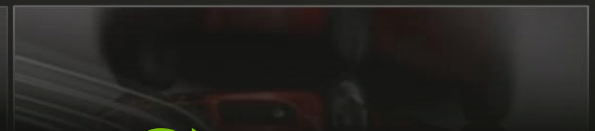
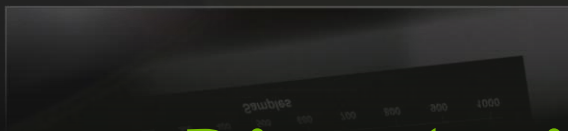
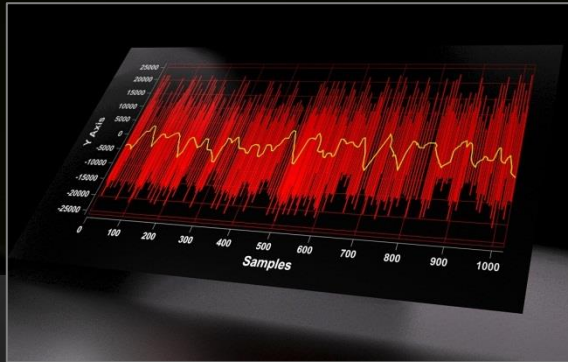
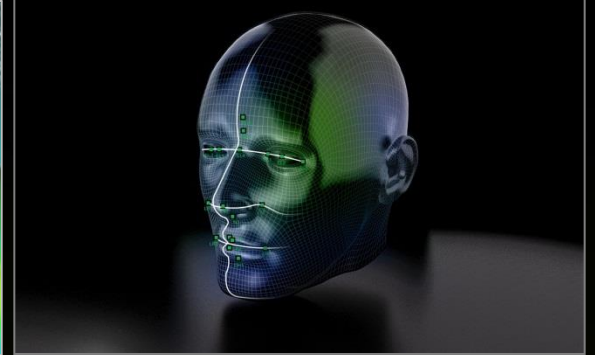
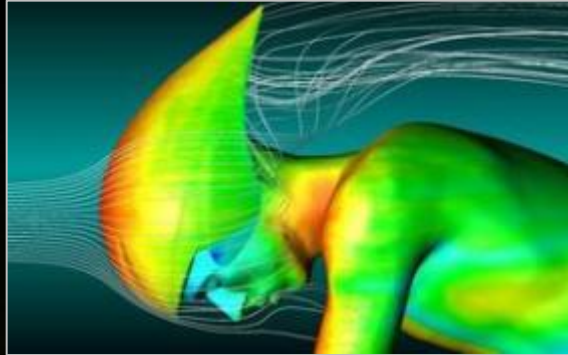


Tesla

GPU Computing

Directives Deep Dive (using C)

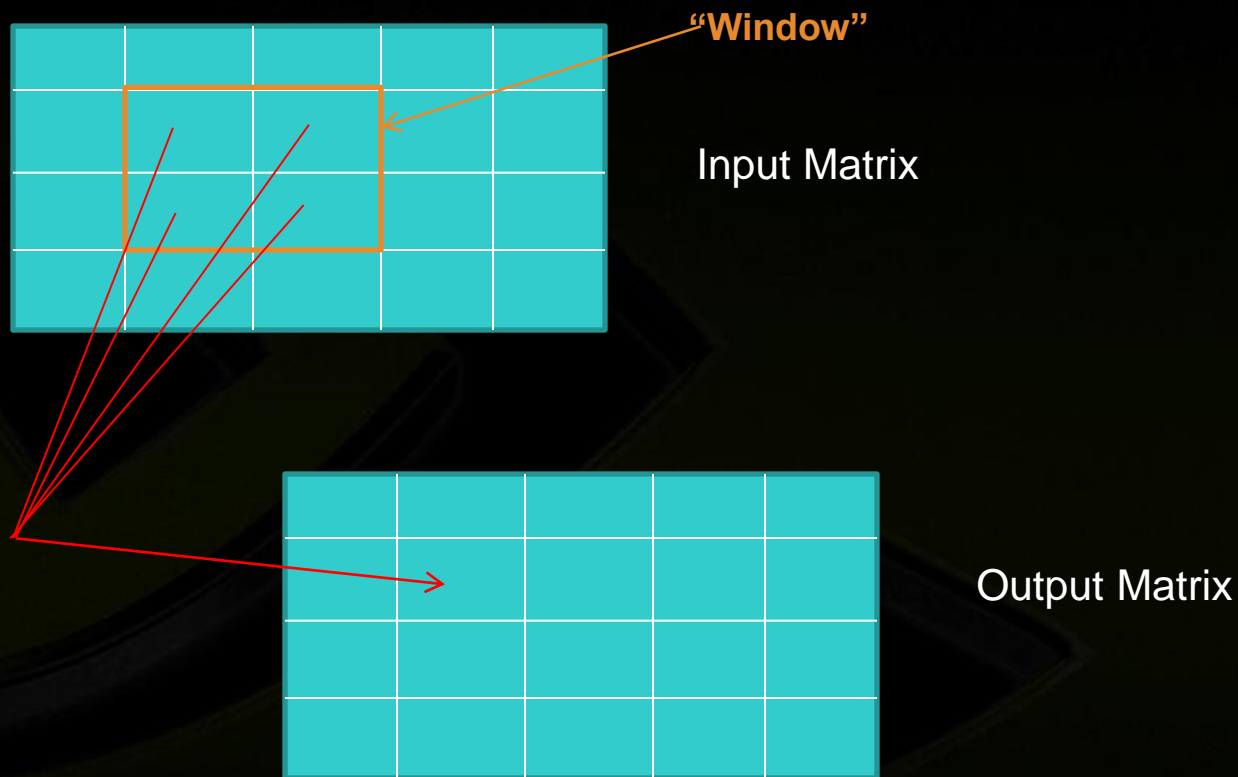


Finding Parallelism in your code



- (Nested) for loops are the best example
- Large pieces of work are needed to offset GPU overhead
- Code must be parallelizable – typically means iterations of the for loop must be independent of each other
- Compiler must be able to figure out sizes of data regions
- Pointers and pointer arithmetic should be avoided if possible
- Best to use subscripted arrays, rather than pointer-indexed arrays.
- Any function calls within the accelerated region must be able to be inlined.

