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A Comparison of a 1D Stencil Code in C+MPI, Co-Array Fortran, Unified Parallel C, X10, and Chapel

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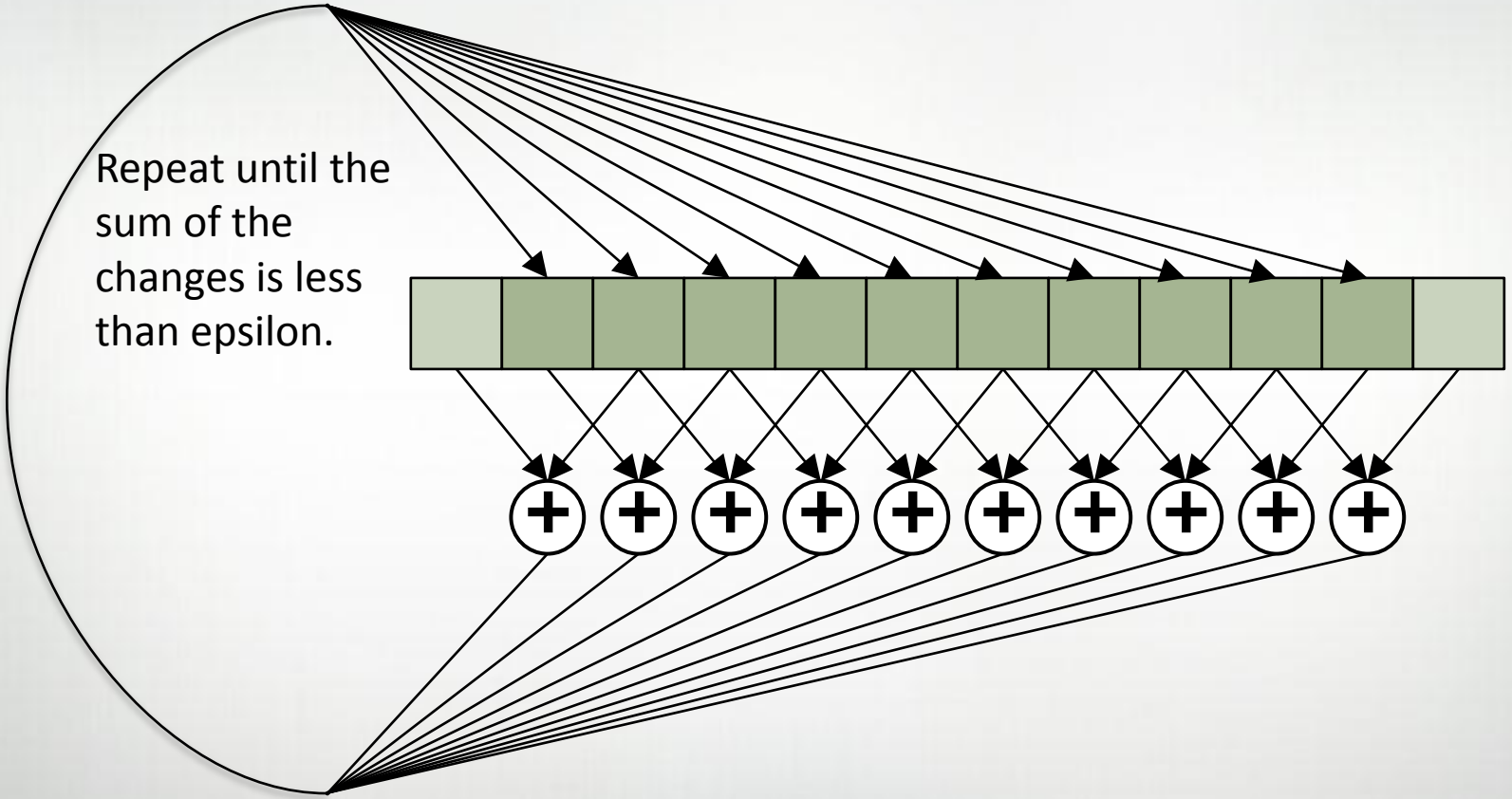
Iterative Averaging



