Physics and the HECToR HPC Service / NAG product update

Craig Lucas

The Numerical Algorithms Group Ltd

craig.lucas@nag.co.uk

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- HECToR
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HECTOR

So what is HECToR?

- Latest high-end academic computing service for UK
  - After CSAR (1996–2006) and HPCx (2002-2010)
  - **H**igh **E**nd **C**omputing **T**erascale **R**esource
  - Managed by EPSRC on behalf of RC-UK
  - Funded by EPSRC, NERC & BBSRC
  - Will run from 2007-2013

HECToR

- Objective:
  - To provide a service to the academic community enabling it to do true capability science
- Partners:
  - Service Provision: UoE HPCx Ltd (EPCC)
    - hardware hosting and maintenance
    - user services, helpdesk, etc
  - Hardware: Cray Inc
  - Computational Science & Engineering Support: NAG Ltd

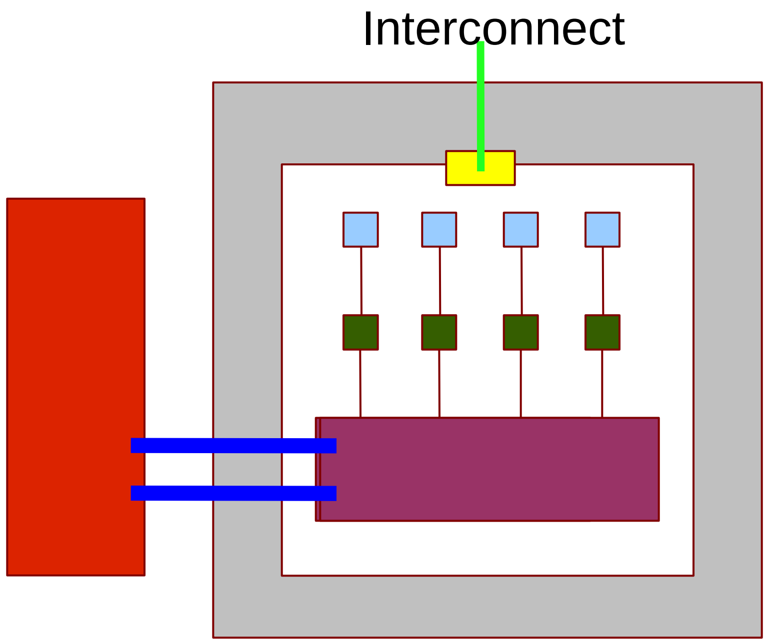
Hardware Solution

- Phase 1 (16 October 2007 – 2009)
  - Cray XT4 (63 Tflops) – 5664 dual core Opterons
  - Cray X2 Vector Processor (2.9 Tflops)
- Phase 2a (June 2009)
  - Cray XT4 (210 Tflops) – 5664 quad core Opterons
- Phase 2b (June – December 2010)
  - New “Gemini” interconnect for XT allow true async comms
  - 12 core processors
  - 2 socket SMP node
- Phase 3 (2011? – late 2013)
  - Contract yet to be awarded

Phase 2a: Cray XT4

- 5,664 compute nodes, i.e. 22,656 cores
- One 2.3GHz quad-core Opteron per node
- 8 GB memory per node, 2 GB per core
- Peak performance of 210 TFlops
  - 22,656 cores * 9.2 GFlops per core, double precision
  - SSE (Streaming SIMD Extensions) instructions
  - 128 bit registers (4 single precision or 2 dp numbers)
  - 2 floating point units, operating on whole registers
  - 2.3 GHz * 2 dp words * 2 units = 9.2 GFlops

Phase 2a: Quad-core nodes



Single core (incl. 64KB L1)

