Programming Graphics Hardware

GPU Applications

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Overview

- Per-Pixel Displacement Mapping with Distance Functions
- Percentage-Closer Soft Shadows
- Introduction to General-Purpose Computation on GPUs
- Cloth Simulation on GPU

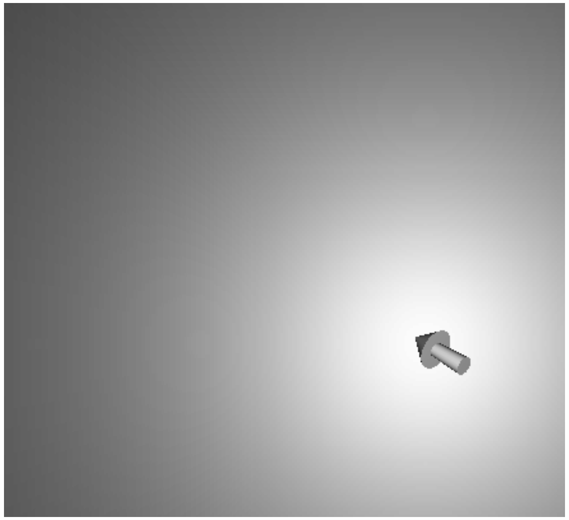
Programming Graphics Hardware

Per-Pixel Displacement Mapping with Distance Functions

Cyril Zeller

Goal

- Adding small-scale geometric details stored as a texture:
  - To reduce memory
  - To simplify authoring
- Applications: wall, grating, fence, etc.



Diffuse light without bump

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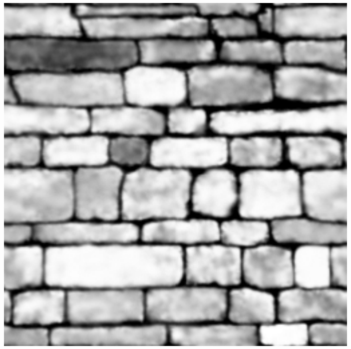
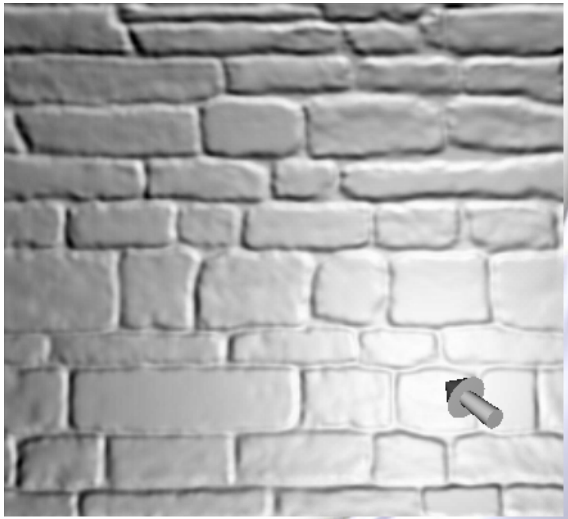


