendered in 1920x1200

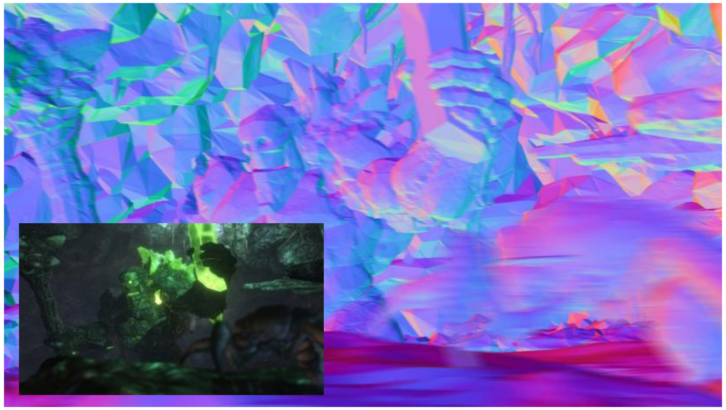
Results

Spiders & Stone giant



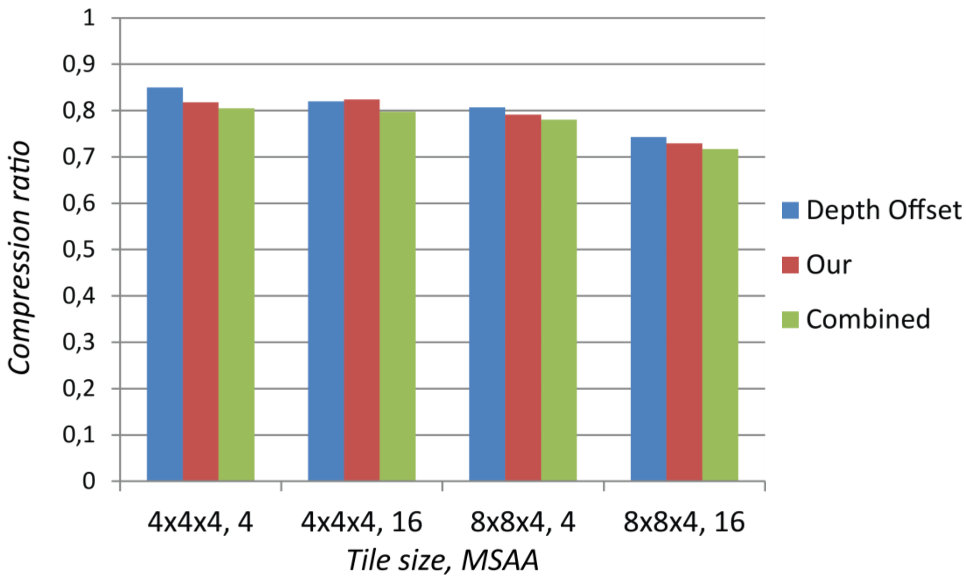


Original images courtesy of BitSquid

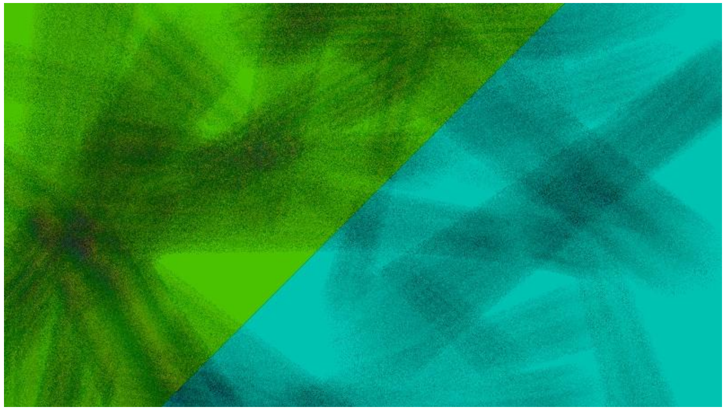


Images are rendered in 1920x1200

Results
Spheres

