High-Performance Computing
By Advanced Stream Processing Using GPU

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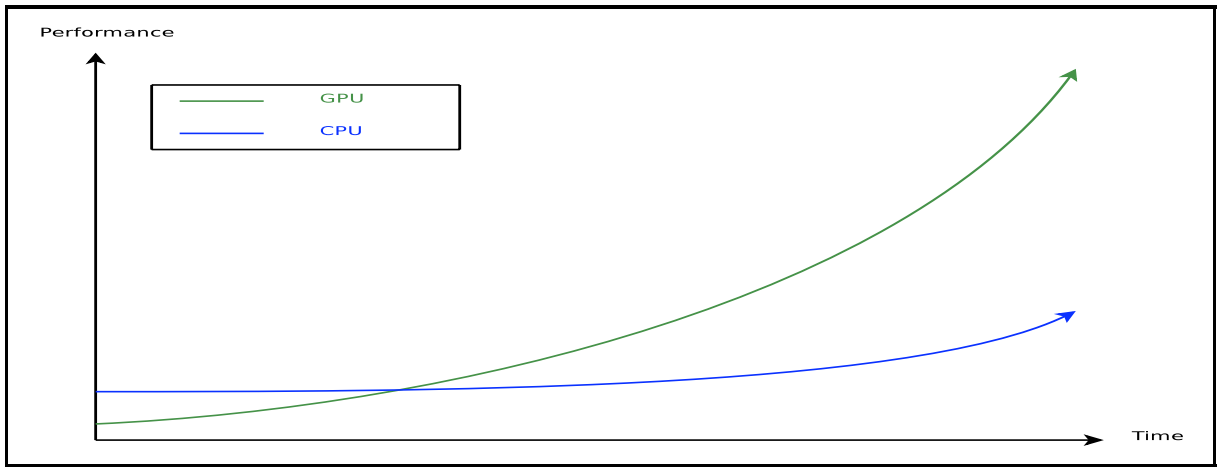
BACKGROUND



performance growth of GPUs and CPUs

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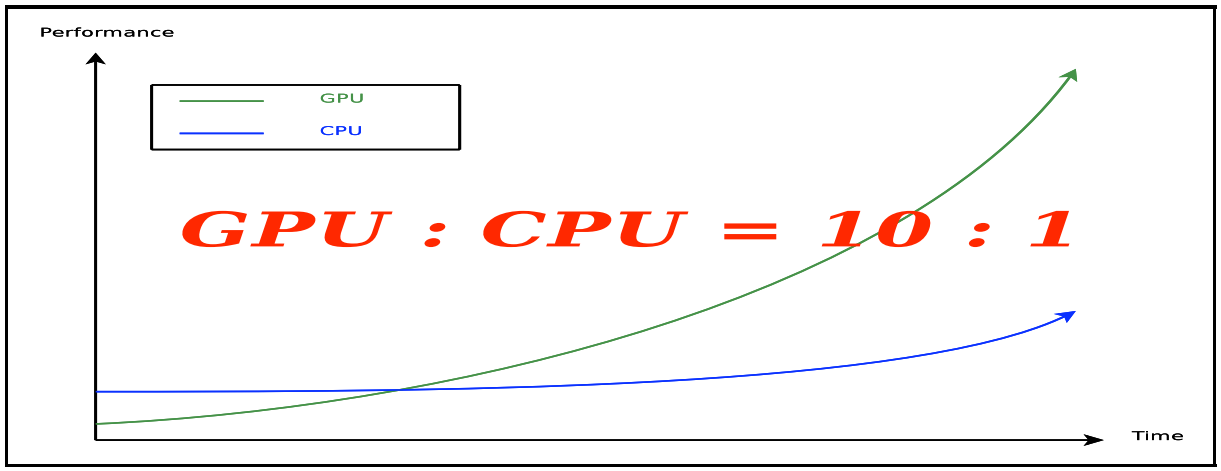