L2 Cache 512KB

L3 Cache 4MB

Quad-core die

AMD Barcelona processor

Hyper Transport port

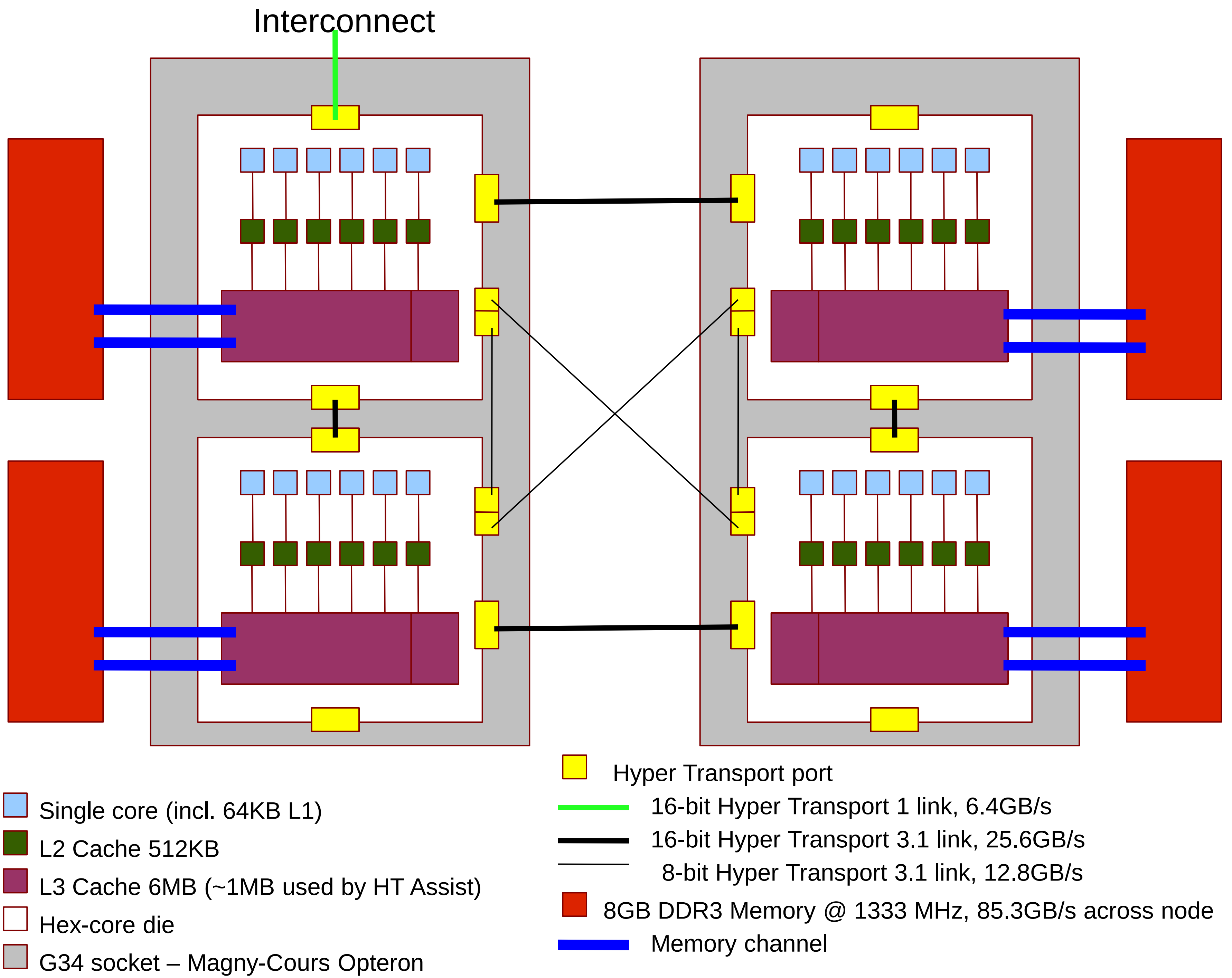
16-bit Hyper Transport 1 link, 6.4GB/s

8GB DDR Memory @ 800 MHz, 12.3GB/s across node

Memory channel

Phase 2b: Cray XT6

- 44,544 cores from 1856 nodes, 2 x 12, 2.1GHz cores.
- 32 GB memory per node, 1.33 GB per core
- Peak performance of around 340 Tflops
- Initially interconnect remains at SeaStar, then upgraded to Gemini by the end of 2010.
- Half of XT4 will remain until this time.
- Gemini will allow one-sided communication in MPI, UPC and **Co-Array Fortran**.


Interconnect
Hyper Transport port
16-bit Hyper Transport 1 link, 6.4GB/s
16-bit Hyper Transport 3.1 link, 25.6GB/s
8-bit Hyper Transport 3.1 link, 12.8GB/s
8GB DDR3 Memory @ 1333 MHz, 85.3GB/s across node
Memory channel
Single core (incl. 64KB L1)
L2 Cache 512KB
L3 Cache 6MB (~1MB used by HT Assist)
Hex-core die
G34 socket – Magny-Cours Opteron

Performance at Phase 2

- Code must vectorize to benefit from the increased (2 dp numbers) SSE registers.
- There is increased contention for the communication network. So users looking at mixed mode or System V for MPI all-to-alls etc.
- Memory per core decreasing, maybe no longer enough for an MPI process on each core.
- Performance likely to be best as 4 6-way SMP, or under populated nodes.

Storage

- Shared by both machines
- 70 TB NAS storage (/home)
  - Backed up
  - Not accessible from the compute nodes
- 864 TB Lustre (/work)
  - High performance parallel filesystem
  - Not backed up
- Moving to eLustre.
- Archive facility (finally!)

XT Software Environment

- OS:
  - UNICOS/lc
    - SuSE Linux on login nodes
    - Compute Node Linux (CNL) on compute nodes
- Compilers:
  - PGI, Pathscale, GNU (Fortran 95, C, C++)
  - NAGware f95
- Tools:
  - CrayPat + Apprentice2 for performance profiling
  - Totalview debugger

XT Software Environment

- Libraries
  - Cray MPT (based on MPICH-2. Includes MPI2 and Cray SHMEM)
  - xt-libsci (BLAS, LAPACK, ScaLAPACK, SuperLU, IRT)
  - FFTW
  - Older Cray FFT interfaces
  - AMD ACML (BLAS, LAPACK, FFTs, RNGs)
  - NAG Fortran, SMP and Parallel Libraries (PGI only)
- Batch scheduler - PBS Pro

Third Party Application Codes

- Chemistry and Life Sciences
  - AMBER, CASINO, CASTEP, CHARMm, CPMD, CRYSTAL, DALTON, DL_POLY, GAMESS_UK, LAMMPS, NAMD, NWChem, SIESTA, VASP
- Engineering
  - ParaFEM, Pnewt, ROTORMBMGP
- Other
  - NEMO, HDF5, NetCDF, PetSc, AIMPRO, GS, H2MOL, HELIUM, PCHAN, POLCOMS, PRMAT, Globus, R

