Auto-optimization on parallel hydrodynamic codes: an example of COHERENS with OpenMP for multicore

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Guidelines

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   - Cost Analysis
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Main Objective

Establish some simple strategies for the development of a parallel code with auto-optimization capacity for multicore system

- Carry out an analysis on a secuencial code, COHERENS.
- Extract some loops of the code and parallelize them.
- Analyze the execution time obtained for these loops run in different system and size problems.
- Expose some auto-optimization strategies and the result obtained when we applied it to the loops extracted.

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What's COHERENS (COupled Hydrodynamical-Ecological model for RegioNal and Shelf seas)

The 3D hydrodynamic model called COHERENS was developed between 1990 and 1998 by the Management Unit of the North Sea Mathematical Models, Napier University, Proudman Oceanographic Laboratory and British Oceanographic Data Center, within the European project MAST PROFILE, NOMADS AND COHERENS.

- It has been used to carry out coastal hydrodynamic studies, not only by Universities but also by private companies.
- It's opensource software, so we can change the code when we like.
- It has a very structure code, which allow us a greater understanding of how it's work.

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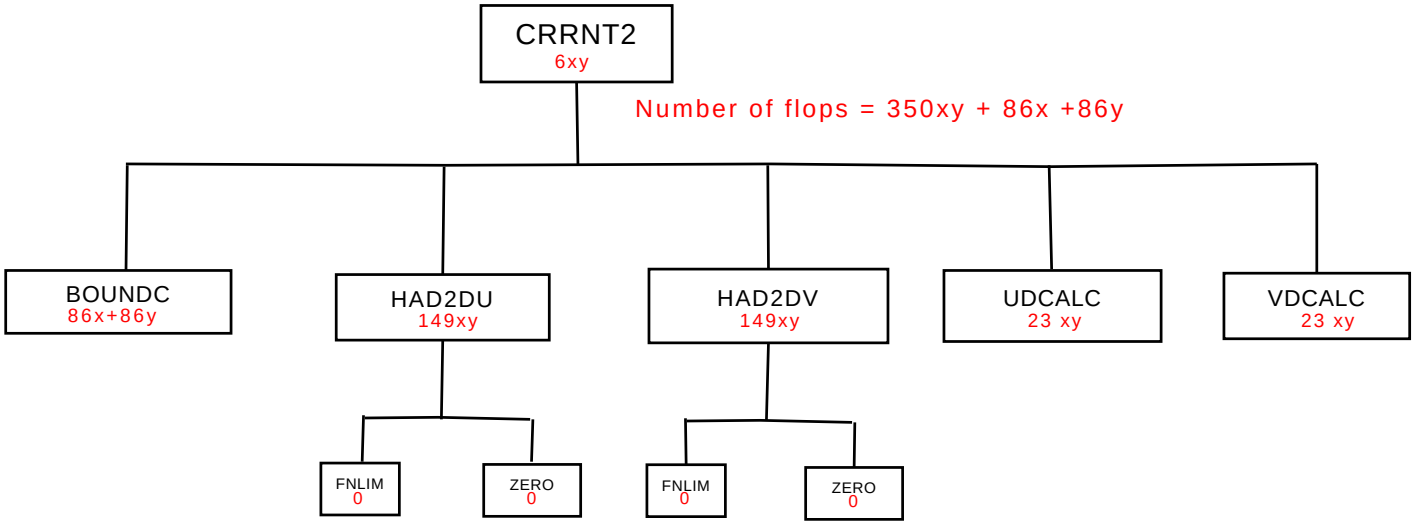
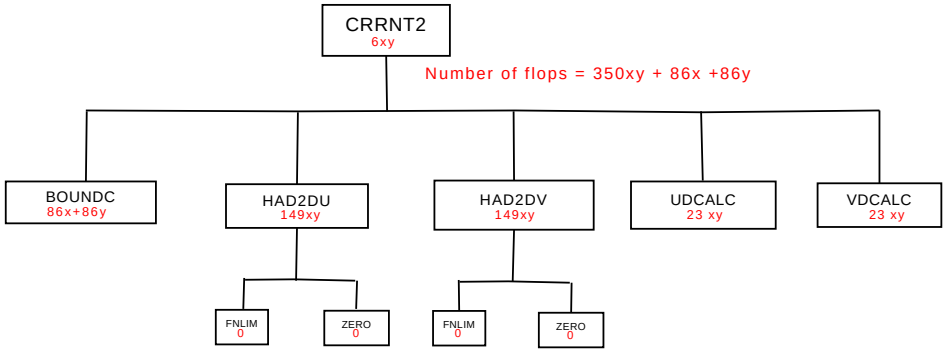
Loop from subroutine HAD2DV cost (8 flops) = 7 xy + y

