24th Workshop on Sustained Simulation Performance

A Directive Generation Approach Using A Code Translation Framework

Kazuhiko Komatsu, Ryusuke Egawa,
Hiroyuki Takizawa, Hiroaki Kobayashi

Tohoku University

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Introduction

- Increase of variety of HPC systems
  - Scalar-type system
    - A large number of scalar processors with many cores and large cache
    - Massively parallel calculations
  - Accelerator-type system
    - Accelerators with lots of simple cores
    - Data parallel calculations
  - Vector-type system
    - Vector cores with a high memory bandwidth
    - calculates set of data elements at one time

System-dependent information has to be written in a code to exploit the potential of each HPC system

To Write System-Dependent Information

- By effectively utilizing the features of each HPC system
  - Directly writing system-dependent information
    - Low level programming, CUDA/OpenCL, AVX intrinsic, …
    - **Several versions** of an application code (or IF/DEF HELL)
      - Each version is optimized for an HPC system
  - Directive-based programming
    - OpenMP, OpenACC, compiler-specific directives, etc
    - **Only one version** of a code
      - Multiple directive sets can be written in a code

Motivation

- Pitfalls: Directive-based approach is
  - High productivity
  - High maintainability

  ➜ **<u>Can it be REALLY true?</u>**
- Single version of a code for various HPC systems
  - Different kinds of directive sets has to be inserted
    - OpenMP, OpenACC, compiler-specific, etc
  - Different implementations using the same directive set
    - OpenMP parallel vs OpenMP task
    - ACC kernels vs ACC parallel, etc

Motivating Example: Himeno Kernel

- Three implementations in one code
  - OpenMP parallel
  - OpenACC kernels
  - OpenACC parallel
- Many lines spent for directives
  - 46% of code lines
    - 26 lines of the whole 56 lines
- NOT allowed different impl. using the same directive set
  - OpenACC kernels and parallel

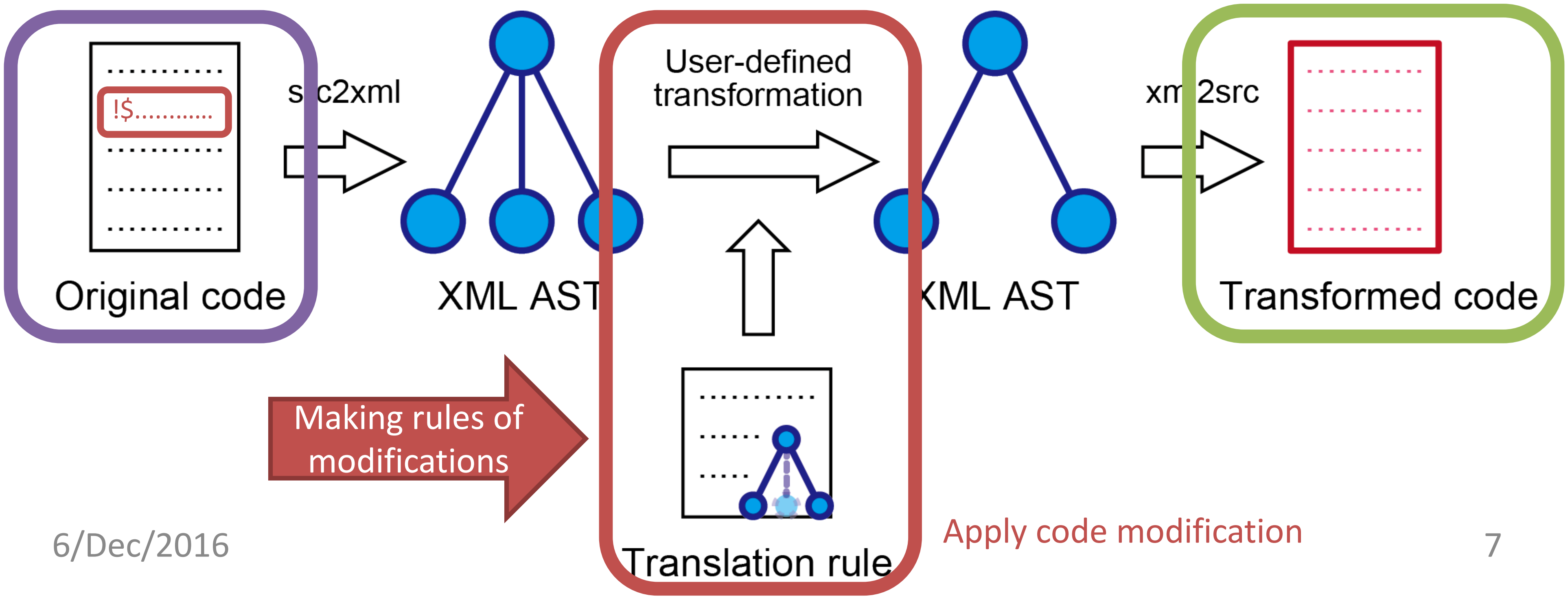
```
!$OMP PARALLEL SHARED () &
!$OMP PRIVATE
!$acc data present () &
!$acc present
  do loop=1,nn
  gosa= 0.0
!$OMP DO REDUCTION
!$acc kernels
!$acc loop gang
!!$acc parallel loop collapse(3) reduction
    do k=2,kmax-1
      do j=2,jmax-1
!$OMP SIMD
!$acc loop vector(256) reduction( + :gosa)
        do i=2,imax-1
          s0=a(I,J,K,1)*p(I+1,J,K) &
...
          wrk2(I,J,K)=p(I,J,K)+OMEGA *SS
        enddo
!$OMP END SIMD
      enddo
    enddo
!!$acc end parallel loop
!$OMP END DO NOWAIT
!$OMP BARRIER
```

