Accelerated Test Execution Using GPUs

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Mathworks
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THE UNIVERSITY of EDINBURGH

EPSRC Centre for Doctoral Training in Pervasive Parallelism

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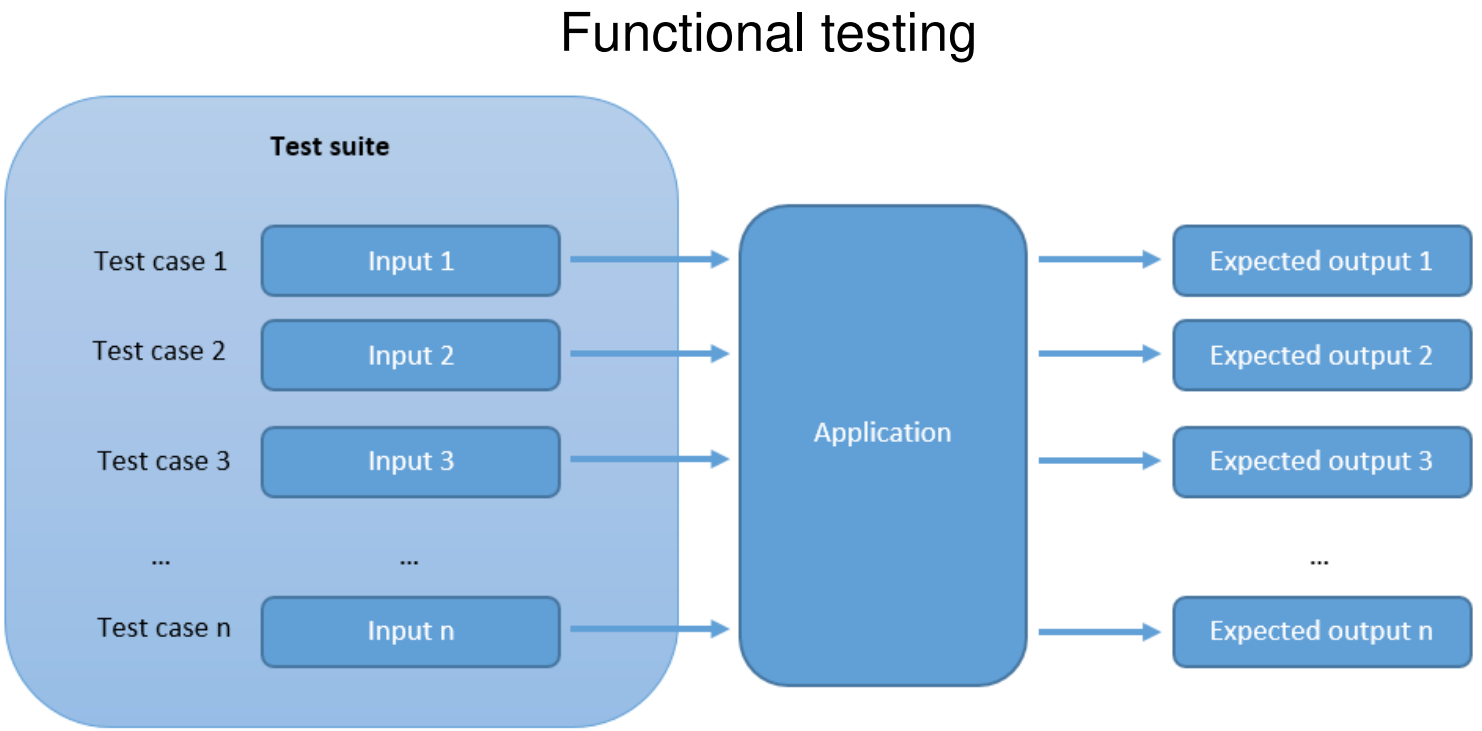
The Problem

