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Objekttyp: **Article**

Zeitschrift: **Helvetica Physica Acta**

Band (Jahr): **62 (1989)**

Heft 6-7

PDF erstellt am: **26.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-116161

Connection of parallel computers using Navier-Stokes-equation for data flow optimization

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Abstract

The Navier-Stokes equation (NSE) can be derived from the principle of least action, that means liquid particles in a field of forces are moving with least action. It will be examined, if — instead of liquid particles in a field of forces — datas can stream in a field of computers. The resulting self-organisation would have to be an optimal connection of data sources and sinks. The NSE can be solved numerically and globally or asynchronously and locally.

1 Introduction

The idea of applying the principle of least action on tranport problems in a computer-network is not new. Like shown in [1] it is more appropriate to use the Navier-Stokes-Equations (NSE) to calculate the optimal field of velocity vectors rather than using the Lagrangian equations of motion for each data packet. Each term of the NSE must be interpreted conveniently if one wants to get a fluid-like behaviour of the data stream (tab. 1).

Variable (NSE)	Meaning at computer network	choosen relation for simulation
external force $\vec{F}$	mean destination of datas	$\lvert\vec{F}\rvert \sim \sum(\text{destination}) - \sum(\text{position})$
pressure p	nonlinearly depends on number of datas	$p \sim \rho^2$
velocity $\vec{v}$	probability for data transport in direction $\vec{n}$	probability $\sim \vec{v} \cdot \vec{n}$
viscosity η	gives typical length scale of the network	100
density ρ	gives typical time scale of the network	2.5

Table 1: Analogies between parameters in the NSE and the computer network

The idea of optimal transport could also be applicated in telephone systems or the traffic management. Self-organizing systems like our field of parallel computers need no superior management device and can deal very flexibly with changing conditions.

What we want to show in this paper is, that the mechanism of self-wiring also works when no global variable is used in the network and if the each computers has a slightly different speed.

Example: Bénard's Problem

In our simulation we produce datas with the target-adress 'top'; arrived on the top they get the adress 'bottom'. Fig. 1 shows the results of a typical simulation run.

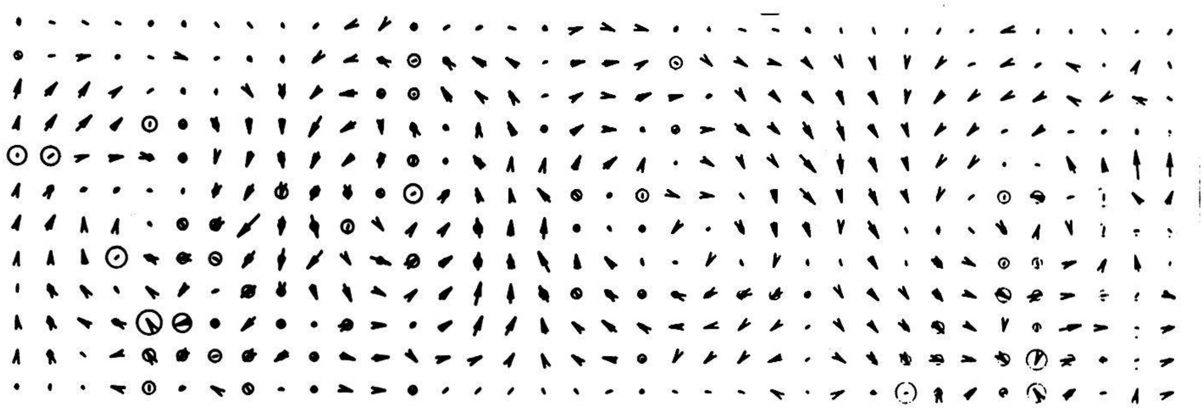

Figure 1: convection rolls at the Bénard-problem with $\rho = 2.5$, $F_0 = 10$, $p_0 = 5$, $\eta = 100$ after 2000 time steps ($\frac{dt}{dx} = 0.001$). Each time step two datas were generated. Data transportation was suppressed if the absoulte value of the velocity was < 0.2 . Plotted are the relative velocities (arrows) and data concentrations (circles) at each grid point of a $12x36$ matrix

2 Asynchronous Control

For practical applications it is not always possible to realize a synchronous calculation of the velocity field. Recently [4] it has been shown that — even for binary cellular automata (e.g. Game of Life) — some of the global characteristics of the dynamics of the field are retained when the asynchronicity is not too big. If the states of the cells are reals numbers, the effect of synchronicity should not be essential. For small rates (5 %) of asynchronicity we observed no difference to the pictures shown above.

A remaining question is, how cellular automata models for the NSE [3] can be combined with this simulation in order to reduce the necessary computing power in each cell.

We like to thank O. Wohofsky, A. Hayd and P. Meinke for their continuos support. This work was supported in part by MAN.

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