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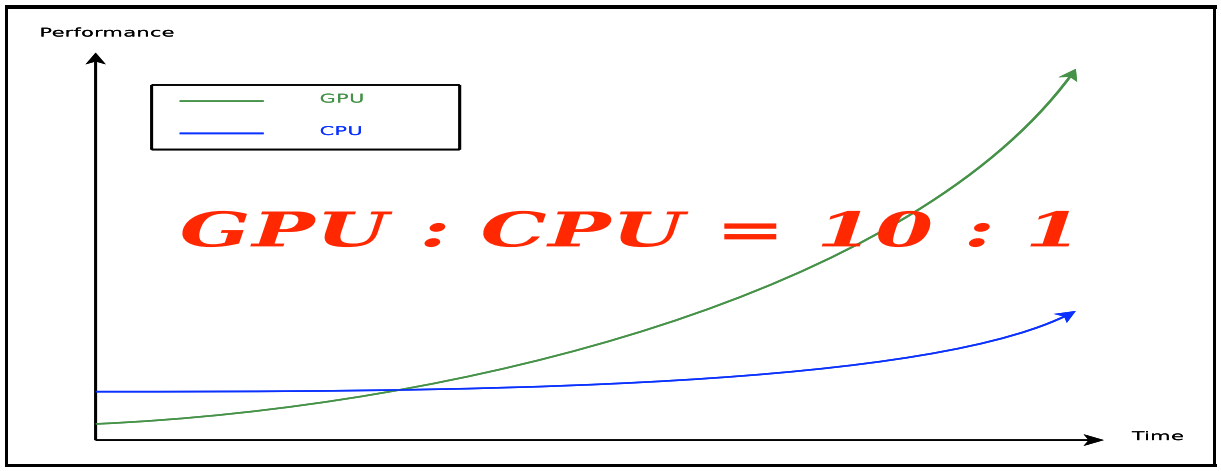

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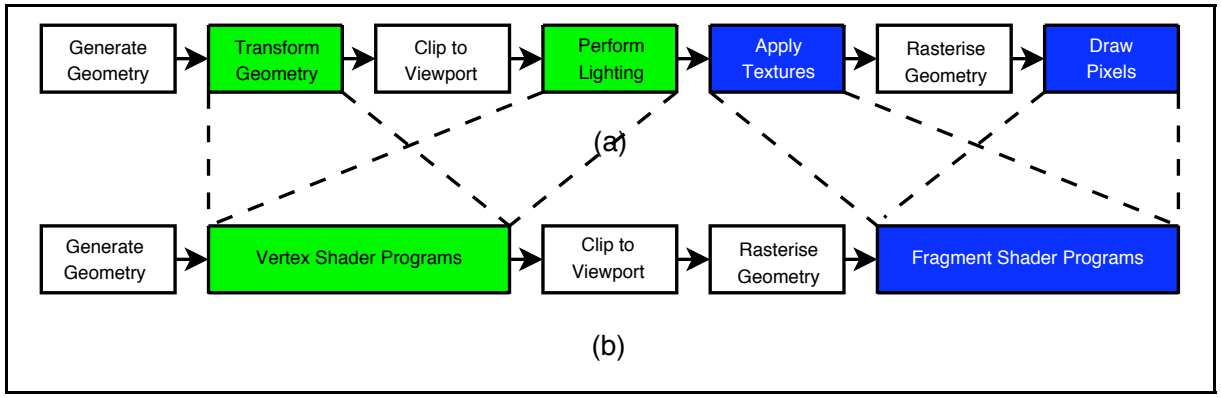

(a) fixed non-programmable pipelines and (b) programmable pipelines

WHAT DO I WANT TO DO WITH GPU?

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NDP (Nested Data Parallelism) on GPU.

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NDP (Nested Data Parallelism) on GPU.

Why?