Software testing is time consuming



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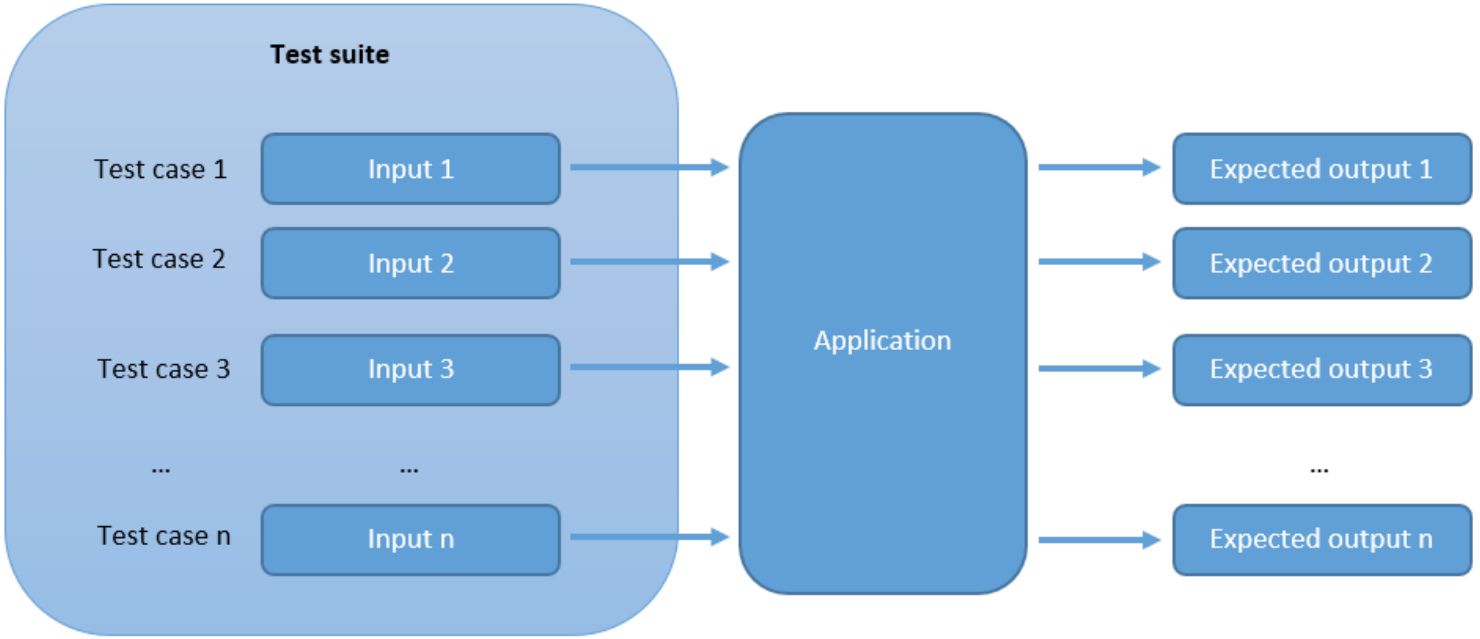
Functional testing



The test suite of a non-trivial system:

- could have **thousands** of test cases
- could take **hours**, **days** or even **weeks** to execute

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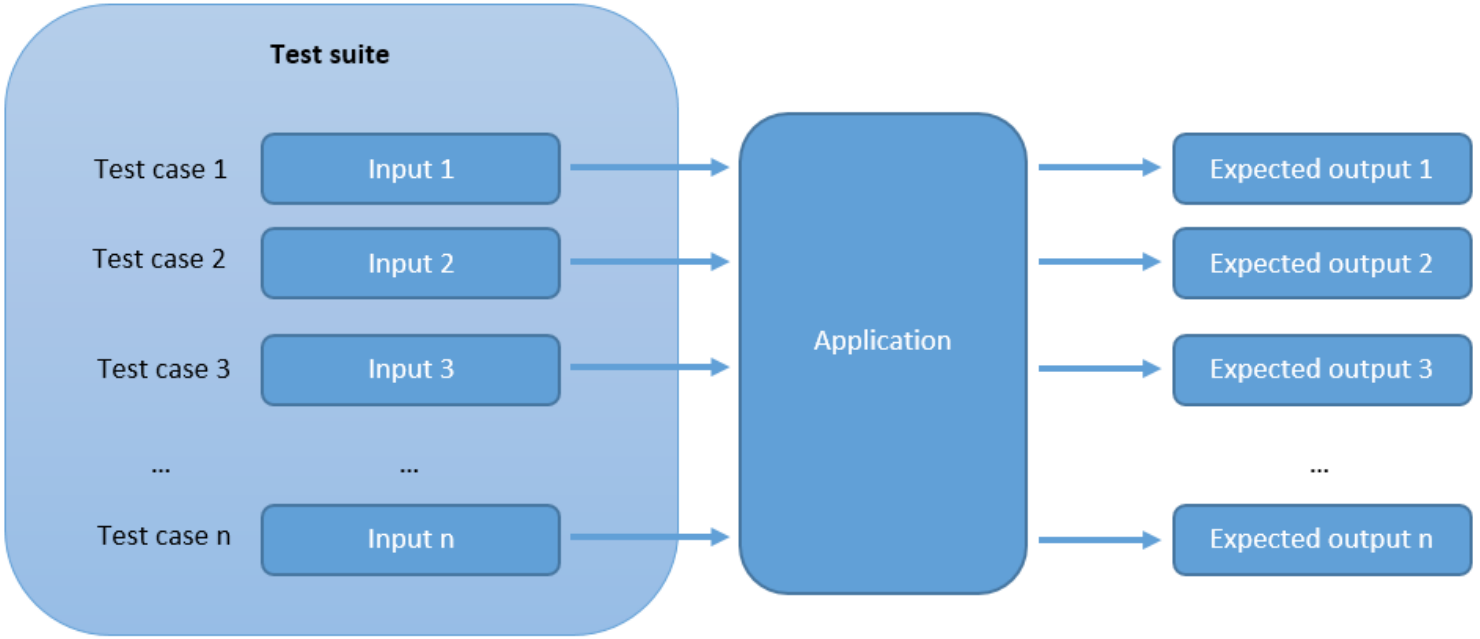

