

XcalableACC parallel language

Overview

XcalableACC (XACC) is a directive-based language extension of C and Fortran for accelerated cluster systems (C++ on the table).

- High productivity by directives
- High performance by direct communication between accelerators

Components

- XcalableMP (XMP) for distributed-memory parallelism

XcalableMP XMP is a directive-based language extension of C and Fortran for cluster systems

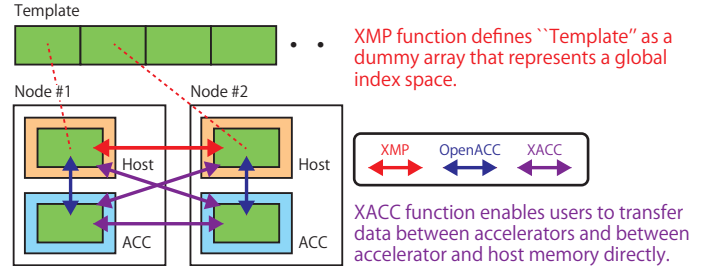
- OpenACC for offloading works for accelerators



OpenACC is also directive-based language extension for heterogeneous CPU/Accelerator systems

- XACC for communication of data on accelerators

Memory Model



Omni XcalableACC Compiler

- <http://omni-compiler.org>

- Developed by RIKEN AICS and Center for Computational Sciences in University of Tsukuba



Implementation of Lattice QCD code using XcalableACC

What is Lattice QCD ?

- Solve the quantum chromodynamics (QCD) theory of quarks and gluons

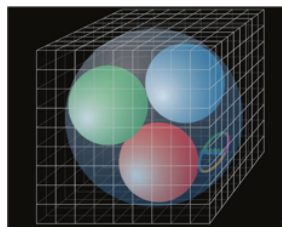
$$D_{x,y} = \delta_{x,y} - \kappa \sum_{\mu=1}^4 \{ (1 - \gamma_{\mu}) U_{\mu}(x) \delta_{x+\hat{\mu},y} + (1 + \gamma_{\mu}) U_{\mu}^{\dagger}(x - \hat{\mu}) \delta_{x-\hat{\mu},y} \}$$

- The four-dimensional space-time continuum is replaced by a four-dimensional hypercubic lattice

- We have used the Lattice QCD mini-application developed by Hideo Matsufuru (KEK)

- The Lattice QCD mini-application uses a part of the Bridge++, which is a real world application (<http://bridge.kek.jp/Lattice-code/>)

- Typical stencil application



A part of code

A programmer adds XMP and OpenACC directives into the sequential Lattice QCD code.

```
QCDSpinor_t v[NT][NZ][NY][NX]; // Quark
QCMatrix_t u[4][NT][NZ][NY][NX]; // Gluon
...
#pragma xmp align v[i][j][k][l] with t[i][j]
#pragma xmp align u[*][i][j][k][l] with t[i][j]
#pragma xmp shadow v[1][1][0][0]
#pragma xmp shadow u[0][1][1][0][0]
...
#pragma xmp reflect (v) width(/periodic/1,/periodic/1,0,0) orthogonal acc
#pragma xmp reflect (u) width(0,/periodic/1,/periodic/1,0,0) orthogonal acc
...
#pragma acc data present(v, u, ...)
#pragma acc parallel loop collapse(4) ...
#pragma xmp loop (it,iz) on t[it][iz]
for(it = 0; it < NT; it++){
  for(iz = 0; iz < NZ; iz++){
    for(iy = 0; iy < NY; iy++){
      for(ix = 0; ix < NX; ix++){
        ...
      }
    }
  }
}
```

Define XMP distributed arrays

Exchange halo region

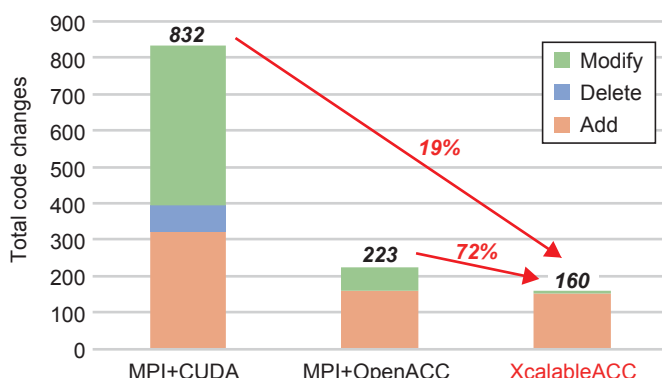
Parallelize loop

OpenACC directive parallelizes the loop statement parallelized by XMP directive

Evaluation on HA-PACS/TCA

Productivity

- Count code changes for developing a parallel code from a serial code
- Total code changes of XcalableACC is the smallest of all



Performance

- Data size is 32 x 32 x 32 with strong scaling
- The performance of XcalableACC is 100 - 104% of that of MPI+OpenACC, and 95 - 99% of that of MPI+CUDA