Height map

=



Diffuse light with bumps

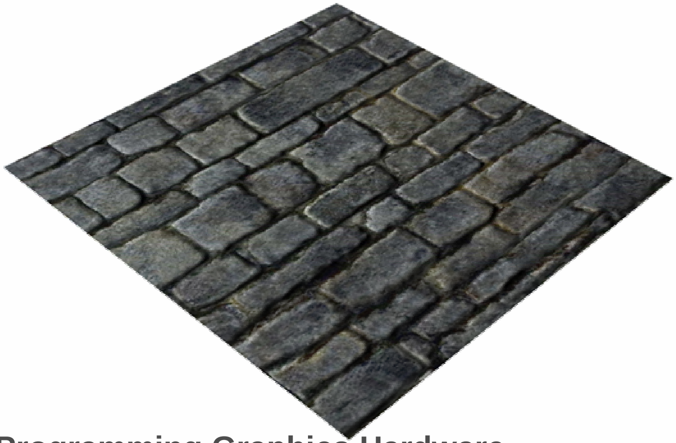
Traditional Methods

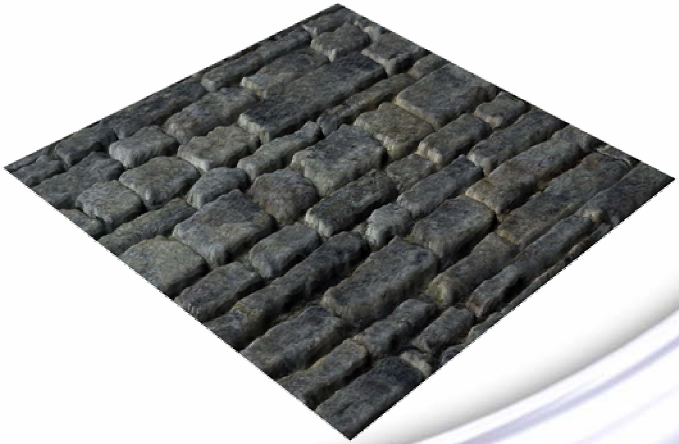
- Displacement mapping [Cook]:
  - Iteratively tessellate the mesh based on the height map

  Caveat: Requires multiple rendering passes and VTF [Bunnell]
- Bump mapping [Blinn]:
  - Shade using the normals computed from the height map

