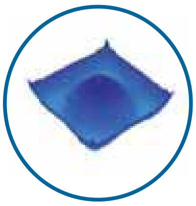
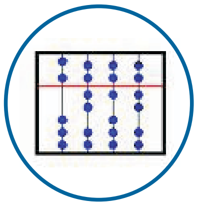
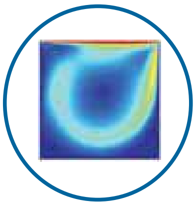
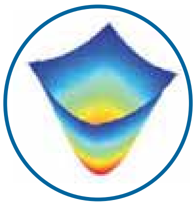
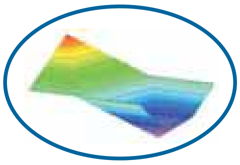
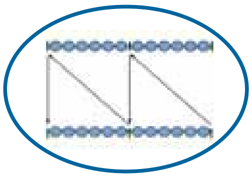
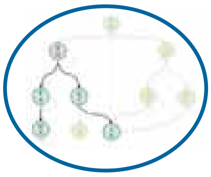
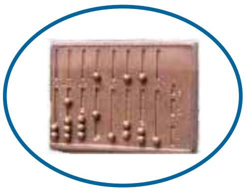
SNE SIMULATION NEWS EUROPE


Special Issue

Parallel and Distributed Simulation Methods and Environments

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Journal on Developments and Trends in Modelling and Simulation

Special Issue

ARGESIM

Dear readers,

We are glad to present the first SNE Special Issue - a Special Issue on 'Parallel and Distributed Simulation Methods and Environments'. The idea for special issues was born in ASIM, the German Simulation Society. As there was and as there still is a need for state-of-the-art publications in topics of modelling and simulation, ASIM first tried to publish monographs on this subject. But publication of such books showed disadvantages: too slow production time, too high costs, and lack of publication issues. ASIM, seeking for alternatives, contacted ARGESIM with the idea of SNE Special Issues - while ARGESIM itself thought on Special Issues, because of lack in publication space in the regular SNE issues. Now, one year after the first contact, we can present the first Special Issue, edited by Thorsten & Sven Pawletta from University Wismar, Germany.

The editorial policy of SNE Special Issues is to publish high quality scientific and technical papers concentrating on state-of-the-art and state-of-research in specific modeling and simulation oriented topics in Europe, and interesting papers from the world wide modeling and simulation community. This Special Issue 'Parallel and Distributed Simulation Methods and Environments' (SNE 16/2), will be sent to all ASIM members - together with the regular SNE 16/1 (SNE 46), and sample copies will be sent to other European Simulation Societies; furthermore, it is available on basis of an individual subscription of SNE - SNE Special Issues are open for everybody, for publication and subscription (not only for ASIM). We think also on Special Issues publishing selected papers from EUROSIM conferences.

We hope, you enjoy this Special Issue, which presents state-of-the-art in parallel and distributed simulation, from theory with lookahead formulas via implementation with HLA and other systems to applications in ship desgin and blood flow simulation.

It is planned to publish a SNE Special Issue each year, for 2007 a Special Issue on 'Verification and Validation' (Guest Editor Sigrid Wenzel, University Kassel) is scheduled (SNE 17/2). I would like to thank all people who helped in managing this first Special Issue, especially the Guest Editors, Thorsten and Sven Pawletta from Wismar University.

Felix Breitenecker, Editor-in-Chief SNE; *Felix.Breitenecker@tuwien.ac.*at

Content

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ARGESIM Benchmark on Parallel and Distributed Simulation

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This new ARGESIM Benchmark addresses benefits of parallel and distributed computing in the area of continuous, discrete, and hybrid simulation and in related areas. The benchmark may be of interest for users of all types of parallel and distributed facilities. The spectrum may range from parallelisation strategies and strategies for distributing tasks, via general purpose programming languages to simulation languages, andfrom networks of workstations, via special parallel computers, to very high performance computers.