Example Computation

0	1	2	3	4	5	6
0.0	0.00000	0.00000	0.00000	0.00000	0.00000	6.0
0.0	0.00000	0.00000	0.00000	0.00000	3.00000	6.0
0.0	0.00000	0.00000	0.00000	1.50000	3.00000	6.0
0.0	0.00000	0.00000	0.75000	1.50000	3.75000	6.0
0.0	0.00000	0.37500	0.75000	2.25000	3.75000	6.0
0.0	0.18750	0.37500	1.31250	2.25000	4.12500	6.0
0.0	0.18750	0.75000	1.31250	2.71875	4.12500	6.0
0.0			…			0.0
0.0	1.00000	2.00000	3.00000	4.00000	5.00000	6.0

Parallel Languages

- C + MPI
  - Serial base language and two-sided message passing library
- Co-Array Fortran (CAF)
  - Modest extension to Fortran 95 (co-dimensions)
- Unified Parallel C (UPC)
  - Small set of extensions to C (shared data)
- X10
  - New HPCS language designed for high productivity
- Chapel
  - New HPCS language designed for high productivity

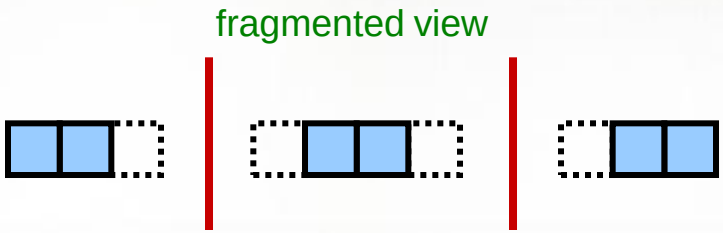
Array Allocation

C + MPI

```
my_n = n * (me+1)/p - n*me/p;
A = (double *)malloc((my_n+2)*sizeof(double));
```

Co-Array Fortran

```
MY_N = N*ME/P - N*(ME-1)/P
MAX_MY_N = (N+P-1)/P
ALLOCATE(A(0:MAX_MY_N+1)[*])
```

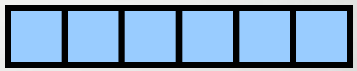


Unified Parallel C

```
A = (shared double*)upc_all_alloc((n+2), sizeof(double));
```

Chapel

```
var D : domain(1) dmapped Block([1..n]) = [0..n+1];
var InnerD : subdomain(D) = [1..n];
var A : [D] real;
```



Array Initialization

C + MPI

```
for (i = 0; i <= my_n; i++)
  A[i] = 0.0;
if (me == p - 1)
  A[my_n+1] = n + 1.0;
```

Co-Array Fortran

```
A(:) = 0.0
IF (ME .EQ. P) THEN
  A(MY_N+1) = N + 1.0
ENDIF
```

Unified Parallel C

```
upc_forall (i = 0; i <= n; i++; &A[i])
  A[i] = 0.0;
if (MYTHREAD == THREADS-1)
  A[n+1] = n + 1.0;
```

Chapel

```
A = 0.0;
A(n+1) = n + 1.0;
```

Stencil Computation

C + MPI

```
if (me < p-1)
  MPI_Send(&(A[my_n]), 1, MPI_DOUBLE, me+1, 1, MPI_COMM_WORLD);
if (me > 0)
  MPI_Recv(&(A[0]), 1, MPI_DOUBLE, me-1, 1, MPI_COMM_WORLD, &status);
if (me > 0)
  MPI_Send(&(A[1]), 1, MPI_DOUBLE, me-1, 1, MPI_COMM_WORLD);
if (me < p-1)
  MPI_Recv(&(A[my_n+1]), 1, MPI_DOUBLE, me+1, 1, MPI_COMM_WORLD, &status);
for (i = 1; i <= my_n; i++)
  Tmp[i] = (A[i-1]+A[i+1])/2.0;
```