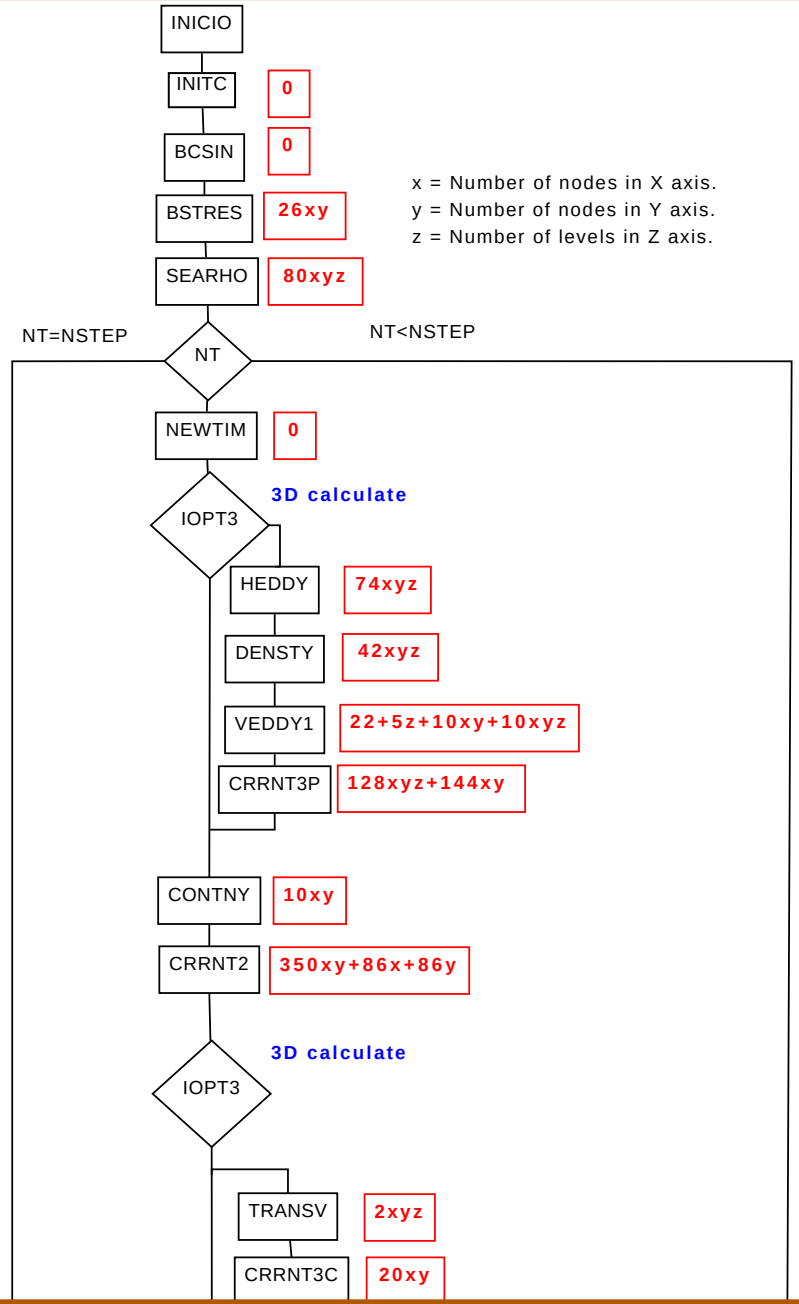
```
      do i=2,nc
      do  j=1,nr
       if (npix(j,i).eq.1) then
        ud2(j,i) = dheddyvu(j,i)*((vd2atc(j,i)/h2atc(j,i)
     1                -vd2atc(j,i-1)/h2atc(j,i-1))/gx2u(j,i)
     2                +sphcur(j)*ud2(j,i)/h2atu(j,i))

       endif
       end do
      end do
```

