German Research School
for Simulation Sciences

Parallelization of fluid animate application with Intel CnC

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Agenda

- **Problem Definition**
- Approach
- Evaluation
- Conclusion

Team background

- We are not experts in CnC
- We are not the experts in this domain
- One month time

Problem Definition

- **Fluid Animate**
  - Parallelize with CnC
  - Analyze the performance gains

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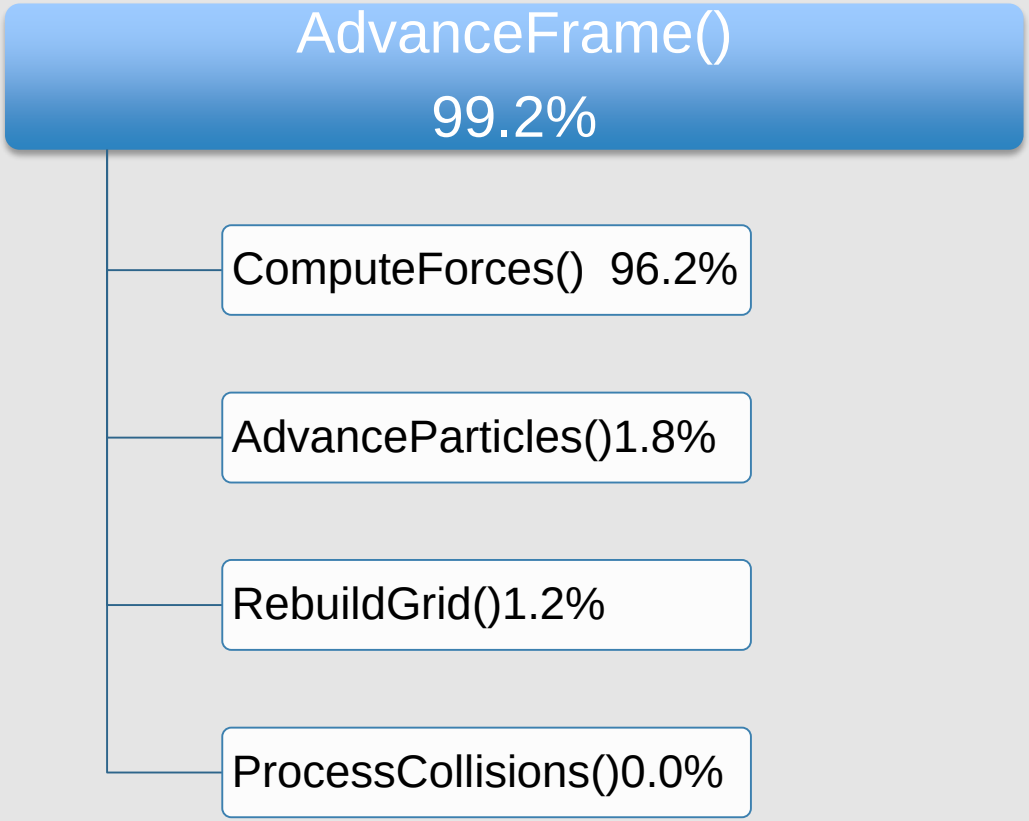
Problem Definition: Hotspots