Objective and Approach

- Objective
  - Easily utilize multiple kinds of directive sets
- Approach
  - Generation of various kinds of directive sets using user-defined rules and a special placeholder
    - Flexible and easy generation
      - ***Xevolver***: Code translation framework
      - ***Xevtgen***: Fortran-like rule generator
    - Keep maintainability
      - The original code as unchanged as possible

Xevolver: Code Translation Framework

- Xevolver [Takizawa, 2014]
  - Can separate system-awareness from a code as user-defined rules
  - Minimize modifications and then keep maintainability.



Xevtgen: Translation Rule Generator

- Xevtgen [Suda, 2015]
  - Easily generation of translation rules for Xevolver
    - *Dummy Fortran code*
      - Fortran-like code with some special tgen directives
    - ***source*** and ***destination*** *patterns* of a dummy Fortran code

Standard Fortran programmers can easily learn and generate rules

Source pattern

```
!$xev tgen src begin
IF (I .EQ. 0) EXIT
!$xev tgen src end
```

```
!$xev tgen dst begin
IF (I == 0) THEN
EXIT
END IF
!$xev tgen dst end
```

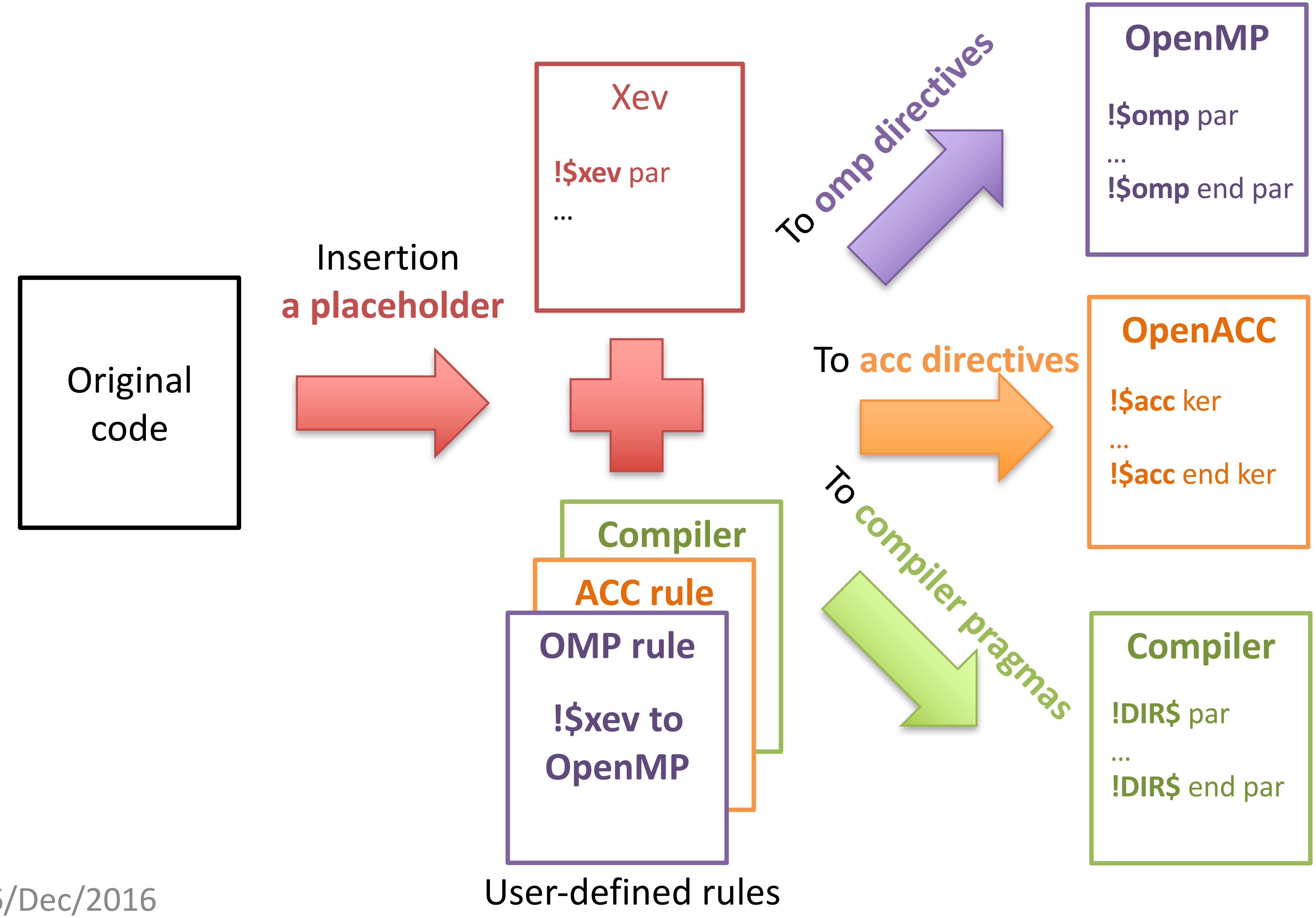
Destination pattern

Proposed Directive Generation

- Key ideas
  - Directive generation by Xevolver framework
    - **User-defined rules**
      - Appropriate directives for individual HPC systems
    - **Special placeholders**
      - Specify a unique code pattern where several directives are inserted
      - Trigger directive generation

Multiple directive sets can be replaced into a smaller number of special placeholders

Overview of the Proposed Generation



Ex. Directive Generation of Himeno

- Translation triggered by “!$xev jacobi” placeholder

Original + placeholder

```
!$xev jacobi
do loop=1,nn
  gosa= 0.0
   do k=2,kmax-1
     do j=2,jmax-1
       do i=2,imax-1
         s0=a(I,J,K,1)*p(I+1,J,K) &
…
         wrk2(I,J,K)=p(I,J,K)+OMEGA *SS
       enddo
     enddo
   enddo
   do k=2,kmax-1
     do j=2,jmax-1
       do i=2,imax-1
         p(I,J,K)=wrk2(I,J,K)
       enddo
     enddo
   enddo
 enddo
```