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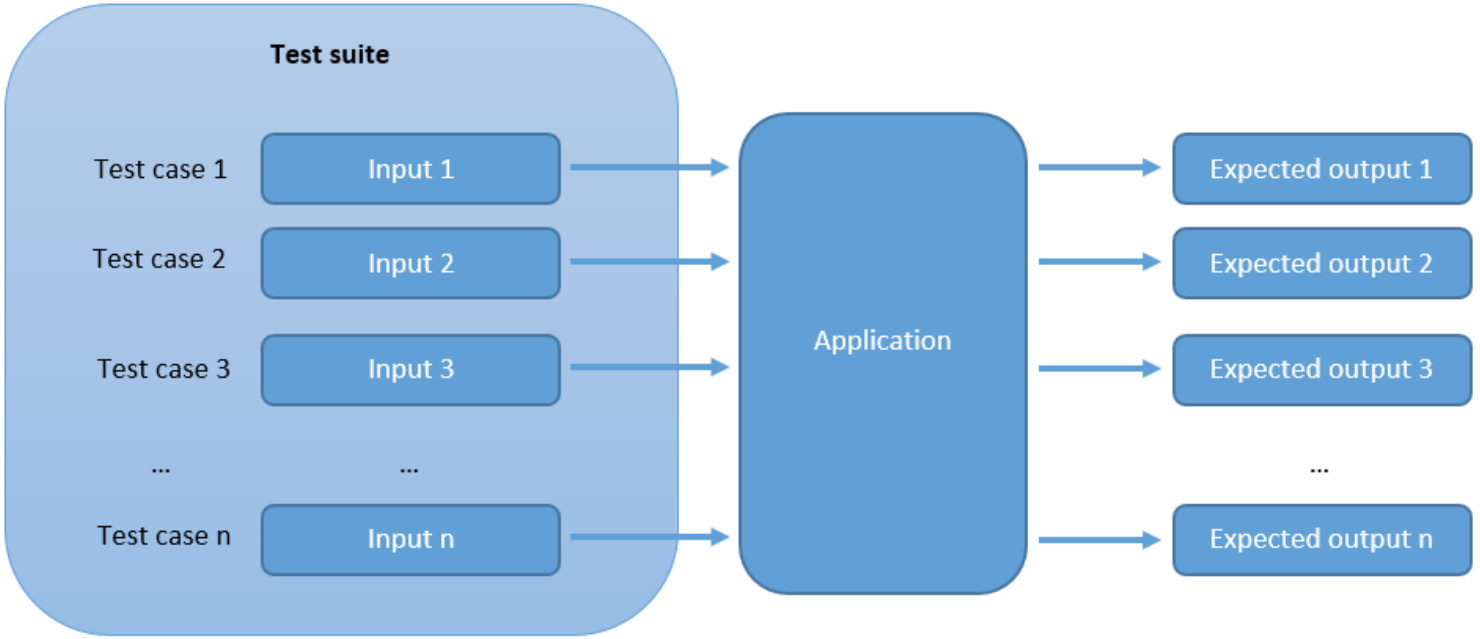