Getting Time On HECToR

- Precise mechanism varies between research councils
  - EPSRC and BBSRC: Apply direct to RC
  - NERC via 4 consortia or direct
  - See individual website for more information
  - Resources awarded in terms of *Allocation Units* 1 Gflop for 1 hour (which have a notional value)

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Getting Time On HECToR

- Full Peer Reviewed Access (Class 1a)
  - Typically peer-reviewed and part of larger research proposal
  - Application form requires you to provide info on previous HPC experience, type of jobs to be run, software needed, support requirements, etc
  - Requires Technical Assessment from NAG as part of full proposal

- See www.hector.ac.uk for more details

Getting Time On HECToR

- Direct Access (Class 1b)
  - New pilot scheme designed to give quicker access to a large (>125,000 core hours) resource
  - Valid for 6 months, could be used for:
    - bridging access between grant applications
    - trialing application developments at scale
    - providing preliminary results to aid grant applications
  - Independent panel assesses application every 4 months, next deadline 21st September.
  - Requires Technical Assessment

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Getting Time On HECToR

- Pump Priming/New Research (Class 2a)
  - For pump-priming projects or new users of national service
  - Requires Technical Assessment from NAG
  - Requires short (1 page) outline of project
  - Limited resources (up tp 25,000 core hours))

- Distributed CSE (Class 2b)
  - Awarded by NAG, via independent panel.
  - Can include up to 50,000 core hours for new users

Technical Assessments

- Confirm whether project is suitable for HECToR
  - capability science
  - not practical on local resources
  - all software is available/budgeted for
  - expectations from service are reasonable
  - HPC aspects of proposal are plausible
- Gather information about use of service
  - job profile
  - software requirements
  - CSE requirements

CSE SERVICES

Overview of the CSE Service

- Partnership with HECToR user community to assist in deriving maximum benefit from the hardware
- Central Team
  - ~8 FTEs based in Oxford and Manchester
- Distributed Team
  - ~12 FTEs seconded to particular users, research groups or consortia

The Central Team

- Technical Assessments of applications
- Helpdesk
  - Part of single HECToR helpdesk
  - Available to deal with problems that may take several days to resolve
- Documentation
- Help with porting, parallelizing and code optimisation
  - Could be several weeks of effort
- **Training**
- Manage **Distributed CSE Support**

Training

- Some HECToR-specific
  - Introduction to HECToR
  - Debugging, Profiling and Optimising (2 days)
  - X2 Programming (2 days)
  - Multicore (2 days)

- Application Specific Courses
  - DL_Poly
  - CASTEP

Training

- More General Courses
  - Parallel Programming with MPI (3 days)
  - OpenMP (2 days)
  - Fortran 95 (3 days)
  - Others covering IO, Core HPC Algorithms, Visualization, Portability, Testing etc
- Open to user requests
  - Training for specific projects
  - Training on specific application codes

Training

- The current schedule of courses is available at http://www.hector.ac.uk/cse/training/
- A full list of the courses we offer can be found at http://www.hector.ac.uk/cse/training/courselist/
- All of these courses are free to HECToR users and to anyone whose work comes under the remit of EPSRC, NERC or BBSRC.
- So you don't need to be currently funded.

Distributed CSE Support

- Allocated to specific individuals or groups
- Awards for software development to improve the capability of codes on HECToR
- Usually at least 6 months of effort for
  - Porting
  - Tuning, optimisation, scaling
  - Functional enhancements, etc.

Distributed CSE Support

- Regular calls for proposals
  - Next deadline is 21st June
  - Open to any HECToR user funded by a sponsoring Research Council
  - Also available for potential HECToR users
- “Panel-style” evaluation process
  - Independent experts rank proposals
  - NAG negotiates agreements according to available resources
  - Whole process is open and transparent

Distributed CSE Support

- Staff managed by, and part of, CSE team
  - Programme of work/targets agreed in advance with PI
  - Managed/co-ordinated by member of central team
  - Could be based in PI's institution, at NAG, or elsewhere
  - Could be employed directly by NAG or by host institution via contract
- More information

  http://www.hector.ac.uk/cse/distributedcse

Where to find more information

- Main HECToR website:
  - www.hector.ac.uk
- CSE pages at:
  - www.hector.ac.uk/cse
- EPSRC
  - www.epsrc.ac.uk/ResearchFunding/FacilitiesAndServices/HighPerformanceComputing/
- NERC
  - www.nerc.ac.uk/research/sites/facilities/hpc/
- BBSRC
  - www.bbsrc.ac.uk/funding/hpc_access.pdf

Where to find more information

- More information on hardware, software and operation.
  - www.cray.com Marketing and technical.
  - docs.cray.com In depth reference materials.

- Stay in touch, send subject of:

  SUBSCRIBE HECTOR-INTERESTED *Forename Surname*

  To: LISTSERV@jiscmail.ac.uk

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HECToR Summary

- Cray XT4 and X2 vector machines in service
- Cray XT6 coming very soon. c/w programming challenges!
- Several routes for getting HECToR time.
- CSE Service available to help users get the most out of HECToR.
- Distributed CSE awards available for software development.
- Training available to all.

