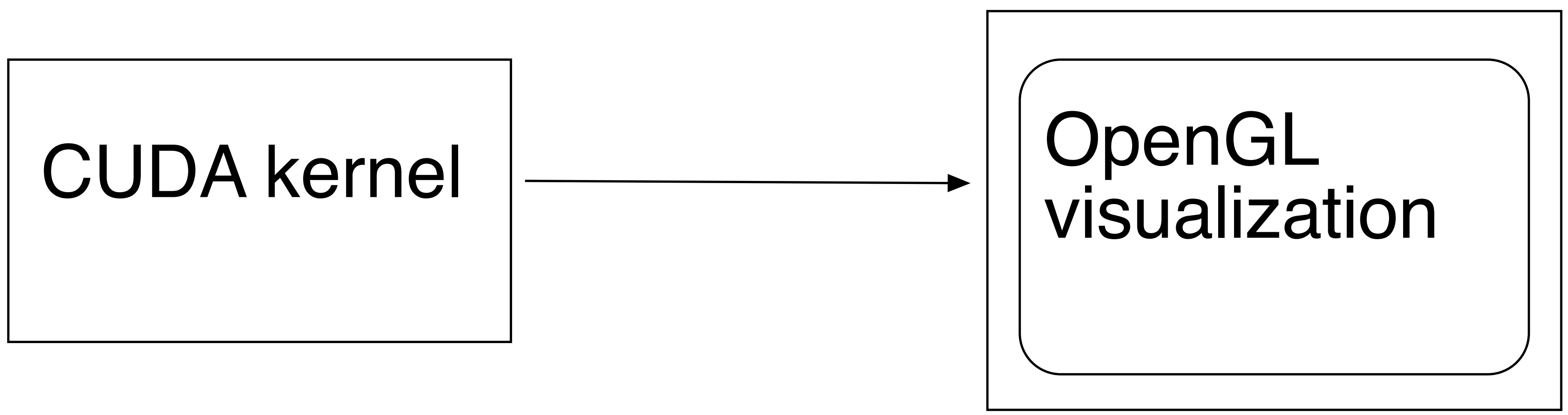
CUDA-OpenGL Interoperability

Visualize results with OpenGL

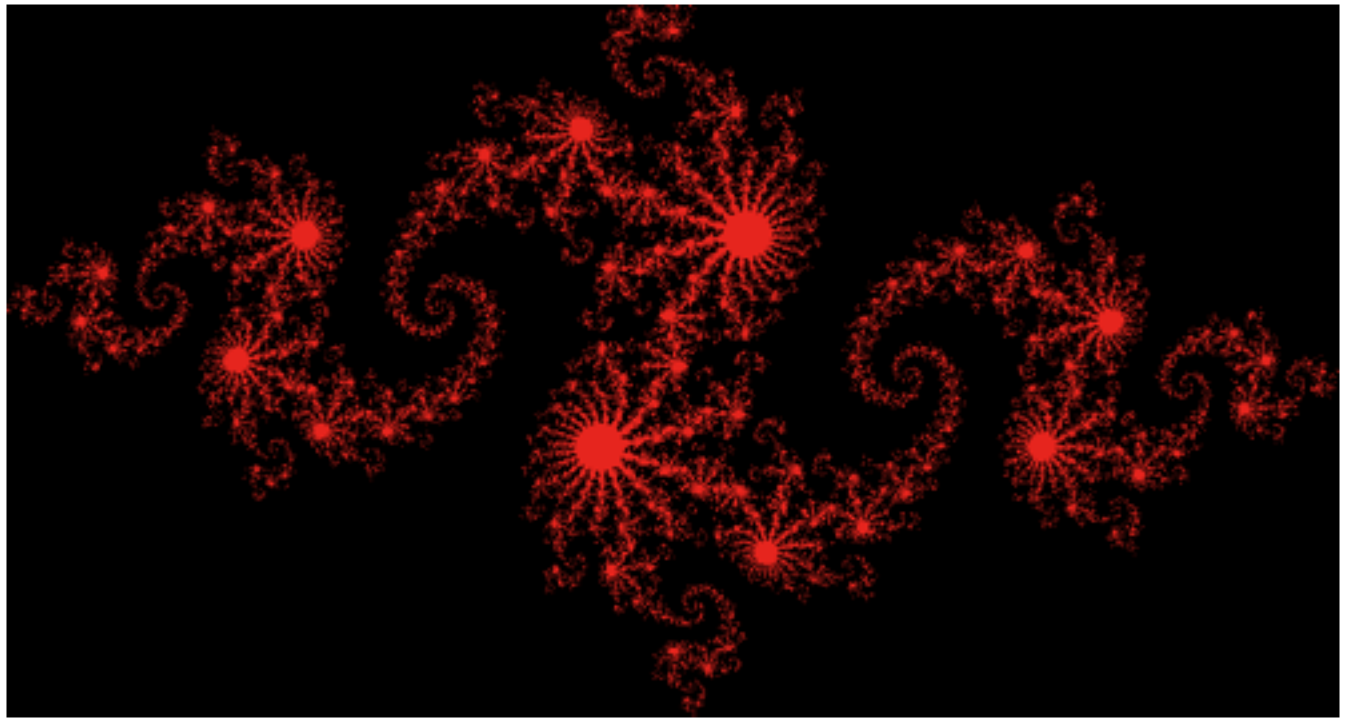


CUDA and graphics

Simplest way: Pass output from CUDA, typically to an OpenGL texture.

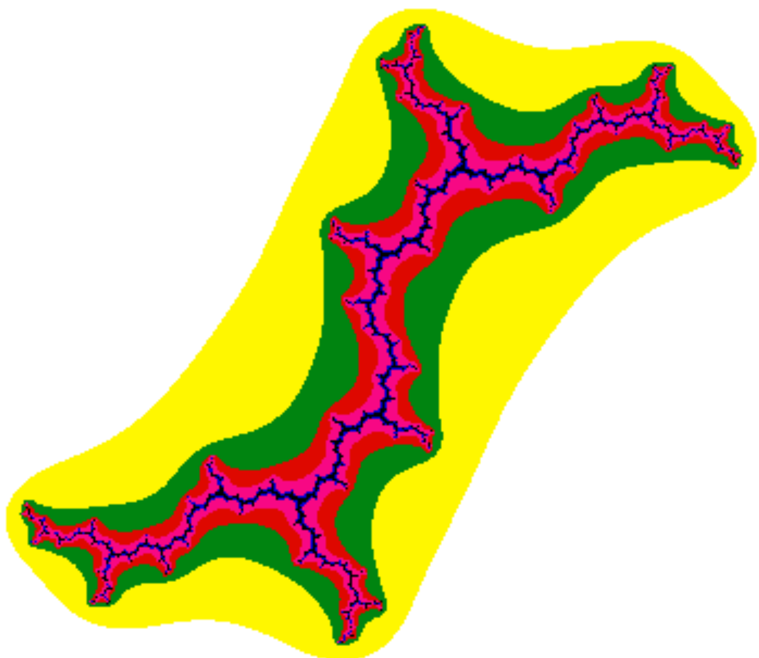
Example: Julia set, Lab 4 Mandelbrot, ray caster...

Good for visualizing results. Better methods exist, without having to move data to CPU and back.



The Julia set

$$z_{k+1} = z_k^2 + \lambda$$



Julia set for
$\lambda = (0, 1) = 0 + j$

Start with position in complex space.

