Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

NLR TP 96424

NICE: do-it-yourself flow solutions for engineers and scientists

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TITLE
NICE: Do-It-Yourself flow solutions for engineers and scientists

PRESENTED AT
the International EUROSIM Conference HPCN challenges in telecomp and telecom, Delft, June 10-12, 1996.

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DESCRIPTORS
Computational fluid dynamics
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Netherlands
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Parallel processing (computers)
Software tools
Supercomputers
Technology utilization
Three dimensional models

ABSTRACT
This report contains the presentation of the NICE project at the scientific exhibition at the International EUROSIM Conference HPCN challenges in telecomp and telecom, Delft, June 10-12, 1996.

Summary

This report contains the presentation of the NICE project at the scientific exhibition at the International EUROSIM Conference HPCN challenges in telecomp and telecom, Delft, June 10-12, 1996.

Contents

(6 pages in total)

1 Introduction

In 1996 the NICE project, under a contract of the Dutch HPCN Foundation, started its work to disseminate HPCN in the Netherlands. The NICE project is a consortium of the following partners: National Aerospace Laboratory NLR, Delft Hydraulics, Maritime Research Institute MARIN, TNO-Institute for Applied Physics, J.M. Burgers Centrum (including the Dutch universities TUD, UT and RUG), and the Centre for Mathematics and Computer Science CWI.

Development and use of flow simulation techniques through HPCN is the purpose of the NICE project. The title of this report is motivated by this purpose: in the end state-of-the-art flow simulation techniques developed by scientists and engineers shall be easily attainable for engineers in the application field. Necessary resources shall be easily accessible nation-wide.

The project presented itself at the scientific exhibition at the International EUROSIM Conference HPCN challenges in telecomp and telecom, Delft, June 10-12, 1996. This report contains the presentation in the next chapter. The material of the presentation was delivered by the partners in the NICE project, NLR combined the contributions to the present presentation.

2 The presentation

The panels of the presentation are presented in the following pages.

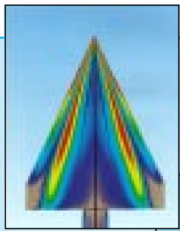
NICE:

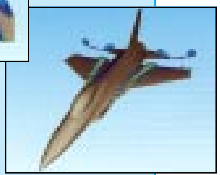
NLR
Air

Apart from the development of HFS NLR is involved in the field of parallel computing in the following subjects.

Parallelization of the flow simulation system ENFLOW.

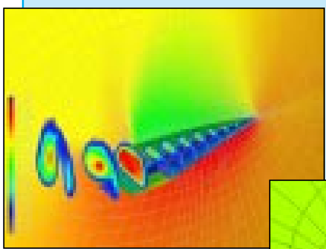
Optimization of use on the newest generation of supercomputers for a wide range of applications.



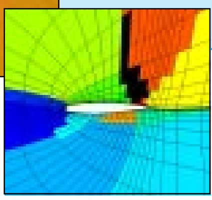


Development of domain decomposition methods for (time accurate) adaptive, unstructured flow solvers.

– *dynamic load balancing*
– *message passing paradigm*
– *balance between integration, adaptation and repartitioning*



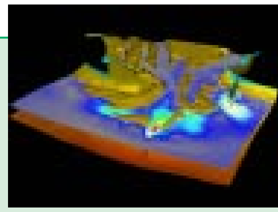
Vortex structure over delta wing computed by adaptive unstructured flow solver



Partitioning of single airfoil by dynamic load balancing tool

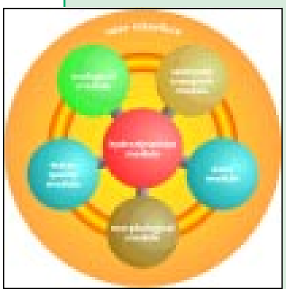
WL
Water

The need to protect the Netherlands against the continuous threat of natural water systems has made 'water' a factor of considerable economic interest. In order to deal with all information required to design, construct, operate and optimize major infrastructural projects, HPCN is becoming an indispensable tool.



Flow field and changes in bottom topography in the coastal area of the Waddenzee (The Netherlands)

The scope of the sector 'Water' is *to realize an interactive information system that is capable of generating and processing information for the optimization of large engineering projects and operations by following an integrated approach of design, construction and environmental impact.*



System components for integrated modeling and design

Activities include
– system definition for system integrity, flexibility and maintainability
– modeling of interactions between hydrodynamics, transport of pollutants and morphodynamics
– development of optimal parallel numerical algorithms

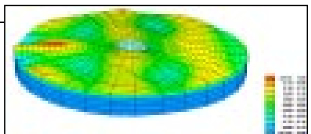
Specific applications are aimed are situations in the Southern Chinese Seas.