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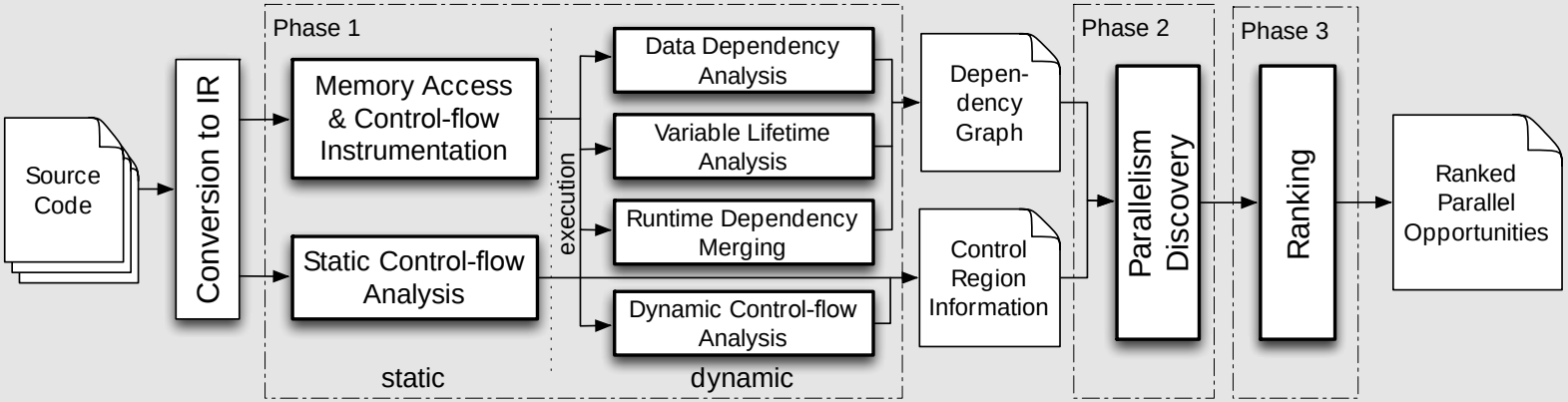
DiscoPoP: Discovery of Potential Parallelism

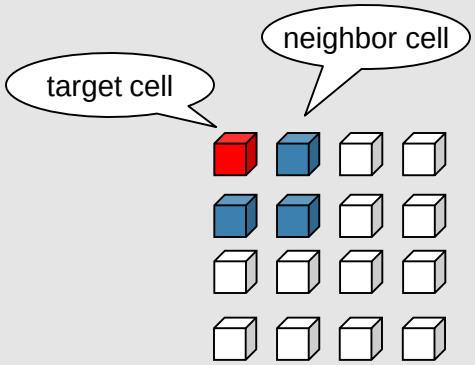
- Target parallelism:
  - DOALL loops
  - Pipeline
  - taskingReveal concrete data dependences that prevent parallelization
- Efficient in time and space