Introduction

In 1994, ARGESIM has set up the *ARGESIM Comparison on Parallel Simulation Techniques* (CP1). There, three test examples have been chosen to investigate the types of parallelisation techniques best suited to particular types of simulation tasks. The new *ARGESIM Benchmark on Parallel and Distributed Simulation* (CP2) extends the previous comparison, addressing not only simulation software and predefined given algorithms, but also allowing use of different algorithms for solving the tasks and comparing different strategies for parallelisation or distribution of the tasks.

1 Contribution to the Benchmark CP2

The *ARGESIM Benchmark on Parallel and Distributed Simulation* tests benefits of parallel and distributed simulation with three case studies:

- Monte Carlo - Study
- Lattice Boltzmann Simulation
- PDE Solution

Participation at this benchmark requires:

- Documentation of the algorithms for solving the case studies (one or more algorithms)
- Documentation of the strategy for parallelising or distributing the case studies (one or more strategies)
- Serial solution of the case studies
- Parallel / distributed solutions of the case studies
- Determination and documentation of efficiency of parallelisation

In detail, a contribution to this benchmark should for each case study describe first the approach or the algorithms for calculating solutions, followed by information about the method of parallelisation or distribution of tasks and subtasks. It is highly appreciated, if more than one solution for a particular case study is given, either using different parallelisation strategies or strategies for distribution, or by using different hardware environments, or by using different algorithms for calculating solutions. In the following, results of the case studies should be presented, based on a comparison of a serial solution and the parallel / distributed simulation of each case study.

For quantitative comparison of serial solution and parallel or distributed solutions, performance should be assessed in terms of the relative speed-up factor, a numerical value found by dividing the time for serial solution by the time for the parallel solutions (speed-up factor ***f***). Measurements of time, whenever necessary, should be in terms of the total elapsed time for running the task. Furthermore, a rough indication should be provided for the (time) effort for implementing a parallel or distributed simulation (at best compared with implementation time for the serial solution).

Contributions to this benchmark will be published in the journal SNE – *Simulation News Europe*. Solutions sent in should not exceed three SNE pages and will be reviewed by the editorial board and by authors of the benchmark.

2 Case Study 1 – Monte Carlo Study

The first case study is a Monte Carlo study. In a damped dynamic mass – spring system the damping factor is randomly disturbed, and the mean of a sample of dynamic outputs is to be calculated.
The second order mass-spring system is described by the following ODE, where the damping factor d should be chosen as a random quantity uniformly distributed in [800, 1200]:

$$m\,\ddot{x}(t) + d\,\dot{x}(t) + k\,x(t) = 0$$

$$x(0) = 0,\ \dot{x}(0) = 0.1,\ k = 9000,\ m = 450$$

The task is to calculate a sample of M = 1000 results $x(t, d_i)$ of the motion (Figure 1 shows $x(t,1000)$) and to calculate the mean motion $x_{mean}(t)$ over the time interval [0, 2] with a resolution (stepsize) of 0.01 (n = 200 steps):

$$x_i(t_j) = x(t, d_i), \quad j = 0,\ldots,n,\ i = 1,\ldots,m$$

$$x_{mean}(t) = \frac{1}{M}\sum_{k=1}^{M} x_i(t_j)$$

As the model is a linear one, the solution can be provided also analytically, not only by using an ODE solver:

$$x(t,d) = Ke^{-\alpha t}\sin(\omega t)$$

$$\alpha = \frac{d}{2m},\ \omega^2 = \frac{k}{m} - \alpha^2,\ K = \frac{\dot{x}(0)}{\omega}$$

While the ODE may be basis for a parallelisation of the varying damping factor, the analytical formula may be a basis for parallelisation of the 201 time instants, where a solution is to be calculated.

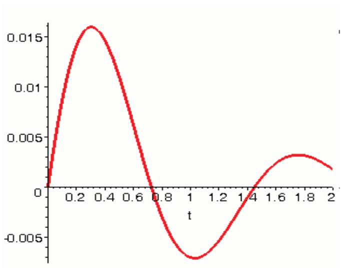

Figure 1: Plot of the analytical solution of the second order mass – spring system with $d = 1000$.