Large-scale wave problems

Goals:
– Reducing computational costs and turn-around time of simulations
– Enabling the computation of large-scale wave problems by using massively parallel systems

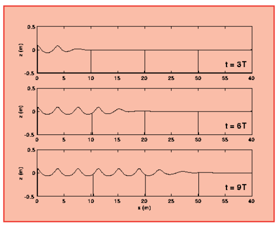
Domain decomposition is a technique which introduces a natural division of the computation and enables the use of parallel processors with more memory.

Results:
– Large speed-up using only a few processors on a heterogeneous cluster
– Possibilities for the application to large-scale wave systems



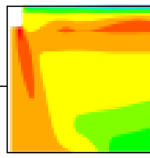
Wave reflecting on offshore structure

Three snap shots of water surface simulated using four subdomains



CWI
HPCN actions

– interactive visualization
– computational steering
– presentation of massive data
– software tools for HPCN
  – dynamic (re)distribution
  – visual parallel programming
  – multi platform coupling
  – massive parallelism
– multi-media and virtual reality support

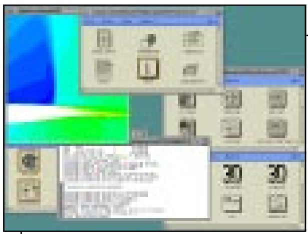


Temperature distribution in heated room

SME benefit from NICE

Biddle BV is an SME specialized in high quality air technical equipment. In close cooperation with NLR and RuG, Biddle develops a new air heater design.
In this way NLR applies proven HPCN techniques to SME's.

do-it-yourself flow solutions for



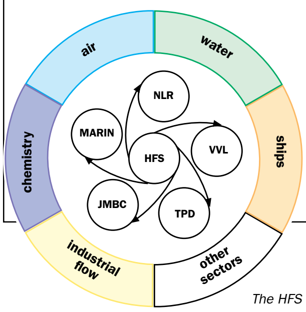
An HFS prototype

Centre for Flow Simulation HFS

HFS is a digital working environment for flow simulation and information exchange.

This common working environment serves four purposes:
– working environment for flow simulations
– public relations
– project management
– knowledge transfer

Each contractor will develop and maintain its own part of the infrastructure. Each of these local infrastructure will be integrated in one large virtual infrastructure.

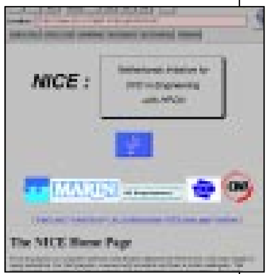


The HFS infrastructure

The Project

Flow simulation on computer systems considerably enhances the effectivity of product design in many industries. For this purpose, commercially available software is often inadequate. The development of suitable simulation systems require thorough knowledge of the physics of flow patterns, a deep understanding of numerical mathematics and powerful computer systems.

The methods for the simulation of different flow types for the different kinds of industries in the Netherlands have a lot in common, but also differ in some crucial aspects. Development of the simulation techniques takes place in large technological institutes, universities and industries.



Detail of NICE home page

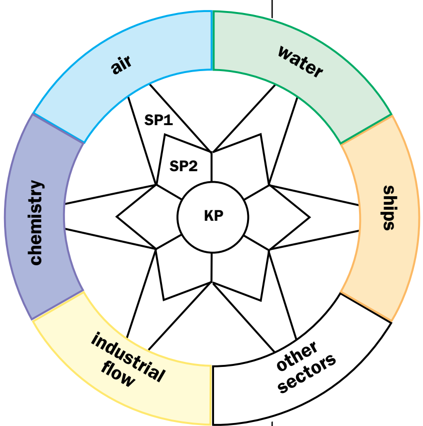
The required powerful computers are available in the Netherlands. However, it is necessary to make these systems available from the different locations where the simulation techniques are developed and applied.

Development and use of flow simulation techniques through HPCN is the purpose of the NICE project.

The NICE project is sponsored by the Dutch HPCN Foundation.

The partners in NICE are active in the following application sectors:

The NICE project works in close cooperation with the industry and important goal is the dissemination of knowledge to SME's.