PHYSICS ON HECTOR

Physics Codes on HECToR

- **Electronic Structure**
- These codes provide a periodic description of the electronic structure of the system and are often used for studying condensed-phase systems.
  - cp2k
  - **CASTEP**
  - CPMD
  - Siesta
  - CRYSTAL
  - VASP
  - ONETEP
  - Wein-2k

Physics Codes on HECToR

- **Classical Molecular Simulation**
- These codes use an empirically derived 'force-field' to describe the interaction between particles and can often treat much larger systems than the electronic structure codes.
  - Amber
  - DL_POLY
  - Gromacs
  - CHARMM
  - LAMMPS
  - NAMD
  - ChemShell

Physics Codes on HECToR

- **Plasma Physics**
- Codes used for studying the properties of high-energy plasmas.
  - CENTORI
  - GS2
  - H2MOL
  - **HELIUM**

- Top three codes for usage on HECToR are all Physics codes, and VASP accounts for 22%!

Case Study

- We look at two codes in a little more detail:

- Helium
- CASTEP

HELIUM

- HELIUM models the interaction between a single Helium atom and an intense, short laser pulse.
- The code is used to study the interaction between the two electrons as they ionize
- To solve this problem HELIUM directly solves the full Time-Dependent Schroedinger Equation, with a linearly-polarised laser field, this is a time-dependent PDE with 5 spatial dimensions.
- No simplifying assumptions made in the physics.

HELIUM

- One of the HECToR benchmarks.
- Fortran chosen as there are a lot of 3D and 4D arrays, and the need for array operations.

- Implements the 5 spatial dimensions as a 2-D finite-difference grid for the two radial co-ordinates, and a basis set of coupled spherical harmonics for the three angular co-ordinates.

HELIUM

- Has a 3-D array of ~2000-3000 2-D radial grids (or "partial waves"), each of size ~5000x5000 grid points, so ~10-100 billion grid points in total.
- At timestep t we update each 2-D radial grid based upon the values at timestep t-1 of that 2-D radial grid and some number of other 2-D radial grids.

HELIUM

- Parallelised with MPI over the 2-D radial grids.
- So each MPI task will have a square block of every 2-D radial grid.
- Communications are mostly nearest-neighbour halo exchange, plus some global sums.
- The code has been tested on over 70,000 cores on Jaguar (Oak Ridge ~2PFlop system)
- Regularly run on 8,000 - 16,000 cores on HECToR.

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HELIUM

- Currently a dCSE is to look at hybrid parallelism to OpenMP parallelise over the basis set of partial waves within each MPI task.
- There is a limit to how small we can make each square block on each MPI task. Communication worsens for smaller blocks per MPI task.
- Proposed crossed-fields (two different laser field at 90 degrees to each other) will make this a full 6-D calculation increasing basis set in memory.

HELIUM

- Thus a hybrid MPI-OpenMP approach could allow scaling to larger numbers of cores in total by paralleling the work currently done by an MPI process.
- Help to accommodate increases in the size of the basis set in memory.
- And perhaps improve efficiency by reducing the MPI communication overhead.

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CASTEP

- CASTEP is a software package which uses density functional theory to provide atomic-level description of materials and molecules.
- It can provide information about total energies, forces and stresses on an atomic system, as well as calculating optimum geometries, band structures, optical spectra, phonon spectra etc
- It can also perform molecular dynamics simulations.

CASTEP

- CASTEP began in 1999, with the first release in 2001.
- There was a written specification, prior to coding.
- Implemented in Fortran 90 with TR 15581 (allocatable dummy arguments and derived type components.)
- Modular approach
- Data abstraction using derived data types
- Overloading for simple, clear subroutine names

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CASTEP

- CASTEP consists of three coding levels.
- “Utility” routines – these provide the core algorithms to CASTEP along with FFTs, communication routines (built on MPI) and the IO.
- “Fundamental” routines – the building blocks with definitions of types, density, potential, wave function etc,
- “Functional” routines – the physics.

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CASTEP

- This approach allows for functionality to be express in physics notation at the functional level.
- Easier to add new functionality.
- All machine dependent code at the lowest utility level.
- This allows all the work required for a move to HECToR Phase 2b, to be done at the utility level.

CASTEP

- CASTEP links to appropriate vendor libraries for BLAS, LAPACK and FTTs.
- Most of the computational time is spent in these routines.

- Also 3D FFT responsible for much of the communication.
- For each dimension x, y, z, each process performs a subset of 1D transforms in that direction.
- Before moving from one dimension to the next data must be “transposed” so that each process has the data it needs. This requires a call to MPI_Alltoallv.

CASTEP

- Two optimization techniques are being used that result in only one MPI message being sent per node.
- Option 1 - Use MPI_Gather to marshal the outgoing data and MPI_Scatter to distribute the incoming data.
  - Synchronous
- Option 2 - System V shared memory segments - allow processes on a node to collate data prior to an MPI message.
  - One segment that all processes in a node can **write** their outgoing data directly **into**.
  - One that all processes in a node can **read** incoming data **from**.
  - Asynchronous

Options on XT4

al3x3 Benchmark				
Nprocs	Default	Option 1	Option 2	
64	2261	3103	2665	
128	1788	1784	1572	1.1X
256	1564	1191	1087	1.4X

- Time in seconds

- Both options show a speed up, but only on larger jobs, where there is a lot of communication.
- Option 2 is best.
- This should be really important on Phase 2b...

