intel Look Inside™

Obtaining the Last Values of Conditionally Assigned Privates

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2016/10/04 OpenMPCon2016

Legal Disclaimer & Optimization Notice

Last Value through Lastprivate

```
#pragma omp simd lastprivate(x)
for(int i=0; i<N; i++){
   x = A[i];
   …
}

// use of x.
```

➔ x is A[N-1].

Unspecified isn't very useful.
Can we do better?

```
#pragma omp simd lastprivate(x)
for(int i=0; i<N; i++){
   if (A[i]>0) {
     x = A[i];
     …
   }
}

// use of x.
```

➔ x is A[N-1] if A[N-1]>0,
else **unspecified**.

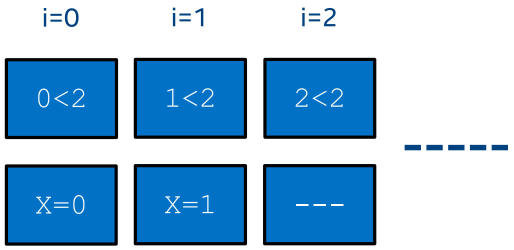
Problem

- The value from `lastprivate(`*list*`)` clause is unspecified if the list item is not assigned in the last iteration.
- Typically, what programmer wants under such circumstances is the value from the last iteration that actually performed the assignment.

```
#pragma omp simd lastprivate(x)
for(int i=0; i<N; i++){
    if (A[i]>0){ // may be FALSE for i=N-1.
        x = A[i];
        // possible use of x
    }
}
// use of x.
```

Does ORDERED construct help?

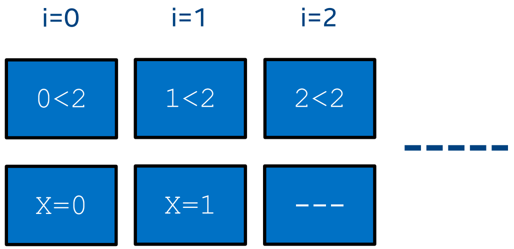
```
#pragma omp simd
for(i=0;i<N;i++){
    if (i<2){
#pragma omp ordered simd
        { x = i }
    } // x is 1 here. Good.
}
// use of x after the loop
```



X needs to be shared, but it could work for this case.....

Does ORDERED construct help? (cont)

```
#pragma omp simd
for(i=0;i<N;i++){
    if (i<2){
#pragma omp ordered simd
        { x = i }
    } // x is 1 here. Good.
    if (i<1){
#pragma omp ordered simd
        { x = i }
    } // x is 0 again. Bad.
}
// use of x after the loop
```



Unfortunately, this doesn't go too far.

Why ORDERED Failed?

- Each ORDERED is individually processed.
- Even if an ORDERED assigns at iter-N1, the next ORDERED can override it at iter-N2, where N2 < N1.

➔ Something at loop-level is needed to support multiple assignments.

How does ICC auto-vec handle it?

- Local reduce, per vector element, of last valid value and last assigned index
- Global reduce after the end of the vector loop

➔ It’s a bit more elaborate than typical reduction, but it almost look like reduction.

➔ Same concept applicable to threading? Absolutely!

How does ICC auto-vec handle it?

```
int foo(int *A, int N){
  int i, x = 0;
  for (i=0;i<N;i++){
    if (A[i]>0){
      x = A[i];
    }
  }
  return x;
}
```

```
..B1.13:
    vmovdqu   (%rdi,%rcx,4), %ymm4
    vpcmpgtd  %ymm2, %ymm4, %ymm5
    vmovdqa   %ymm2, %ymm6
    vptest    %ymm1, %ymm5
    je        ..B1.15
..B1.14:
    vmovdqa   %ymm4, %ymm3
    vmovdqa   %ymm5, %ymm6
..B1.15:
    vmovmskps %ymm6, %r9d
    testl     %r9d, %r9d
    je        ..B1.17

    cmpq      %rsi, %rcx
    jb        ..B1.13
```

Not exactly tracking the loop index value, but vector code can afford to use element position within vector register.

Can we then call it a reduction???

```
#pragma omp simd reduction(=:x)
for(i=0;i<N;i++){
    if (cond(i)){
        x = …
    }
}
// use of x after the loop
```

- Informal poll is showing that some people are allergic to calling it a reduction.
- Lastprivate() is already taken, and it's more efficient if it can be used.
  - We can't change lastprivate().
- Something that can coexist with lastprivate() is needed.

How about `lastvalue()` clause?

```
#pragma omp simd lastvalue(x)
for(i=0;i<N;i++){
    if (cond(i)){
        x = …
    }
}
// use of x after the loop
```

- Other than the name and lack of reduction op, it's the same as "assignment reduction."
- Applicable to any construct where lastprivate() makes sense.
    - Actual operation is reduction-like. As such, construct should also support reduction.

Should we support list item appearing as an R-value?

- If we were to call it a reduction, we wouldn’t like to see it outside of reduction operation (which is assignment in this case).
- Some optimizations are easier to perform if we know R-value usage does not exist.
- Programmer can introduce new privates and mechanically get rid of R-value usages of the list items.
- Is this good enough reasons for not supporting R-value usage?
  - At least, this is worth explicitly discussing.

Can we have aggregates as list item?

- Yes, we should.
- However, unlike `lastprivate()`, `lastvalue()` has book-keeping overhead.
    - There is a limit to what we can feasibly do. Need to strike a right balance.
- Supporting something like below would be prohibitively expensive.

```
#pragma omp simd lastvalue(A)
for(i=0;i<N;i++){
    if (B[i]>0){ A[i] = …}
    j = …
    if (C[i]>0){ A[j] = …}
}
```

What should we do with aggregates?

- List item as the unit of book-keeping
- No runtime check for matching against list item
- Whole array/struct as a list item should be supported
- Avoid supporting array subsection
- Support one array element as long as the subscript is compile time constant.
- Individual struct field should be supported

What's Next?

- Now that we defined the clause that keeps track of two values to perform something similar to reduction, can we do max location? Can we go more than 1-D?

```
for(i=0;i<N;i++){
    if (max<A[i]){
      max = A[i];
      loc = I;
    }
}
// use of loc.
```

Other Ideas We are Working On

- Vectorization of Indirect Calls
- Compress/Expand
- Conflict
- Loop w/ early exits
- Generalized Induction

Shameless Advertisement

- Today at 4:45pm: Panel Discussion
- Friday at 9:50am: Compress/Expand and Conflict

Summary of Proposal

1. `lastvalue(`*list*`)` clause syntax and spelling
2. Applicability same as `lastprivate` clause (`for`, `simd`, `for simd`, ...)
3. Aggregate variable as list item allowed, but subject to limitations to minimize book-keeping overhead.