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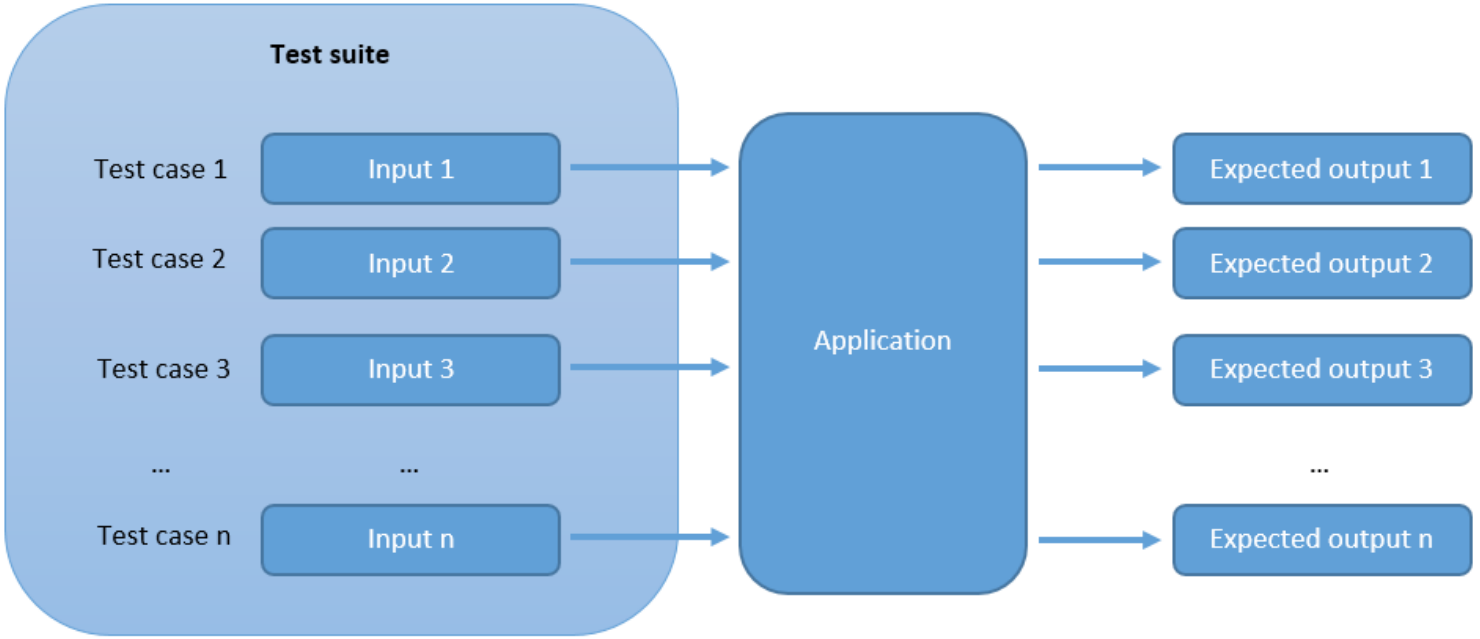

Characteristics:

1. Executions are independent
2. Executions are data parallel
3. Parallel executions are already employed in industry

CPU Servers vs. GPUs

CPU Servers

GPUs

- Comparatively expensive
- Do **not** scale to thousands of test cases
- Extremely under-utilised during testing (up to 90% stays idle)

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- SIMD architecure → suitable for testing

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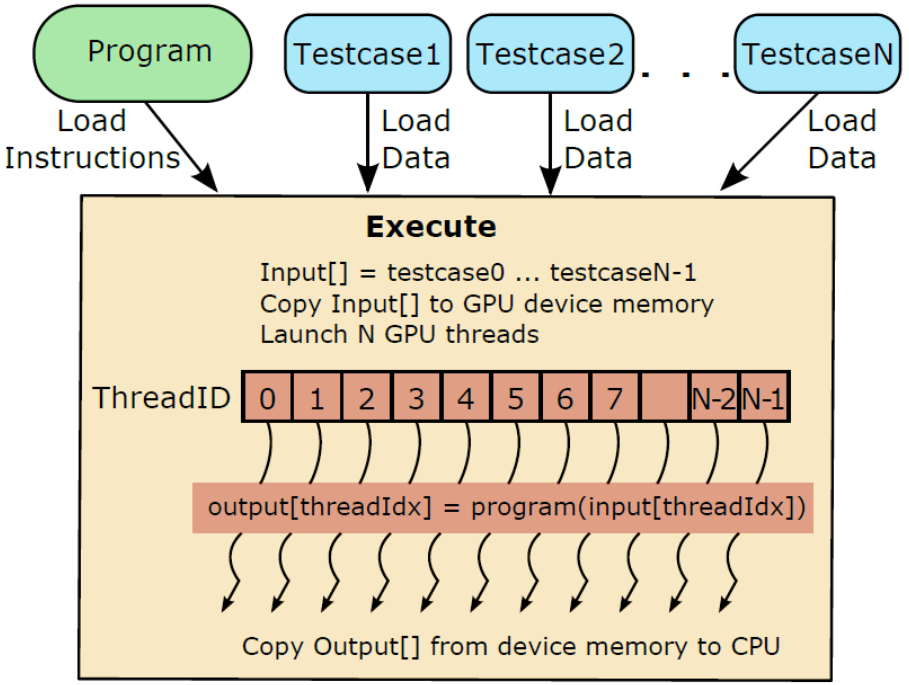
GPUs have the potential to make a huge impact on **development schedules** and **costs** associated with testing.

