A MASSIVELY PARALLEL DISTRIBUTED N-BODY APPLICATION IMPLEMENTED WITH HPX

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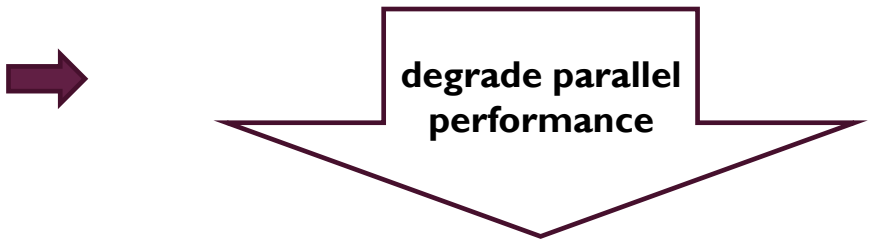
INTRODUCTION

- Computer scientists and programmers face the difficultly of improving the scalability of their applications while using conventional programming techniques only.
- N-Body:
  - communication intensive,
  - large message latencies,
  - large overheads



WHAT DO WE NEED?

reducing:

a. poor utilization of resources caused by lack of available work (Starvation),
b. the time-distance delay of accessing remote resources (Latencies),
c. the cost for managing parallel actions (Overhead)
d. the cost imposed by oversubscription of shared resources (Waiting)

HPX

- HPX is a parallel C++ runtime system that facilitates distributed operations and enables fine-grained task parallelism. Using fine-grained tasks results in better load balancing, lower communication overheads, and better system utilization:
  - future concept
  - dataflow object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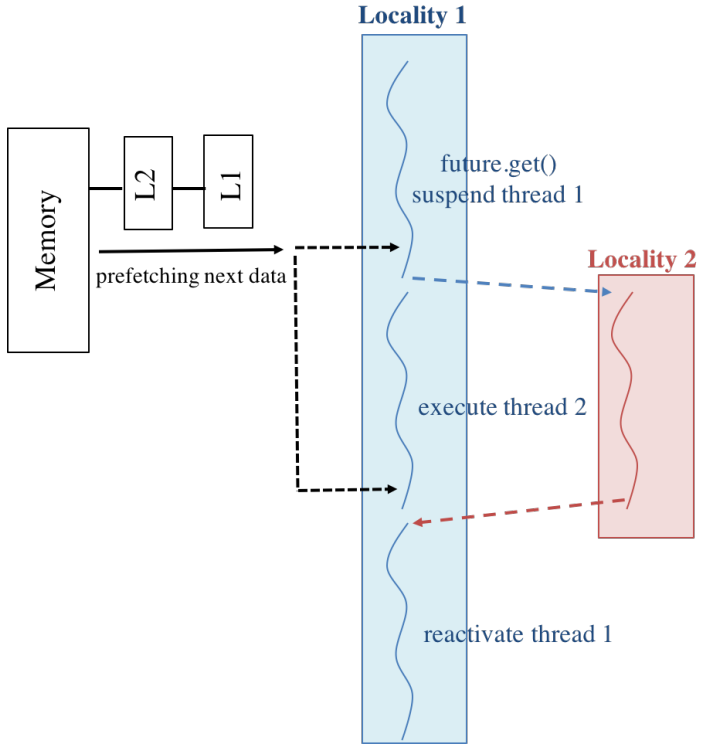
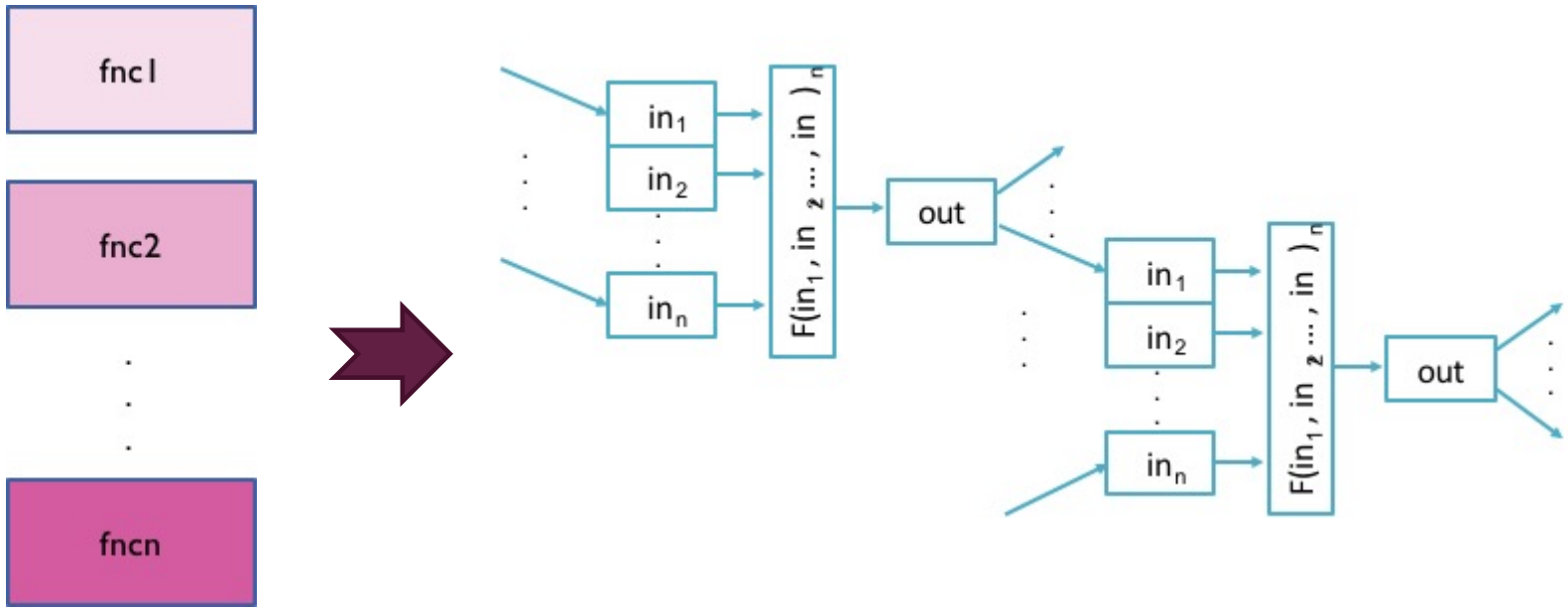
FUTURE

