MONASH University
Engineering

Department of Electrical and
Computer Systems Engineering

ECE4095 Final Year Project 2016

James Anastasiou
Supervisor: Dr. David Boland

Your Code Sucks: With CAPA, Maybe It'll Suck A Little Less

Why Your Code Sucks

You're unlikely to have written your program in such a way that it exploits parallelism to extract performance. Modern compilers try to do this for you, however a targeted approach provides superior results. What if you had a tool that could tell you what to fix?

Project Aim

To develop a source code analyser which generates a report detailing how regions of a codebase could be potentially parallelised, exploiting the massively parallel computational power of Graphics Processing Units (GPUs) through General Purpose GPU programming.

Enter CAPA

CAPA is a tool which utilises static analysis techniques to identify and isolate potentially parallelisable regions of code, and generate a report detailing potential performance improvements that could be gained by refactoring the identified code onto a GPU.


```
01.  #include ...
02.
03.  int main(){
04.      const size_t ELEMS = 1000*1000;
05.      float starting_vec[ELEMS];
06.      initialise(starting_vec, ELEMS);
07.
08.      for (size_t i = 0; i < ELEMS; ++i){
09.          starting_vec[i] /= 2;
10.          starting_vec[i] += 4;
11.      }
12.
13.      // Calculate mean
14.      float k = 0;
15.      for (size_t i = 0; i < ELEMS; ++i)
16.          k += starting_vec[i]/ELEMS;
17.
18.      // Renormalise all values and compute cumulative sum
19.      float cum_sum[ELEMS];
20.      cum_sum[0] = starting_vec[0]/k;
21.      for (size_t i = 1; i < ELEMS; i++)
22.          cum_sum[i] = starting_vec[i]/ELEMS + cum_sum[i-1];
23.      /* ... */
24.  }
25.
26.  void mmult(float **A, float **B, float **C, size_t dim){
27.      for (size_t i = 0; i < dim; ++i)
28.          for (size_t j = 0; j < dim; ++j)
29.              for (size_t k = 0; k < dim; ++k)
30.                  C[i][j] += A[i][k] * B[k][j];
31.  }
```

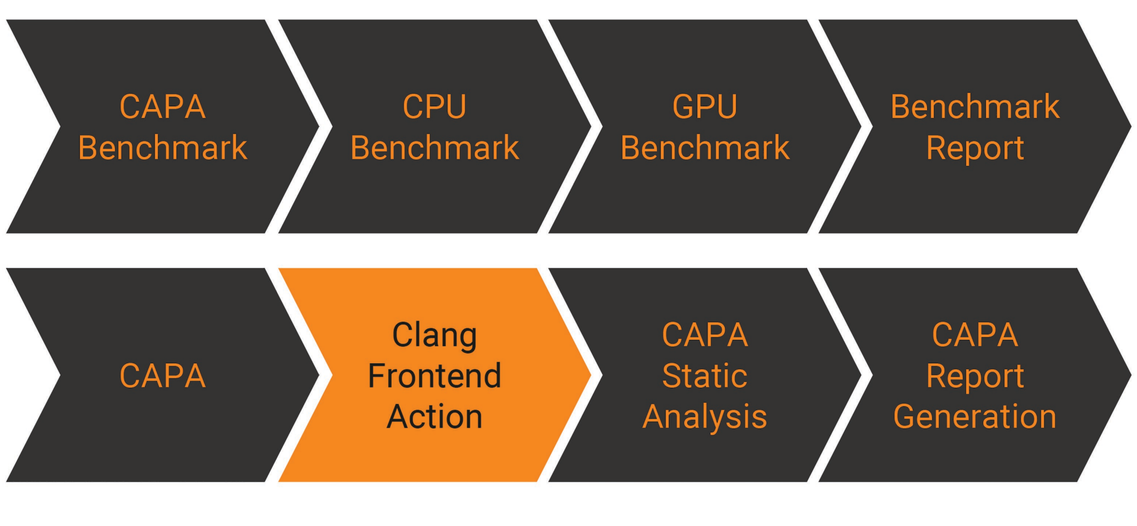
```
CAPA Report

Summary: TotalFiles=1 Files With Improvements=1

/home/james/Projects/CAPA/case/CodeUnderTest.cpp:26:1
Pattern: Vectorisable Function Declaration Priority: 3 Info: Function Declaration
void mmult(float ** A, float ** B, float ** C, size_t dim);

/home/james/Projects/CAPA/case/CodeUnderTest.cpp:8:5
Pattern: Map Priority: 3 Info: Stride Size: 1. Number of Elements: 1000000.
Potential Speedup: 158.03 ~ 140.51
for (size_t i = 0; i < ELEMS; ++i){
        starting_vec[i] /= 2;
        starting_vec[i] += 4;
    }

/home/james/Projects/CAPA/case/CodeUnderTest.cpp:15:5
Pattern: Reduce Priority: 2 Info: Stride Size: 1. Number of Elements: 1000000.
Potential Speedup: 30.30 ~ 34.33
for (size_t i = 0; i < ELEMS; ++i)
        k += starting_vec[i]/ELEMS

/home/james/Projects/CAPA/case/CodeUnderTest.cpp:21:5
Pattern: Scan Priority: 2 Info: Stride Size: 1. Number of Elements: 1000000.
Potential Speedup: 19.72 ~ 30.11
for (size_t i = 1; i < ELEMS; i++)
        cum_sum[i] = starting_vec[i]/ELEMS + cum_sum[i-1]

/home/james/Projects/CAPA/case/CodeUnderTest.cpp:27:5
Pattern: Matrix Multiplication Priority: 1 Info: A Matrix Multiply
Potential Speedup: 16.72 ~ 229.00
for (size_t i = 0; i < dim; ++i)
        for (size_t j = 0; j < dim; ++j)
            for (size_t k = 0; k < dim; ++k)
                C[i][j] += A[i][k] * B[k][j]

[CAPA v0.10.2]
```