Proposed Approach

Execute test cases in parallel on the GPU threads

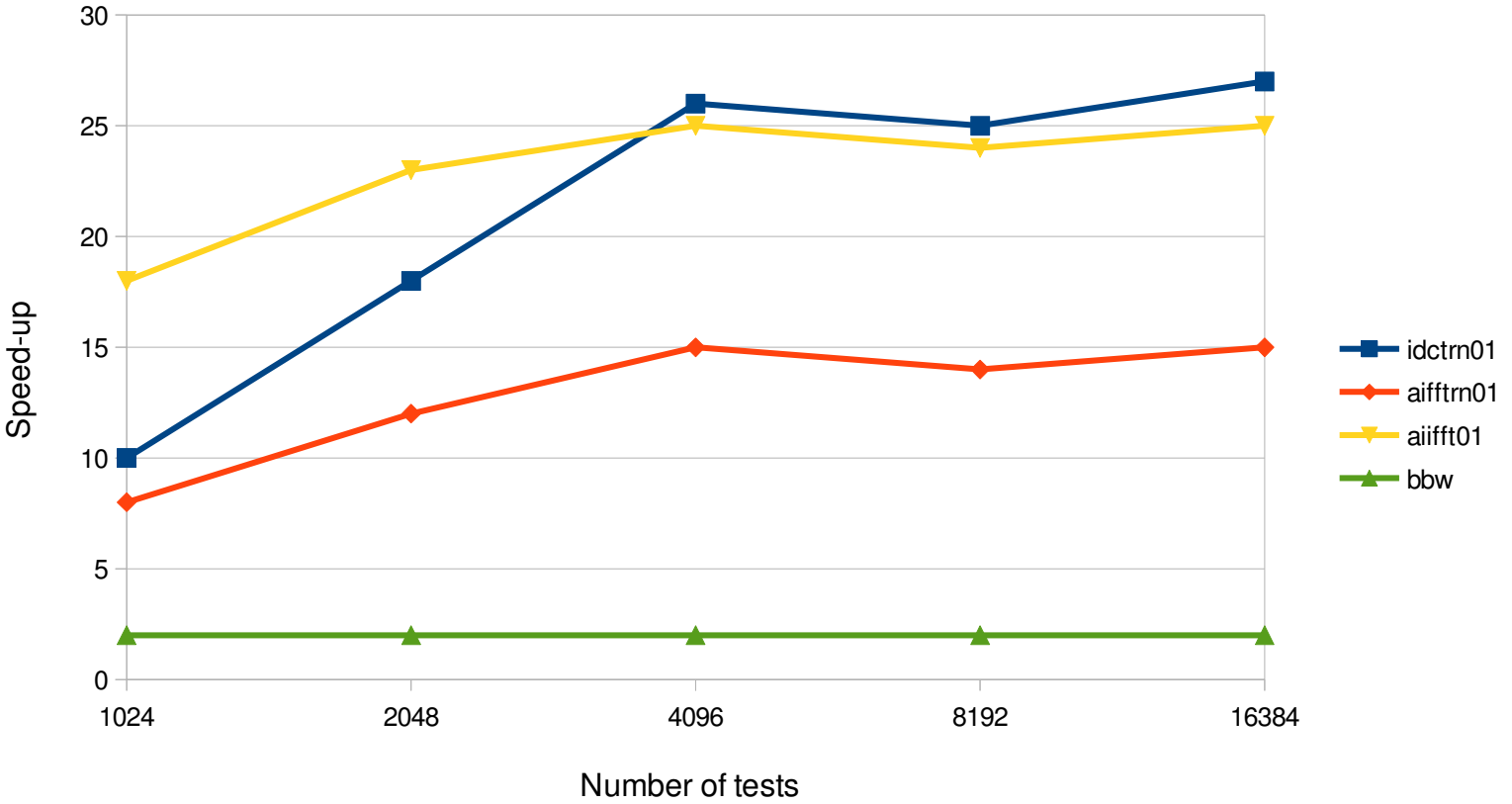


- Test cases are stored in an array and transferred to the GPU.
- Each GPU thread executes the same program on a single element of the array, i.e. on a single test case.
- Original program fuctionality is **unmodified**.