- A future is a computational result that is initially unknown but becomes available at a later time. The goal of using future is to let every computation proceed as far as possible.
- Other threads do not stop their progress even if the thread, which waits for the value to compute, is suspended. Threads access the future value by performing a future:get() . When the result becomes available, the future resumes all HPX suspended threads waiting for the value.



DATAFLOW

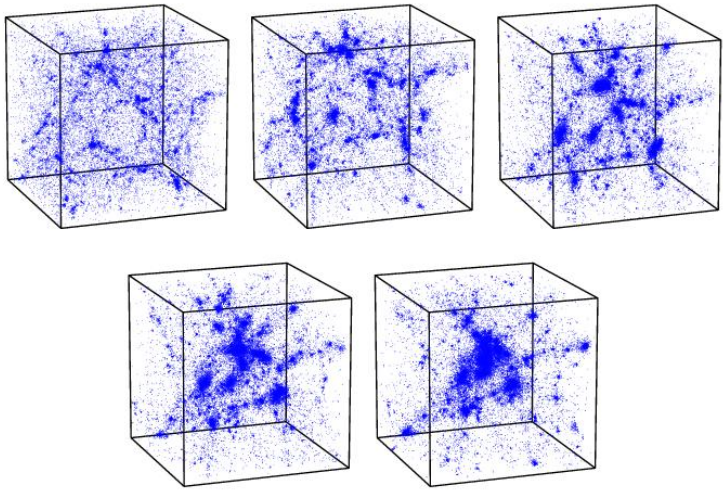

fnc1
fnc2
fncn
in1
in2
inn
F(in1, in2 ... , inn)n
out
in1
in2
inn
F(in1, in2 ... , inn)n
out

ADVANTAGES

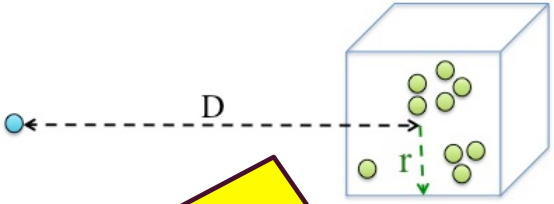
1. removing unnecessary barrier synchronization
2. interleaving different loops
3. automatically creating the dependency tree
4. dynamically determining the parameters during running time