Co-Array Fortran

```
CALL SYNC_ALL()
IF (ME .LT. P) THEN
  A(MY_N+1) = A(1)[ME+1]
  A(0)[ME+1] = A(MY_N)
ENDIF
CALL SYNC_ALL()
DO I = 1,MY_N
  TMP(I) = (A(I-1)+A(I+1))/2.0
ENDDO
```

Unified Parallel C

```
upc_barrier;
upc_forall (i = 1; i <= n; i++; &A[i])
  Tmp[i] = (A[i-1]+A[i+1])/2.0;
```

Chapel

```
forall i in InnerD do
  Tmp(i) = (A(i-1)+A(i+1))/2.0;
```

Reduction

C + MPI

```
my_delta = 0.0;
for (i = 1; i <= my_n; i++)
  my_delta += fabs(A[i]-Tmp[i]);
MPI_Allreduce(&my_delta, &delta, 1, MPI_DOUBLE, MPI_SUM, MPI_COMM_WORLD);
```

Co-Array Fortran

```
MY_DELTA = 0.0
DO I = 1,MY_N
  MY_DELTA = MY_DELTA + ABS(A(I)-TMP(I))
ENDDO
CALL SYNC_ALL()
DELTA = 0.0
DO I = 1,P
  DELTA = DELTA + MY_DELTA[I]
ENDDO
```

Unified Parallel C

```
my_delta = 0.0;
upc_forall (i = 1; i <= n; i++; &A[i])
  my_delta += fabs(A[i]-Tmp[i]);
upc_lock(lock);
delta = delta + my_delta;
upc_unlock(lock);
```

Chapel

```
delta = + reduce abs(A(InnerD)-Tmp(InnerD));
```

Reduction

C + MPI

```
my_delta = 0.0;
for (i = 1; i <= my_n; i++)
  my_delta += fabs(A[i]-Tmp[i]);
MPI_Allreduce(&my_delta, &delta, 1, MPI_DOUBLE, MPI_SUM, MPI_COMM_WORLD);
```

Co-Array Fortran

```
MY_DELTA = 0.0
DO I = 1,MY_N
  MY_DELTA = MY_DELTA + ABS(A(I)-TMP(I))
ENDDO
CALL SYNC_ALL()
DELTA = 0.0
DO I = 1,P
  DELTA = DELTA + MY_DELTA[I]
ENDDO
```

Unified Parallel C

```
my_delta = 0.0;
upc_forall (i = 1; i <= n; i++; &A[i])
  my_delta += fabs(A[i]-Tmp[i]);
upc_lock(lock);
delta = delta + my_delta;
upc_unlock(lock);
```

Chapel

```
delta = 0.0;
forall i in InnerD do
  delta += abs(A(i)-Tmp(i));
```

Output

C + MPI

```
if (me == 0)
  printf("Iterations: %d\n", iters);
```

Co-Array Fortran

```
IF (ME .EQ. 1) THEN
  WRITE(*,*) 'Iterations: ', ITERS
ENDIF
```

Unified Parallel C

```
if (MYTHREAD == 0)
  printf("Iterations: %d\n", iters);
```

Chapel

```
writeln("Iterations: ", iters);
```

Summary Comparison

Features \ *Languages*	C+MPI	CAF	UPC	Chapel
Global view of computation				✔
Global view of data			✔	✔
Data distributions			✔	✔
Arbitrary data distributions				✔
Multi-dimensional arrays		✔		✔
Syntactic execution model	✔	✔		
One-sided communication	½	✔	✔	✔
Support for reductions	✔	↗	↗	✔
Simple mechanisms		✔	✔	✔

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