DiscoPoP: Discovery of Potential Parallelism

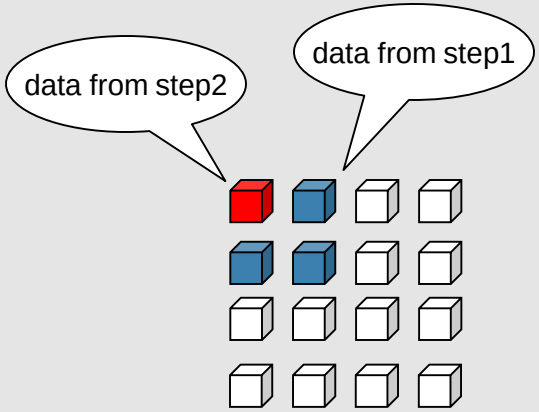
- Architecture



Fluid Animate Dependencies



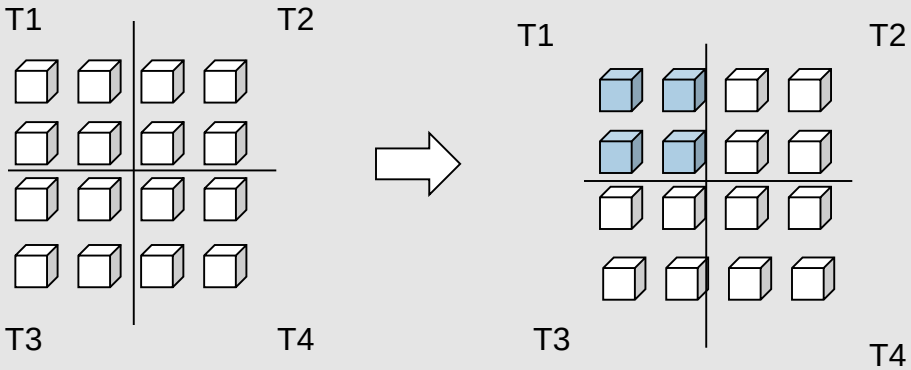
Step 1



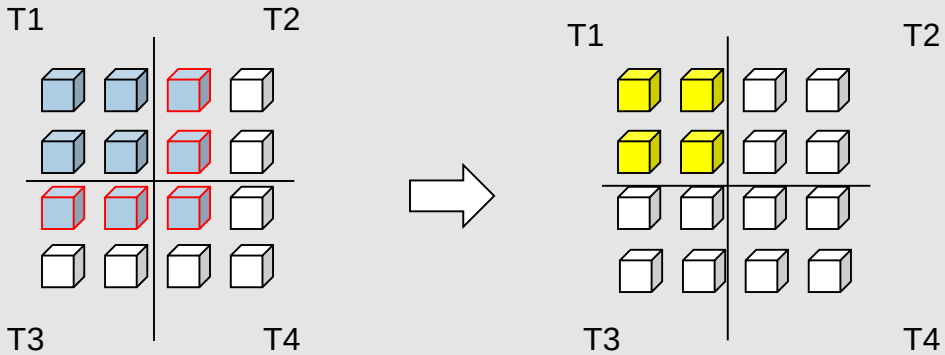
Step 2

Fluid Animate Dependencies

Function 1



Function 2



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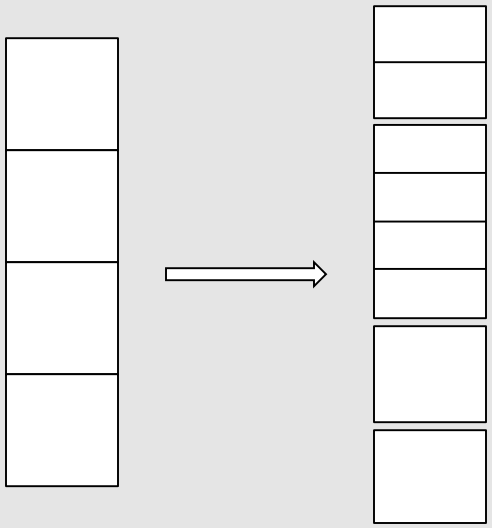
TBB

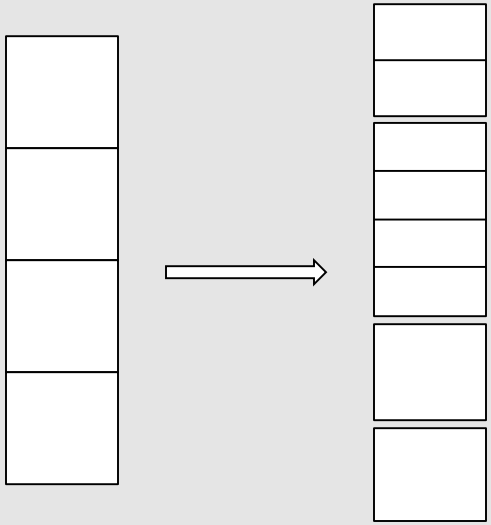


```
struct Grid {
  union {
    struct {
      int sx, sy, sz;
      int ex, ey, ez;
    };
  };
} *grids;
```

In functions:

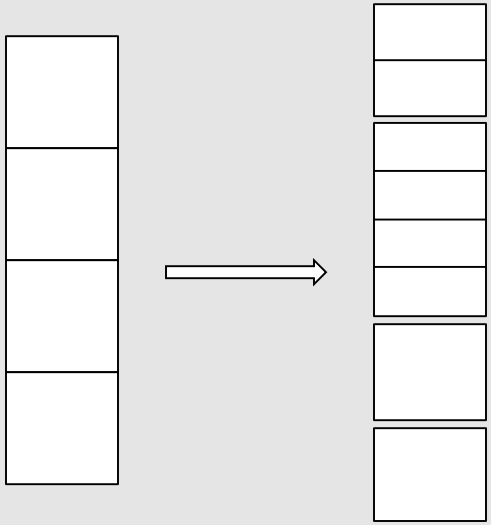
```
    for(int iz = start + block*pid; iz < sz + block; ++iz)
      for(int iy = grids[tid].sy; iy < grids[tid].ey; ++iy)
        for(int ix = grids[tid].sx; ix < grids[tid].ex; ++ix)
        {
          int index = (iz*ny + iy)*nx + ix;
          …
```

