YML: Language, framework and applications

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LI-PaRAD/Maison de la Simulation

3rd Workshop on Parallel Programming Models - Productivity and Applications, Aachen

SPPEXA - 2018/03/15

Plan

YML from user's point of view

YML architecture and interaction with middleware

Application

1 YML from user's point of view

2 YML architecture and interaction with middleware

3 Application

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YML a parallel programming environment

- http://yml.prism.uvsq.fr/
- Component approach for re-usability, and maintainability
- A high-level language to **express coarse grain parallelism**, portability, re-usability, and maintainability
- Multilevel parallel programming for performances (YML-XMP)
  - coarse grain parallelism expressed by a graph of tasks (Yvette)
  - fine grain parallelism expressed in component (XMP)
- **Ease of use**
- **separation** of Computation, Data and Communication

Summary

- Development process using YML
- Remarks on 2-level MPI programming
- **How YML provides information to middleware ?**
- Experiments on various environment.

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YML from user's point of view

BGJ as an example

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- **Block Gauss-Jordan Inversion**
- Successive elimination to obtain $B = MA$ diagonal.
- Algorithm is written by block
- **Coarse grain:** algorithm written with YML
- **Fine grain:** linear algebra library written with XMP

$$A_k = E_{k-1}P_{k-1}\dots E_2P_2E_1P_1A_1 = \begin{pmatrix} a^k_{1,1} & & & a^k_{1,k} & \dots & a^k_{1,n} \\ & a^k_{2,2} & & a^k_{2,k} & \dots & a^k_{2,n} \\ & & \ddots & \vdots & & \vdots \\ & & & a^k_{k,k} & \dots & a^k_{k,n} \\ & & & \vdots & & \vdots \\ & & & a^k_{n,k} & \dots & a^k_{n,n} \end{pmatrix}$$

Algorithm 1 The block-based Gauss-Jordan matrix inversion

Input: A (partitioned into $p \times p$ blocks)
Output: $B = A^{-1}$
For $k = 0$ to $p-1$
  $B_{kk} = {A^{-1}}_{kk}$
  For $i = k+1$ to $p-1$ **(1)**
    $A_{ki} = B_{kk} \times A_{ki}$
  End For
  For $i = 0$ to $p-1$ **(2)**
    If $(i \neq k)$
      $B_{ik} = -A_{ik} \times B_{kk}$
    End If
    If $(i < k)$
      $B_{ki} = B_{kk} \times B_{ki}$
    End If
  End For
  For $i = 0$ to $p-1$ **(3)**
    If $(i \neq k)$
      For $j = k+1$ to $p-1$
        $A_{ij} = A_{ij} - A_{ik} \times A_{kj}$
      End For
      For $j = 0$ to $k-1$
        $B_{ij} = B_{ij} - A_{ik} \times B_{kj}$
      End For
    End If
  End For
End For

Figure : Block Gauss-Jordan Algorithm, M. Hugues *et.al.*

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Developing an application with YML

1. Create tasks defining **components** (using XML language)
2. Write an application with a **graph of tasks with Yvette language**
3. Execute the application in distributed environment

1. Task definition

A task is a service define by:

- **interface**: «abstract» component
  - Input / Output data
- **realization**: «implementation» component
  - C/C++/XMP-C/XMP-FORTRAN
  - libraries etc.

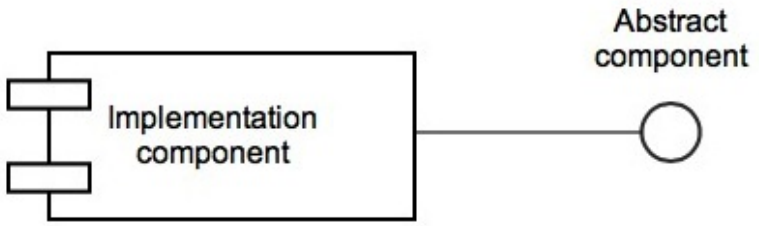

Figure : A service

Component approach

- modularity
- reusability

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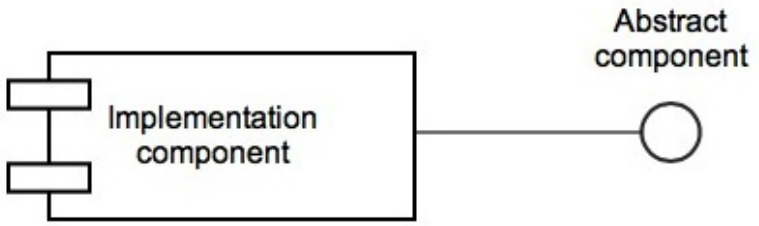