Cost of the function CRRNT2 = 350 xy + 86 x +86 y



Cost Analysis





Why OpenMP?

- The parallelization in shared memory is the easier to apply in codes with a great number of loops and in multicore systems.
- Multicore systems are widely used: used: they are on nodes of supercomputers and clusters, and also on laptops and desktops.
- OpenMP is simple to implement in the code.

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Example of paralell code

```
c$omp parallel
c$omp& private (i,j,ydifv,xdifv,ydifu)
c$omp do
      do i=1,nc
      do j=2,nr
       if (npiy(j,i).eq.1) then
        ydifv = (ydiflv(j,i)-ydiflv(j-1,i))/(gy2v(j)*cosphiv(j))

        xdifv = 0.5*(xdiflv(j,i+1) + xdiflv(j-1,i+1) -
     1               xdiflv(j,i)   - xdiflv(j-1,i))/gx2v(j,i)
        if (i.eq.1) then
         ydifu = (ydiflu(j,i+1) - ydiflu(j,i))
     1           /(0.5*gx2v(j,i+1)+1.5*gx2v(j,i))
        elseif (i.eq.nc) then
         ydifu = (ydiflu(j,i) - ydiflu(j,i-1))
     1           /(0.5*gx2v(j,i-1)+1.5*gx2v(j,i))
        else
         ydifu = (ydiflu(j,i+1) - ydiflu(j,i-1))
     1           /(0.5*(gx2v(j,i-1)+gx2v(j,i+1))+gx2v(j,i))
        endif
        vdh2d(j,i) = ydifv + xdifv + ydifu
        vdh2d(j,i) = vdh2d(j,i) + sphcurv(j)*
     1      (0.5*(xdiflu(j-1,i)+xdiflu(j,i))
     2       -2.0*sphcurv(j)*dheddyvv(j,i)*vd2(j,i)/h2atv(j,i))
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Paralellizated three types of loop with diferents flops number, 3f, 8f and 19f, and execute in 4 systems:

- Rosebud:4 itanium dual core. 8 cores. Polytechnic University of Valencia.
- Hipatia : 2 Xeon E5462 quad-core. 8 cores. Polytechnic University of Cartagena.
- Ben : HP Integrity Superdome. 128 cores. Supercomputing Center of the Fundación Parque Científico of Murcia
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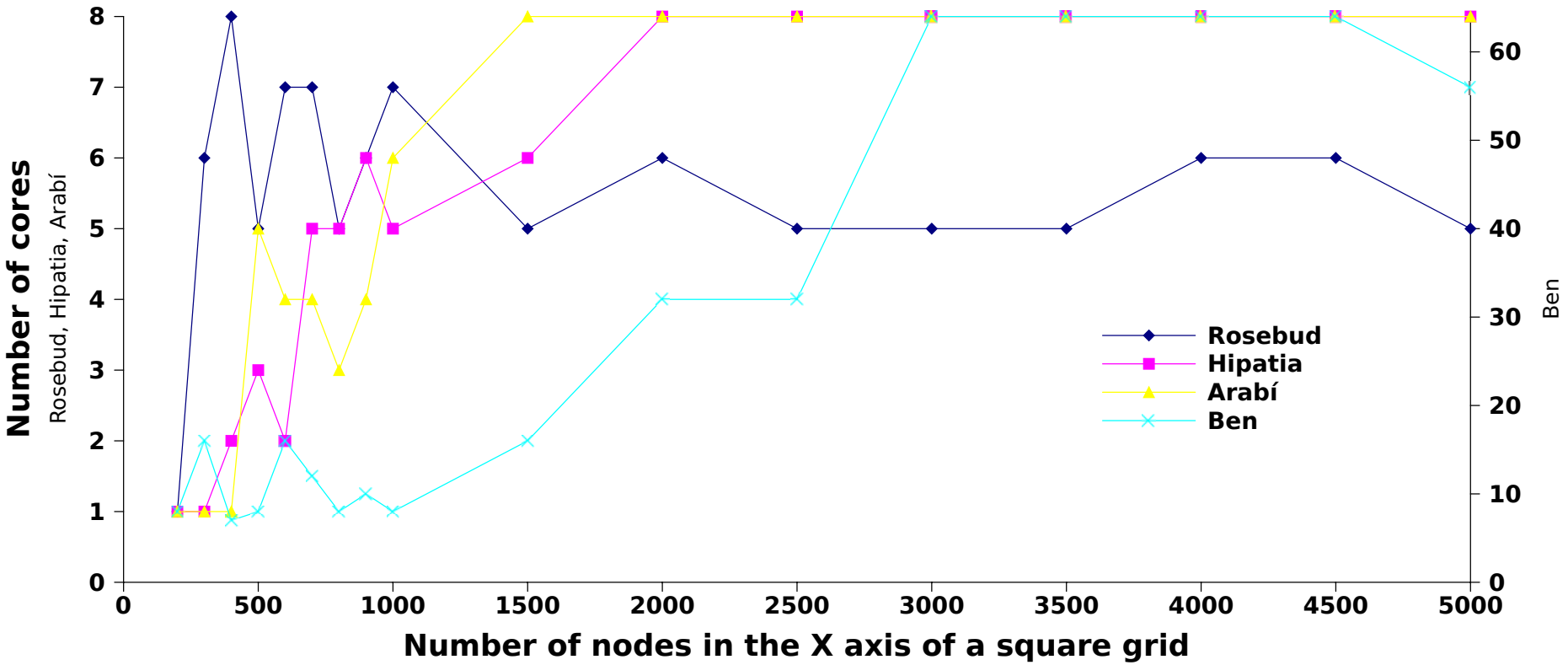
Optimum core number for different systems and size problem