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System V on XT6

#cores per node	Default CASTEP (Initial)	Option 2 - System V (Initial)	
1	4139 (78.7)		
2	4820 (85.6)		
4	9775 (134.8)	2646 (81.8)	
8	21957 (258.1)	2515 (62.4)	8.7X
12	36605 (407.7)	6177 (82.8)	5.9X Why?
24	? (869)	? (700.3)	

- Using sparsely populated jobs (i.e. using fewer MPI processes per node than number of cores per node)
- Shows improved performance. (Less contention on resources, memory and interconnect)
- Using the executable with System V gives up to 8X speed up.

CASTEP

- A third approach is the use of shared memory libraries – hybrid MPI/OpenMP code via use of threaded (OpenMP) BLAS and LAPACK.
- First we compare just using all and one core per node on the XT4:

al3x3 Benchmark			
MPI Prcesses	Packed	1 core / node	Speedup
64	2483	1933	1.3X
128	1573	1103	1.4X
256	1258	761	1.7X

But 4X AU cost!

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CASTEP

- When using only one core per node we have three idle cores.
- So with threaded libraries:

al3x3 Benchmark					
MPI Processes	Packed	1 core / node	Speedup	Threaded	Speedup
64	2483	1933	1.3X	1688	1.5X
128	1573	1103	1.4X	974	1.6X
256	1258	761	1.7X	676	1.9X
1024	1895				

Good, but still not 4X

CASTEP

- We are still using 4 times the resources!
- We therefore need a reason to do it.
  - There are limits to scalability. E.g. al3x3 case using 1024 processes takes 1895s. Using the same number of cores the 256 process, 4-thread case takes 676s
  - Large problem that exceeds the memory-per-core limit (currently 2GB, soon 1.3GB). Idle cores, so make them do something. (This is considered critical and being investigated now.)
  - You want the result as soon as possible.

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References

- CSE/dCSE reports:
  - www.hector.ac.uk/cse/reports
- Shared memory report:
  - www.hector.ac.uk/cse/reports/castep_m.pdf
- (Draft) Phase 2b guide:
  - www.hector.ac.uk/cse/documentation/Phase2b

Nag Product Update

Craig Lucas

June 2010

nag® Experts in numerical algorithms and HPC services

Contents

The NAG Fortran Compiler

- 1991 – World's first Fortran 90 Compiler (f90)
- 1997 – Fortran 95 (f95)
- 1999 – TR 15580 and 15581 added
  - IEEE modules
  - Allocatable attribute extensions
- 2003 – First new F2003 features
- 2008 – Release 5.2, most of F2003 (nagfor)
- 2010 – Release 5.3 later this year

Key Features

- Standards Conformance
- Very few language extensions
- Extensive error checking
  - As required by the ISO standard
  - Checking for likely programming mistakes
  - Additional run time checking – -C=undefined, -C=array
- Portable

Portability

- Compiler converts internal representation to C
- Output C
- Use native C compiler as code generator
  - Available on major platforms
  - Allows “one-off” implementations, e.g. IBM z9/Linux

Fortran 2003 – not yet implemented

- Ad hoc type comparison (EXTENDS_TYPE_OF & SAME_TYPE_AS)
- Parameterised derived types
- Finalisation (priority for 5.3)
- Defined I/O
- Structure constructor syntax enhancements

Fortran 2003 Features implemented in 5.2

- Unlimited polymorphic
- Procedure pointers
- Object-bound procedures
- Allocatable scalars
- Deferred character length
- More intrinsic functions in initialisation expressions
- Reallocating assignment
- Recursive I/O
- ASSOCIATE
- MOVE_ALLOC
- New KIND= optional argument to some intrinsics
- CHARACTER argument to some intrinsics
- Type-spec for array constructor
- Asynchronous I/O
- Enhanced complex constants
- Pointer lower bound setting
- Renaming operators on USE
- C_F_PROCPOINTER
- Changes to SYSTEM_CLOCK
- BOZ constants allowed in CMPLX, DBLE, INT and REAL
- C Interoperability
- Enum types
- Type bound procedures
- New I/O features
- I/O of NaNs
- Abstract derived types
- Deferred bindings
- PROCEDURE statement
- Public entities of PRIVATE Type
- ISO_FORTRAN_ENV module
- IMPORT statement
- INTENT for pointers
- Square bracket array constructors
- SOURCE in ALLOCATE
- GET_COMMAND etc
- GET_ENVIRONMENT_VARIABLE
- …

Summary of F2003 Features

- All of the object-oriented features (except finalisers which will be in 5.3)
- All of C interoperability
- All the main new intrinsics
- Most of the new I/O features

Also in Release 5.2

- Double-double quadruple precision on all platforms that don’t have native quad precision.
  - Sun SPARC – native
  - Linux, Windows & Mac – double-double
- 31 decimal digits precision
- Slightly smaller exponent range than double

What’s next?

- Fortran 2008?
  - Big new addition to the language
  - First new features in Release 5.3, later this year
- OpenMP
  - We’d like to introduce some OpenMP support, in a future release.
- Improved checking
- Improved efficiency
- Better debugger

Strengths

- Great pedigree – team headed by NAG principal consultant, Malcolm Cohen, secretary to the international working group on Fortran, ISO/IEC JTC1/SC22/WG5.
- Co-author of "Fortran 95/2003 Explained" with John Reid and Michael Metcalf.