  Caveat: Bumps don’t occlude each other

Bump mapping

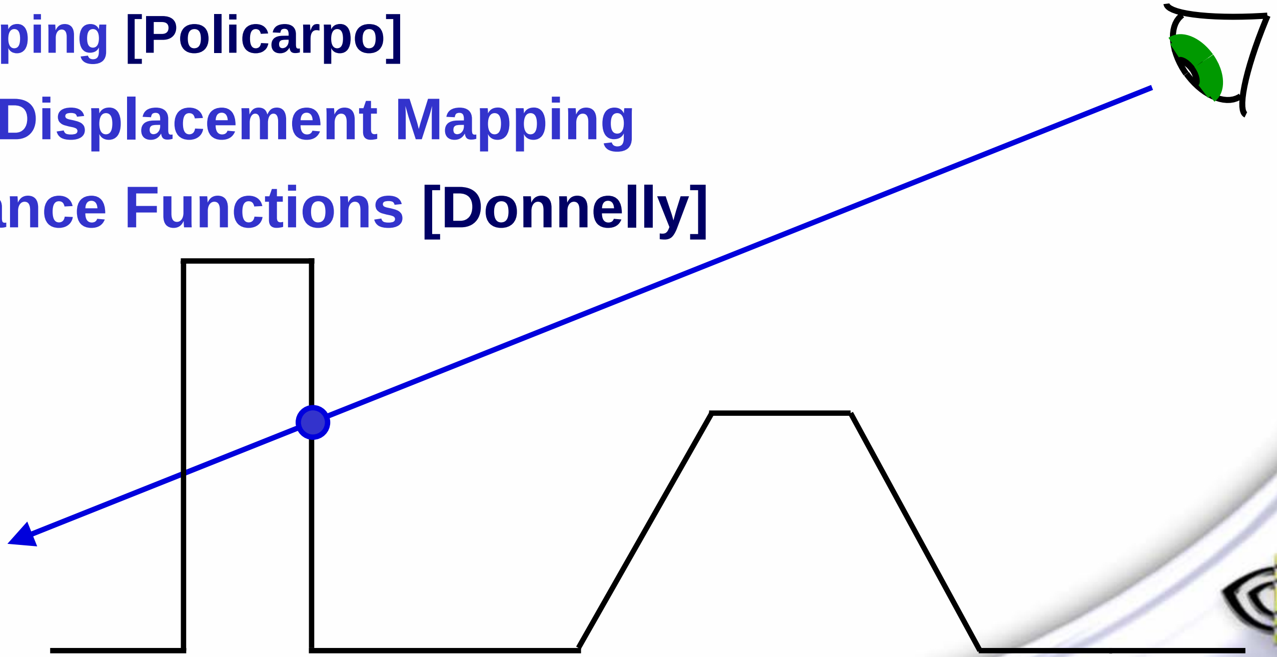




Per-pixel displacement mapping

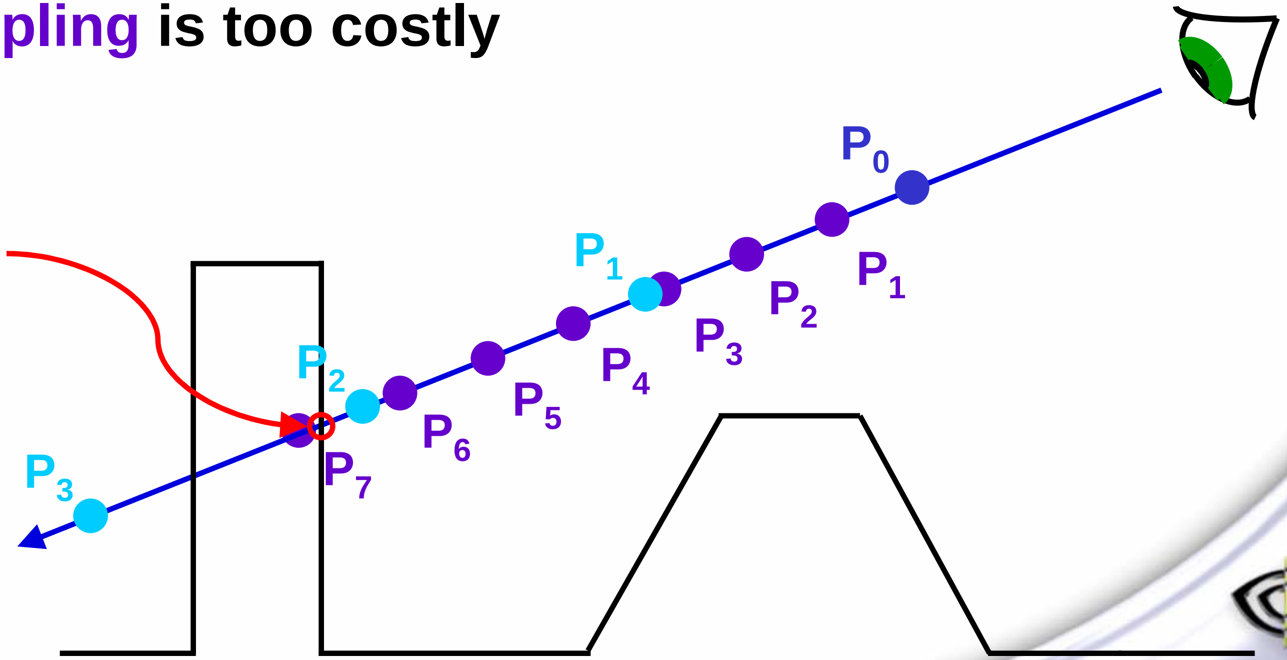
Ray Tracing Based Methods

- To handle bump occlusion, we need to intersect the view vector with the height field:
  - View-dependent displacement mapping [LWang]
  - Generalized displacement mapping [XWang]
  - Parallax mapping [Kaneko, Welsh]
  - Relief mapping [Policarpo]
  - Per-Pixel Displacement Mapping with Distance Functions [Donnelly]



Finding the Intersection: Uniform Sampling

- One way of finding the intersection is to sample the height map at uniformly spaced locations
- But:
  - Undersampling is too risky (missed intersections)
  - Oversampling is too costly



