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OpenGL Instancing

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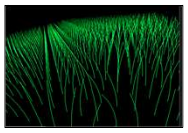

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What is Instancing?

Imagine that you needed to draw multiple copies of the same object. Here would be one way to do it (assuming we are using our vertex buffer object C++ class):

```
VertexBufferObject   Object;
Object.Init( );

Object.glBegin( GL_LINE_STRIP );
Object.glVertex3f( ??, ??, ?? );
          . . .
Object.glEnd( );
          . . .
for( int i = 0; i < numInstances; i++ )
{
          Object.Draw( );
}
```

This would work, but it would require *numInstances* command transmissions from the CPU to the GPU. Is there a better way?

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What is Instancing?

OpenGL, like most graphics APIs (Vulkan, for example), supports a concept called *Instancing* in which you specify what to draw and how many times to draw it. Using our C++ class, we would use it like this:

```
VertexBufferObject    Object;
Object.Init( );

Object.glBegin( GL_LINE_STRIP );
Object.glVertex3f( ??, ??, ?? );
          . . .
Object.glEnd( );
          . . .
Object.DrawInstanced( numInstances );
```

This only requires *one* command transmission from the CPU to the GPU. It essentially moves the execution of the for-loop over to the GPU side.

However, the big problem here is that all those copies of the Object *will be drawn identically and on top of each other.* Stay tuned.

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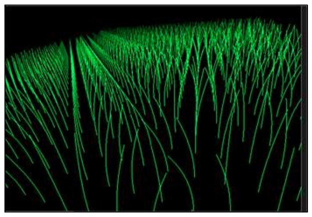
An Example – Waving Grass

We will instance a single blade of grass to make a waving field:



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Making Each Instance Look Differently

There is a built-in vertex shader variable called **gl_InstanceID** that tells us which instance number is being drawn right now. We can use it to change positions, transformations, colors, etc.

Here's how we draw the straight up-and-down blades of grass in a grid:

Vertex shader:

```
#version 330 compatibility
uniform float           uTime;
uniform float           uXmin, uXmax;
uniform float           uYmin, uYmax;
uniform float           uPeriodx,  uPeriody;
uniform int             uNumx, uNumy;

const float TWOPI  =  2.*3.14159265;

void  main( )
{
          int ix = gl_InstanceID  % uNumx;
          int iy = gl_InstanceID   /  uNumx;

          float  x = uXmin + float(ix) * (uXmax-uXmin)  / float(uNumx-1);
          float  y = uYmin + float(iy) * (uYmax-uYmin)  / float(uNumy-1);

          vec4 vert = vec4( x, y, gl_Vertex.zw  );

          gl_Position  = gl_ModelViewProjectionMatrix  * vert;
}
```

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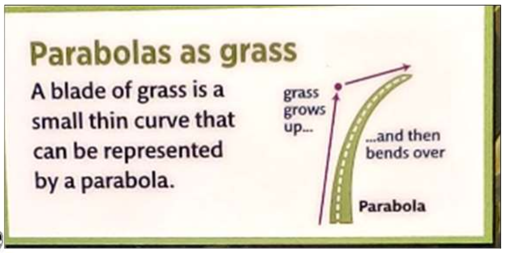
An Example – Waving Grass

To make the blades sway, we take inspiration from a trick that Pixar used in the movie *A Bug's Life*:



Parabolas as grass

A blade of grass is a small thin curve that can be represented by a parabola.

grass grows up...
...and then bends over
Parabola

From the traveling museum exhibit *The Science of Pixar*

An Example – Waving Grass

The **vertex shader** uses the **gl_InstanceID** built-in variable to place the blades of grass:

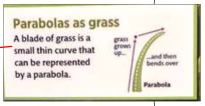
Vertex shader:

```
void  main( )
{
          int ix = gl_InstanceID % uNumx;
          int iy = gl_InstanceID  /  uNumx;
          float x = uXmin + float(ix) * (uXmax-uXmin) / float(uNumx-1);
          float y = uYmin + float(iy) * (uYmax-uYmin) / float(uNumy-1);

          float kx = cos( TWOPI * uTime * float(ix)  / uPeriodx );
          float ky = sin(  TWOPI * uTime * float(iy)  / uPeriody );

          vec4 vert = vec4( x, y, gl_Vertex.zw );
          float zsq = vert.z*vert.z;
          vert.x += kx * zsq;
          vert.y += ky * zsq;

          gl_Position = gl_ModelViewProjectionMatrix * vert;
}
```


Parabolas as grass

A blade of grass is a small thin curve that can be represented by a parabola.

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Waving Grass – Creating the Shader Program and Setting Uniform Variables in InitGraphics( ):

```
Grass.Init( );
bool valid = Grass.Create( "grass.vert",  "grass.frag" );
if( ! valid )
          fprintf( stderr, "Shader cannot be created!\n" );
else
          fprintf( stderr, "Shader created.\n" );
Grass.SetVerbose( false );

Grass.Use( );
Grass.SetUniformVariable( "uNumx", NUMX);
Grass.SetUniformVariable( "uNumy", NUMY);
Grass.SetUniformVariable( "uXmin",  XMIN);
Grass.SetUniformVariable( "uXmax", XMAX);
Grass.SetUniformVariable( "uYmin",  YMIN);
Grass.SetUniformVariable( "uYmax", YMAX);
Grass.SetUniformVariable( "uPeriodx", PERIODX);
Grass.SetUniformVariable( "uPeriody", PERIODY);
Grass.UnUse( );
```

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Waving Grass – Create the Grass-Blade Vertex Buffer Object in InitGraphics( ):

```
Blade.Init( );
Blade.glBegin( GL_LINE_STRIP );
for( int i = 0; i < NUMPOINTS; i++ )
{
          float z = ZMIN + (float)i * (ZMAX-ZMIN) / (float)(NUMPOINTS-1);
          Blade.glVertex3f( 0., 0., z );
}
Blade.glEnd( );
```

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Waving Grass – Drawing the Field of Grass in Display( ):

```
// turn on the shader and set the time:

Grass.Use( );
Grass.SetUniformVariable( "uTime",  Time );

// draw the grass field:

Blade.DrawInstanced( NUMX*NUMY );

Grass.UnUse( );
```

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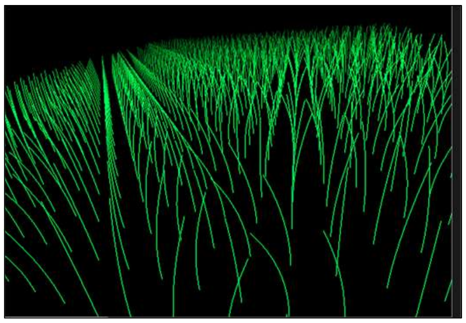

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