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Abstract component

```
 <?xml version="1.0" ?>
<component type="abstract" name="XMP_mProdMat">
<params>
<param name="B0" type="Matrix" mode="in"  />
<param name="A0" type="Matrix" mode="in"  />
<param name="C0" type="Matrix" mode="out" />
</params>
</component>
```

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Implementation

```
<?xml version="1.0"?>
<component type="impl" name="XMP_mProdMat" abstract="XMP_mProdMat" description="C = -(B x A)">
<impl lang="XMP" nodes="CPU:(2,2)">
  <templates>
    <template name="t" format="block,block" size="64,64"/>
  </templates>
  <distribute>
    <param template="t" name="B0(64,64)" align="[i][j]:(j,i)"/>
    <param template="t" name="A0(64,64)" align="[i][j]:(j,i)"/>
    <param template="t" name="C0(64,64)" align="[i][j]:(j,i)"/>
  </distribute>
<header>
<header>
<![CDATA[
#include<xmp.h>

double A[64][64];
double B[64][64];

#pragma xmp align A[i][j] with t(j,i)
#pragma xmp align B[i][j] with t(j,i)
</header>
<source>
/* XMP CODE HERE */
</source>
<footer />
</impl>
</component>
```

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Workflow programming

- facilitate the expression of parallelism for user
- close to computational methods (Algorithm)
- high level language (Yvette) -> workflow
- deduce dataflow
- $\Rightarrow$ enable optimization combining two aspects: workflow and dataflow.

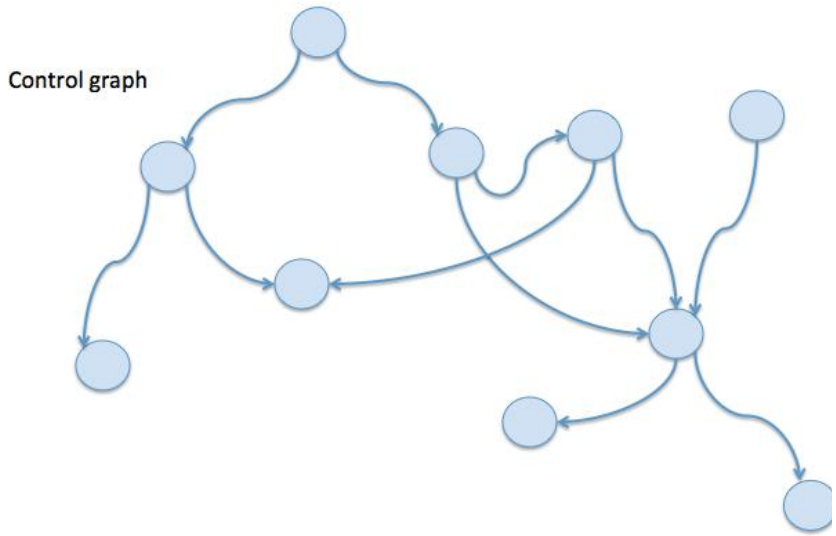

Figure : Graph of tasks

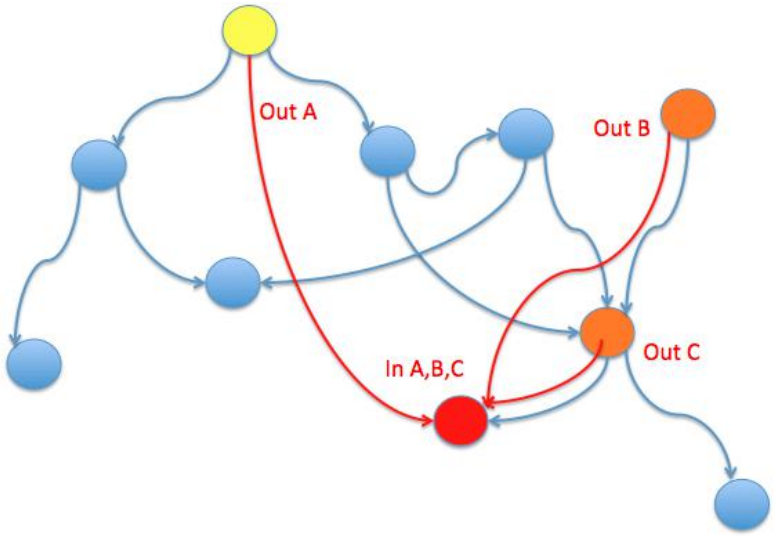

Figure : Deducing dataflow

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Yvette Language

- **Parallel Section:** par section1 // ... // section N endpar
- **Sequential loop:** seq (i:=begin;end) do ... enddo
- **Parallel loop:** par (i:=begin;end) do ... enddo
- **Conditional structure:** if (condition) then ... else ... endif
- **Synchronization:** wait(event) / notify(event)
- **Component call:** compute NameOfComponent(args,...,...)

