

OpenMP 4.0 and later



- Version 4.0 was released in July 2013
 - accelerator offloading, thread affinity, more task support
- Version 4.5 was released in Nov 2015
 - corrections and a few new features
 - now available in most production compilers (apart from the accelerator offloading features)
- Version 5.0 was released in Nov 2018
 - some extra features, extensions to offloading, new memory model, recent base language version support
 - some implementations support this
- Version 5.1 was released in Nov 2020 and 5.2 was released in Nov 2021
 - mostly minor changes
 - implementation mostly work-in-progress



Overview



- User defined reductions
- Construct cancellation
- Portable SIMD directives
- Extensions to tasking
- Thread affinity



User defined reductions



- As of 3.1 cannot do reductions on objects or structures.
- UDR extensions in 4.0 added support for this.
- Use declare reduction directive to define new reduction operators
- New operators can then be used in reduction clause.

```
#pragma omp declare reduction (reduction-identifier :
typename-list : combiner) [identity(identity-expr)]
```





- reduction-identifier gives a name to the operator
 - Can be overloaded for different types
 - Can be redefined in inner scopes
- typename-list is a list of types to which it applies
- combiner expression specifies how to combine values
- identity can specify the identity value of the operator
 - Can be an expression or a brace initializer



Example: merging vectors



```
#pragma omp declare reduction (merge : std::vector<int>
: omp out.insert(omp out.end(), omp in.begin(), omp in.end()))
```

- Private copies created for a reduction are initialized to the identity that was specified for the operator and type
 - Default identity defined if identity clause not present
- Compiler uses combiner to combine private copies
- omp out refers to private copy that holds combined values
- omp in refers to the other private copy
- Can now use merge as a reduction operator.



Construct cancellation



- Clean way to signal early termination of an OpenMP construct.
 - one thread signals
 - other threads jump to the end of the construct

```
!$omp cancel construct [if (expr)]
```

where *construct* is **parallel**, **sections**, **do** or **taskgroup** cancels the construct

!\$omp cancellation point construct

checks for cancellation (also happens implicitly at cancel directive, barriers etc.)



Example



```
!$omp parallel do private(eureka)
do i=1,n
   eureka = testing(i,...)
!$omp cancel parallel if(eureka)
end do
```

- First thread for which **eureka** is true will cancel the parallel region and exit.
- Other threads exit next time they hit the cancel directive

Portable SIMD directives



- Many compilers support SIMD directives to aid vectorisation of loops.
 - compiler can struggle to generate SIMD code without these
- OpenMP 4.0 provides a standardised set
- Use simd directive to indicate a loop should be SIMDized

#pragma omp simd [clauses]

- Executes iterations of following loop in SIMD chunks
- Loop is not divided across threads
- SIMD chunk is set of iterations executed concurrently by SIMD lanes



- Clauses control data environment, how loop is partitioned
- safelen (length) limits the number of iterations in a SIMD chunk.
- linear lists variables with a linear relationship to the iteration space
- aligned specifies byte alignments of a list of variables
- private, lastprivate, reduction and collapse have usual meanings.
- Also declare simd directive to generate SIMDised versions of functions.
- Can be combined with loop constructs (parallelise and SIMDise)







taskloop directive provides a convenient way to turn loop iterations into tasks

```
#pragma omp taskloop grainsize(16)
for (int i=0; i<n; i++) {
    a[i] = somefunc(i);
}</pre>
```

- Each set of 16 consecutive iterations will form a task
- Can specify the number of tasks with the num_tasks clause instead of grainsize



Task dependencies



depend clause on task construct

```
!$omp task depend(type:list)
```

where type is in, out or inout and list is a list of variables.

- list may contain subarrays: OpenMP 4.0 includes a syntax for C/C++
- in: the generated task will be a dependent task of all previously generated sibling tasks that reference at least one of the list items in an out or inout clause.
- out or inout: the generated task will be a dependent task of all previously generated sibling tasks that reference at least one of the list items in in, out or inout clause.



Example



```
#pragma omp task depend (out:a)
    { ... }

#pragma omp task depend (out:b)
    { ... }

#pragma omp task depend (in:a,b)
    { ... }
```

- The first two tasks can execute in parallel
- The third task cannot start until both the first two are complete



Thread affinity

epcc

• OpenMP 4.0 gives much more control



Affinity environment



- Since many systems are now NUMA and SMT, placement of threads on the hardware can have a big effect on performance.
- Increased choices for OMP_PROC_BIND
- Can still specify true or false
- Can now provide a list (possible item values: master, close or spread) to specify how to bind parallel regions at different nesting levels.
- Added OMP PLACES environment variable
- Can specify abstract names including threads, cores and sockets
- Can specify an explicit ordered list of places
- Place numbering is implementation defined

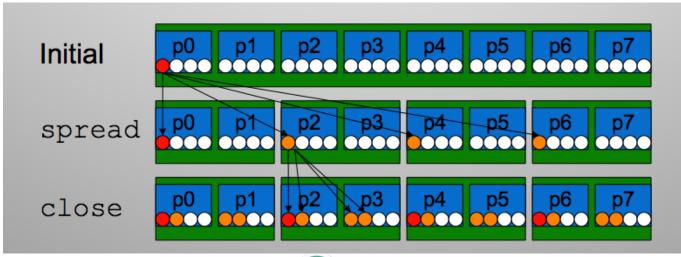


Example



- Two levels of nested parallel regions
- Hardware with 8 cores and 4 hardware threads per core

```
export OMP_NUM_THREADS=4,2
export OMP_PLACES=threads
export OMP_PROC_BIND="spread,close"
```



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