Hooking Into Clang

CAPA hooks into the Clang C Compiler to perform Static Analysis on your source code. Clang takes care of lexing and parsing the source file, generating an AST at which point CAPA hooks into Clang via the libtooling interface. CAPA leaves the heavy lifting to Clang, and focuses entirely on finding optimisation op portunities in your code.

CAPA exploits Clangs C level optimisation engine as well, utilising the Constant Folding to extract as much information from the source as possible.

Because Clang is capable of compiling many C family languages, with some additional work CAPA could be used to analyse more than just C, working with C++, Obj-C and Obj-C++



Benchmarking Host & Device

CAPA uses CAPA-Benchmark in order to gather performance information about the target system. This information is gathered by running a set of benchmark tests on both the CPU and GPU of the target.

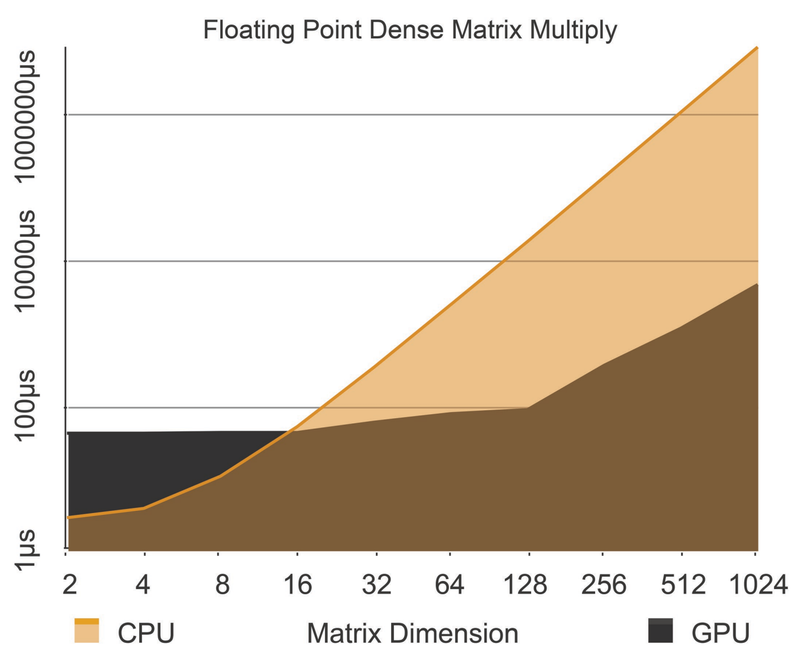
CAPA-Benchmark uses 3rd party libraries to provide the actual testing functionality. Device code is written in CUDA C++, CuBLAS and the Thrust library for memory management.

Host Code is benchmarked using Thrust and Eigen in order to provide more in depth analysis of the code.

Where benchmark information isn't available, CAPA uses theoretical improvements gathered from epirical analysis through development.

What's The Point?

GPU's are fast, massively fast. Parallel code provides orders of magnitude greater performance, for wxample a floating point dense matrix multiply is over 200 times faster on my bottom class GPU (750ti). This is not easy to extract. CAPA Provides a simple tool for assisting programmers in their decision making. CAPA aims to be an intelligent system for recommending optimisations within your code base. CAPA looks at your code, finds the areas where it sucks and points you in the direction of fixing it. With CAPA and a good engineer, maybe your code will suck a little less.



A Little Bit Extra

During the process of building CAPA I created a typesafe interface to CUDA over the parallel primitives through C++ template metaprogramming, making parallel code easy to write.

Where To Find It

Source for CAPA can be found at:
http://github.com/jhana1/CAPA

Source for CAPA-Benchmark can be found:
http://github.com/jhana1/CAPA-Benchmark