Computation in heterogeneous-hierarchical environments

Project COPABIB:
Univ. Alicante, Castellón, La Laguna, Murcia, Polytechnic of Valencia
Spain

European Network ComplexHPC, October 2009, Lisbon
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Spanish Network

High Performance Computation in Heterogeneous Architectures (CAPAPAP-H), approximately 20 universities, organisms and companies
Spanish groups in the European Network

13 centres: Numerical Analysis 4, Libraries 2, Mapping 6, Applications 9
Spanish project COPABIB

Automatic Building and Optimization of Parallel Scientific Libraries
Spanish project COPABIB: research lines

- **Specification of problems, algorithms and architectures**: mathematical formulation and tag-based languages to define specification languages

- **Software tools for transformation**: translators, symbolic processors and skeletons to obtain libraries from specifications

- **Matrix algebra libraries**: libraries for dense and sparse linear algebra

- **Libraries of dynamic programming for optimization problems**: libraries for discrete mathematics problems

- **Optimization environments**: models, simulators, analyzers, tuning for linear algebra and optimization

- **Tools for the construction of high-level interfaces**: tools to assist in the construction of interfaces to provide user-friendly access to the libraries

- **Scientific applications**: interdisciplinary applications using the previous results
Scientific Computing and Parallel Programming

2 doctors + 10 PhD students, from:
Universidad Católica de Murcia
Centro de Supercomputación de Murcia
Marine studies company
Universidad Politécnica de Cartagena
Universidad Miguel Hernández de Elche
Universidade Federal do Estado da Bahia

- Information
  - Group page:
    http://www.um.es/pcgum/
  - Publications:
    http://dis.um.es/~domingo/investigacion.html
Research lines

- Mathematical and statistical modelling of scientific problems
- Development of efficient or approximated (methaeuristic) algorithms to solve these problems
- Software optimization, autotuning
- Parallel computing
  - Parallel matrix computing
  - Parallel algorithms and algorithmic schemes
  - Optimization and autooptimization of parallel software
  - Adaptation of parallel software to heterogeneous and hierarchical systems
  - Applications of parallel computing
Parallel computing

- Parallel matrix computation
  - Modelling and automatic optimization of parallel matrix algorithms in systems of different characteristics
- Parallel algorithmic schemes
  - Modelling and automatic optimization of parallel algorithmic schemes in systems of different characteristics
- Parallel computing applications
  - Simulation of marine bio-systems - Taxon Estudios Ambientales
  - Simultaneous equation models - Temporal series group, applications for medicine and psychology
  - Design of signal filters - Computational electromagnetic group
  - Regional meteorology simulations - Regional climate modelling group
  - ...
Interdisciplinary Computation and Communication Group (INCO2)

6 doctors + 6 PhD students, from:
  Spain
  Cuba
  Mexico
  Brazil

- Information
  - Group page:
    http://users.dsic.upv.es/grupos/inco2/
Research lines

- High Performance Computing applied to Numerical Linear Algebra problems
  Eigenvalue problems, svd, structured problems, . . .

- Heterogeneous Parallel Computing
  Development and optimization of parallel algorithms on clusters, multicore computers, GPUs, . . .

- High Performance Computing applied to Communication problems
  Signal processing, detection, design of devices, . . .
Projects

- Spatial audio systems based on Massive parallel processing of multichannel acoustic signals with General Purpose-Graphics Processing Units (GP-GPU) and Multicores (with the GTAC-iTeam Group in UPV)

- Automatic Building and Optimization of Parallel Scientific Libraries (with the universities of La Laguna, Jaume I of Castellón, Alicante, Murcia, University College Dublin)

- High performance computing and architectures in signal processing problems (with the university Jaume I of Castellón and the GTAC-iTeam in UPV)
Possible collaborations

- Application of Parallel Numerical Linear Algebra in Engineering: signal processing, detection, electromagnetic problems, design of new devices, ...
- Software optimizations for multicores, GPUs, Clusters...
- Simulation in Engineering...
- Efficient solution of scientific problems: modeling, algorithms, approximate solutions, parallelism...
- Sequential and parallel algorithmic schemes and their optimization and autotuning
High Performance Computing Group ULL (CAPULL)

