Heterogeneous Habanero-C

The Hetrogeneous Habanero-C (H2C) language under development in the Habanero project at Rice University provides an implementation of the Habanero execution model for modern heterogeneous (CPU + GPU) architectures.

Overview

The Heterogeneous Habanero-C (H2C) *language*, *compiler* and *runtime* framework is specifically designed to achieve **portability**, **productivity** and **performance** on modern heterogeneous (CPU+ GPU) architectures. The main goal is to take a machine independent program written in H2C and generate a machine specific executable.

Some highlights of H2C include:

1. Minimal, intuitive, language extensions makes it easier to write new programs and port existing programs.
2. Two stages compilation targets both domain experts and ninja parallel programmers.
3. **Shared Virtual Memory (SVM)** supports recursive pointer data structures on the GPU.
4. **Meta Data layout** framework generates target specific data layout.
5. Embedded DSLs for stencils and re-use patterns take advantage of local scratchpad buffers.

H2C requires the underlying platform to support OpenCL. The H2C compiler relies on a *M*achine *Des*cription (MDes) file. It can be provided by the user or automatically generated by an auto-tuner. H2C uses an *offload* model wherein the CPU is the host and both CPUs and GPUs are devices.

A short summary of the H2C framework is included below. Details on the underlying implementation technologies can be found in the Habanero publications web page. The H2C implementation is still evolving. If you would like to try out H2C, please contact one of the following people: Deepak Majeti, or Vivek Sarkar.

H2C Language Summary

The language constructs are classified into communication, computation and synchronization constructs.

Communication Constructs

The *async* construct, is used to asynchronously transfer data among multiple devices. One can easily overlap computation with the asynchronous data transfers.

The *finish* statement, *finish* <*stmt*>, ensures all the data transfers within <*stmt*> have completed.

> *async [copyin (var1, var2, ...)] [copyout (var1, var2, ...)] [at (dev1, dev2, ...)] [partition (ratio)];*

- `'copyin' clause is used to specify the data that needs to be copied to the device from the host`
- `'copyout' clause is used to specify the data that needs to be copied to the host from the device`
- `'at' clause is used to specify the targeted devices`
- `'partition' clause is used to specify the ratio of partition`

Computation Constructs

The *forasync* construct is a data/task parallel loop. It is the programmer's responsibility to ensure that loop iterations are independent.

> *forasync [in (var1, var2, ...)] [point (ind1, ind2, ...)] [range (siz1, siz2, ...)] [seq (seq1, seq2, ...)][scratchpad (var1, var2, ...)][at (dev1, dev2, ...)] [partition (ratio)]{Body}*

- `'point' clause is used to specify the loop indices in each dimension`
- `'range' clause is used to specify the number of iterations in each dimension`
- `'seq' clause is used to specify the tile size or the work-group size`
- `Body represents the loop iteration`