N-BODY

1. Octree construction
2. Interaction list creation
3. Force computation

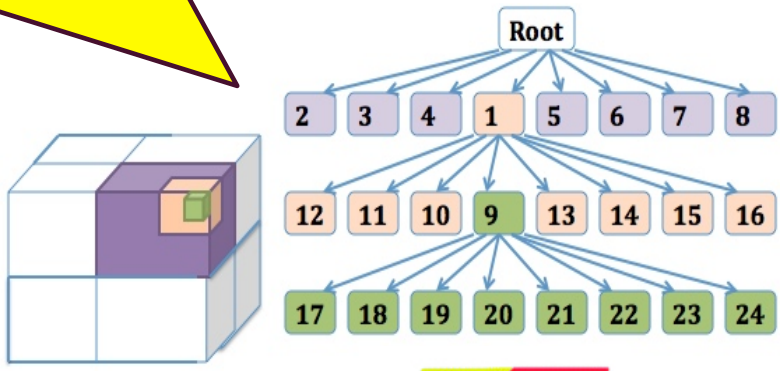


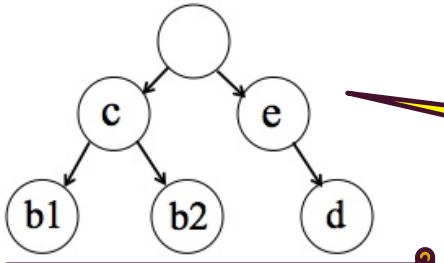
N-BODY



The gravitational potential of a distant group of particles is approximated as the potential of a single particle located in the center of mass of all particles in the cube.

Each cube is subdivided into eight equally sized subcubes if it has more than N particles and in each step, each particle is reassigned to one of the newly created subcubes.



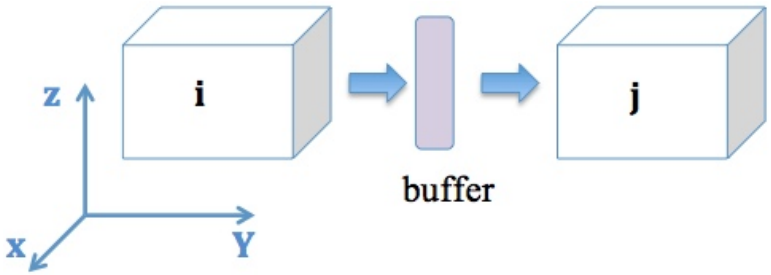


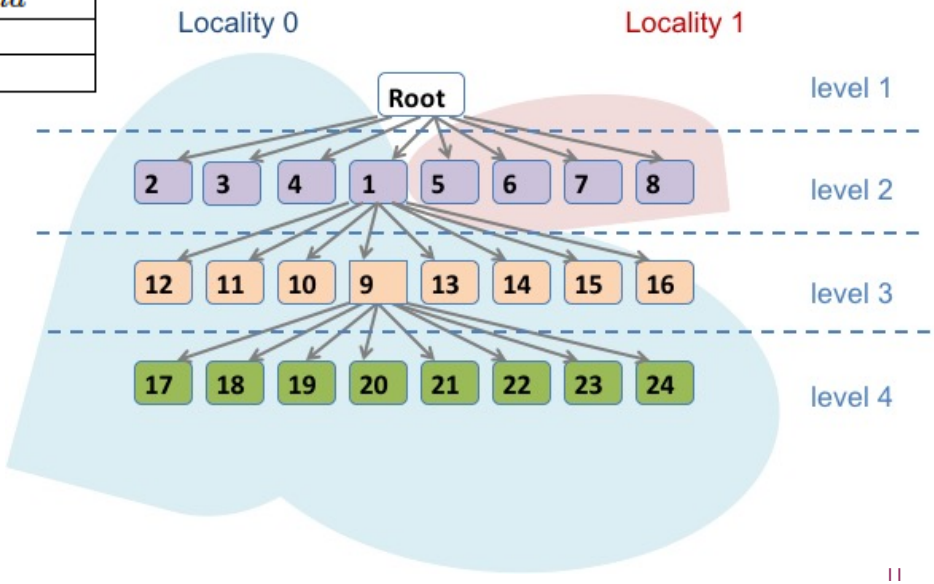
Improved based on FMM

The interaction list of the particle holds the list of the particles that are near objects to that particle and the cubes that are modeled as faraway objects to that particle.