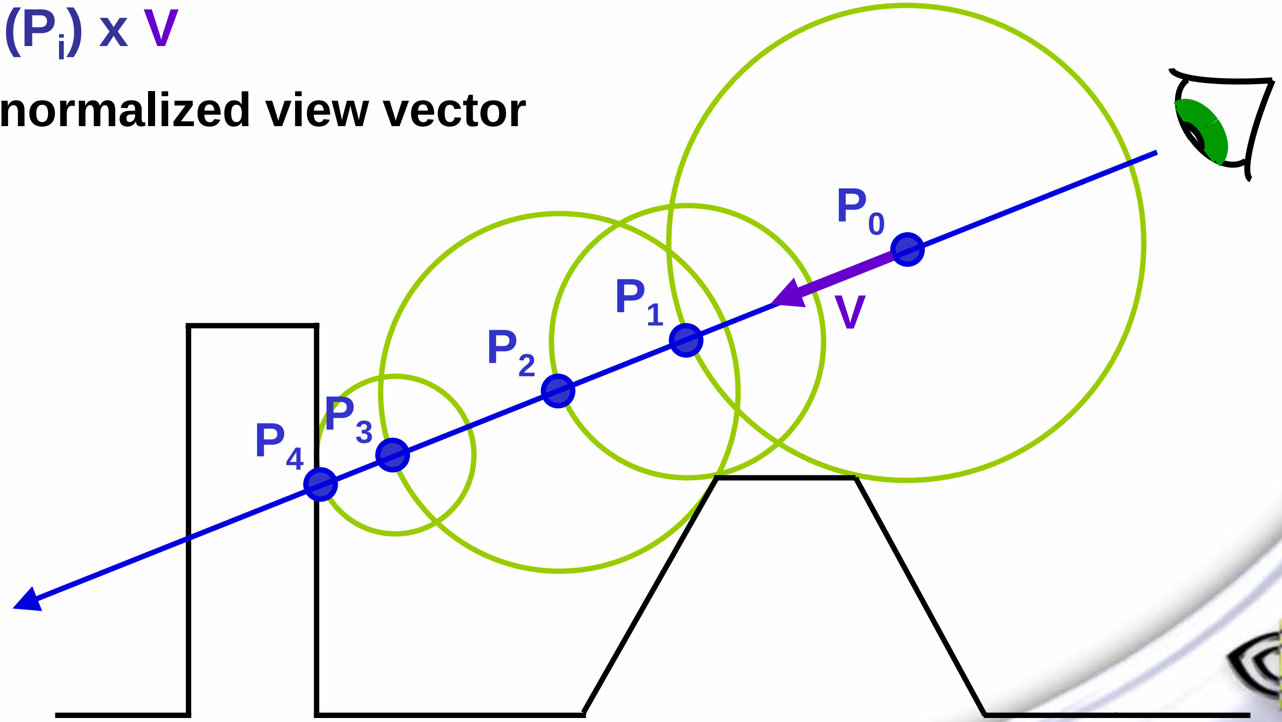
Missed when undersampling!

Finding the Intersection: Sphere Tracing

- Sphere tracing is used to accelerate raytracing of implicit surfaces [Hart]
- We pre-compute a distance function d(P) that maps any 3D point P to its distance to the height field *H*: d(P) = distance(P, *H*)
- Then at run time, we step along the ray using the following formula:

