Lecture 13

Image filters

OpenCL

GPU computing with GLSL

OpenGL Compute shaders

Lecture questions

1) What kind of devices will OpenCL run on?

2) What does an OpenCL work group correspond to in CUDA?

3) What geometry is typically used for shader-based GPU computing?

4) Are scatter or gather operations preferrable? Why?

Lab 5

- **Image filtering with shared memory**
- **Low-pass filters**
- **Median filter**

New lab last year. Worked well as continuation of previous image filtering lab.

Lab 6

- OpenCL
- Reduction
- Sorting using bitonic sort

Also new last year, with good results.

Image filters (lab 3 and 5)

Linear filters: Convolution

Box filter

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

/25

Gaussian approximation

1	4	6	4	1
4	16	24	16	4
6	24	36	24	6
4	16	24	16	4
1	4	6	4	1

/256

And others

1	0	1
2	0	2
1	0	1

0	-1	0
-1	4	-1
0	-1	0

Separable filters

1
1
1
1
1

/5

⊕

1	1	1	1	1

/5

=

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

/25

1
4
6
4
1

/16

⊕

1	4	6	4	1

/16

=

1	4	6	4	1
4	16	24	16	4
6	24	36	24	6
4	16	24	16	4
1	4	6	4	1

/256

Repeated box filters converge to Gaussian!

$$\begin{bmatrix}1\\4\\6\\4\\1\end{bmatrix}/16 = \begin{bmatrix}1\\2\\1\end{bmatrix}/4 \oplus \begin{bmatrix}1\\2\\1\end{bmatrix}/4 = \begin{bmatrix}1\\1\end{bmatrix}/2 \oplus \begin{bmatrix}1\\1\end{bmatrix}/2 \oplus \begin{bmatrix}1\\1\end{bmatrix}/2 \oplus \begin{bmatrix}1\\1\end{bmatrix}/2$$

Central limit theorem

Compare to dice!

Non-linear filters

Median filter

Outputs median of neighborhood.

Requires some method to find the median.

Important application noise suppression.
Preserves edges!

Separable only as approximation.

Median filters

How to filter edges

The filter kernel reaches outside the image!

My answer: clamp!

Solved for you in the Lab 5 code.

Why? Avoid branching!

```
if (x < imagesizex && y < imagesizey)
{
// Filter kernel (simple box filter)
sumx=0;sumy=0;sumz=0;
for(dy=-kernelsizey;dy<=kernelsizey;dy++)
 for(dx=-kernelsizex;dx<=kernelsizex;dx++)
 {
  // Use max and min to avoid branching!
  int yy = min(max(y+dy, 0), imagesizey-1);
  int xx = min(max(x+dx, 0), imagesizex-1);

  sumx += image[((yy)*imagesizex+(xx))*3+0];
  sumy += image[((yy)*imagesizex+(xx))*3+1];
  sumz += image[((yy)*imagesizex+(xx))*3+2];
 }
out[(y*imagesizex+x)*3+0] = sumx/divby;
out[(y*imagesizex+x)*3+1] = sumy/divby;
out[(y*imagesizex+x)*3+2] = sumz/divby;
}
```

In the lab

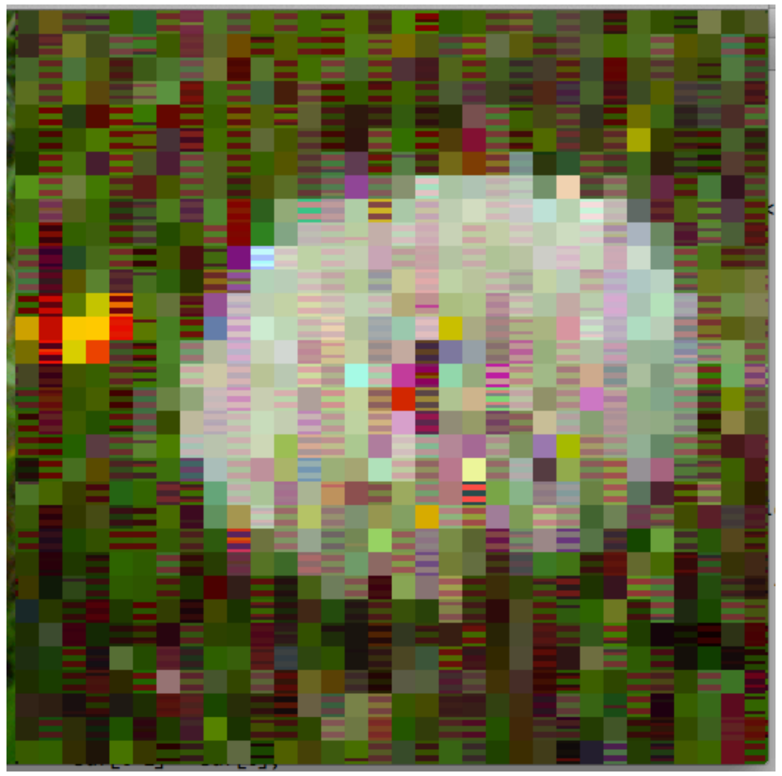
1. Shared memory
Use shared memory to reduce global memory access.
Major part of the lab!

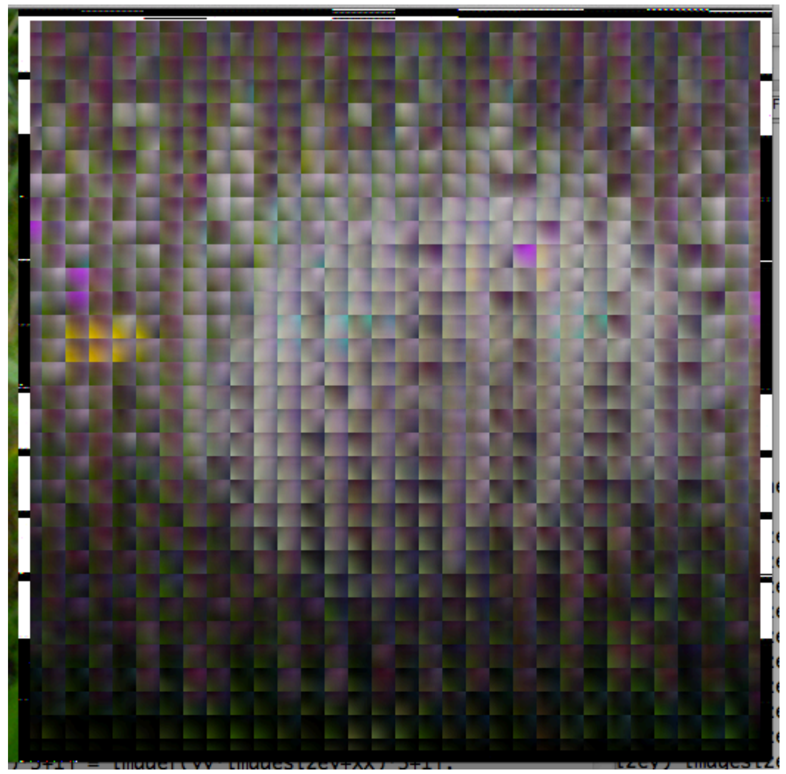
2. Separable filters
Easy if step 1 is done right.

3. Weighted kernels
One size is enough.

4. Median filter
Variable size, modest demands.

Bonus: Unintentional fun!





Coding filters in CUDA is like a box of chocolate…