OpenMP version

```
!$OMP PARALLEL SHARED () &
!$OMP PRIVATE
do loop=1,nn
  gosa= 0.0
!$OMP DO
   do k=2,k
     do j=2,
!$OMP SIM
       do i=
         s0=
…
         wrk
       endd
!$OMP END
     enddo
   enddo
!$OMP END
!$OMP BAR
…
```

ACC kernels version

```
!$acc data present () &
!$acc present
do loop=1,nn
gosa= 0.0
!$acc kerne
!$acc loop
  do k=2,k
    do j=2,
!$acc loop
      do i=
        s0=
…
        wrk
      endd
    enddo
  enddo
…
```

ACC parallel version

```
!$acc data present () &
!$acc present
  do loop=1,nn
  gosa= 0.0
!$acc parallel loop collapse(3) reduction
   do k=2,kmax-1
     do j=2,jmax-1
       do i=2,imax-1
         s0=a(I,J,K,1)*p(I+1,J,K) &
…
         wrk2(I,J,K)=p(I,J,K)+OMEGA *SS
       enddo
     enddo
   enddo
!$acc end parallel loop
…
```

Easy Rule Generation by Xevtgen

```
!$xev tgen src begin
!$xev jacobi
do ll = lb, le, ls
gosa=0.0
do kk = kb, ke, ks
do jj = jb, je, js
do ii = ib, ie, is
!$xev tgen stmt(body1)
end do
end do
end do
do kk = kb, ke, ks
do jj = jb, je, js
do ii = ib, ie, is
!$xev tgen stmt(body2)
end do
end do
end do
end do
!$xev tgen src end
```

```
!$xev tgen dst begin
!$OMP PARALLEL SHARED () &
!$OMP PRIVATE (k,j,i,s0,ss,loop)
do ll = lb, le, ls
gosa=0.0
!$OMP DO REDUCTION(+:gosa)
do kk = kb, ke, ks
do jj = jb, je, js
!$OMP SIMD
do ii = ib, ie, is
!$xev tgen stmt(body1)
end do
!$OMP END SIMD
end do
end do
!$OMP END DO NOWAIT
!$OMP BARRIER
```

```
!$OMP DO
do kk = kb, ke, ks
do jj = jb, je, js
!$OMP SIMD
do ii = ib, ie, is
!$xev tgen stmt(body2)
end do
!$OMP END SIMD
end do
end do
!$OMP END DO NOWAIT
!$xev tgen dst end
```