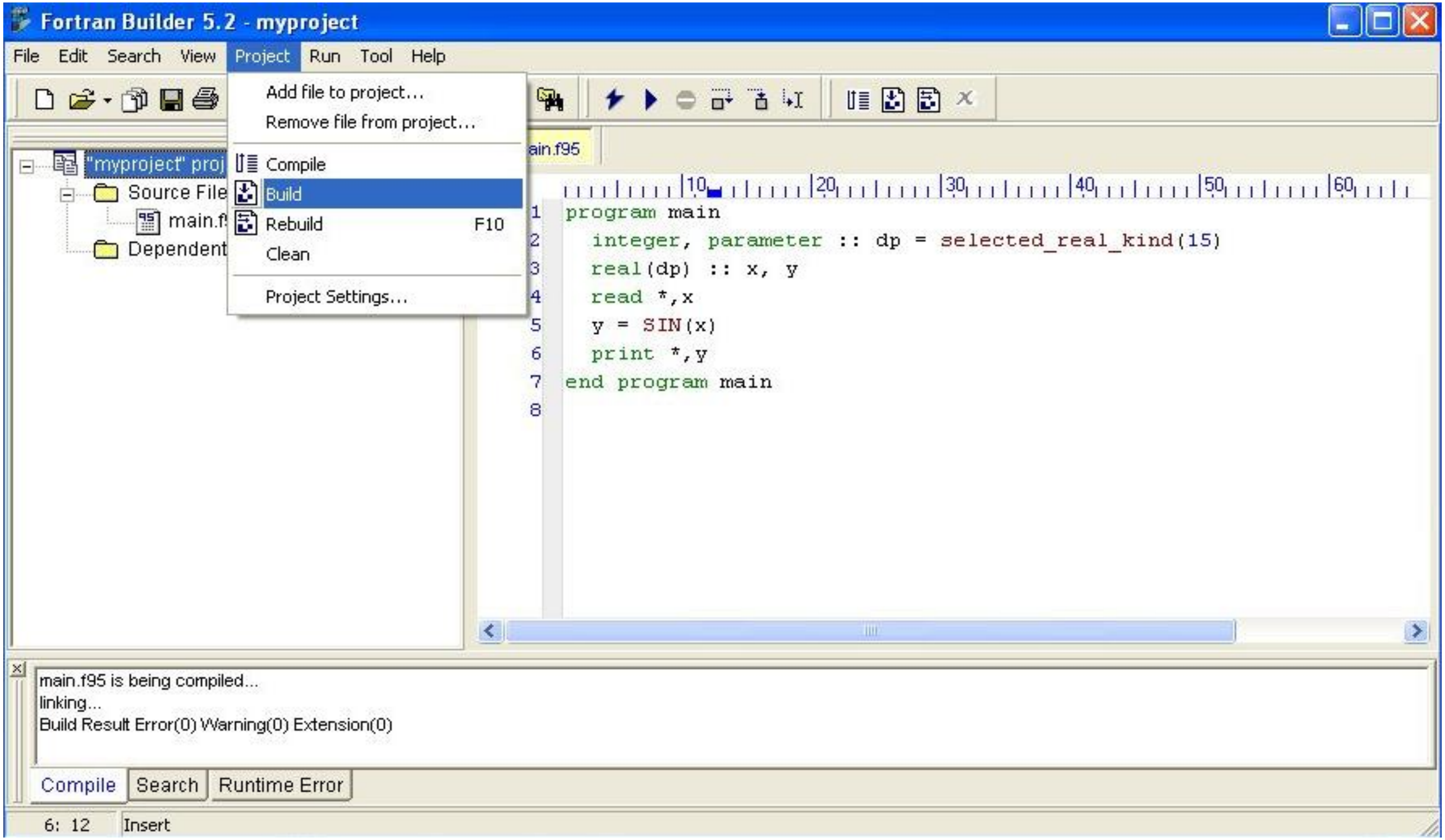
Strengths

- World's first Fortran 90 compiler
- Developed and enhanced to include Fortran 95 and most features of Fortran 2003.
- Regularly updated, fully supported.
- EXCELLENT (the world's best) checking compiler

Unique Selling Point

Fortran Builder

- Integrated Development Environment for NAG compiler on Windows PC
- Perfectly integrated with NAG Library
  - NAG example program templates
- Extra facilities: tools e.g. Fortran Polisher, Fortran converter, LAPACK examples
- Integrated debugger


Fortran Builder 5.2 - myproject
File Edit Search View Project Run Tool Help
Add file to project...
Remove file from project...
Compile
Build
Rebuild F10
Clean
Project Settings...
"myproject" proj
Source File
main.f
Dependent
ain.f95
program main
integer, parameter :: dp = selected_real_kind(15)
real(dp) :: x, y
read *,x
y = SIN(x)
print *,y
end program main
main.f95 is being compiled...
linking...
Build Result Error(0) Warning(0) Extension(0)
Compile
Search
Runtime Error
6: 12
Insert

Release 5.2 Availability

- x86 Linux
- x64 Linux
- SPARC
- Mac
  - Intel
  - PowerPC
- Windows (Fortran Builder)

The NAG Numerical Libraries

- NAG Fortran Library
- NAG C Library
- NAG SMP Library
  - for symmetric multi-processor machines (OpenMP)
- NAG Parallel Library
  - for distributed memory parallel machines (MPI)
- NAG Toolbox for MATLAB

- Documented with error & accuracy information and example programs.

