Parallel programming in the last 25 years — forward or backward?

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Summary

- **Until around early '90s, there were "parallel languages" available on high-performance computers.**
- **They are no longer there.**
- **HPF is the last to die (still available on NEC parallel vector machines)**
- **Why did this happen? What could/should we do?**

Talk structure

- **Parallel Programming @2011**
- **Parallel Programming @1986**
- **Why things has changed?**
- **What could we do?**
- **What should we do?**

Parallel Programming @2011

Intelspeak (http://www.intel.com/intelpress/sum_mcp.htm)

Software developers can no longer rely on increasing clock speeds alone to speed up single-threaded applications; instead, to gain a competitive advantage, developers must learn how to properly design their applications to run in a threaded environment. Multi-core architectures have a single processor package that contains two or more processor "execution cores," or computational engines, and deliver-with appropriate software-fully parallel execution of multiple software threads. Hyper-Threading Technology enables additional threads to operate on each core.

Parallel Programming @2011

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Sounds like a description of Cray XMP. Are we back in 1982?

In practice...

- **Use MPI for multi-node parallelism**
- **Use either Ptherad or OpenMP for multi-core**
- **Use either automatic vectorization or SIMD intrinsics for SIMD units**

MPI

- Based on message-passing model
- Probably the model with lowest possible programming productivity
  - Each process can only access its local memory
  - Need to use library calls (usually on both sides of communication) to access remote data
  - "correct" parallel execution managed by barriers and handshakes

An non-MPI program

```
int main(int argc,char *argv[])
{
    int  n,  i;
    double PI25DT = 3.14159265358979323846264643;
    double  pi, h, sum, x;
    n=100000000;
    h   = 1.0 / (double) n;
    sum = 0.0;
    for (i = 0; i < n; i ++){
       x = h * ((double)i - 0.5);
       sum += f(x);
    }
    pi = h * sum;
    printf("pi is approximately %.16f, Error is %.16f\n",
          pi, fabs(pi - PI25DT));
    return 0;
}
```

A MPI program

```
int main(int argc,char *argv[])
{
    int done = 0, n, myid, numprocs, i;
    double PI25DT = 3.14159265358979323846264643;
    double mypi, pi, h, sum, x;
    int  namelen;
    char processor_name[MPI_MAX_PROCESSOR_NAME];
    MPI_Init(&argc,&argv);
    MPI_Comm_size(MPI_COMM_WORLD,&numprocs);
    MPI_Comm_rank(MPI_COMM_WORLD,&myid);
    MPI_Get_processor_name(processor_name,&namelen);
    if (myid == 0) {
       n=100000000;
        MPI_Bcast(&n, 1, MPI_INT, 0, MPI_COMM_WORLD);
    }
```

```
    h   = 1.0 / (double) n;
    sum = 0.0;
    for (i = myid + 1; i <= n; i += numprocs){
       x = h * ((double)i - 0.5);
       sum += f(x);
    }
    mypi = h * sum;
    MPI_Reduce(&mypi, &pi, 1, MPI_DOUBLE, MPI_SUM, 0, MPI_COMM_WORLD
    if (myid == 0) {
       printf("pi is approximately %.16f, Error is %.16f\n",
              pi, fabs(pi - PI25DT));
    }
    MPI_Finalize();
    return 0;
}
```

Problem with MPI

- Program becomes 2x or more longer...
- Each process need to figure out what it is supposed to do from its ID.
- Data layout and almost every control structure need to be changed
- mapping between local array and "global" array should be taken care of manually. Nothing is automatic

Parallel Programming @1986

```
void node_domain::calc_accel()
{
    int myindex;
    mono int i,k;
    double dx[NDIM];
    acc[0] = acc[1] = acc[2] = 0.0;  potential = 0.0;
    myindex = (int) this - (int) &node[0];
```