```
call omp_set_num_threads(14)
c$omp parallel
c$omp& private (i,j)
c$omp do

       do i=2,nc
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        if (npix(j,i).eq.1) then
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Empiric time model

Carrying out various test with different size problem, we will be able to determine the optimum core number in each of the test carried out. This data will represent a cloud of point. Making a regression we can get the empirical equation.

$$Core = \alpha + \beta X + \gamma Y$$

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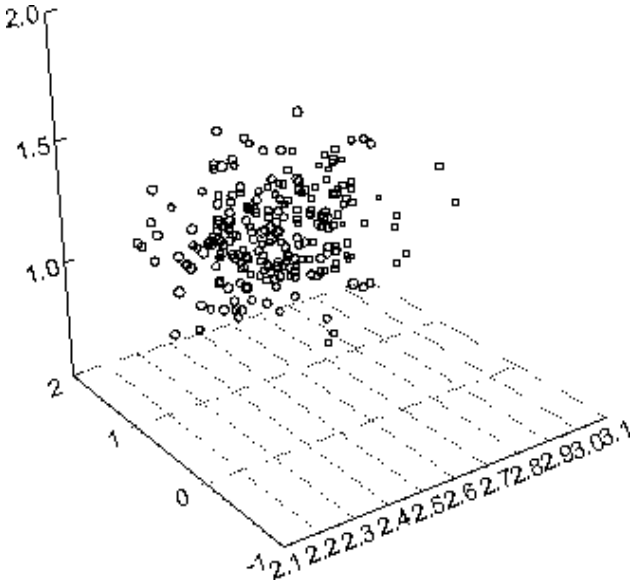