$$P_{i+1} = P_i + d(P_i) \times V$$

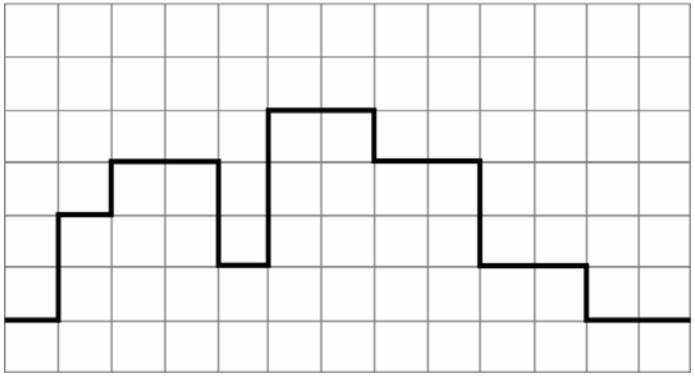
where V is the normalized view vector



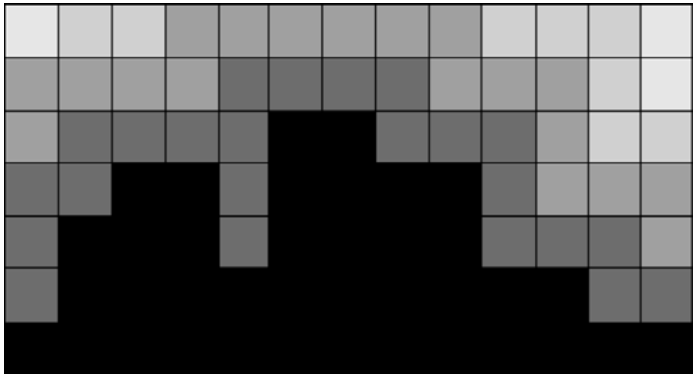
Distance Map

- The distance function is stored in a “thin” 3D texture (e.g. H_{width} x H_{height} x 16) called a distance map
- The computation of the distance map is based on [Danielsson]

1	3	4	4	2	5	5	4	4	2	2	1	1



A sample 1D height field

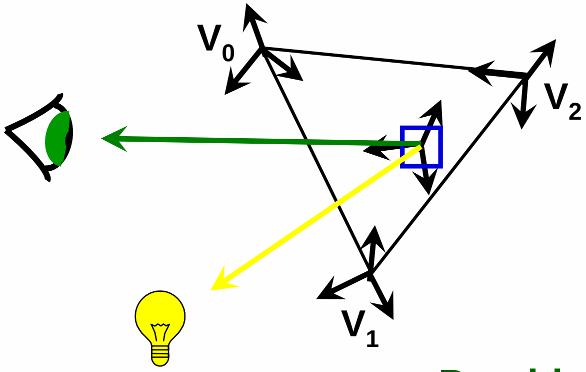


The corresponding 2D distance map

Vertex Shader

```
void VertexShader(
  float4 position, // In model space
  float3x3 modelToTangent, // Local tangent, normal and binormal
  float4 eye, // In model space
  float4 light, // In model space
  uniform float4x4 modelToProjection,
  out float4 positionProj,
  inout float2 texCoord,
  out float3 viewVector,
  out float3 lightVector
)
{
  // Transform position to projection space
  positionProj = mul(modelToProjection, position);

  // Transform view and light vectors to tangent space
  viewVector = mul(modelToTangent, eye - position);
  lightVector = mul(modelToTangent, light - position);
}
```



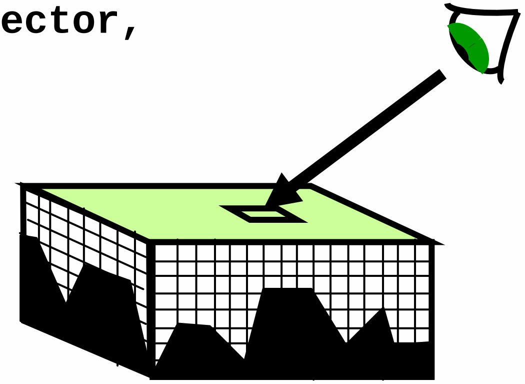
Provide the pixel shader with the view and light vectors in tangent space

