Looking at OpenCL Assembly Code

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How to Extract the OpenCL Assembly Language

particles.cl, I

typedef float4 point;
typedef float4 vector;
typedef float4 color;
typedef float4 sphere;

constant float4 G = (float4) (0., -9.8, 0., 0.);
constant float DT = 0.1;
constant sphere Sphere1 = (sphere)(-100., -800., 0., 600.);

particles.cl, II

kernel void Particle( global point * dPobj, global vector * dVel, global color * dCobj )
{
  int gid = get_global_id(0); // particle #
  point p = dPobj[gid];
  vector v = dVel[gid];
  point pp = p + v*DT + .5*DT*DT*G; // p' 
  vector vp = v + G*DT; // v'
  dPobj[gid] = pp;
  dVel[gid] = vp;
}

particles.cl, III

vector Bounce( vector in, vector n )
{
  n.w = 0.;
  n = normalize(n);
  vector out = in - 2. * n * dot(in.xyz, n.xyz);
  out.w = 0.;
  return out;
}

vector BounceSphere( point p, vector v, sphere s )
{
  vector n;
  n.xyz = fast_normalize(p.xyz - s.xyz);
  n.w = 0.;
  return Bounce(in, n);
}

NVIDIA OpenCL Assembly Language Sample

FMA = “Fused Multiply-Add”

ld.global.v4.f32 {%f188, %f189, %f190, %f191}, [%r1]; // load dPobj[gid]
ld.global.v4.f32 {%f156, %f157, %f158, %f159}, [%r2]; // load dVel[gid]
mov.f32 %f17, 0f3DCCCCCD; // put DT (a constant) → register f17
fma.rn.f32 %f248, %f156, %f17, %f188; // (p + v*DT).x → f248
fma.rn.f32 %f249, %f157, %f17, %f189; // (p + v*DT).y → f249
fma.rn.f32 %f250, %f158, %f17, %f190; // (p + v*DT).z → f250
mov.f32 %f18, 0fBD48B43B; // .5 * G.y * DT * DT (a constant) → f18
mov.f32 %f19, 0f00000000; // 0., for .x and .z (a constant) → f19
add.f32 %f256, %f248, %f19; // (p + v*DT).x + 0. → f256
add.f32 %f257, %f249, %f18; // (p + v*DT).y + G.y * DT → f257
add.f32 %f258, %f250, %f19; // (p + v*DT).z + 0. → f258
mov.f32 %f20, 0fBF7AE148; // G.y * DT (a constant) → f20
add.f32 %f264, %f156, %f19; // v.x + 0. → f264
add.f32 %f265, %f157, %f20; // v.y + G.y * DT → f265
add.f32 %f266, %f158, %f19; // v.z + 0. → f266

NVIDIA GPU Sample Code

particles.cl, IV

Global particle coordinates:

dPobj[0] = (float4) (0., -200., 0., 0.);

local particle:

dPobj[gid] = dPobj[0] + v*DT + .5*DT*DT*G;

local particle velocity:

dVel[gid] = (v + DT*G) + .5*DT*(v + DT*G);

local particle color:

dCobj[gid] = (c + DT*G) + .5*DT*(c + DT*G);

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mov.f32 %f20, 0fBF7AE148; // G.y * DT (a constant) → f20
add.f32 %f264, %f156, %f19; // v.x + 0. → f264
add.f32 %f265, %f157, %f20; // v.y + G.y * DT → f265
add.f32 %f266, %f158, %f19; // v.z + 0. → f266

Fused Multiply-Add

Many scientific and engineering computations take the form:

\[ D = A + (B \cdot C) \]

A "normal" multiply-add compilation would handle this as:

\[
\text{tmp} = B \cdot C; \\
D = A + \text{tmp};
\]

A "fused" multiply-add does it all at once, that is, when the low-order bits of \( B \cdot C \) are ready, they are immediately added into the low-order bits of \( A \) at the same time that the higher-order bits of \( B \cdot C \) are being multiplied.

Consider a Base 10 example: \( 789 + (123 \times 456) \)

\[
\begin{array}{c}
123 \\
\times 456 \\
\hline
738 \\
615 \\
492 \\
\hline
56,877
\end{array}
\]

Can start adding the 9 the moment the 8 is produced!

Note: In the lower bits of the result, "Normal" \( A + (B \cdot C) \) ≠ "FMA" \( A + (B \cdot C) \)

Something like:

\[
\text{Sum} = \text{Sum} + (B \cdot C);
\]

would also be suitable to be implemented as an FMA.

Things Learned from Examining OpenCL Assembly Language

- The points, vectors, and colors were typedef'd as float4's, but the compiler realized that they were being used only as float3's and so didn't bother with the 4th element.
- The float3's were not SIMD'ed. (We actually knew this already, since NVIDIA doesn't support SIMD operations in their GPUs.) There is still an advantage in coding this way, even if just for readability.
- The function calls were all in-lined. (This makes sense – the OpenCL spec says 'no recursion', which implies 'no stack', which would make function calls difficult.)
- Me defining \( G, DT, \) and \( \text{Sphere1} \) as \text{constant} memory types was a mistake. It got the correct results, but the compiler didn't take advantage of them being constants. Changing them to type \text{const} throw compiler errors because of their global scope. Changing them to \text{const} and moving them into the body of the kernel function \text{Particle} did result in good compiler optimizations.
- The \text{sqrt}(x^2+y^2+z^2)\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\! assembly code is amazingly convoluted. I suspect it is an issue of maintaining highest precision. Use \text{fast_sqrt()}, \text{fast_normalize()}, and \text{fast_length()} when you can. Usually computer graphics doesn't need the full precision of \text{sqrt}()
- The compiler did not do a good job with expressions-in-common. I had really hoped it would figure out that detecting if a point was in a sphere and determining the unitized surface normal at that point were the same operation, but it didn't.
- There is a 4-argument Fused-Multiply-Add instruction in hardware to perform \( D = A + (B \cdot C) \) in one instruction in hardware. The compiler took great advantage of it.