- GPUs cannot handle nested or irregular data structure such as sparse matrices and nested arrays.
  Their data structure is texture-based.
- There are algorithms that can be efficiently implemented only with nested data structure.
- Manual transformation of nested data structure is error-prone and a tedious task.

What do I want to do with GPU?

NDP (Nested Data Parallelism) on GPU.

In other words:

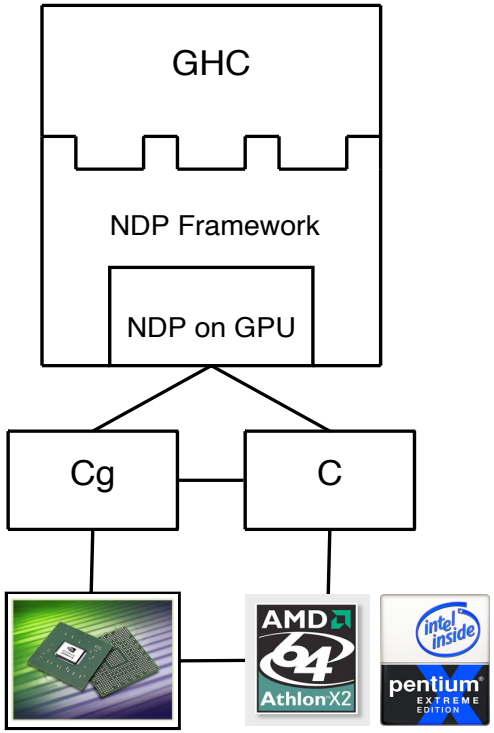
- Enhance the programmability of graphics hardware to the state where:
  - ➜ the *irregular data processing* is supported,
  - ➜ the compiler distinguishes the code to run on GPUs and the code to run on CPUs (*uniform approach*), and
  - ➜ the *hardware virtualisation* is enabled.
- Smooth integration of the enhanced programmability into the graphical applications as well as general-purpose computations.
- Achieve high-performance stream processing in low cost.

What do I want to do with GPU?

Other Programming Systems on GPU:

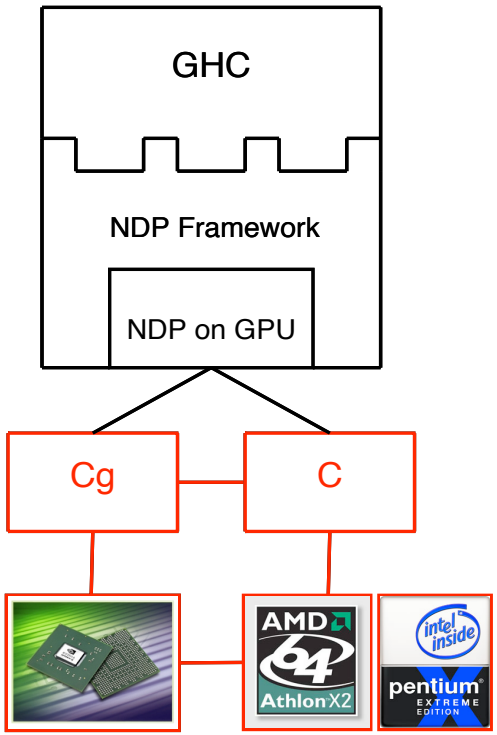
	Brook	Cg	GLSL	Sh
Nested Data Parallelism	✘	✘	✘	✘
C/C++-like syntax	✔	✔	✔	✔
Level of Abstraction	high	Low	Low	High
Standalone Compiler	✔	✔	✘	✔
Uniform Approach	✘	✘	✘	✘
Hardware Virtualisation	✔	✘	✘	✘
Irregular Data Processing Support	✘	✘	✘	✘

The Approach



THE APPROACH

- Implement a C library for NDP on GPU. The library will include all the primitives required NDP operations on GPU.