For documentation, we ask for a precise description of the parallelisation strategy used, and for comparison of the solutions we ask for a plot of the mean motion $x_{mean}(t)$ and of values for the speed-up factors $\boldsymbol{f}$.

3 Case Study 2 – Lattice Boltzmann Simulation

The second case study addresses the lattice Boltzmann method (LBM) for fluid flows, which is widespread in parallel simulation domains today. The method is derived from lattice gas cellular automata in which space, time, particle velocity and particle occupation state are all discrete. In LBM, particle occupation state on nodes is replaced by single-particle distribution functions (real values).

The case study is based on the famous cavity flow problem published by Hou et al in J. Comput. Phys. 118 (1995), where the behaviour of an incompressible fluid in a square enclosure, driven by a constant stream on the top boundary is examined (see Figure 2).

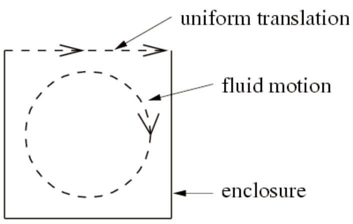

Figure 2: Lid-driven cavity flow.

For a description of the geometry matrix g, cell types are divided into wall cells (W), driving cells (D) and fluid cells (F). For a lattice size of 2x2, g is given at right.

$$g_{2,2} = \begin{pmatrix} D & D & D & D \\ W & F & F & W \\ W & F & F & W \\ W & W & W & W \end{pmatrix}$$

The uniform translation on top of the cavity is given as $u_{0x} = 0.1$, $u_{0y} = 0$, where the Reynolds number is $Re = 1000$. At any grid point, the initial macroscopic velocity is $u_x = 0$, $u_y = 0$ and the initial density is $\rho = 1$.

The task is, to simulate the cavity flow with lattice size 257 x 257 for a number of 350.000 iterations. After this number of iterations, steady state is reached. Simulation results are shown in Figure 3.

For documentation, we ask for a precise description of the parallelisation strategy used, and for comparison of the solutions we ask for a plot of relative macroscopic velocity magnitudes (u/u_0) at steady state and for values of the speed-up factors $\boldsymbol{f}$ (please note, that also a serial solution is necessary for this purpose).

A problem discussion in detail and links to sequential reference implementations as well as to introductory materials for the lattice Boltzmann method are provided at WWW.MB.HS-WISMAR.DE/cea/lbm.

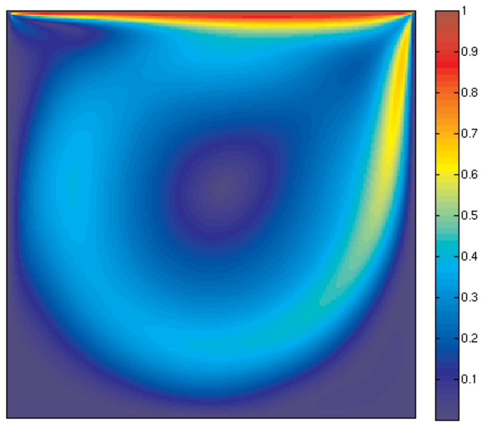

Figure 3: Relative macroscopic velocity magnitude (u/u_0) in cavity flow after 350000 iterations on a 257x257 grid.

4 Case Study 3 – Solution of a Partial Differential Equation

The third case study is based on a second order partial differential equation describing a swinging string with length L, fixed at both ends, excited at the beginning (surface plot shown in Figure 4):

$$u_{xx}(t,x) = \frac{1}{v^2}u_{tt}(t,x)$$

$$u(0,t) = u(L,t) = 0, \quad u_t(x,0) = 0$$

$$u(0 \le x \le \frac{L}{2},0) = 2\frac{h}{L}x, \; u(\frac{L}{2} \le x \le L,0) = 2h(1-\frac{1}{L}x)$$

$$v = 0.6, L = 0.5, h = 0.05$$

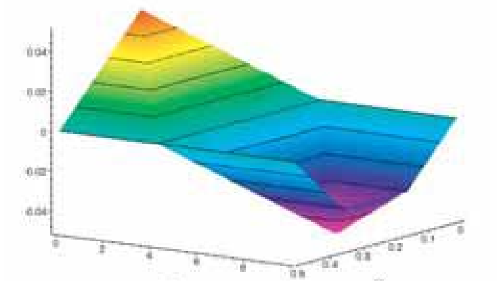

Figure 4: Surface plot for the swinging string – excitation in dependency of space and time.

