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A Novel Parallel Approach for 3D Seismological Problems

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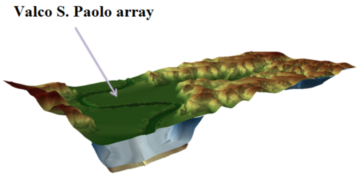
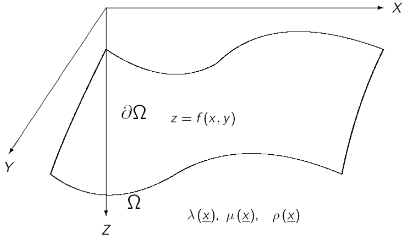
Mathematical description of the geological site



(a) The geological site



(b) The mathematical domain

INITIAL BOUNDARY VALUE PROBLEM

$$
\begin{cases}
\rho(\mathbf{x})\dfrac{\partial^2 \mathbf{u}}{\partial t^2} = \nabla \cdot \sigma + \mathbf{F}(\mathbf{x}, t), \qquad \forall(\mathbf{x}, t) \in \Omega \times (0, +\infty),\\
\sigma = (\lambda(\mathbf{x}) + \mu(\mathbf{x}))\,\nabla \mathbf{u},\\
\mathbf{u}(\mathbf{x}, 0) = 0, \qquad \forall \mathbf{x} \in \Omega,\\
\dfrac{\partial}{\partial t}\mathbf{u}(\mathbf{x}, 0) = 0, \qquad \forall \mathbf{x} \in \Omega,\\
\dfrac{\partial}{\partial \mathbf{n}}\sigma(\mathbf{x}, t) = 0, \qquad \forall(\mathbf{x}, t) \in \partial\Omega \times (0, +\infty),
\end{cases}
$$

Numerical Approach

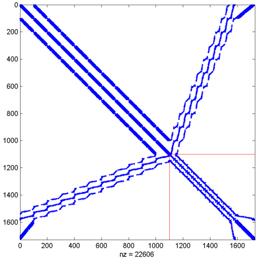
1. **Non structured mesh on the integration domain**
   - Numerical reconstruction of the energy shearing processes;
   - Full agreement between interfaces and elements;

2. **Numerical Discretization**
   - **FEM**: Finite Element Method;
   - Newmark Method

$$A\underline{\ddot{U}}^{n+1} = \underline{b}^{n+1} \tag{1}$$

BLOCK MATRIX PROPERTIES

- Sparse
  ⇒ *optimized C.S.R. Format;*



- Symmetric Pattern;
- Diagonally Dominant a.e.
  ⇒ *Gauss-Seidel Method.*

The Reason of Parallel Approach

Modelling Seismological IBVP more and more realistic

$$\Downarrow$$

- Wider Domains
- High Frequencies
- Dissipation

$$\Downarrow$$

- More Elements
- Higher Computational Cost

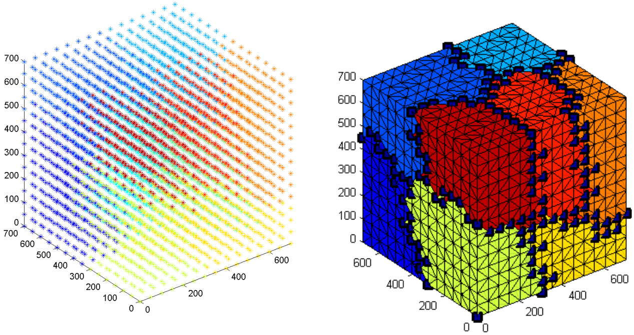
Parallel Approach

1. Distributed Memory $\Rightarrow$ **M.P.I.** on CASPUR Cluster MATRIX (320 nodes);
2. Domain Decomposition:

MeTiS

`http://glaros.dtc.umn.edu/gkhome/node/105`

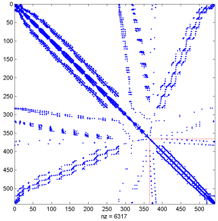
Let us consider an homogeneous cube with side $L = 700$ m, $v_{min} = 1600$ Km/s and $f_{max} = 15$ Hz, discretizated by 3375 nodes connected by 16464 tetraedra, distributed on 10 subdomains.



