Evaluation of UPC on the Cray X1E
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“Evaluation of UPC on the Cray X1”

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Since then,

1. X1@ORNL => X1E

2. NPB-UPC: pragmas inserted.
X1E at ORNL: Phoenix

» 1024 Multi-streaming vector processors (MSP)

» Each MSP
  – 4 Single Streaming Processors (SSP)
  – 4 scalar processors (400 MHz)
  – Memory bw is roughly half cache bw.
  – 2 MB cache
  – 18 GFLOP peak (~18.5 TFLOPS)

» 4 MSPs form a node
  – 8 GB of shared memory.
  – Inter-node load/store across network. 56 cabinets
## Memory Latency

<table>
<thead>
<tr>
<th>Memory location</th>
<th>Relative access time</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-cache</td>
<td>1X</td>
</tr>
<tr>
<td>E-cache</td>
<td>2X</td>
</tr>
<tr>
<td>Local (node) memory</td>
<td>7X</td>
</tr>
<tr>
<td>Remote (off node) memory</td>
<td>10X-32X</td>
</tr>
</tbody>
</table>
A Brief History of UPC

- Extension of ISO C
- Partitioned global address space language. (PGAS)
  - DSM programming model
  - SPMD execution model
  - Tech report: Carlson, Draper, Culler, Yellick, Brooks, and Warren.
- Feb 2001: Spec v1.0
- Dec 2003: UPC Collectives spec.
- July 2004: UPC I/O spec.
- May 2005: v1.2
- Sept 2005: First PGAS meeting in Minneapolis.
A pointer-to-shared can reference all locations in the shared space, but there is data-thread **affinity**.
UPC Execution Model

- A number of threads working independently in a SPMD fashion
  - MYTHREAD specifies thread index (0..THREADS-1)
  - Number of threads specified at compile-time or run-time

- Synchronization when needed:
  - Barriers
  - Locks
  - Memory consistency control
UPC Pointers

How to declare them?

```c
int *p1; /* private pointer pointing locally */
shared int *p2; /* private ptr pointing into the shared space */
shared int *shared p3; /* shared ptr pointing into the shared space */
```

You may find many using “shared pointer” to mean a pointer pointing to a shared object, e.g. equivalent to p2 but could be p3 as well.
Memory Consistency Models

→ Has to do with ordering of shared operations, and when a change of a shared object by a thread becomes visible to others
  
  – Relaxed consistency: shared operations can be reordered by the compiler / runtime system
  
  – Strict consistency: enforces sequential ordering of shared operations. (No operation on shared can begin before the previous ones are done, and changes become visible immediately)
Memory Consistency Models

- User specifies the memory model through:
  - declarations
  - pragmas for a particular statement or sequence of statements
  - use of barriers, and global operations

- Programmers responsible for using correct consistency model
The NAS Parallel Benchmarks (NPB)

- Evolved from NASA applications (CFD)
- Strong scaling.
- Now MPI, OpenMP, HPF, Co-array Fortran, UPC, Java, Grid,…

http://www.nas.nasa.gov/Software/NPB/
NPB problem sizes (Classes)

```python
if (class == 'S')
    problem_size = 12; dt = "0.015"; niter = 100;
else if (class == 'W')
    problem_size = 36; dt = "0.0015"; niter = 400;
else if (class == 'A')
    problem_size = 64; dt = "0.0015"; niter = 400;
else if (class == 'B')
    problem_size = 102; dt = "0.001"; niter = 400;
else if (class == 'C')
    problem_size = 162; dt = "0.00067"; niter = 400;
```
UPC version of NPB

• Modified from NPB2.4-MPI and NPB2.4-OMP
  • F. Cantonnet, Y. Yao, and T. El-Ghazawi

• upc_forall, upc_barrier, upc_notify_wait, upc_lock, upc_memput, upc_memget, upc_reduce_sum

• Relaxed mode

• Future plans: Reduce reliance on global barrier using fence, organization, etc.
Conjugate Gradient (CG)

- Computes an approximation to the *smallest eigenvalue* of an spd matrix.

- Unstructured grid computations requiring *irregular long-range communications*. 
Loopmarking listing file (MG)  
Before Pragmas

1155. 1 2 r------< for ( i1 = d1; i1 <= mm1-1; i1++)
1156. 1 2 r       {
1157. 1 2 r       u((2*i3-d3-1), (2*i2-d2-1), (2*i1-d1-1)) =
1158. 1 2 r       u((2*i3-d3-1), (2*i2-d2-1), (2*i1-d1-1))
1159. 1 2 r       +z((i3-1), (i2-1), (i1-1));
1160. 1 2 r------>   }
1155. m 2  #pragma _CRI concurrent
1156. m 2  #pragma _CRI ivdep
1157. m 2 MV---< for ( i1 = d1; i1 <= mm1-1; i1++)
1158. m 2 MV    {
1159. m 2 MV        u((2*i3-d3-1), (2*i2-d2-1), (2*i1-d1-1)) =
1160. m 2 MV        u((2*i3-d3-1), (2*i2-d2-1), (2*i1-d1-1))
1161. m 2 MV          +z((i3-1), (i2-1), (i1-1));
1162. m 2 MV--->}   }
CG Performance

CG Class B

![Graph showing execution time vs. threads for CG Class B, with lines representing X1E with pragma, X1E w/o pragma, and X1.]
Monte Carlo
“Pleasantly” Parallel (EP)

» Compute independent Gaussian deviates with $\mu = 0$ and $\sigma^2 = 1$.

» Only communication is a summation of ten values at the end of execution.
EP Performance

EP Class B

Execution Time (sec.)

Threads

X1E with pragma  X1E w/o pragma  X1
Fourier Transform (FT)

- Solves a 3D partial differential equation using an FFT-based spectral method, also requiring long range communication.

- FT performs three 1-D FFT's, one for each dimension.
MG: Multi-grid

- uses a V-cycle multi-grid method to compute the solution of the 3-D scalar Poisson equation
- requiring both short and long-range highly structured inter-process communication.
MG Performance

MG Class B

Execution Time (sec.)

Threads

X1E with pragma  X1E w/o pragma  X1
X1E / X1 improvement

Threads

Improvement (%) CG EP FT IS MG
Summary

• X1E has a positive effect on performance for some (FT, MG), little effect for others (CG), and a negative effect for one (EP).

• Guided by loopmark listing, careful insertion of pragmas can have a significant effect.
Acknowledgements

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Cray, esp. Cathy Willis.
PGAS 2006

- October 3-4, Washington, DC (GWU)
- CFP coming soon. (Paper submissions)
- UPC Developers workshop
- CAF Developers workshop