High performance computers

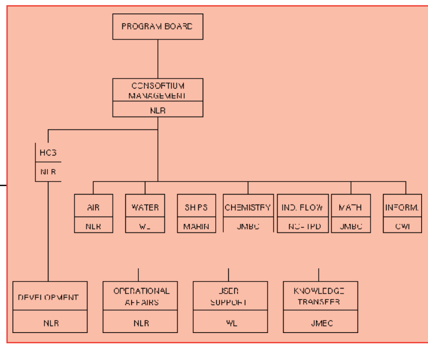
The partners in the NICE project have access to the following supercomputer facilities:

– NEC SX4 with sixteen processors. This is a publicly available shared memory computer with a peak of 32 Gflop/s and 12 GB memory.
– Cray T3E with 64 processors, with 2 to 16 GB/s bandwidth and 128 MB memory per processor.

NEC SX4

For more information please contact: W. Loeve, National Aerospace Laboratory NLR, +31 20 511 3422

You can find us at http://www.nlr.nl/public/projects/nice/



Organogram of NICE

engineers and scientists

Photograph of glass-melting furnace

Simulation of glass-melting furnace

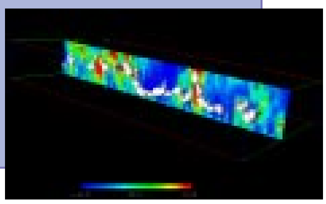
J.M. Burgerscentrum
Chemistry

Supported by HPCN, Philips, Hoogovens and Shell Amsterdam

Motivation: turbulent flows with chemical reactions or fluid-particle interaction are important for many industries and their accurate simulation requires vast computer resources.

Code development concerns LES codes for turbulent flow with reactions, 3D finite volume for high temperature combustion, and 2D finite volume for reacting flow with detailed chemistry and joint probability density functions.

Numerical methods and aspects include scalable, massively parallel solvers including load balancing algorithms, domain decomposition techniques with local grid refinement, and special algorithms for LES, large sets of equations, spectral radiative heat transfer, Monte Carlo representations, and fluid-particle interaction.



LES of reacting flow

TNO-TPD
Industrial flow

WISH3D:
- general purpose CFD code
- flow, combustion, radiation and heat transfer
- process-product interaction
- applications (a.o.) glass, metal and food industry, furnaces, burners and dryers

Parallel WISH3D:
- portability and maintainability more important than performance
- scalability
- distributed memory multiprocessor system
- industrial applicability

Parallelization strategies:

on loop level:
- using PVM/MPI approach
- large programming effort

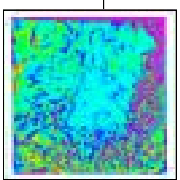
on loop level:
- HPF approach with PREPARE tool
- less programming effort
- parallel compilers not mature (yet)

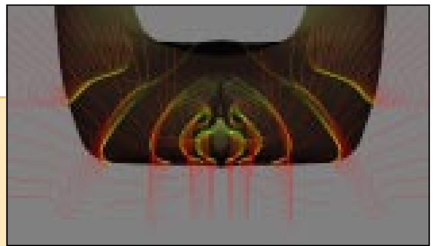
domain decomposition:
- PVM/MPI approach for SPMD
- system specific routines isolated
- lowest amount of data exchange
- can be combined with local grid refinement

RuG
DNS rushes at full scale turbulence

Stormy developments in algorithm development will shortly allow direct numerical simulation (DNS) of fully developed turbulent flow at engineering Reynolds numbers. DNS resolves all the length and time-scales of the flow, without a need for turbulence modeling. Current state-of-the-art algorithms already permit simulation of internal flows at a Reynolds number of 100,000.

The figure shows a snapshot of the vorticity distribution in a three dimensional cavity, driven from left to right by the upper lid. Use of fourth-order space discretization allows full resolution with a 'mere' 10 million grid points. The whole computation fits within 1 GB of memory and was performed at SARA's Cray C90 (with support from NCF).





Flow about a ship

MARIN
Ships

At MARIN the viscous flows around ship sterns sailing at constant speed in still water is computed with the CFD tool PARNASSOS, solving the parabolized Navier-Stokes equations.

Within the NICE project a domain decomposition method will be developed. This will allow for application to *a wider variety of ship geometries* and for *local grid refinement*. New applications will include appendages to ship hulls, and appendages to locally influence the flow.

Domain decomposition will be achieved using a Schwarz iteration method on the level of subdomain blocks. A flexible coupling strategy will optimize the convergence speed.

The figure indicates streamlines of the flow along the bare hull of a ship. It clearly shows the formation of a vortex along the hull, coming off the stern.