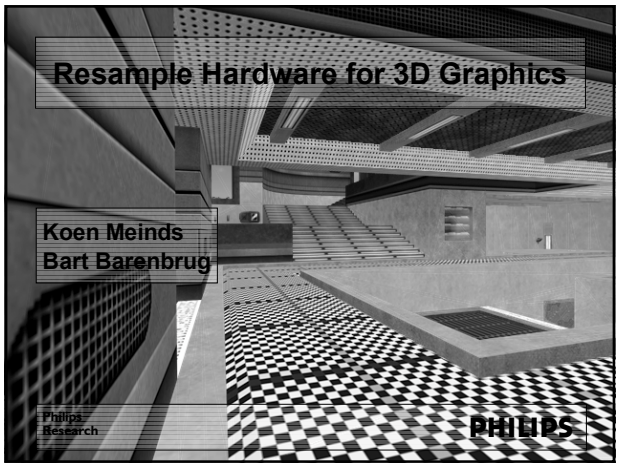

Outline

- High image quality, yet low cost
- Texture anti-aliasing
- Edge anti-aliasing
- Closing remarks

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Goal

3D graphics hardware with

- HIGH IMAGE QUALITY:
  requires proper anti-aliasing
  use of "video" resample technology
- LOW COST:
  reduce off-chip data traffic

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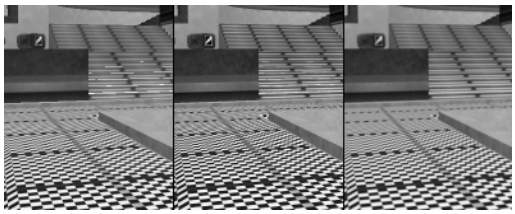
Quality comparison: movie

anisotropic 2x2 | anisotropic 4x4 | Philips



Our quality > 4x4, yet
Bandwidth cost < 2x2

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Outline

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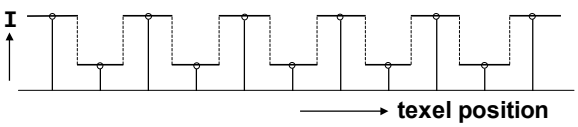
Texture mapping = resampling

Theoretical resample process:

1. **reconstruct continuous signal from texels**
2. transform the continuous signal to screen
3. filter out high frequencies, in screen
4. sample continuous signal at screen pixels



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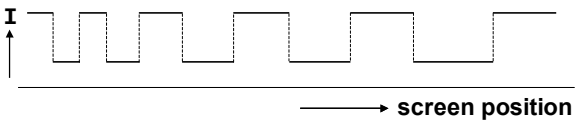

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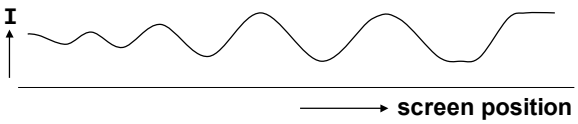

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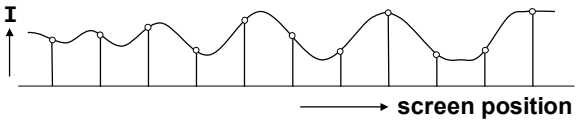

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Proper anti-aliasing

Theoretical resample process:

1. reconstruct continuous signal from texels
2. transform the continuous signal to screen
3. **filter out high frequencies, in screen**
4. sample continuous signal at screen pixels

For proper anti-aliasing step 3 is most important.

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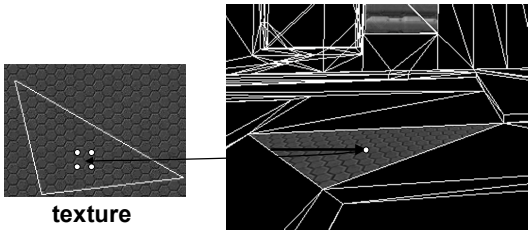
Approximation of resample process: Inverse texture mapping



Proper anti-aliasing filtering = difficult

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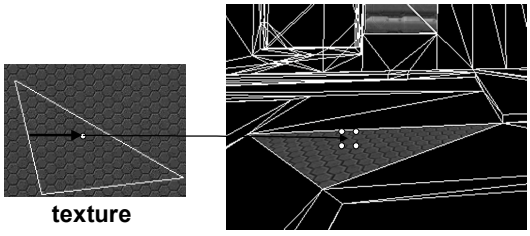
Approximation of resample process: Forward texture mapping



Proper anti-aliasing filtering = easy

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FTM: Forward texture mapping

FTM requires:
Multiple contributions to same pixel in non-sequential order.

- **Problem: contributions to off-chip pixels: high memory data traffic**

- **Solution:**
  - **expensive: write cache.**
  - **better: "two-pass" FTM**

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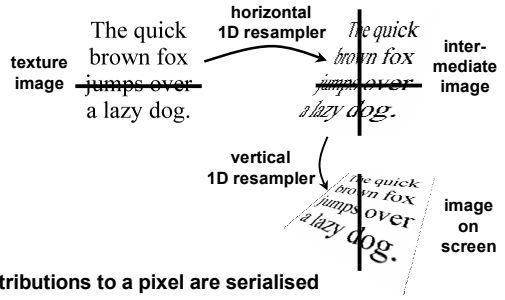
Two-pass FTM



- **Contributions to a pixel are serialised**

enables: accumulation in on-chip memory

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Avoid buffer between two-passes

- **New problem:**

Off-chip data traffic needed for intermediate image

- **Solution:**

Interleave horizontal and vertical pass.