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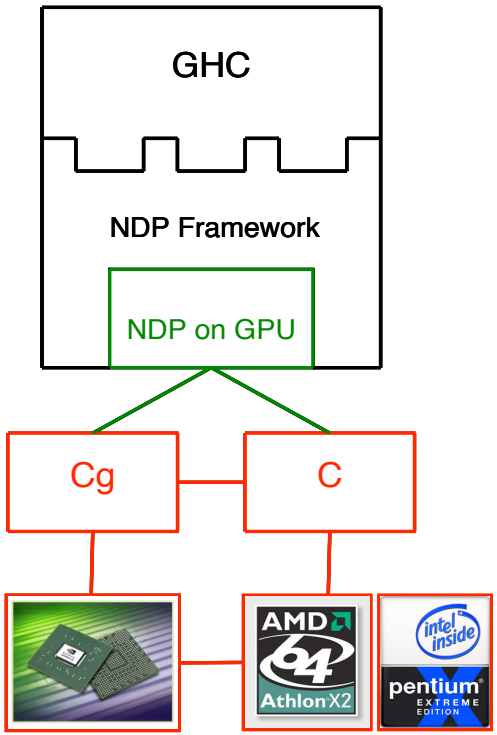
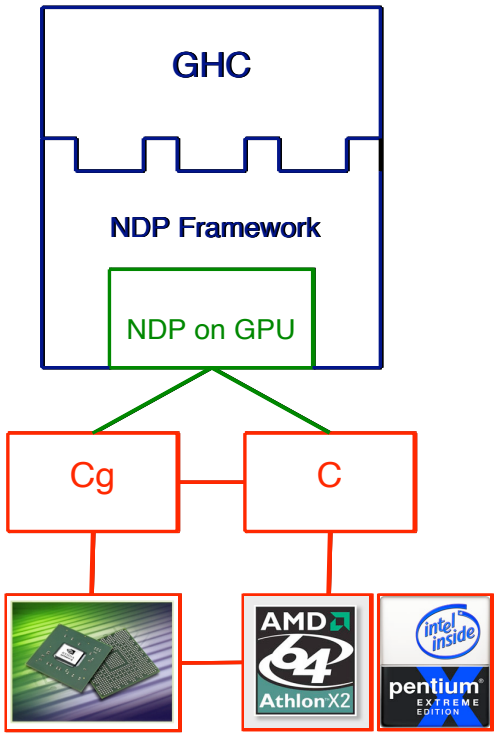
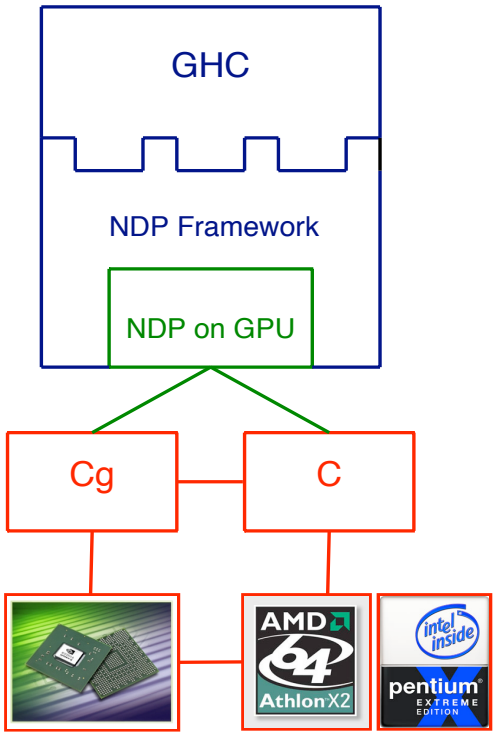


The Approach

- Implement a C library for NDP on GPU. The library will include all the primitives required NDP operations on GPU.
- Develop techniques to tackle the issues such as hardware virtualisation and uniform approach.
- The library will be hooked up to NDP framework, which is being implemented in GHC.