Source: A. RAJAN, S. SHARMA, P. SCHRAMMEL and D. KROENING, *Accelerated Test Execution Using GPUs* in ASE 2014

Previous Work

Performance



GPU used: Nvidia GeForce GTX 670

Source: A. RAJAN, S. SHARMA, P. SCHRAMMEL and D. KROENING, *Accelerated Test Execution Using GPUs* in ASE 2014

Challenges

1. GPUs use low-level programming models, eg. CUDA, OpenCL.
   - Test launching is not trivial to implement.
   - Not available to general programmers.

2. Only a subset of C/C++ features is supported for compilation on the GPU. Unsupported features include:

   recursion, dynamic memory allocation, standard library calls

Challenges

3. Performance is penalised by

- control-flow divergence
- data transfers between the CPU and the GPU memory

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if (cond) {
  // instr 1
} else {
  // instr 2
}
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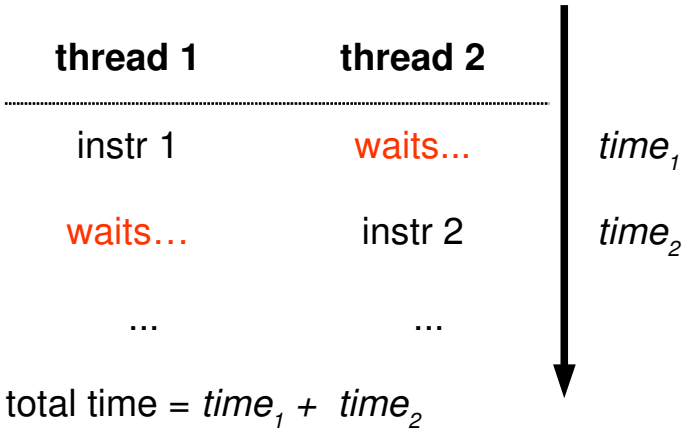

total time = $time_1$ + $time_2$

- data transfers between the CPU and the GPU memory

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```
if (cond) {
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thread 1	thread 2	
instr 1	waits...	$time_1$
waits…	instr 2	$time_2$
...	...	

total time = $time_1$ + $time_2$

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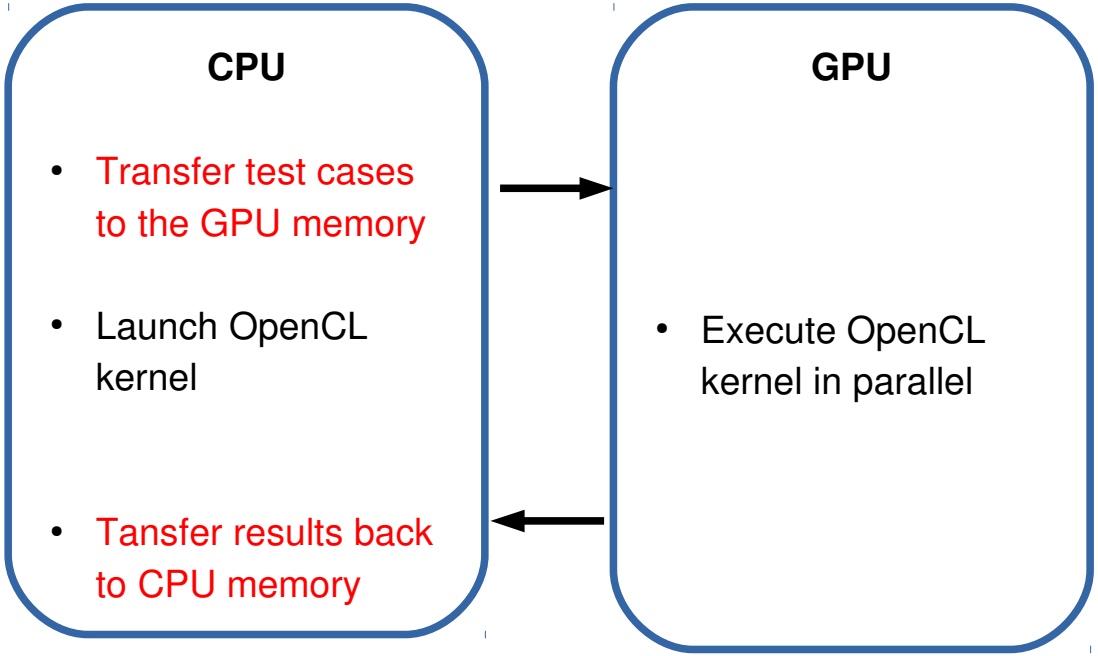

Current Work

Build a tool which generates OpenCL code to launch the test cases in parallel on the GPU.