TBB



```
if(border[cNeigh]) {
    tbbMutex::scoped_lock lock(mutex[cNeigh][iparNeigh % MUTEXES_CELL]);
    neigh->a[iparNeigh % PARTICLES_PER_CELL] -= acc;
}
else {
    neigh->a[iparNeigh % PARTICLES_PER_CELL] -= acc;
}
```

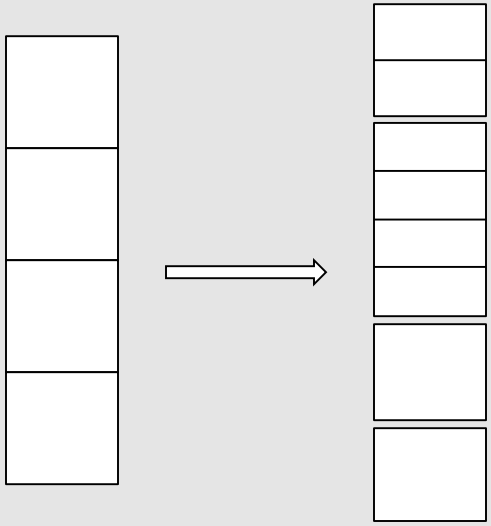
1st CnC Version



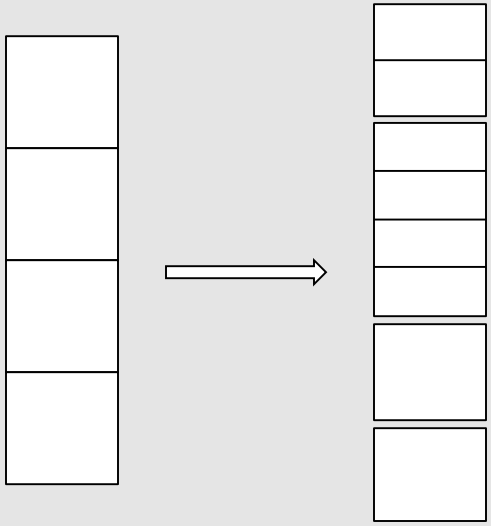
- **4 functions but only 1 hotspot**
  - RebuildGrid
  - ComputeForces (hotspot!)
  - ProcessCollissions
  - AdvanceParticles
- **RebuildGrid and ComputeForces**
  - Can be split into parts, but each part depends on prior part
- **Also have to use TBB locks**

1st CnC Version

```
void ComputeForces()
{
    for(int i = 0; i < num_procs; ++i) ctxt.tagsCF1.put(i);
    ctxt.wait();

    for(int i = 0; i < num_procs; ++i) ctxt.tagsCF2.put(i);
    ctxt.wait();

    for(int i = 0; i < num_procs; ++i) ctxt.tagsCF3.put(i);
    ctxt.wait();

    for(int i = 0; i < num_procs; ++i) ctxt.tagsCF4.put(i);
    ctxt.wait();
}
```



1st CnC Version



In the functions:

```
int sx = (tag%XDIVS)*dx;
int sz = (tag/XDIVS)*dz;
int ex = std::min(sx+dx,nx);
int ez = std::min(sz+dz,nz);
for(int ck = sz; ck < ez; ++ck)
  for(int cj = 0; cj < ny; ++cj)
    for(int ci = sx; ci < ex; ++ci)
    {
      int cindex = (ck*ny + cj)*nx + ci;
      …
```