Only a few on-chip line memories needed

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MIP-map

We have included MIP-map technique for further data traffic reduction

- **Problem:**

Combining MIP-maps and 2-pass forward texture mapping

- **Solution:**

Generate, on-the-fly, 4D MIP-maps from standard 3D MIP-maps

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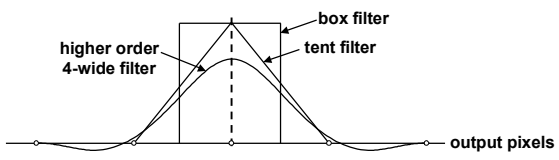
Scalability

We reuse existing video resampler technology:

- **scalable: quality-cost trade-off**

movie



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Outline

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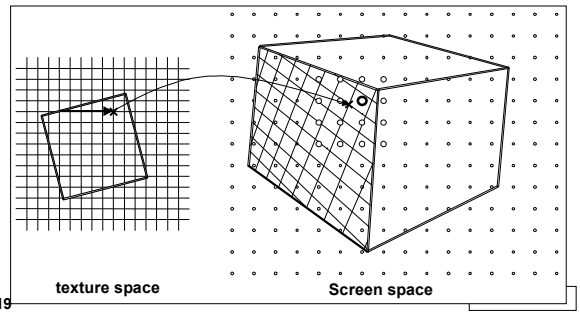
Texture filtering across edges

Forward texture mapping enables high quality edge anti-aliasing



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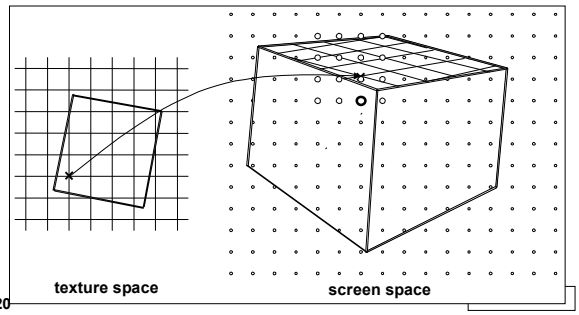
Texture filtering across edges

Forward texture mapping enables high quality edge anti-aliasing



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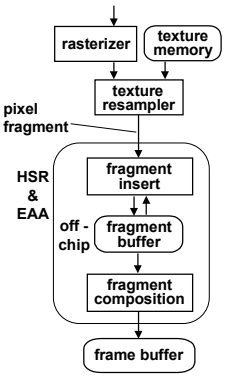
Pixel fragment buffer



Fragment storage:

- **depth sorted**
- **$\leq$ 4 fragments per pixel**

per fragment:

- **Z (4 bytes)**
- **RGBA (4 bytes)**
- **contribution factor (1 byte)**
- **depth sorting index (2 bits)**

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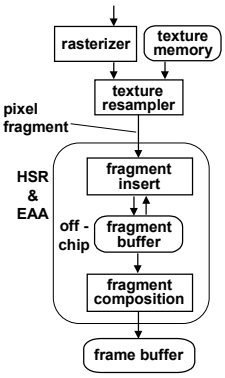
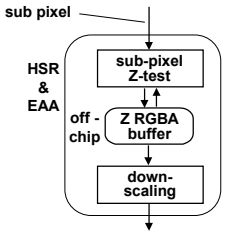
Comparison: Required bandwidth (1)



2x2 super sampling:



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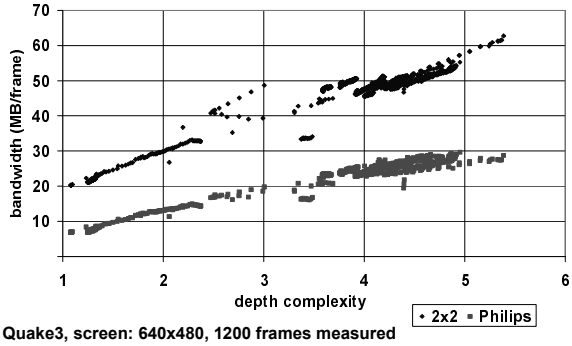
Comparison: Required bandwidth (2)

Measured off-chip data traffic:



Quake3, screen: 640x480, 1200 frames measured

Outline

- **High image quality, yet low cost**
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Closing remarks (1)

Implemented in OpenGL SW pipeline:

- suited to hardware implementation
- two-pass FTM
- extended to edge anti-aliasing

Efficient forward texture mapping, due to:

- use of video resample structures
- Interleaving two passes: reduces data traffic
- integration of MIP-maps

- Uniform solution: texture and edge anti-aliasing

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Closing remarks (2)

Compared to anisotropic inv. texture mapping:

- Quality > 4x4 super sampling, yet
- Bandwidth cost < 2x2 super sampling

Work is “in progress”

- pixel shading
- dependent multi texturing (e.g. bumpmapping)

movie can be found at:
www.extra.research.philips.com/graphics

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