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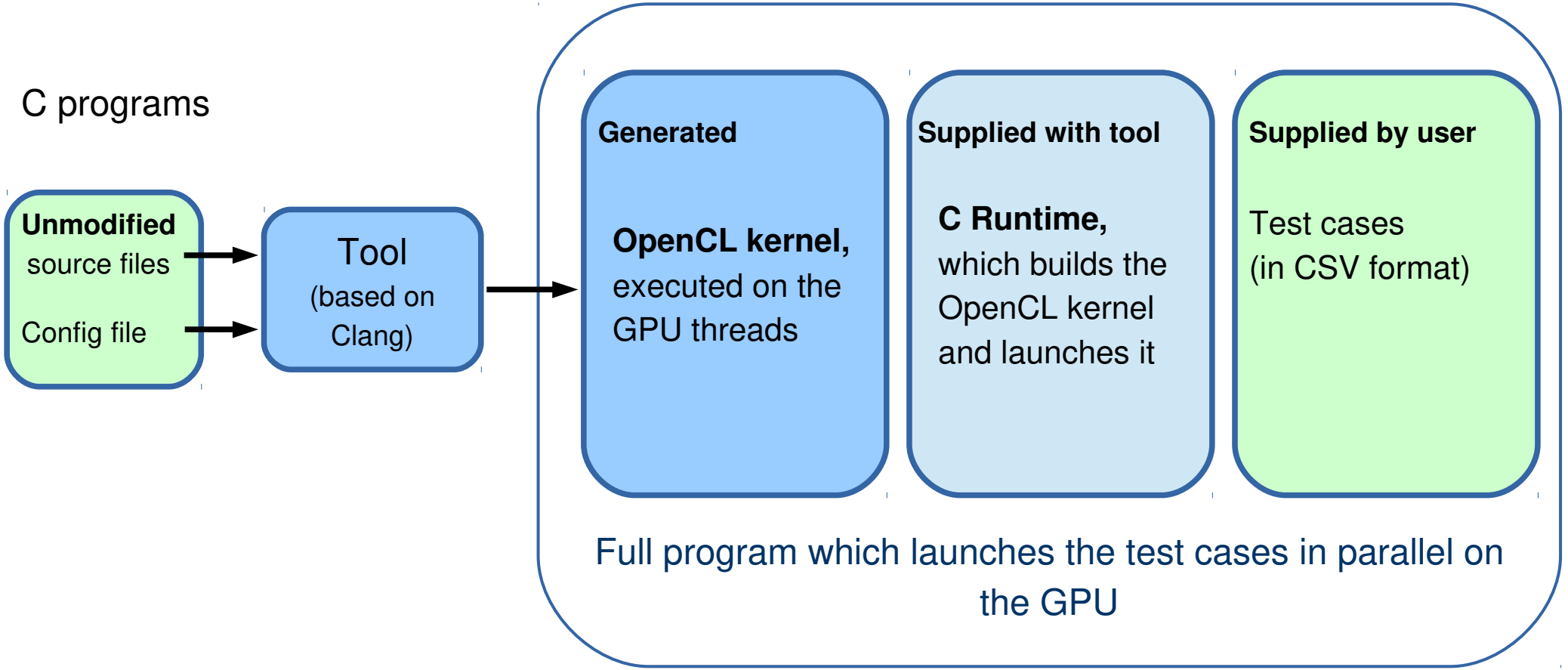

