Neighbour Recycling in Gadget3

Antonio Ragagnin

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Why:

- Gadget3 is a N-Body code, for cosmological hydrodynamical sim'
- Resolves many physical processes (e.g. star formation)
- Each process needs to find neighboursing particles
- T(Neighbour Search) $>$ T(physics) $\Rightarrow$ Needs to improve Neighbour Search

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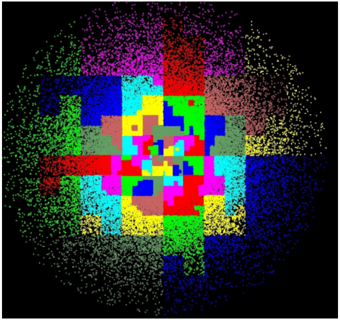
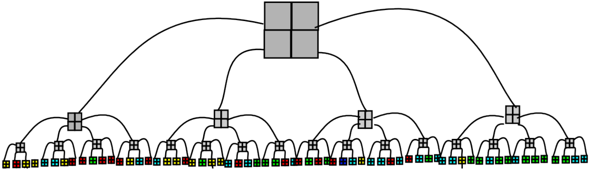
Gadget3 - Short overview

Domain decomposition

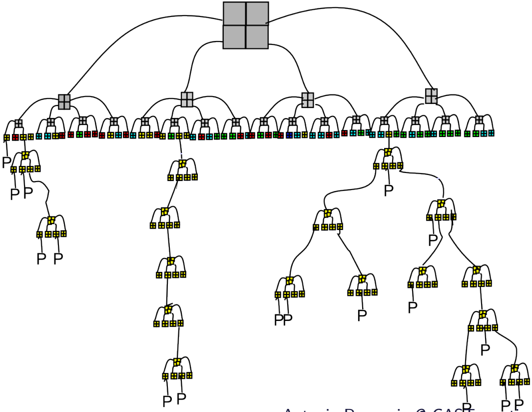




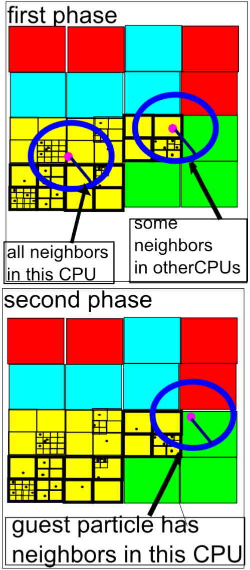
- space divided **recousrively** in 8 sub-cubes, until a minimum size is reached
- **domain decomposition:** each sub-cube is assigned at various CPUs to balance memory/work. At each CPU is assigned a different portion of space.
- to send contiguous block of memory, particles are ordered with a **Hilbert space-filling curve** ordering (remember this point!).

Tree structure

- Let's say I need all neighbouring particles nearer than h of a given particle.
- Number of particles $2 \cdot 81^3$ - $2 \cdot 1526^3$
- You would not loop over **all** particles to find them
- That's why in Gadget, particles are organized in a tree
- Still we have $T(\text{Tree Walk}) > T(\text{physics})$



Neighbour Search



First phase

- For each internal active particle: **walks the tree** and find neighbours
- particles that have neighbours on other CPUs are "flagged" to be exported later
- Compute physics on the target particle within those neighbours.

Second phase

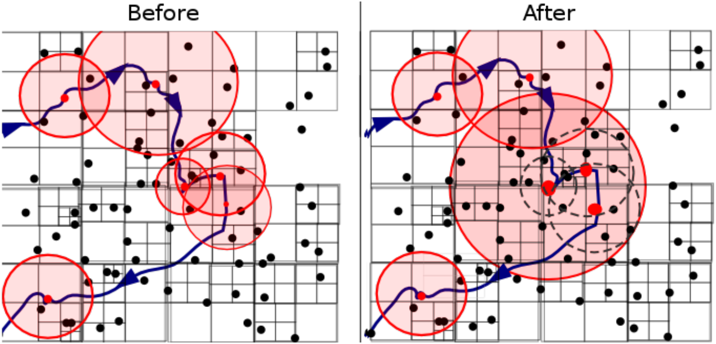
- send particles on boundaries to other CPUs
- current CPU receive "guest particles" of other CPUs.
- find neighbours of that particle in this CPU
- compute physics on that particle
- send particles back

"Green" Tree Walk

Neighbors Recycling (1/4)

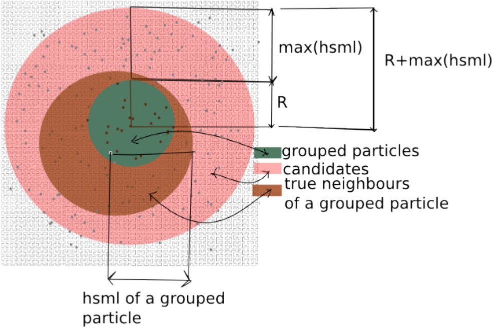
- **The idea**: In Molecular Dynamics, for each particle, there is stored a superset of neighbours (within a bigger sphere) to re-use them in more timesteps (Verlet list).
- **In Gadget3**, particles are ordered with a space filling curve(remember?)
$\Rightarrow$ adjacent particles in memory also particles close in space
$\Rightarrow$ when we find neighbours of a given particles, this list contains most of the neighbours of the next particle
- **This technique**: Instead of search the neighbours for each particle alone, particles are grouped in spheres and a tree walk is performed for each group.