One approach for solving this PDE is the method of lines, using discretisation of space. Discretising the space into N equidistant intervals and replacing the differential quotient $u_{xx}(t,x)$ by a central difference quotient, a set of weakly coupled ODEs replaces the PDE:

$$\frac{k^2}{v^2}\ddot{u}_i(t) = u_{i-1}(t) - 2u_i(t) + u_{i+1}(t), i = 1, N-1$$

$$u_i(0) = 2\frac{h}{N}i, \; i = 0,\ldots,\frac{N}{2},$$

$$u_i(0) = 2h(1-\frac{i}{N}), \; i = \frac{N}{2},\ldots,N, \quad \dot{u}_i(0) = 0$$

Also an analytical solution (approximation) can be calculated because of linearity. A classical separation approach $u(t,x) = X(x)\,T(t)$ can be used for calculating the solution. This yields with given initial and boundary conditions a solution with a Fourier series ([3]; Figure 5 and Figure 6 show lines in x and t, calculated with Fourier series cut at 100 summands):

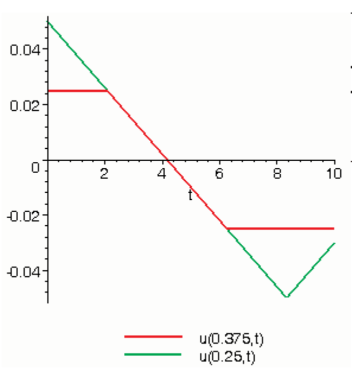

Figure 5: Solution of the PDE, excitation over time at $x = 0.375$ and $x = 0.25$.

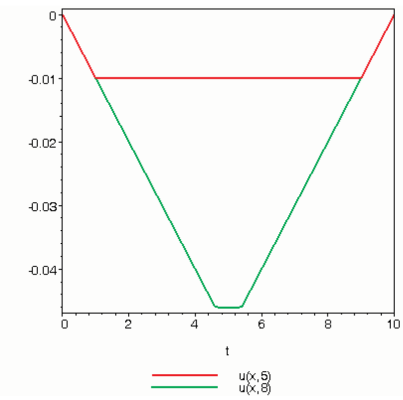

Figure 6: Solution of the PDE, excitation over space at $t = 5$ and $t = 8$.

$$u(x,t) = \frac{8h}{\pi^2}\sum_{j=0}^{\infty}\frac{(-1)^j}{(2j+1)^2}\sin\left(\frac{(2j+1)\pi x}{L}\right)\cos\left(\frac{(2j+1)\pi v t}{L}\right)$$

In principle, also discretisation of space and time may be suitable. For instance, using for space discretisation a central difference quotient as in method of lines, and using for time backwards difference quotients (as well for PDE and for initial condition) yields a linear system for $u(t_k, x_i)$, which may be parallelised for solution.

Of course, other algorithms for solving the PDE may be used, with varying grids etc, which can be parallelised / distributed appropriately.

In general, the system is to be solved with a spatial discretisation of $N = 500$ lines at the interval [0, 10] with time discretisation of 0.01s ($m = 1000$). For documentation, we ask for a precise description of the parallelisation strategy used, and for comparison of solutions we ask for plots of the lines $u(x{=}3L/4, t)$, $u(x{=}L/2, t)$ and $u(x, t{=}15)$, $u(x, t{=}30)$, and of a surface plot (excitation versus space and time). Furthermore, values for the speed-up factors f should be given.

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