Pixel Shader

```
float4 PixelShader(
  float2 texCoord, float3 viewVector, float3 lightVector,
  uniform sampler2D colorMap,
  uniform sampler2D normalMap,
  uniform sampler3D distMap
)
{
  // Normalize interpolated vectors
  viewVector = normalize(viewVector);
  lightVector = normalize(lightVector);

  // Find intersection with height field,
  // assuming the surface is locally planar
  float3 point = float3(texCoord, 1);
  for (int i = 0; i < NUM_ITERATIONS; ++i)
    point += tex3D(distMap, point) * viewVector;

  // Compute final color
  float4 color = tex2D(colorMap, point.xy);
  float3 normal = tex2D(normalMap, point.xy);
  return dot(normal, lightVector) * color;
}
```



Start at the top of the height field

Performance

- `NUM_ITERATIONS` depends on
  - Distance map resolution
  - Smoothness of data
- For the demo (256x256x16), using 16 iterations is more than enough
- Note that each iteration is `{tex; mad;}`, which runs in a single cycle on GeForce FX and GeForce 6
- On a GeForce 6800 GT, the previous shader runs at around 70 fps on 1280 x 1024 pixels with 16 iterations

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- Fabio **Policarpo**. "Relief Mapping in a Pixel Shader Using Binary Search"
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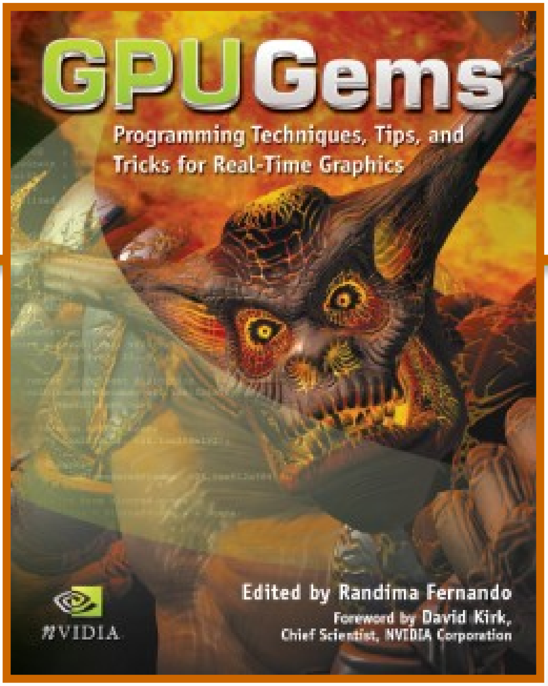
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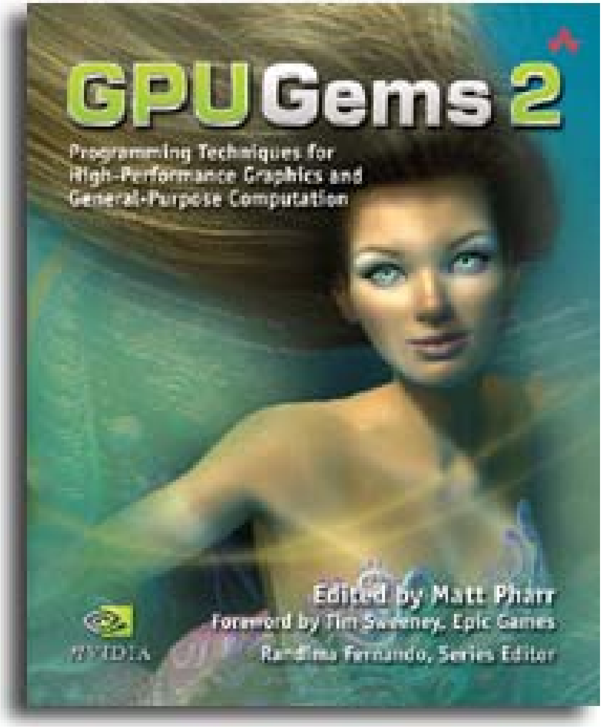
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