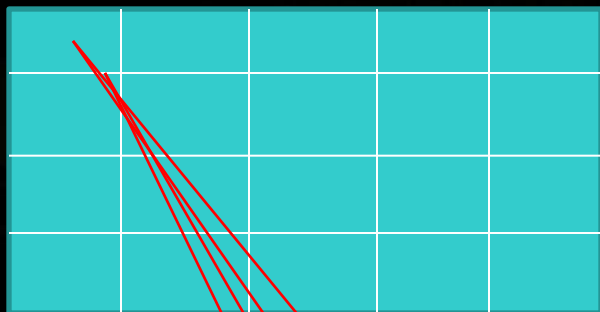
Window Minimum Example



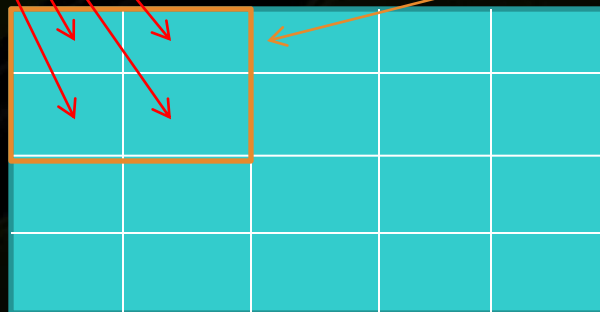
We iterate over the output matrix, reading from each input point several times and **writing to each output point once**.

$$\text{Output}(i,j) = \min(\text{Output}(i,j), \text{Inp}(i,j), \text{Inp}(i,j+1), \text{Inp}(i+1,j), \text{Inp}(i+1,j+1)\dots);$$

Window Minimum – Alternate Realization



Input Matrix



“Window”

Output Matrix

We iterate over the input matrix, reading from each input point once and **writing to each output point several times (perhaps).**

```
Output(i,j) = min(Output(i,j), Inp(i,j));  
Output(i,j+1) = min(Output(i,j+1), Inp(i,j));  
Output(i+1,j) = min(Output(i+1,j), Inp(i,j));  
Output(i+1,j+1) = min(Output(i+1,j+1), Inp(i,j));  
....
```

Code Sample 1



Accelerator Directive

```
#pragma acc region
```

```
{  
  for(i=0; i<(nx-(wx-1)); i++){  
    for(j=0; j<(ny-(wy-1)); j++){  
// loop over the window  
      for (sx=0; sx<wx; sx++){  
        for (sy=0; sy<wy; sy++){  
          // find the minimum value over the window and store in node(i,j)  
          if (node[(j + sy) + ((i+sx)*ny)] > cell[j + (i*(ny-1))]) node[(j + sy)  
+ ((i+sx)*ny)] = cell[j+(i*(ny-1))];  
        }  
      }  
    }  
  }  
}
```

Nested for loops

YUCK!

Compiler is sad!

Code Sample 2



```
#pragma acc region
{ // loop over the data set
  for(i=0; i<(nx-(wx-1)); i++){
    for(j=0; j<(ny-(wy-1)); j++){
      tempnode = node[i][j];
    }
    // loop over the minimization window
    for (sx=0; sx<wx; sx++){
      for (sy=0; sy<wy; sy++){
        // find the minimum value over the window and store in node(i,j)
        if (tempnode > cell[i+sx][j+sy]) tempnode = cell[i+sx][j+sy];
      }
    }
    node[i][j] = tempnode;
  }
}
```

Accelerator Directive

Nested for loops

✓ Independent Loop Iterations

✓ Nice array subscripting

✓ No pointer arithmetic

Compiler is happy!

Process to follow



- Follow the basic rules for identifying parallelizable code
- Drop in directives
- Compile with appropriate flags (-ta=nvidia,cc20 -Minfo)
- Look at compiler info output
- Rewrite code
- Repeat
- Benchmark the code when you have a loop that is parallelized

Example 1



- **Bad code example (grid2o.c)**
- **Getting better (grid2.c)**
- **-Msafepr – discussion of data management**
- **Basic Data movement directive:**
 - **#pragma acc data region copyin(...) copy(...)**

Directives categories

- Accelerator control (#pragma acc region ...)
- Accelerator hints (#pragma acc data ...)
- Data management
- Device control

Tips and Tricks



- Use time option to learn where time is being spent
 - -ta=nvidia,cc20,time
- Eliminate pointer arithmetic
- Inline function calls in directives regions
- Use Contiguous memory for multi-demensional arrays
- Use Data regions to avoid inefficiencies
- Conditional compilation with ACCEL keyword
- More: <http://www.nvidia.com/docs/IO/117442/Top-12-Tricks-for-Maximum-Performance-C.pdf>

Getting started



- www.nvidia.com/gpudirectives
- Download PGI tools
- Up to 30 days free usage (trial license)
- Documentation
- User forums
- All features available to Fortran users as well