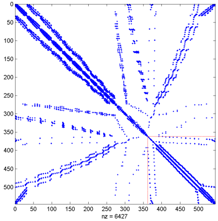
(c) Node Partition

(d) Element Partition

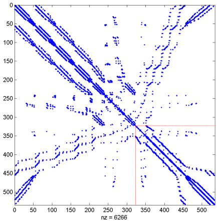
Figure: MeTiS distribution



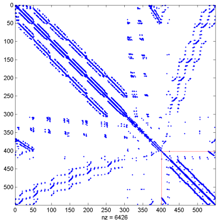
(a) Processor 0 mass matrix



(b) Processor 1 mass matrix



(c) Processor 2 mass matrix



(d) Processor 3 mass matrix

Figure: Local Mass Matrices by 4 processors

Speed up

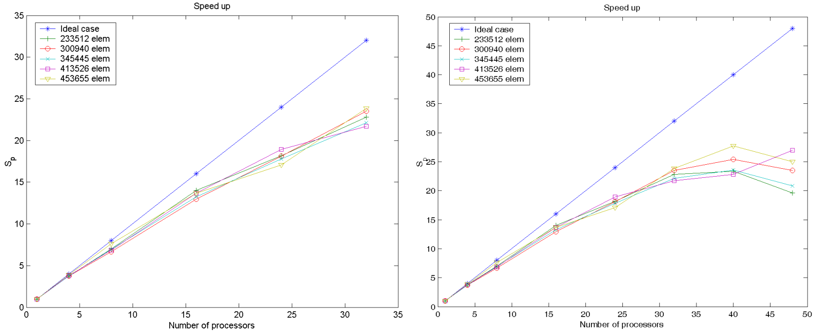
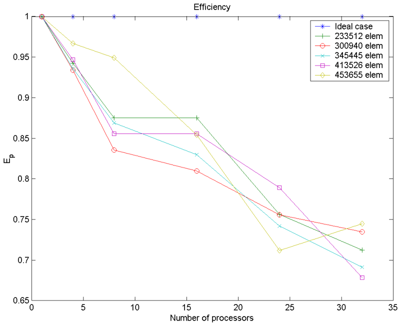


Figure: Speed up: $S_p = \frac{T_1}{T_p}$

Efficiency



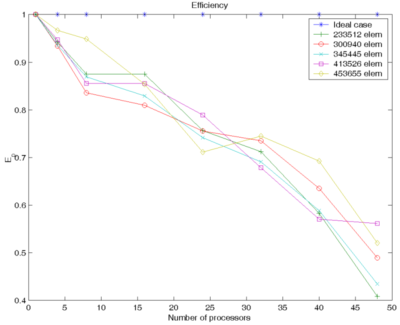


Figure: Efficiency: $E_p = \dfrac{S_p}{np}$

The parallel algorithm can be split in 3 phases.

I data distribution and node reordering;

II assemblage of matrices using the optimized CSR format;

III time integration and linear system solver.

TABLE: Parallel performance on 453.655 elements.

PART	1 PROC	4 PROC	8 PROC	16 PROC	24 PROC	32 PROC
I	177.7665	23.9192	15.01584	13.03564	12.77283	13.12143
II	51.2128	5.82255	2.51800	1.03282	0.62755	0.47853
III	2140.091	627.961	389.342	205.041	152.33111	114.364

The table reports the time (in seconds) spent by a processor to execute a part of the algorithm.

Remarks.

Most of the time is spent on node reordering and reconstruction of the global solution.

Future Work

- Assemblage of global solution in the overlapping nodes
- Scalability
- Simulations with real topography