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2nd CnC Version

```
struct ComputeForcesCnC { int execute(const int &tag, fa_context &ctxt) const; };
struct fa_context : public CnC::context<fa_context> {
    CnC::step_collection<ComputeForcesCnC>  stepsCF4;
    CnC::tag_collection<int>                tagsCF4;
};
fa_context::fa_context() : CnC::context<fa_context>(), stepsCF4(*this), tagsCF4(*this),
{
    tagsCF4.prescribes(stepsCF4, *this);
}
for(int i = 0; i < num_procs; ++i)
    ctxt.tagsCF4.put(i);
ctxt.wait();

int ComputeForces::execute(const int &tag, fa_context &ctxt) const { … }
```

```
CnC::parallel_for(0, num_progs, 1, ComputeForces(), CnC::pfor_tuner< false >());

int ComputeForces::operator()(int tag) const { … }
```


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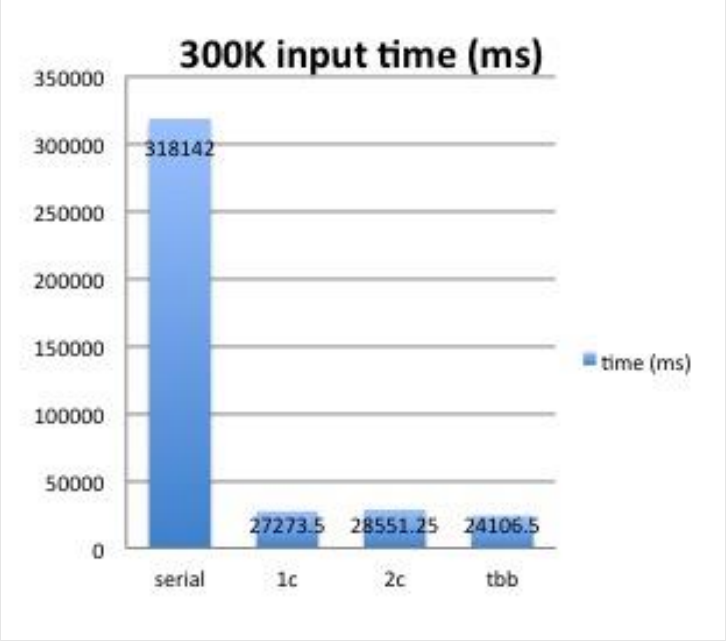
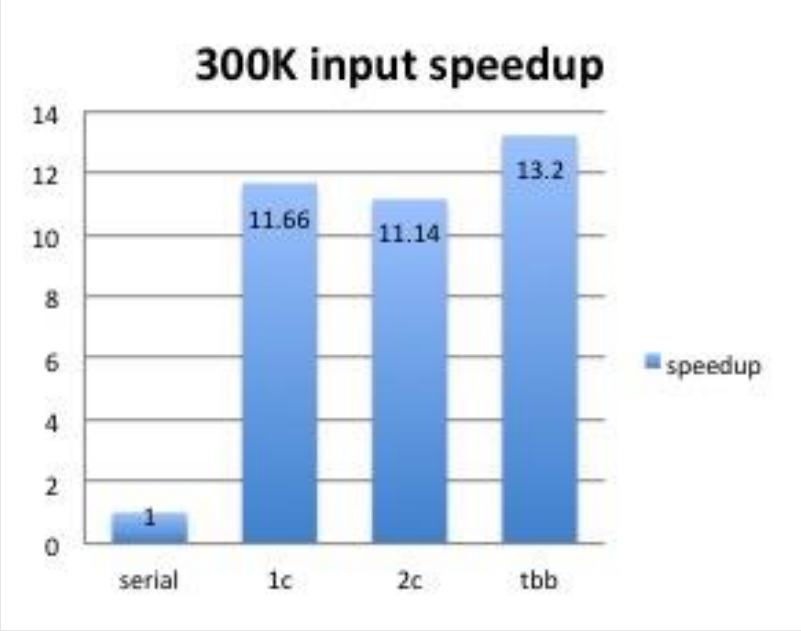
Experiment Setup