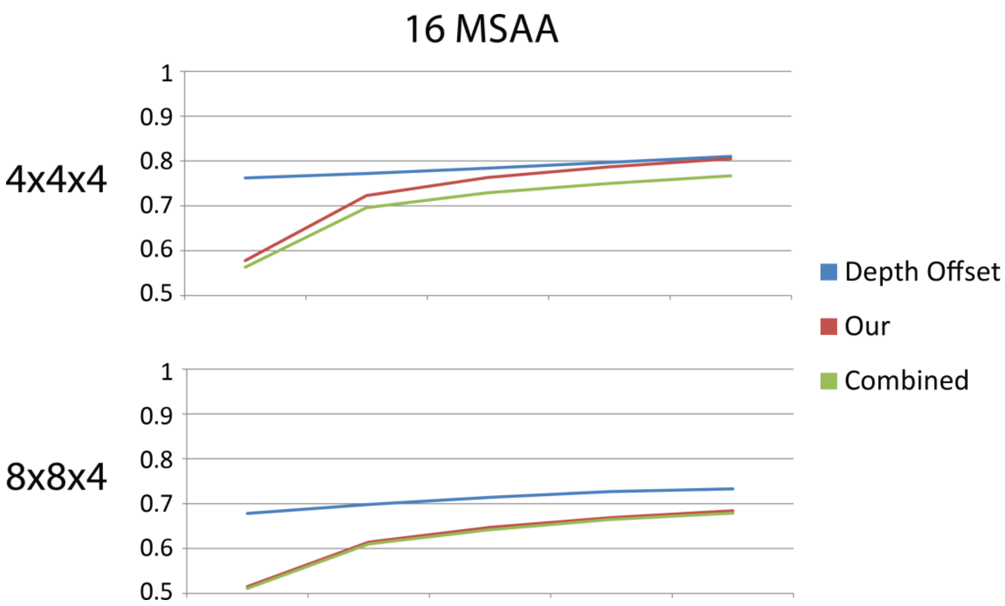


Original image

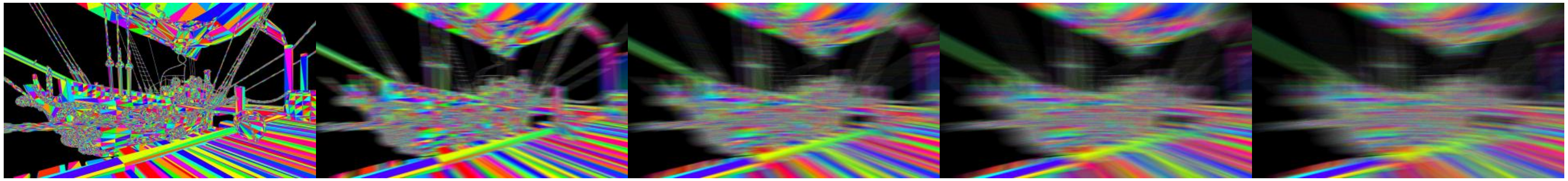


Results

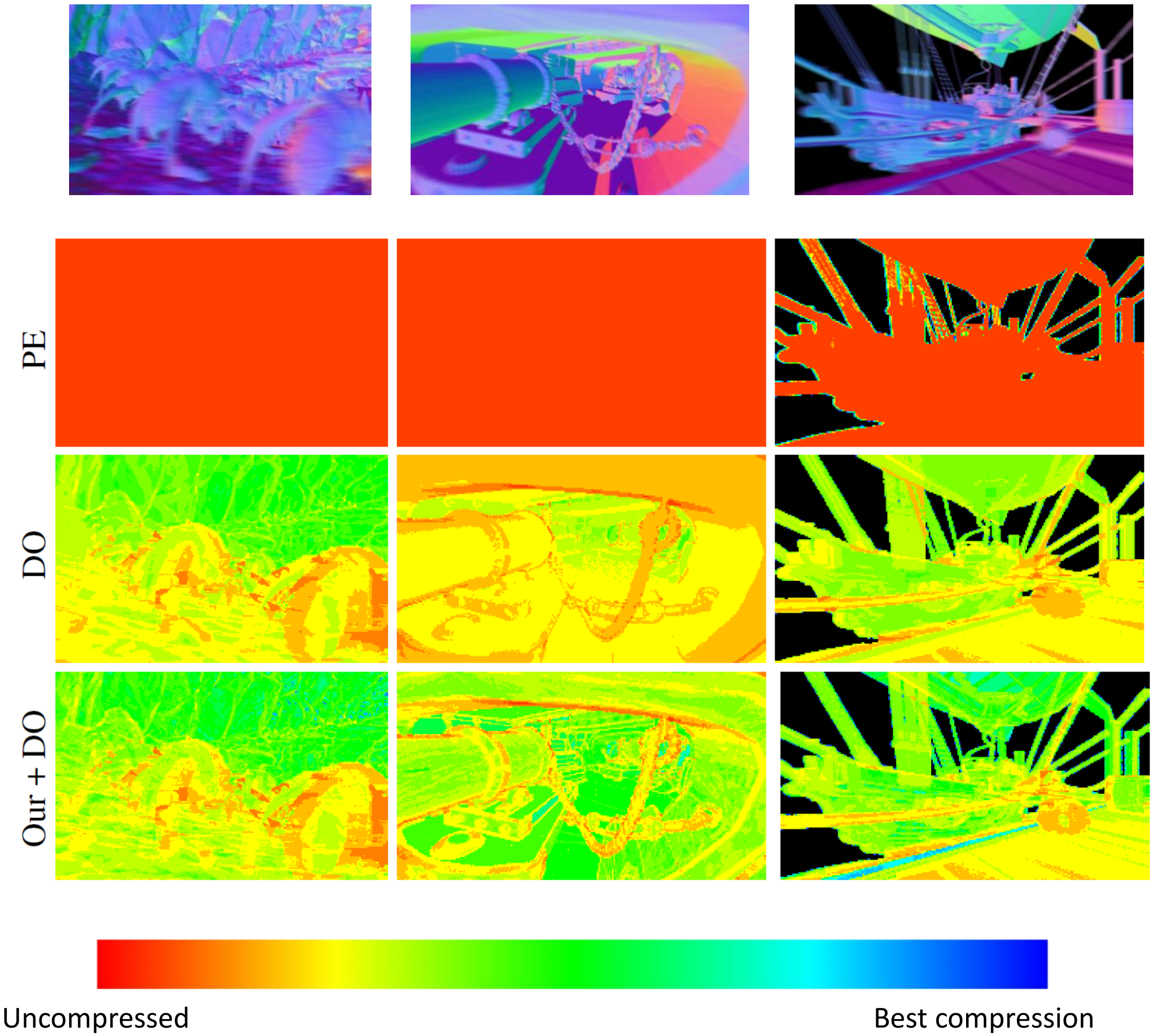
Increasing motion



Increasing motion



Compression Ratio



Conclusions

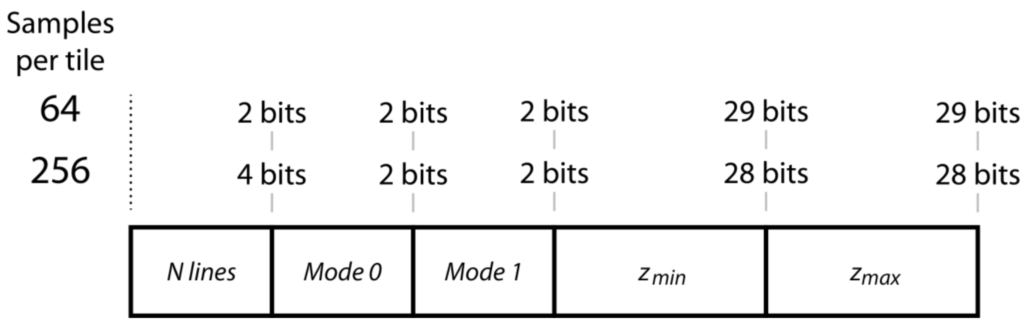
First steps into motion blur depth compression

- Good compression rates are possible on stochastically sampled motion blur buffers
- *DO* is quite good at handling noisy tiles!
  - Good complement to our algorithm
- Linearly approximating *t* works quite well

Thank you!

Questions?