NAG Library Contents

- Root Finding
- Summation of Series
- Quadrature
- Ordinary Differential Equations
- Partial Differential Equations
- Numerical Differentiation
- Integral Equations
- Mesh Generation
- Interpolation
- Curve and Surface Fitting
- Optimization
- Approximations of Special Functions
- Dense Linear Algebra
- Sparse Linear Algebra
- Correlation and Regression Analysis
- Multivariate Analysis of Variance
- Random Number Generators
- Univariate Estimation
- Nonparametric Statistics
- Smoothing in Statistics
- Contingency Table Analysis
- Survival Analysis
- Time Series Analysis
- Operations Research

New at Mark 22

- Global Optimization
- Nearest Correlation Matrix
- Wavelets
- Roots of equations
- Ordinary Differential Equations Solvers
- Various linear algebra
- Various statistics, including random number generators, multivariate methods and time series analyis
- Option pricing
- Sorting and searching

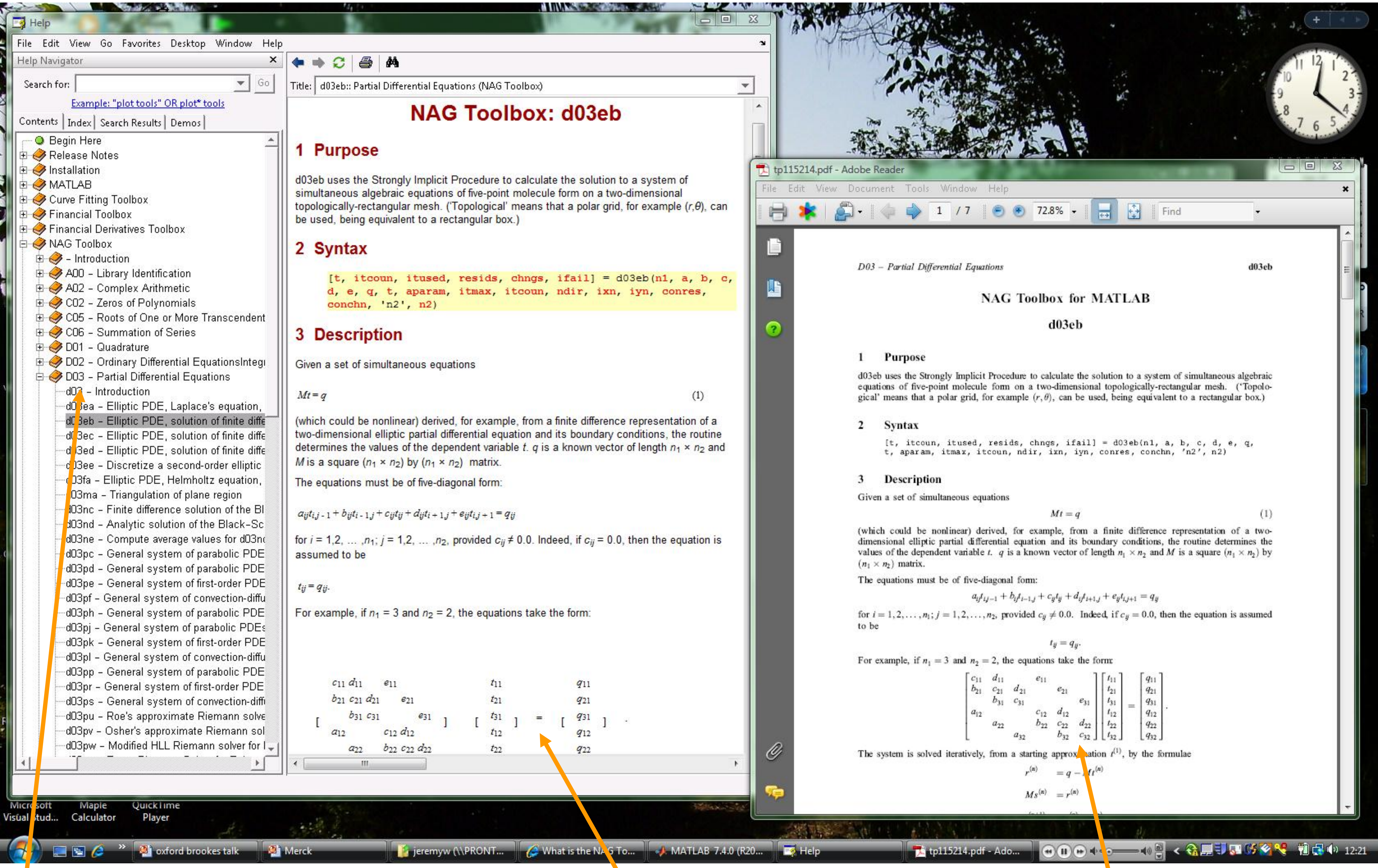
NAG Library Interfaces

- Fortran
- C
- C++
- C# / .NET
- Java
- Borland Delphi
- Python
- …

- Excel
- **MATLAB**
- Maple
- LabVIEW
- R and S-Plus
- SAS
- Simfit
- …

NAG Toolbox for MATLAB

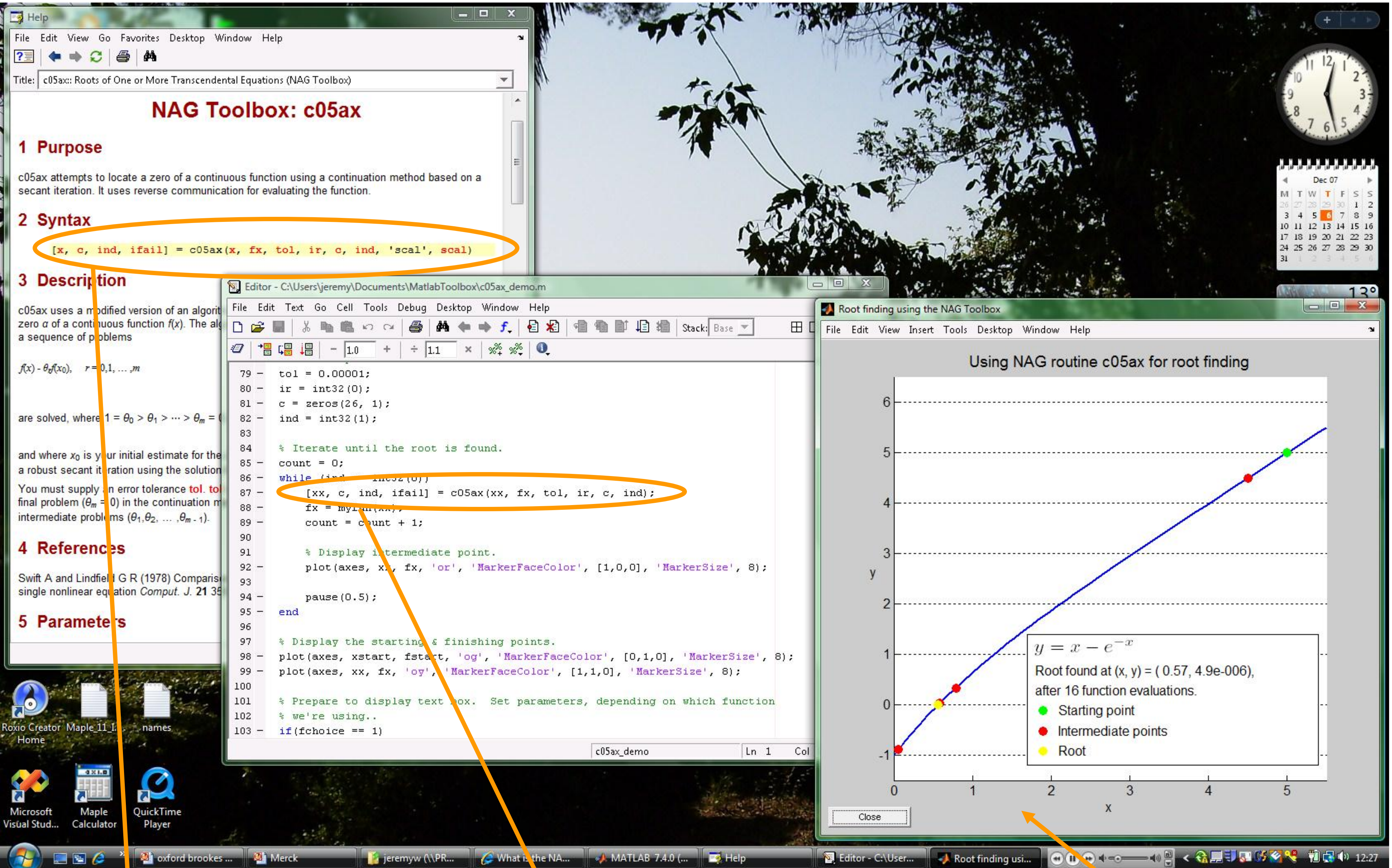
- Comprehensive interfaces to NAG Fortran Library
- Fully integrated into MATLAB
    - many routine arguments become optional
        - easier to read code
    - complete documentation for each routine
        - including examples
- Complementary functionality to MATLAB
- Alternative to several specialist toolboxes



NAG Toolbox help chapters

MATLAB formatting