Apply complex function recursively

Inspect distance to origin

Perfectly parallel algorothm

CUDA-OpenGL Interoperability

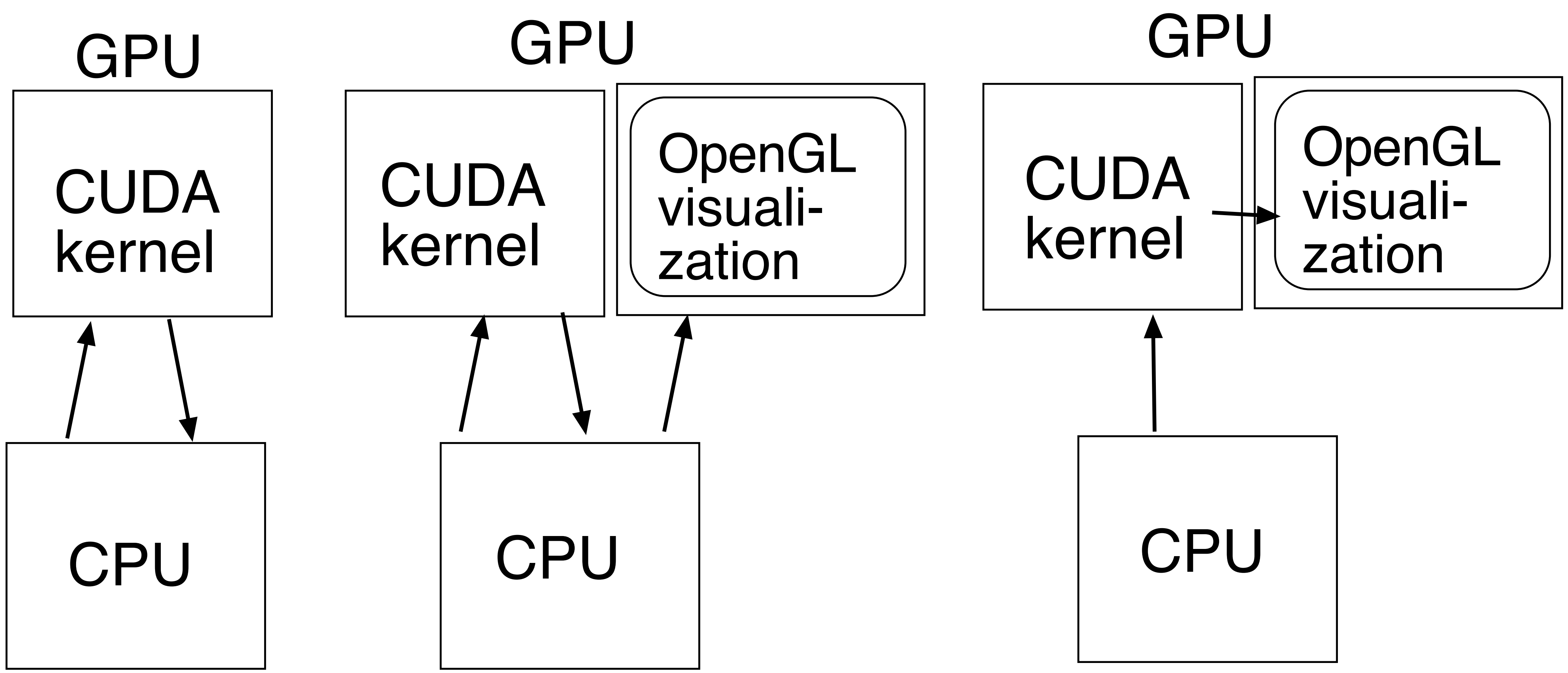
- Integrate for better performance!
- Possible to visualize without leaving GPU

An output which is not the CPU

No visualization

Simple visualization

Visualization with OpenGL interoperability



Steps for interoperability

- Decide what data CUDA will process
- Allocate with OpenGL
- Register with CUDA
- Map buffer to get CUDA pointer
- Pass pointer to CUDA kernel
- Release pointer
- Use result in OpenGL graphics

- **Allocate with OpenGL**
- **Register with CUDA**

Allocate VBO (vertex buffer)

```
glGenBuffers(1, &positionsVBO);
glBindBuffer(GL_ARRAY_BUFFER, positionsVBO);
unsigned int size = NUM_VERTS * 4 * sizeof(float);
glBufferData(GL_ARRAY_BUFFER, size, NULL, GL_DYNAMIC_DRAW);
glBindBuffer(GL_ARRAY_BUFFER, 0);
```

Register with CUDA

```
cudaGraphicsGLRegisterBuffer(&positionsVBO_CUDA, positionsVBO,
cudaGraphicsMapFlagsWriteDiscard);
```

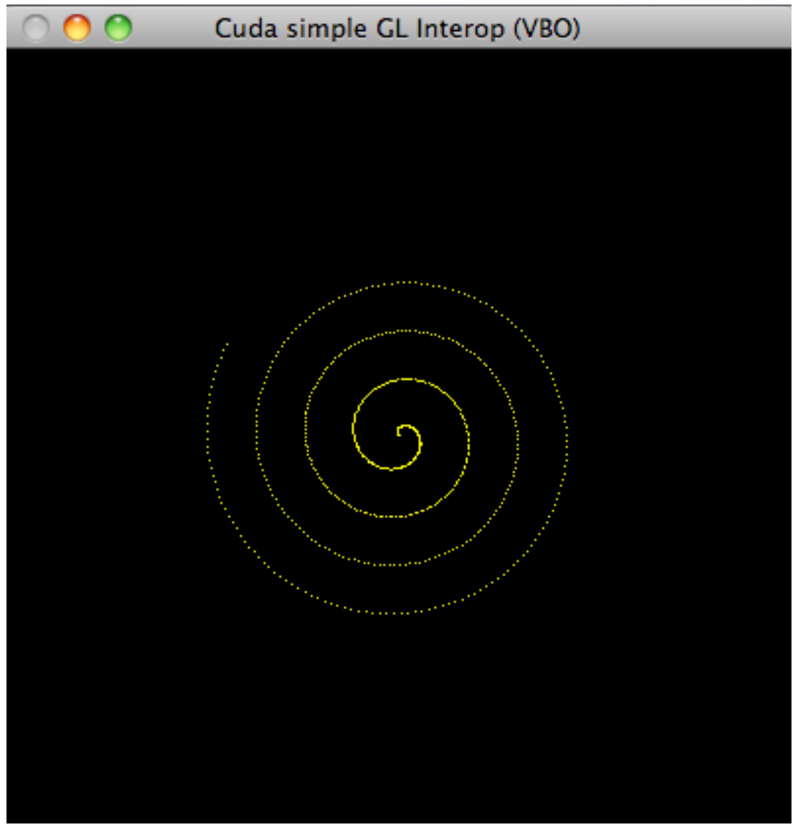
- **Map buffer to get CUDA pointer**
- **Pass pointer to CUDA kernel**
- **Release pointer**