Example

Original code

```
int add(int a, int b) {

  return a+b;

}

int main(int argc, char* argv[]) {

  if(argc > 2)  {

   int a = atoi(argv[1]);

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   printf("%d + %d = %d\n", a, b,

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Generated OpenCL code

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__kernel void main_kernel(
          __global struct input * inputs,
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  int idx = get_global_id(0);
  struct input input = inputs[idx];
  int argc = input.argc;
  results[idx].test_case_num = input.test_case_num;

  if(argc > 2)  {
   int a = input.a;
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C Features

Out of the box

- simple data types, structs, vectors, one-dim arrays
- pure functions, function calls, double precision (for OpenCL 1.2)

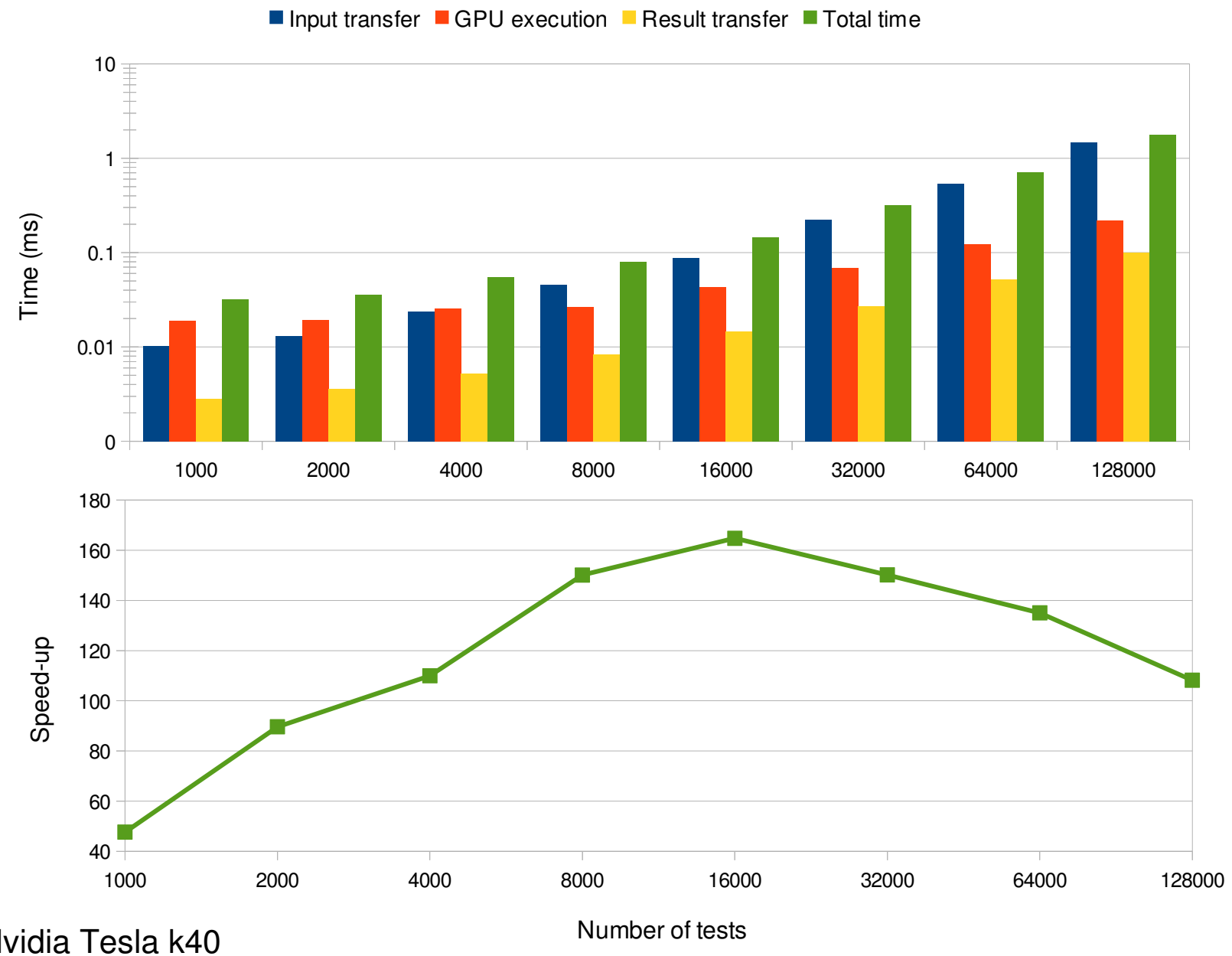
With transformations

- global scope variables: turn them into local variables and pass them as function arguments
- std in/out
- system calls: partition function and perform on the CPU

Currently unsupported

- library calls: study what library implementations exist for OpenCL; use my implementations
- multi-dimensional arrays
- dynamic memory allocation
- recursion: not possible in OpenCL (yet), but can be emulated with a stack

Preliminary Performance Results - tcas



GPU used: Nvidia Tesla k40

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3. Extend the tool to support additional C features