ALGORITHM IMPLEMENTED WITH HPX

hpx::id_type	A global address (GID)
hpx::find_here	Retrieving this' *locality's id*
hpx::find_all_localities	Finding all *localities*
hpx::register_with_basename	Registering a unique GID





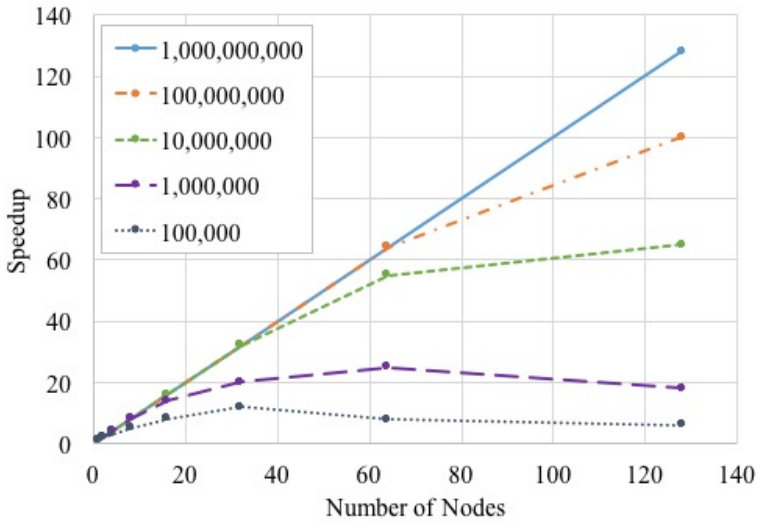
ALGORITHM IMPLEMENTED WITH HPX

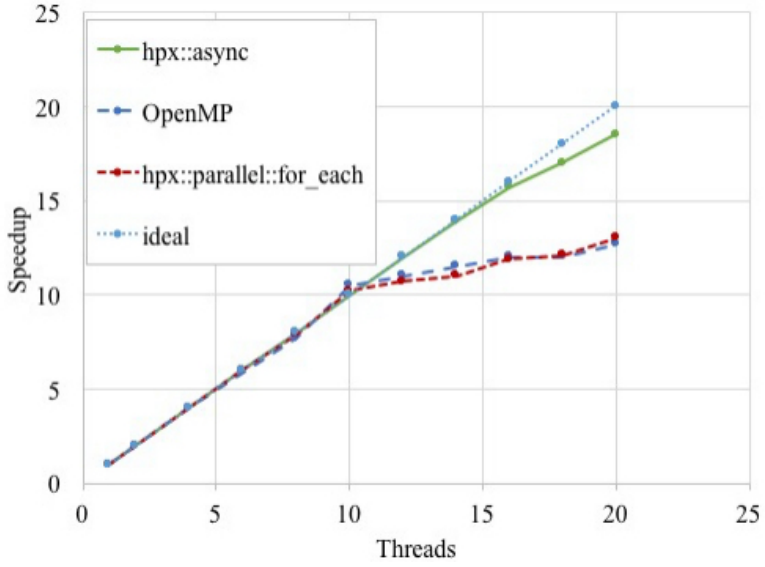
- future-based request buffer is used between different nodes and along each spatial direction to send/receive data to/from the remote nodes
- data distribution across the nodes is designed based on assigning a unique id provided by HPX
- the algorithm minimizes idle nodes and maintains high utilization.

Initialization Steps:
1) Constructing an Octree
2) Assigning id to each cube
3) Finding each *locality*'s id with hpx::find-here()
4) Finding remote *localities*' id with hpx::find-all-localities()
5) Locating each cube and all its descendants with Eq.5
6) Discovering the neighbors of each *locality*
7) Creating shared buffers between two neighbor localities

For each time step Do:
8) Computing the force on each particle with Eq.2
9) Computing the new position of each particle with Eq.4
10) Storing p_i needed to be sent, in the:
    left buffer, if $x_{p_i} > x_{parent}$
    right buffer, if $x_{p_i} < x_{parent}$
    above buffer, if $y_{p_i} > y_{parent}$
    down buffer, if $y_{p_i} < y_{parent}$
    back buffer, if $z_{p_i} > z_{parent}$
    front buffer, if $z_{p_i} < z_{parent}$
11) Receiving p_i that doesn't belong to l_i, from
    left, then storing it in the right buffer
    right, then storing it in the left buffer
    above, then storing it in the down buffer
    down,then storing it in the above buffer
    back, then storing it in the front buffer
    front, then storing it in the back buffer
12) Sending data in buffer i in the direction i,
    $i \in$ { left, right, up, down, back, front }
Loop