Parallel Programming @1986

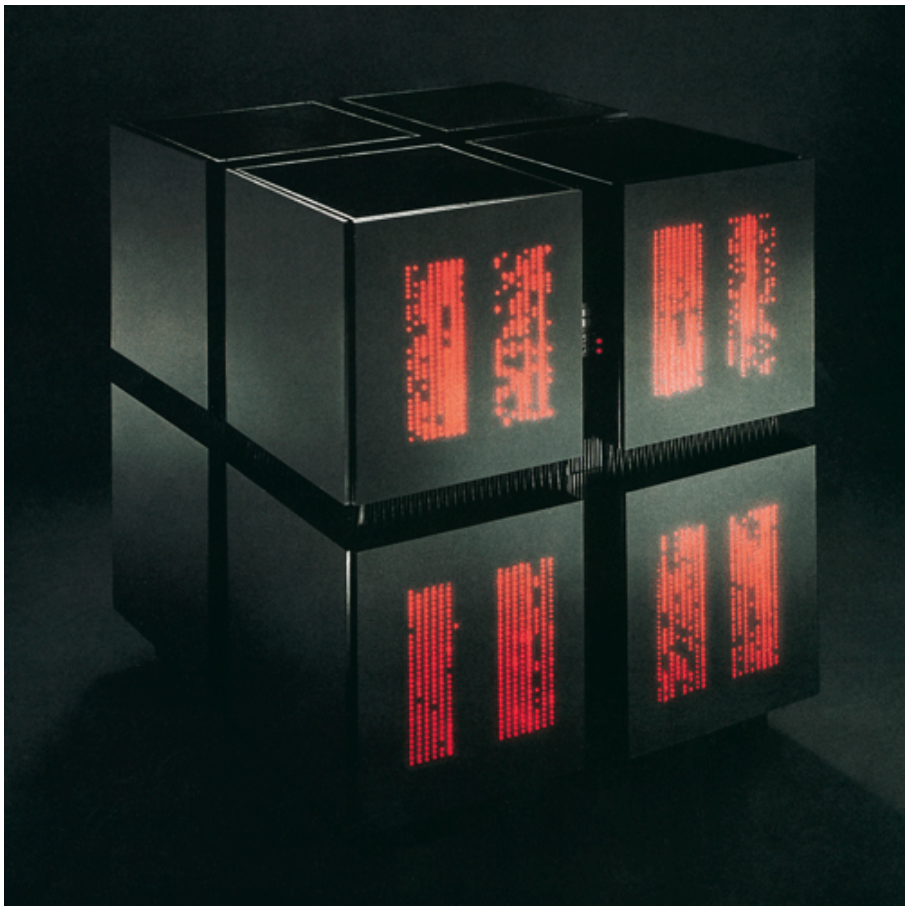
```
    for(i = 0; i < nbody; i++){
        double pot, rsq, rsqinv, rinv;
        if(myindex != i){
            rsq = eps2;
             for (k = 0; k < NDIM; k++){
                 dx[k]=node[i].position[k]-position[k];
                 rsq += dx[k]*dx[k];
             }
             rsqinv = 1.0/rsq;
             rinv = sqrt(rsqinv);
             pot=node[i].mass *rinv;
             potential+=pot;
             pot *=rsqinv;
             for (k=0; k<NDIM; k++)  acc[k]+=pot*dx[k];
         }
    }
}
```

Connection Machine C*

- **Machine image: huge SIMD machine with local memory**
- **Programming model: virtual node. Programmers need not make mapping between physical processors and data structure.**
- **Communication is done through assignment operation.**

You still need to rewrite your program, but it is not 2x longer.

The Connection Machine



1986 Thinking Machine Corporation

SIMD machine with up to 64k one-bit processors

2048 Weitek floating-point processors

around 10Gflops peak

Why things has changed?

- Because Thinking Machines Corporation went bankrupt in 1994
- Vector supercomputers and other parallel machines were all killed by first RISC processors and then x86 processors
- It was impractical to use parallel languages on a cluster of RISC processors

Why parallel languages are bad on clusters

- practical parallel languages are data-parallel languages
- memory hierarchy made efficient implementation of data-parallel languages very difficult
- high-latency, low-bandwidth network added more difficulty

What could we do?

Constraints:
Compared to floating-point performance,

- **Relative bandwidth to off-chip memory will keep decreasing.**
- **Relative communication bandwidth will keep decreasing too.**

So data-parallel languages will become even more unpractical.

What should we do?

What should we do?

...

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