GPUScheduler

User-Level Preemptive Scheduling for NVIDIA GPUs

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Current GPU Model

When Multiple Programs come into picture, the model looks like so.

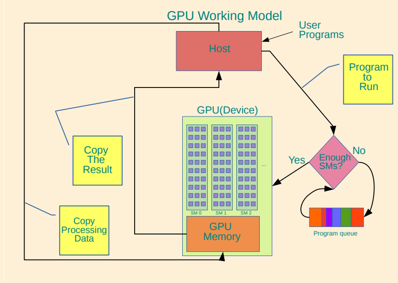

Figure 1: GPU Working Model

Limitations of the Current Model

Assume arrival of two programs in the following order:

- P0(large kernel): Matrix Multiplication program on 2^{13} x 2^{13} sized matrices ($\sim$ 3 seconds).
- P1(small kernel): Matrix Transpose program on 2^{13} x 2^{13} sized matrices ($\sim$ 3 Milliseconds).

The following is what happens when program P0 arrives before program P1.

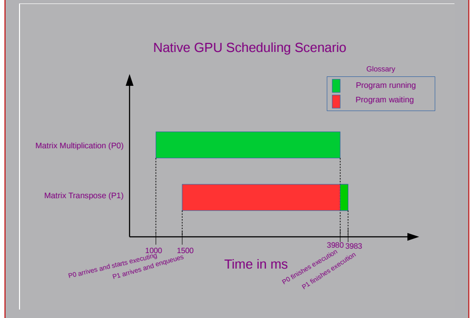

Figure 2: Program P0 arrives before Program P1

Traits of a Good Scheduler

- **Preemptive**: To reduce wait time of a program waiting in the queue.
- **Low Overheads**: To reduce scheduling overheads so as to reduce the response time.
- **Flexibility**: Ability to support different scheduling policies to cater to different scheduling needs and Service Level Agreements(SLAs).

Our Approach

We fullfill the above traits of a good scheduler by using the following technique.

- We break the kernel into smaller micro-kernels to facilitate preemption.
- Our State save policy involves saving one dim3 variable, hence very low overheads.
- The scheduling framework can employ different scheduling policies in a plug and play fashion.

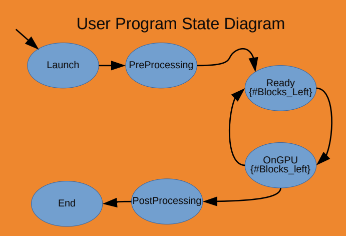

Figure 3: User Program State Diagram

Saving the State

Consider a GPUScheduler compliant program running. Its state needs to be saved in order to resume computations when it is context switched back at a later stage.

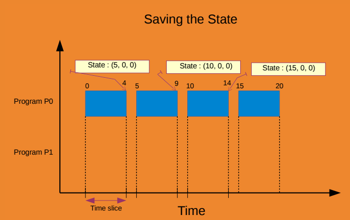

Figure 4: Example Round Robin

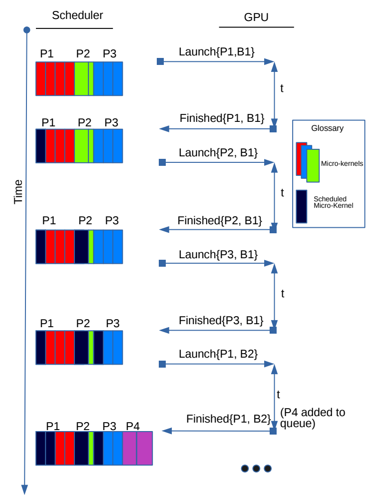

Figure 5: Example Round Robin

Example

Here is an example to show conversion of a native GPU program to a GPUScheduler compliant GPU program.

Native vectorAdd Kernel Call

```
//############ WITHOUT USING THE SCHEDULER ##############
vecAdd <<<Block, ThreadSize>>>(d_a, d_b, d_c, numElements);
```

GPUScheduler compliant vectorAdd Kernel Call

```
//############ USING THE SCHEDULER ###############
//Finished Preprocessing
WantToRunKernel();
//Tells the Scheduler that preprocessing is finished.(Enqueue)

//Block is a dim3 variable defined and populated by the user
//It is the grid the user wants to run
KernelCall(Block,
vecAdd<<<Sc_Blocks, ThreadSize>>>(d_a, d_b, d_c, numElements));
//Sc_Blocks is a Scheduler defined dim3 variable
//Scheduler controls the block dimension to run per slice

FinishedKernel();
//Tells the Scheduler that Kernel process is finished.(Dequeue)
//Start Post Processing
```

Native Kernel Code for vectorAdd

```
//########## Kernel Code WITHOUT USING THE SCHEDULER ##########
__global__ void vecAdd(double *a, double *b, double *c, int n)
{
    int id = blockIdx.x * blockDim.x + threadIdx.x;
    //Makes sure we dont go out of bounds
    if(id <= n)
        c[id] = a[id] + b[id];
}
```

GPUScheduler compliant Kernel Code for vectorAdd

```
//############## Kernel Code USING THE SCHEDULER ###########
__global__ void vecAdd(double *a, double *b, double *c, int n)
{
    int id = BlockIdx * blockDim.x + threadIdx.x;
    //BlockIdx is a scheduler provided API for the user

    //Makes sure we dont go out of bounds
    if(id <= n)
        c[id] = a[id] + b[id];
}
```

Experimental Results

Overheads ratio when Matrix Multiplication program is run with and without using GPUScheduler.

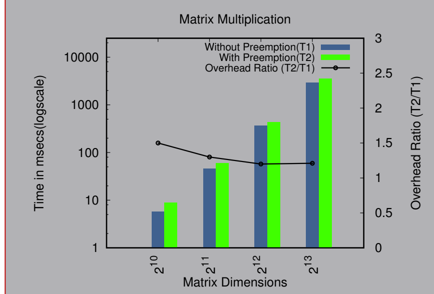

Figure 6: Overheads for Matrix Multiplication

Scheduling Scenario when GPUScheduler is used for two programs.

Matrix Transpose and Matrix Multiplication program run together in a round robin fashion.

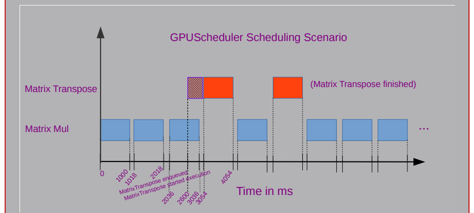

Figure 7: Slice Diagram for Matrix Multiplication and Matrix Transpose

[1]For further queries, contact shaleen.garg@research.iiit.ac.in