Synchronization Constructs

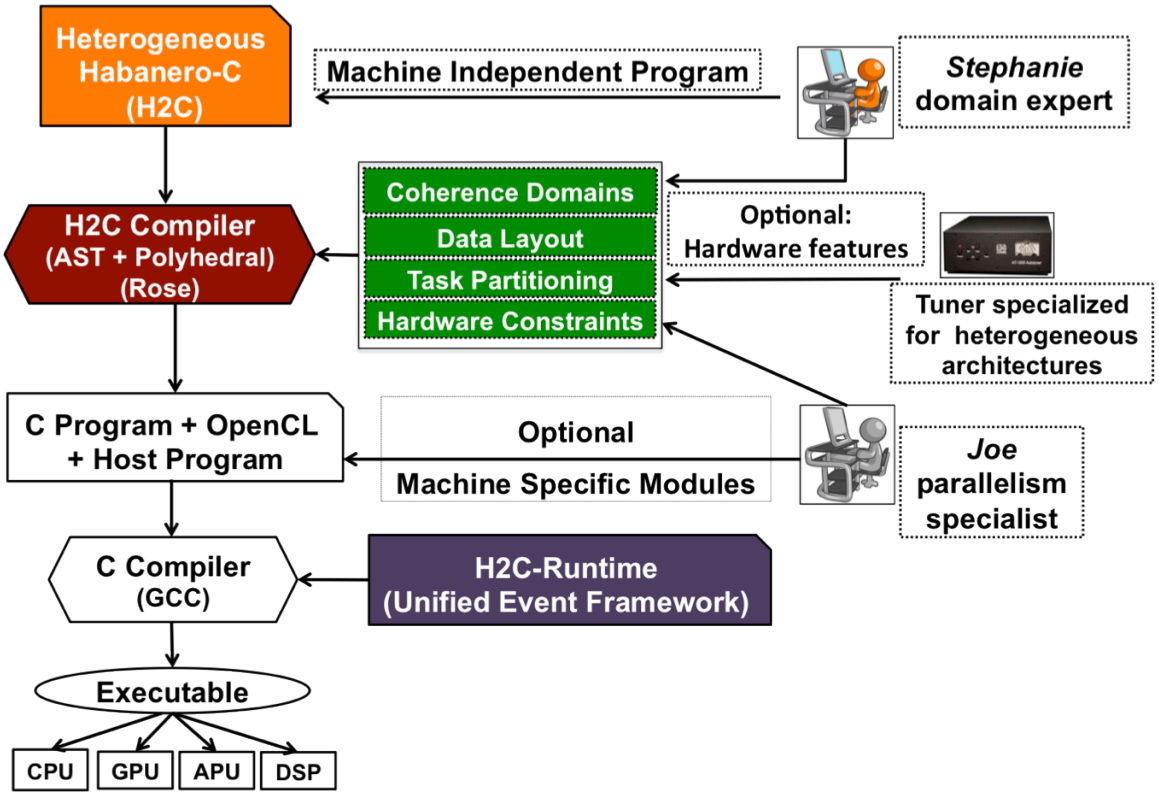
The *finish* construct ensures all the tasks spawned inside it are completed.

H2C Compiler and Runtime Framework

Two Phase Compilation

In the first phase, the H2C compiler translates a H2C program down to a C program, OpenCL kernel and the corresponding host program. Parallelism experts can optionally choose to add optimized OpenCL kernels. The compiler uses a *M*achine *De*scription(MDes) file to generate a target specific OpenCL kernel and communication. The MDes file can either be specified by the programmer or automatically generated by an auto-tuner.

In the second phase, a standard C compiler is used to build an executable from the generated intermediate files along with the H2C runtime and OpenCL runtime.



Runtime

The H2C runtime includes a memory manger, scheduler and interfaces with the OpenCL runtime.

Example H2C program

Matrix Multiply in H2C

```
finish{
     async copyin(a,b) at(dev);
     foo(); //asynchronously copy data while executing foo
}
finish{
    forasync in(a,b,c,m,n,p) point(i,j) range(0:m,0:n) seq(4,128) shared(a,b)
at(dev){
        float temp =0;
   for(int k=0;k<p;k++){
           temp += a[i*p+k]*b[k*n+j];
        }
        c[i*n+j] =temp;
   }
}
finish{
     async copyout(c) at(dev);
     bar(); //asynchronously copy data while executing bar
}
```

Current H2C limitations

There are some limitations and pitfalls in the current implementation of the H2C programming model. These limitations are not inherent to the programming model, but rather are a result of incompleteness in the current compiler or runtime implementation.

1) The forasync construct cannot be nested in the current implementation.

2) There is no compiler check for correctness on the forasync body. Any code pattern not supported on the target device will result in runtime errors.

3) Pointer arithmetic on arrays which are communicated between CPU and GPU is not supported.

Installation

H2C Branch: https://svn.rice.edu/r/parsoft/src/Habanero-C/branches/hcConcordBranch
Dependencies:
Rose Version: ROSE 0.9.5a: orion.cs.rice.edu:/home/vc8/habanero-git-repo/hc/ROSE.git
EDG with H2C keywords: orion.cs.rice.edu:/home/vc8/habanero-git-repo/hc/ROSE-EDG.git
branch.dm14-hc-forasync.remote=origin
branch.dm14-hc-forasync.merge=refs/heads/dm14-hc-forasync
Boost Version: boost_1_38_0
Polyopt 0.2.1: http://web.cs.ucla.edu/~pouchet/software/polyopt/

Steps:

1. Build **boost_1_38_0**

2. Build **Rose 0.9.5a**
3. Build **Polyopt**
4. run **h2cpolyopt.sh** script located in H2C branch. This script copies the necessary files from the polyhedral installation
5. Build **H2C branch** using the makefile provided

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