- 6 doctors
- 7 PhD students

Information
  Group page:
  http://cap.pcg.ull.es/
Research lines - High Performance Computing Group ULL (CAPULL)

- Parallel Computing and Heterogeneous Systems
- Modeling, Instrumentation and Performance Analysis
- Parallelization of Scientific Applications - Combinatorial Optimization Problems
  - Parallelization of the GEANT 4 Simulation Code in cooperation with CIEMAT.
- Tools and Frameworks for Parallel Computing
  - Skeletal Programming
    - DPSKEL
    - llc
  - Cloud Computing - Web Services - OpenCF
DPSKEL: The Goal

- Skeletons that can be architectural independent
- A specification language describing the domain of the application, independent of the architecture.
- Transformers of data documents expressed in that language as instances for the skeleton.
DPSKEL: Skeletons for Dynamic Programming

- No need for codification. The user specifies the problem and does not codify the algorithm.
- Independence from specific programming languages or skeleton libraries. Once the problem has been specified, it can be transformed into several implementation proposals.
- Delivery of new applications due to the rapid development time.
- Improved application quality.
- Increased use of parallel architectures by non-expert users.
- Rapid inclusion of emerging technology into their systems. New transformers can be delivered when needed.
DPSKEL: The Architecture

\[ KP \equiv \left\{ \begin{array}{l}
    \text{Input Data} = \{ n \in N, C \in N, p_k \in N; k \in \{1\ldots n\}, w_k \in N; k \in \{1\ldots n\} \} \\
    \text{Output Data} = \{ x_k \in \{0,1\}; k \in \{1\ldots n\} \} \\
    \text{DP Recurrence} = f_{kc} = \left\{ \begin{array}{ll}
    p_k & \Rightarrow d_k = 1 \\
    0 & \Rightarrow d_k = 0 \\
    \max \{ f_{k-1c}, d_k = 0, f_{k-1c-w_k} + p_k \} & \Rightarrow d_k = 1
    \end{array} \right. \\
\end{array} \right. \]

From Latex specifications to parallel codes

Save as XML

MathML

Transformer

DPSPEC

Transformer

DPSKEL

OpenMP, MPI, OpenMP + MPI, etc.

Parallel Architectures
llc

**llc: La Laguna C**

llc is a high-level parallel language that aims to combine and exploit the best features of both MPI and OpenMP.

http://llc.pcg.ull.es

- llc follows the simplicity of OpenMP and avoids its well-known drawbacks.
- An OpenMP code cannot be ported to distributed memory architectures.
- In llc the code annotated with parallel directives is compiled with llCoMP, the llc compiler-translator.
- llCoMP produces an efficient and portable parallel source code, valid for shared, distributed memory and hybrid architectures.
# llc

## llc: features

- ANSI C syntax
- Parallelism is expressed using compiler directives (\#pragma)
- The language implements a basic set of parallel constructs
- OpenMP-like syntax: llc extends OpenMP to distributed memory and it is compatible with its directives and clauses
- A small set of llc directives is added
- The language is based on Collective Computational Model (OTOSP)
Main llc constructs

- **Parallel loops / forall:**
  - `#pragma omp for`

- **Parallel Sections:**
  - `#pragma omp sections`
  - `#pragma omp section`

- **Pipelines:**
  - `#pragma llc pipeline`

- **Workqueues:**
  - `#pragma intel omp taskq`
  - `#pragma intel omp task`
The 11CoMP translation process
Cloud Computing - OpenCF: The Goal

- To provide an easy, standard and free solution
- An user friendly interfaz
- Open and collaborative project
- Modular and extensible solution
OpenCF: Open Computational Framework

- Implemented as a (web) gateway to computational systems

**Free Open Source Application**

- Licenced under GPL
- Downloadable from [http://opencf.pcg.ull.es](http://opencf.pcg.ull.es)
  - Available as a Debian package or as a .tar.gz file
- Access to the code repository (*subversion*)

**Developed using lightweighted technologies**

- Implemented in PHP, Perl and Python
- Only the interpreters and server modules are needed
- OpenCF is mainly composed of two modules: the client and the server.
- The client module is the interfaz access to the system and implements services independent from the HPC.
- The server implements the actual web service. Implements the services depending on the HPC.
OpenCF: A proof of concept