The Approach



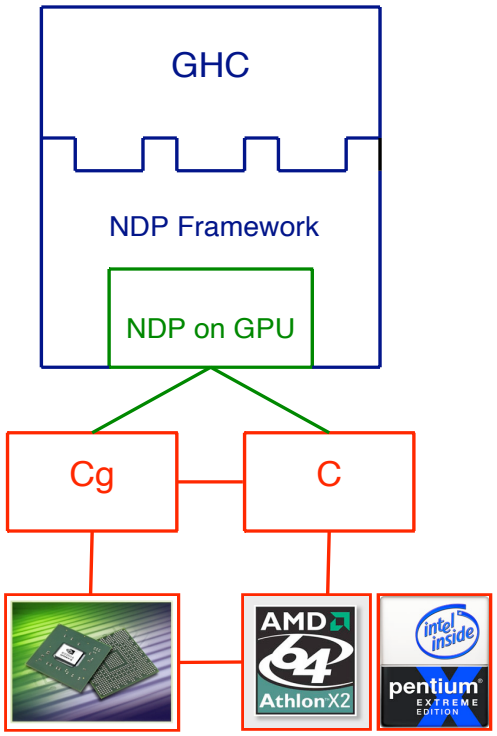
On Haskell:

```
filter ( \x->x 'mod' 2 == 1 ) input
```

On C:

```
filter (
        [[ \x->x 'mod' 2 == 1 ]],
        input, inputsize, output
);
```

The Approach



On Cg:

```
float4 main ( ... data from the host CPU ... ) : COLOR {
  ... local data declaration ...
  result.a = 0;
  index[0] = ( lW * floor ( coord.y ) + floor ( coord.x )) * s;
  for ( i = 0; i < s ; i++, index[0]++ ) {
    if ( index[0] < numElems ) {
      index[1] = index[0];
      index[2] = 0;
      while ( index[1] >= fbWidth ) {
        index[1] -= fbWidth;
        index[2]++;
      }
      V1 = ( texRECT ( elements, float2 ( index[1], index[2] ))).r;
      if ( int ( V1 ) % 2 == 1 ) {
        if ( result.a == 0 ) result.r = V1;
        else if ( result.a == 1 ) result.g = V1;
        else if ( result.a == 2 ) result.b = V1;
        result.a++;
      }
    }
  }
  return result;
}
```

Where Am I?

`libndpgpu`:

Implemented operations:

- `scanl`, `scanlS`, `scanr`, `scanrS`
- `foldl`, `foldlS`, `foldr`, `foldrS`
- `map`
- `filter`

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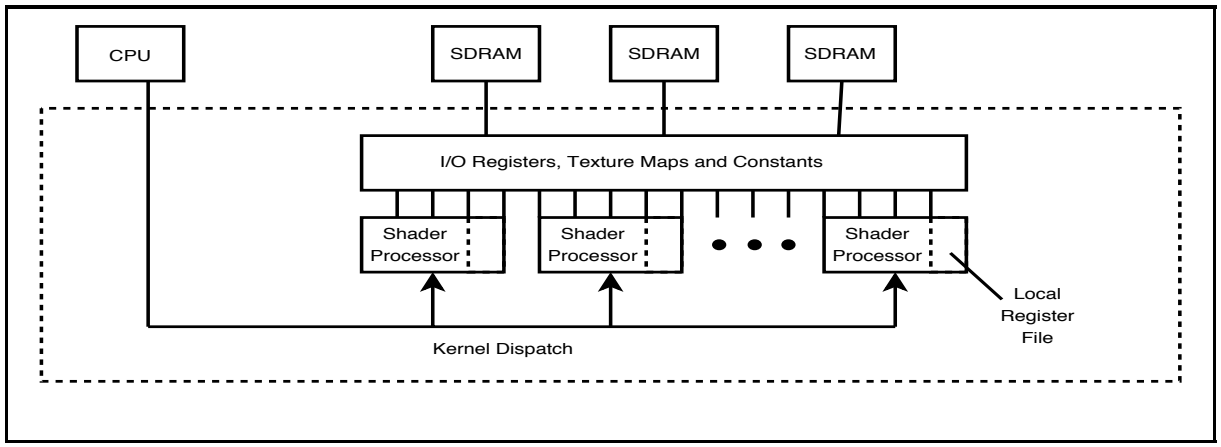

modern GPU architecture

Where Am I?