Tile header layout

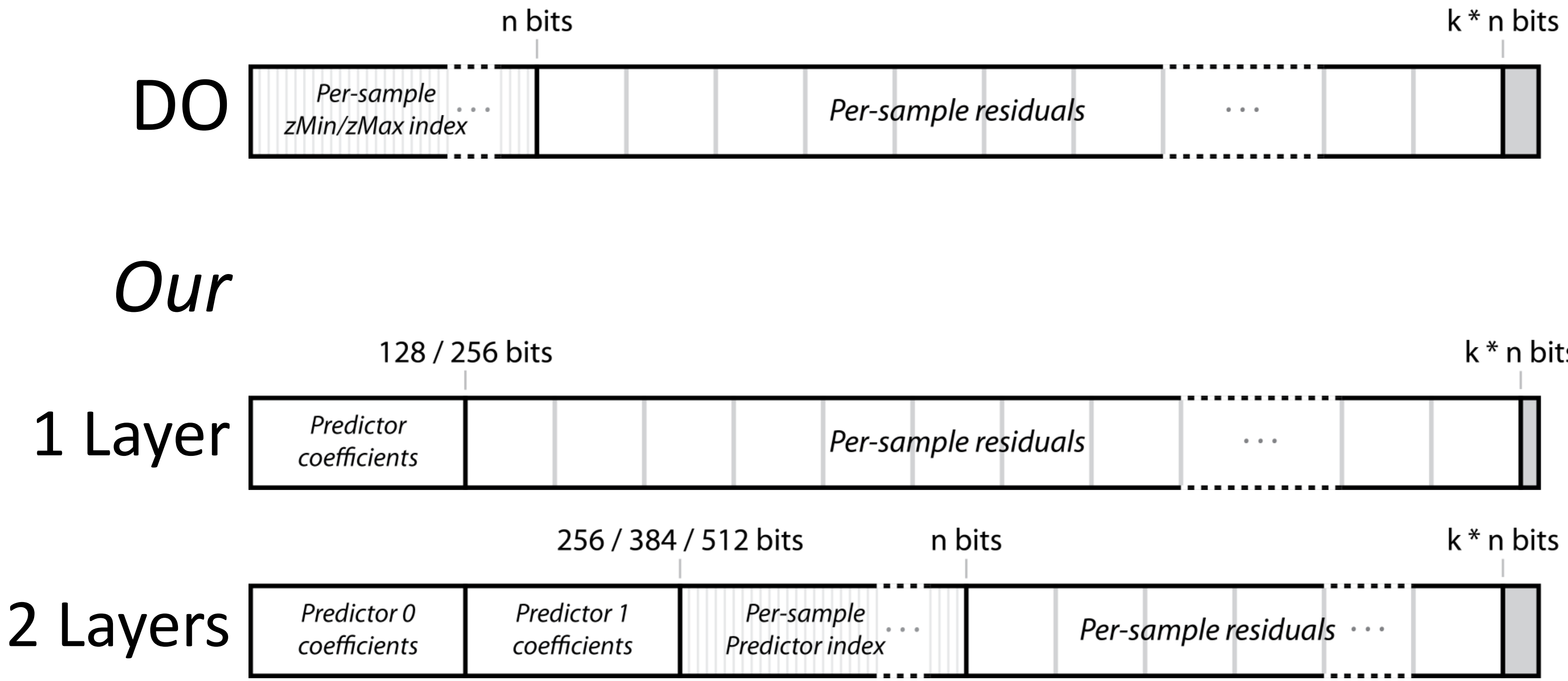


= 64 bits

Bit combination ***Tile status***

- N lines = 0 → Uncompressed
- Mode 0 = 00
  - Mode 1 = 00 → Cleared
  - Mode 1 = 01 → Compressed with DO
- Mode 0 = 01, 10, 11 → Layer 1 predictor mode
  - Mode 1 = 00 → No second predictor
  - Mode 1 = 01, 10, 11 → Layer 2 predictor mode

Compressed tile layout



Mode 0 & 1: 256 bits

Mode 2: 512 bits

n: Number of samples per tile

k: Residual bits

Acknowledgements

Thanks to Tobias Persson from BitSquid for letting us use the StoneGiant demo, and to Denis Shergin from Unigine for letting us use images from Heaven 2.0. Tomas Akenine-Möller is a Royal Swedish Academy of Sciences Research Fellow supported by a grant from the Knut and Alice Wallenberg Foundation. In addition, we acknowledge support from the Swedish Foundation for strategic research.

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