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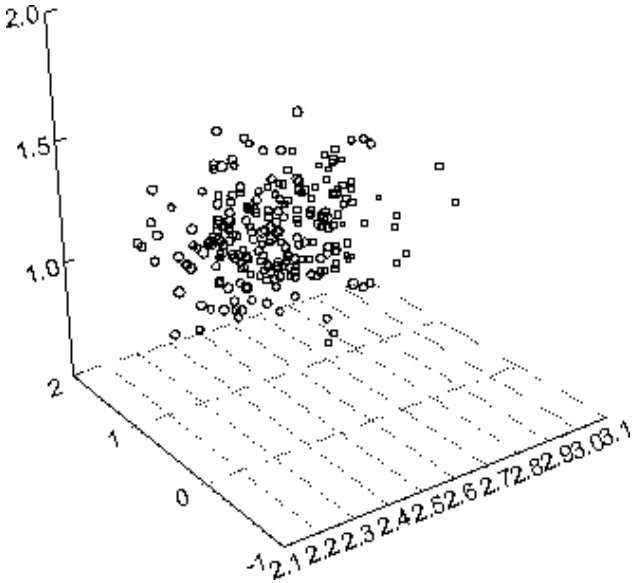

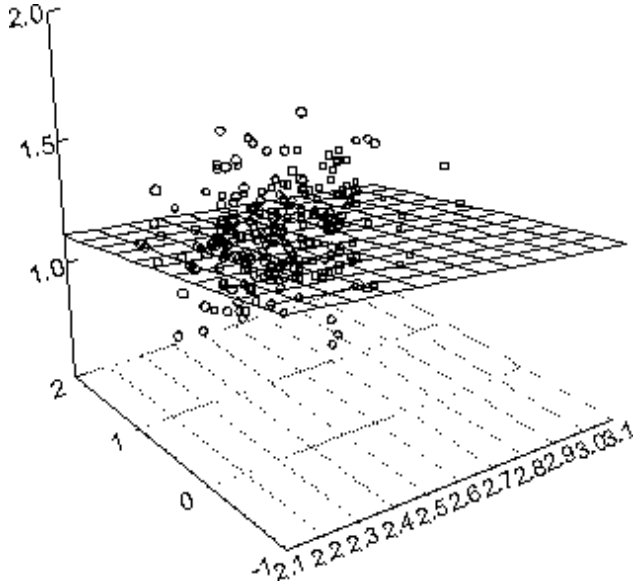

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Test during installation

During installation some experiments for representative problem sizes can be carried out to determine the number of cores on each loop. The optimum number of cores will be determined at running time for each loop and from the problem size (experimented at installation time) closest to that of the problem being solved.

Problem Size	Optimum Core	Problem Size	Optimum Core
200	1	2000	8
300	1	2500	8
400	2	3000	8
600	3	3500	8
800	5	4000	8
1000	7	4500	8

Adaptative code

Obtain the optimum number of cores for each loop at running time.

- In the first time step, get the time execution with 1 core (t1).
- In the second time step, get the time execution with 2 core (t2).
- If t2 >t1, the optimum core number = 1. Stop adaptation.
- If t2<t1 continue with 3 core in the third time step, and compare if t3 > t2