Almost similar cost to writing directives into the original code

Experimental Environments

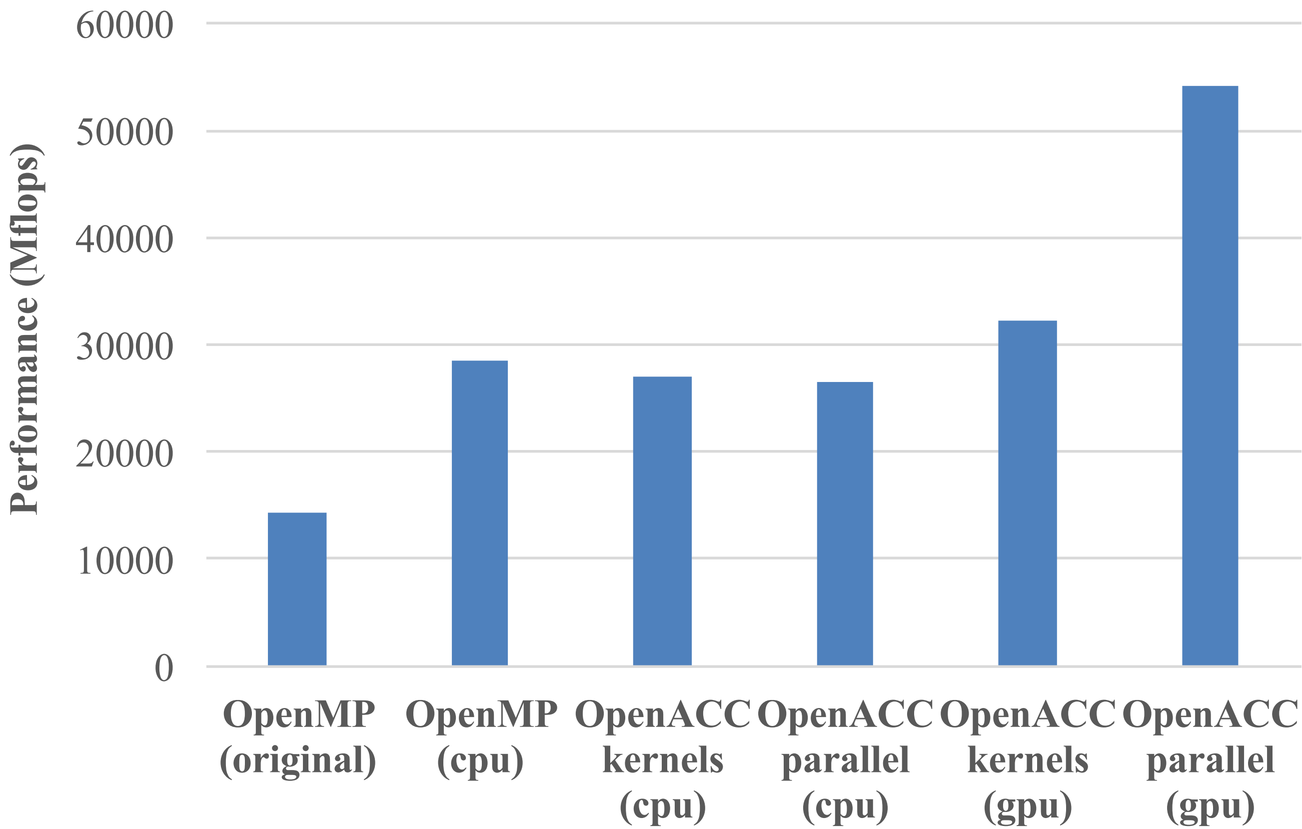
- Himeno benchmark
  - Original OpenMP
  - OpenMP parallel
  - OpenACC kernels
  - OpenACC parallel
- Environments
  - Intel Xeon E5-2630 x 2sockets
  - Nvidia Tesla K20
  - PGI compiler 16.4
  - Xevolver ver. 1.1.0-1.1.0 + Xevtgen gamma2

Comparisons of Modified Code Lines

Himeno version	#. directives	#. code lines	#. rule lines
OpenMP parallel	23	427	0
OpenACC kernels	19	423	0
OpenACC parallel	16	420	0
MP and ACC	51	455	0
Placeholder	3	407	118+114+111

- Proposed approach
  - **Minimum number of directive lines** in the code
  - **Affordable additional lines of user-defined rules**
    - The writing cost is the almost similar to the inserting cost of directives into the code

Performance comparisons



- CPU: MP and ACC versions are Faster than the original version
  - Aggressive optimization using MASTER thread and barrier leads degradation
- GPU: ACC parallel version is faster than the others
  - Suitable parameters for parallelization such as grid sizes are selected

The proposed approach can choose the best one!

Conclusions

- Multiple directive sets for exploiting the potential of various HPC systems
  - Decreases maintainability and productivity

- Directive generation approach by code translation
  - User-defined rules by Xevtgen rule generator
    - ➜ Flexible and easy generation
  - A special placeholder
    - ➜ Keep the original as unchanged as possible

- Future work
  - More detailed evaluation using practical applications
    - The number of placeholders and code lines of dummy codes
    - The positions of placeholders might be different among platforms