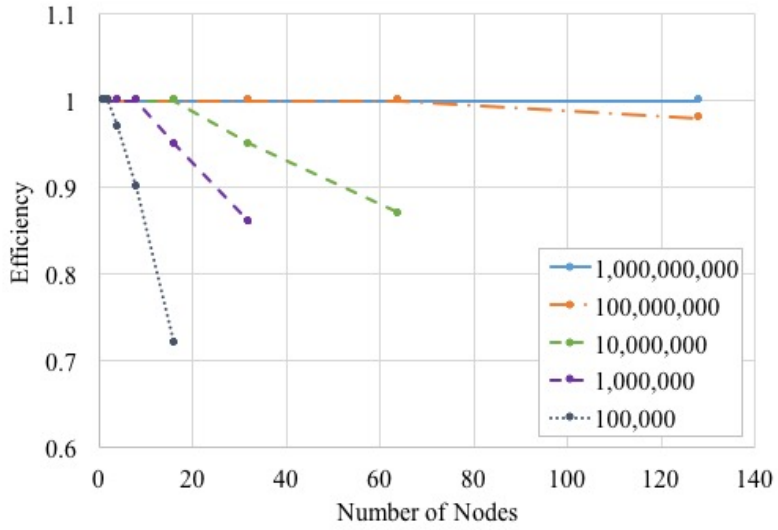
EXPERIMENTAL RESULTS

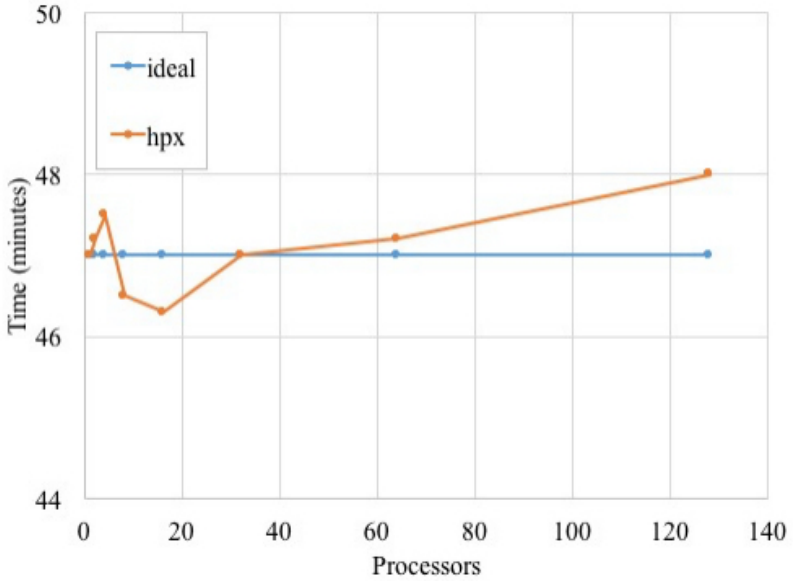




STE||AR GROUP

EXPERIMENTAL RESULTS





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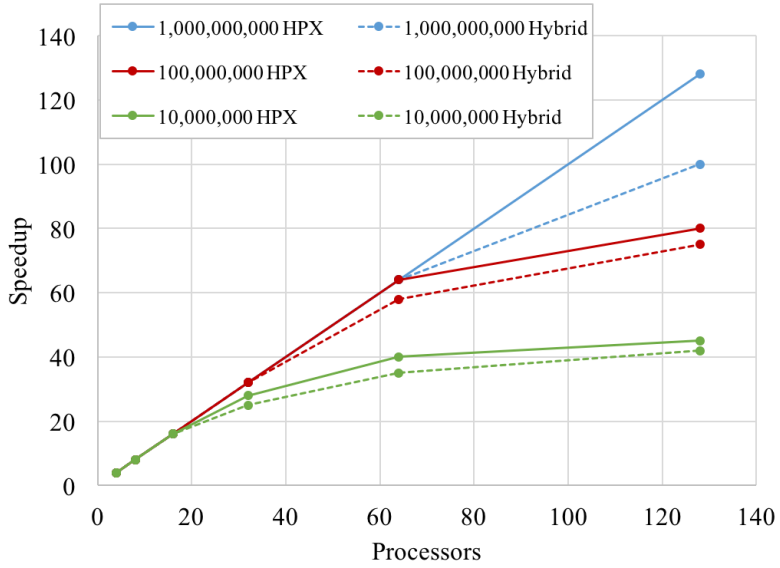
EXPERIMENTAL RESULTS



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CONCLUSION

- HPX is able to control a grain size at runtime by using for_each and as a result the resource starvation is reduced as well.
- HPX helps keeping the better load balancing and lower overheads compared to MPI and OpenMP.
- The better performance by HPX for the larger number of the nodes, which is due to using a future -based request buffer between the remote nodes that allows the continuation of the process without waiting for the previous step to be completed.
- 128x speedup on 128 distributed nodes for 1 billion particles using HPX that indicates it has the potential to continue to scale on more even cores

Thank you for your attention