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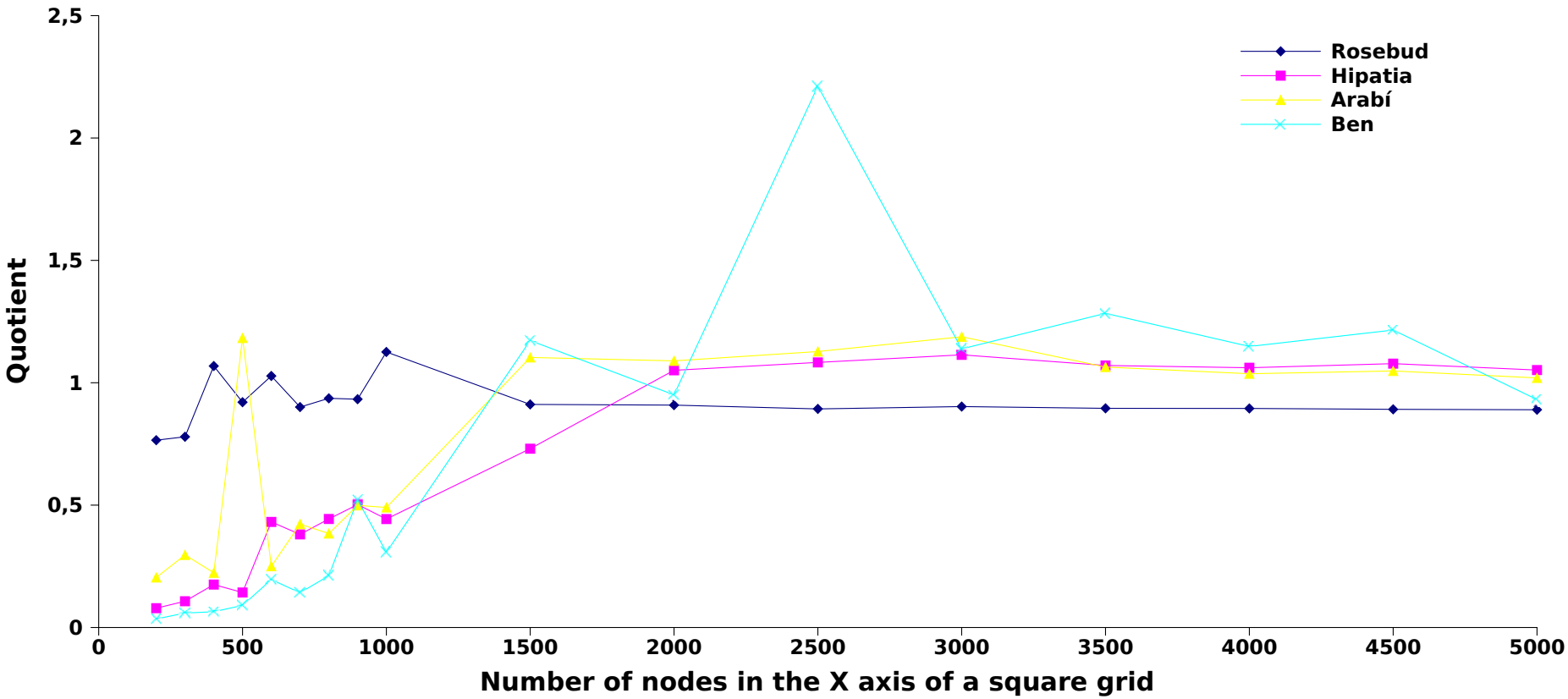
Mixed Strategies

Very important in system with a large number of cores. We know where to start to look for.

Empiric Time Model + Adaptative code



Values lower than 1 in the Y axis, indicate execution times better than those using the complete system.

Conclusions

- OpenMP can be easily used for development and auto-optimization of massively simulation codes for shared memory systems.
- The methodology has been analysed with COHERENS, but it can be used in other packages with a similar structure.
- The strategies explained is applicable to a wide range of systems.
- The use of all the core avaible don't ensure us that we are getting the lower execution time.
- The tests carried out show the importance of having incorporated auto-optimization strategies for our parallel code which assure us that our computational time is near the optimum of our system.
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Thank's a lot

Presentation done with:

LaTeX