Benchmarks:

- Intel Core Duo 2.0GHz, 1 GB DDR2 RAM
- NVIDIA GeForce Go 7400 TurboCache 256MB

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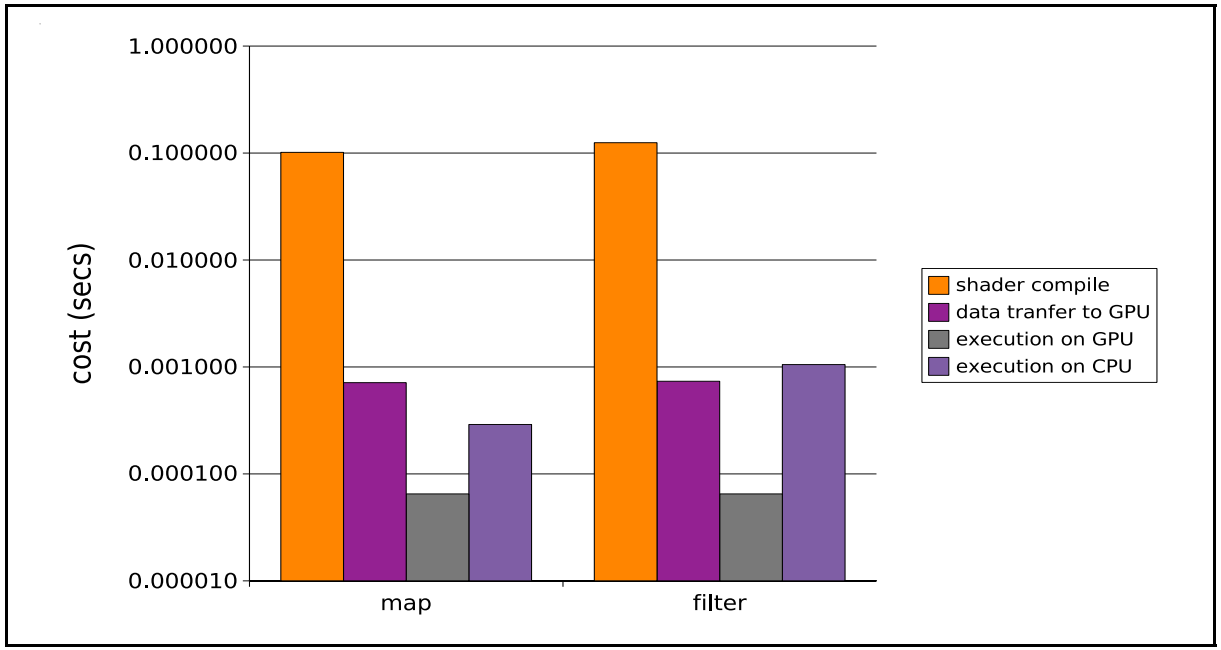

CHALLENGES AND FUTURE WORKS (SHORT TERM)

Challenges and Future Works (short term)

Preprocessor:

- Profile based dynamic Cg assembly generation.
- Assembly level optimisation.
- Translation of functions passed from Haskell level to lower level as inputs to higher-order functions.

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Data organisation and transfer:

- Reduce the data tranfer cost.
- Handle arrays whose number of elements are greater than the maximum size of textures using multi-pass strategy.

Challenges and Future Works (short term)

More bulk array operations:

- permute, zip and its variations, zipWidth and its variations

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Release:

- Release it as a complete library by July 2007.

QUESTIONS?