Neighbors Recycling (2/4)



The speedup will depend on the radius R of the clustering, and it has been found "experimentally" (so running various sims and varying R).

Neighbors Recycling (3/4)



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R =grouping radius
$\langle N_{ngb} \rangle \sim (\langle hsml \rangle)^3 \rho$
$\langle N_{group} \rangle \sim R^3 \rho + 1$
$\langle N_{candidates} \rangle \sim$
$(R + max(hsml))^3 \rho$

Adaptive tree-walk

$$R = f \cdot \langle hsml \rangle$$

$$f = \left(\frac{N_{candidates}}{N_{ngb}} \right)^{\frac{1}{3}} - 1$$

So, if we asks for having $N_{candidates} \simeq 3N_{ngb}$ then $f = 0.4$.

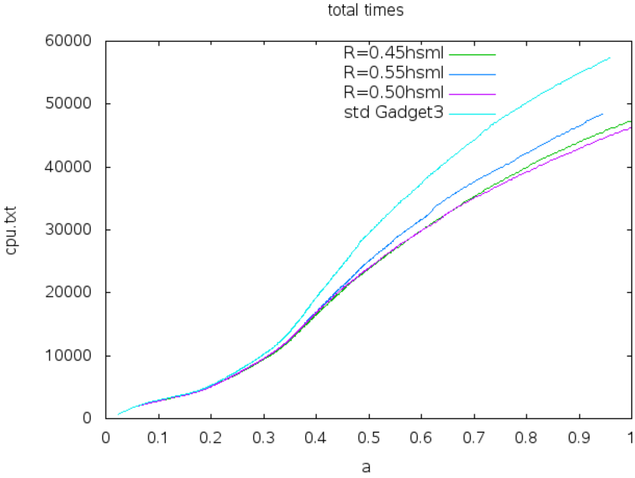
Neighbors Recycling (4/4)

Last but not least about this alg'..the name!

- Various concepts:
- - recycling
- - not wasting/re-using tree (walks)
- That's why the first name I gave to it was Green Tree Walk.
- This stuff will be published in a conference of Computer Science, and Green is usually refered to the matematician surname
- one prof. of the TUM (in the past he reviewed papers for this conferences) suggested to change names
- this prof. of TUM suggested to find a name related to a forest with few trees
- if you think of a name, you can tell me!

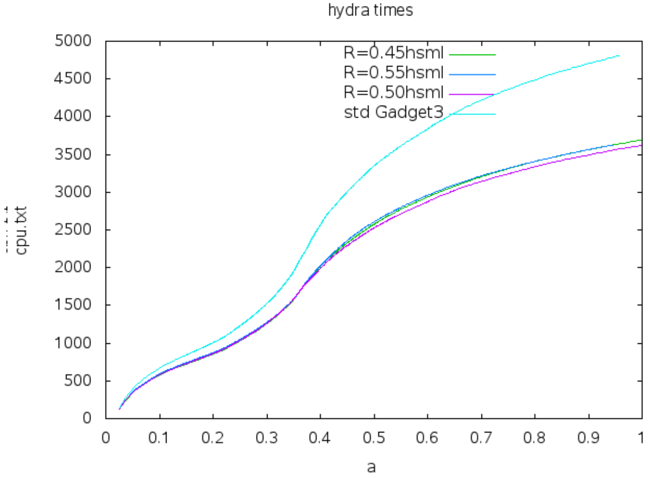
Results: Total Times

Adaptive green treewalk for **box5hr**, $R = 0.5hsml$



Results: Hydra times

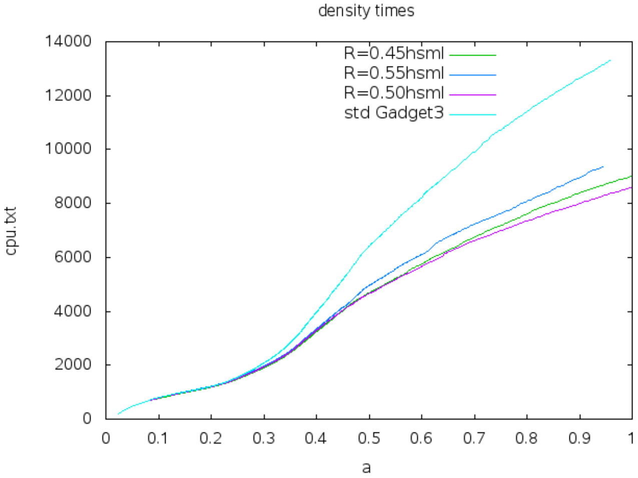
Adaptive green treewalk for **box5hr**, $R = 0.5hsml$



Results: Density Times

Adaptive green treewalk for **box5hr**, $R = 0.5hsml$

$\frac{T_{std}}{T_{new}} \simeq 1.70 \Rightarrow$ **density 40% faster**!



Conclusions

So,

- doing fewer tree walks with a large radius(but not too much large) is better than doing more tree walks with a smaller radius

with a speed up in density of $1.7 - 1.8$ (**40%**)

What's next

- I have reasons to belive that the number of grouped particles is lower than the one I predicted (..remember that N_{group}?)