NAG formatting (in PDF)



How to call the NAG routine

Calling the routine in MATLAB

MATLAB plot

Mark 23

- Code freeze imminent for Mark 23 of NAG Fortran Library and NAG Toolbox for MATLAB will be out soon after.
  - Global Optimization
  - Image processing
  - Dense Linear Algebra
  - Sparse Linear Algebra
  - Correlation and Regression Analysis
  - Random Number Generators
  - Nonparametric Statistics
  - FFTs
  - ODE
  - Integration
  - Roots of Equations
  - Option Pricing
  - Wavelets
  - Special functions

NAG Library for SMP and Multicore

- NAG Library for SMP and Multicore will follow much quicker from Mark 23.
- The same interface to serial library, just re-link

- NAG-specific routines parallelised with OpenMP
  - Focus of future NAG SMP library development work
  - Seeking to broaden scope of parallelism to different parts of the library

NAG Library for SMP and Multicore

- Root Finding
- Summation of Series (e.g. FFT)
- Quadrature
- Ordinary Differential Equations
- Partial Differential Equations
- Numerical Differentiation
- Integral Equations
- Mesh Generation
- Interpolation
- Curve and Surface Fitting
- Optimisation
- Approximations of Special Functions
- Dense Linear Algebra
- Sparse Linear Algebra
- Correlation and Regression Analysis
- Multivariate Analysis of Variance
- Random Number Generators
- Univariate Estimation
- Nonparametric Statistics
- Smoothing in Statistics
- Contingency Table Analysis
- Survival Analysis
- Time Series Analysis
- Operations Research

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