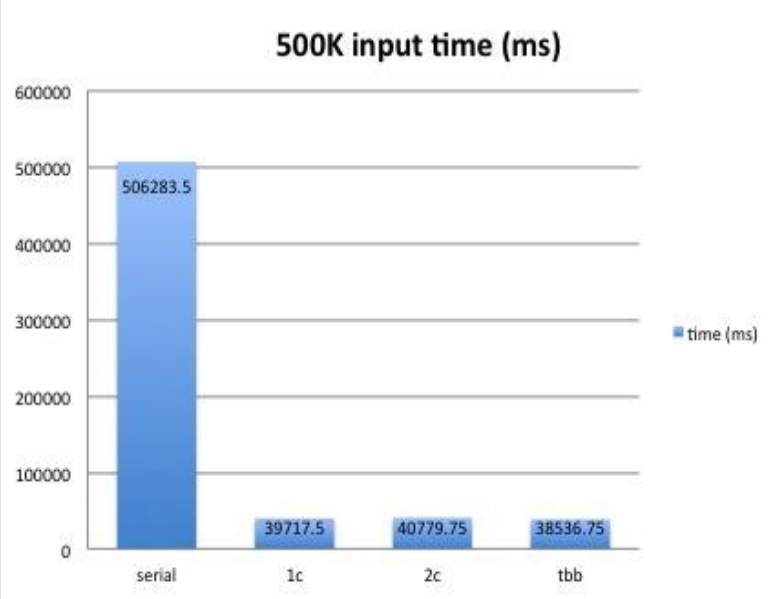
- 2 x 8-core Intel Xeon E5-2650 2 GHz processors with
- 32 GB memory
- Ubuntu 12.04 (64-bit server edition)
- Average of 4 measurements was calculated for each version

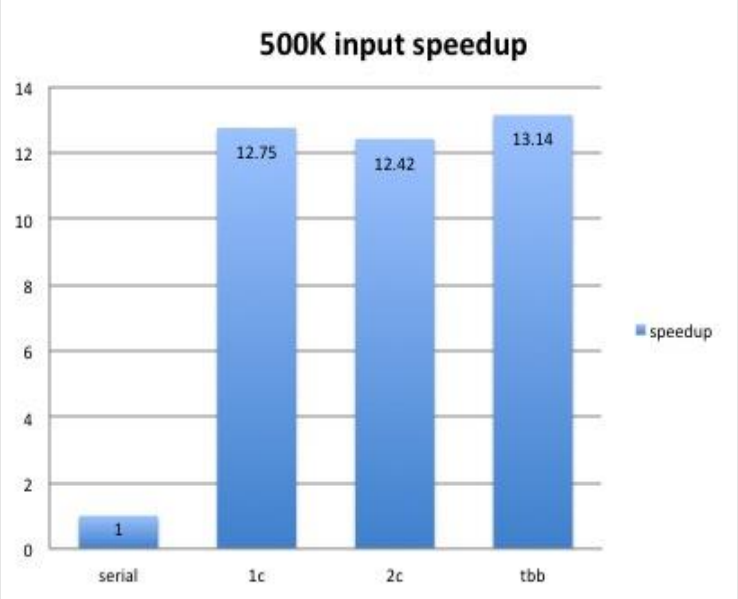
Speedup


300K input time (ms)
350000
300000
250000
200000
150000
100000
50000
0
318142
27273.5
28551.25
24106.5
serial
1c
2c
tbb
time (ms)


300K input speedup
14
12
10
8
6
4
2
0
1
11.66
11.14
13.2
serial
1c
2c
tbb
speedup

Speedup


500K input time (ms)
600000
500000
400000
300000
200000
100000
0
506283.5
39717.5
40779.75
38536.75
serial
1c
2c
tbb
time (ms)


500K input speedup
14
12
10
8
6
4
2
0
1
12.75
12.42
13.14
serial
1c
2c
tbb
speedup

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Conclusions

- We are beginners and had only one month, but still we got a reasobable speedup
    - CnC is good for beginners
- In terms of performance, TBB and CnC showed comparable results