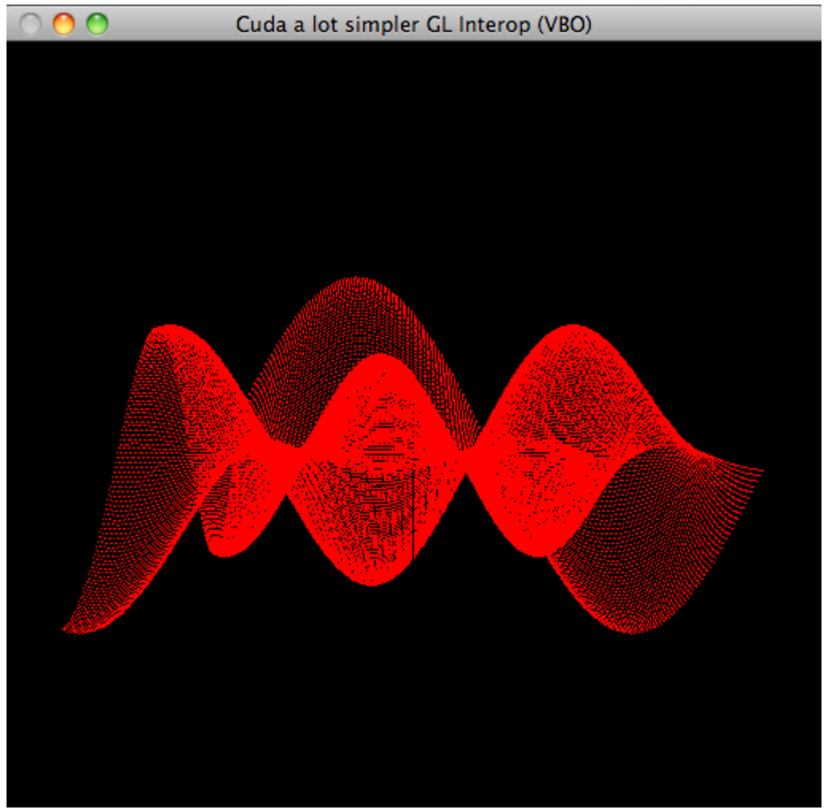
```
cudaGraphicsMapResources(1, &positionsVBO_CUDA, 0);
size_t num_bytes;
cudaGraphicsResourceGetMappedPointer((void**)&positions, &num_bytes,
positionsVBO_CUDA);printError(NULL, err);

// Execute kernel
dim3 dimBlock(16, 1, 1);
dim3 dimGrid(NUM_VERTS / dimBlock.x, 1, 1);
createVertices<<<dimGrid, dimBlock>>>(positions, anim, NUM_VERTS);

// Unmap buffer object
cudaGraphicsUnmapResources(1, &positionsVBO_CUDA, 0);
```

Simple CUDA kernel for producing vertices for graphics

```
// CUDA vertex kernel
__global__ void createVertices(float4* positions, float time, unsigned int num)
{
 unsigned int x = blockIdx.x*blockDim.x + threadIdx.x;

 positions[x].w = 1.0;
 positions[x].z = 0.0;
 positions[x].x = 0.5*sin(kVarv * (time + x * 2 * 3.14 / num)) * x/num;
 positions[x].y = 0.5*cos(kVarv * (time + x * 2 * 3.14 / num)) * x/num;
}
```

Simple examples:





Just vertices - but you can draw surfaces, compute textures, use any OpenGL effects (light, materials)

But should we use CUDA for OpenGL?

Great for visualizing

Faster than going over CPU

Slower than plain OpenGL for graphics!

and OpenGL has CUDA-like functionality built-in!
(Compute Shaders.) (Later lecture)

Conclusions

CUDA can be coupled closer to OpenGL than the simple way we have done before!

Moving data back and forth is wastefui, there is performance to gain!

Some interesting alternatives exist as well.