Syntaxe

```
<?xml version="1.0"?>
<application name="Gauss-Jordan">
<graph>
blockcount:=4;
par
  par(i:=0;blockcount-1)(j:=0;blockcount-1)
  do
    compute XMP_genMat(A[i][j],i,j);
    compute XMP_copyMat(A[i][j],C[i][j]);
  enddo
//
  par(i:=0;blockcount-1)(j:=0;blockcount-1)
  do
    if (i neq j) then
      compute XMP_fillMatrixZero(B[i][j]);
    endif
  enddo
endpar
```

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Development workflow

1. Register «abstract» component (name of service, parameters in, out, inout) with yml_component
2. Register «implementation» component (parse code, get information on impl (grid topology for XMP: CPU(:,:), **compile**) with yml_component
3. **compile Application with yml_compiler**
4. **schedule application with yml_scheduler**

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Multilevel programming paradigm

- **High level**: communication inter nodes/group of nodes
- **Low level**: group of nodes / cores

Multilevel programming

- **High level: YML** - coarse grain parallelism - asynchronous communication
- **Low level: XMP** programming with pragma, PGAS language

Multilevel programming

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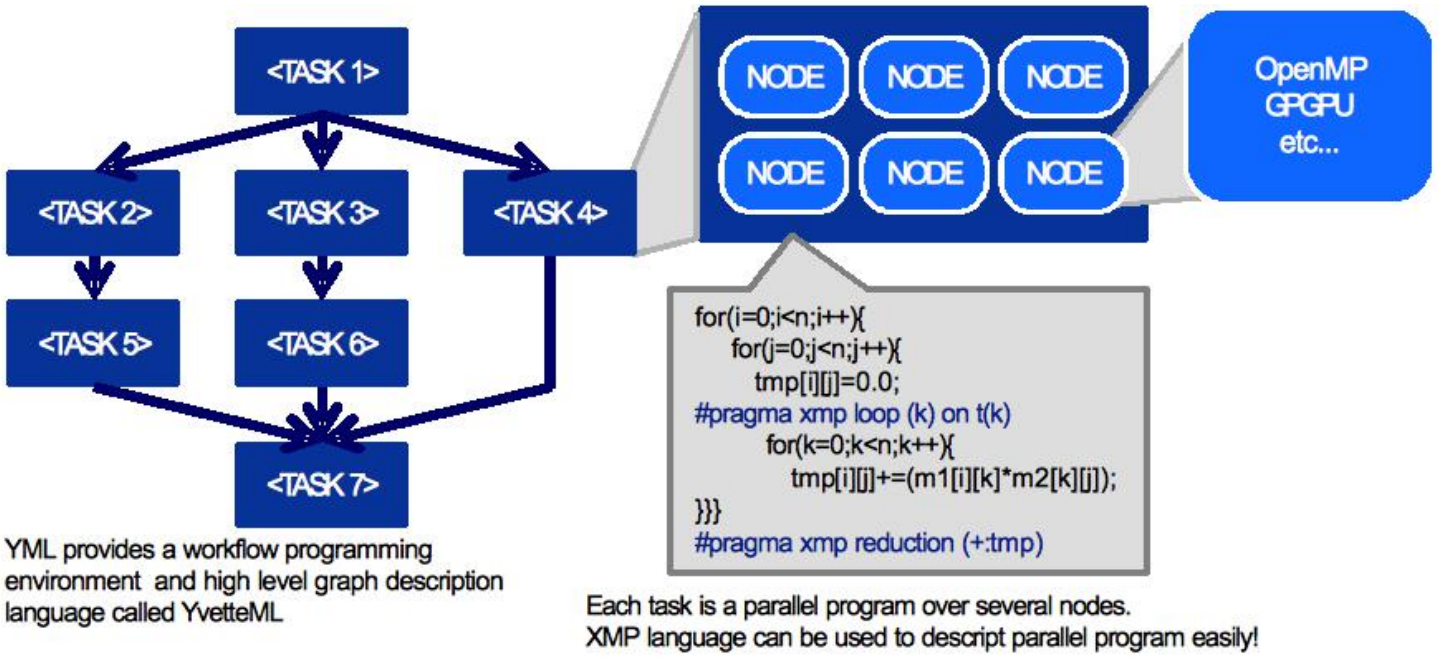

Figure : Multilevel programming

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Architecture overview

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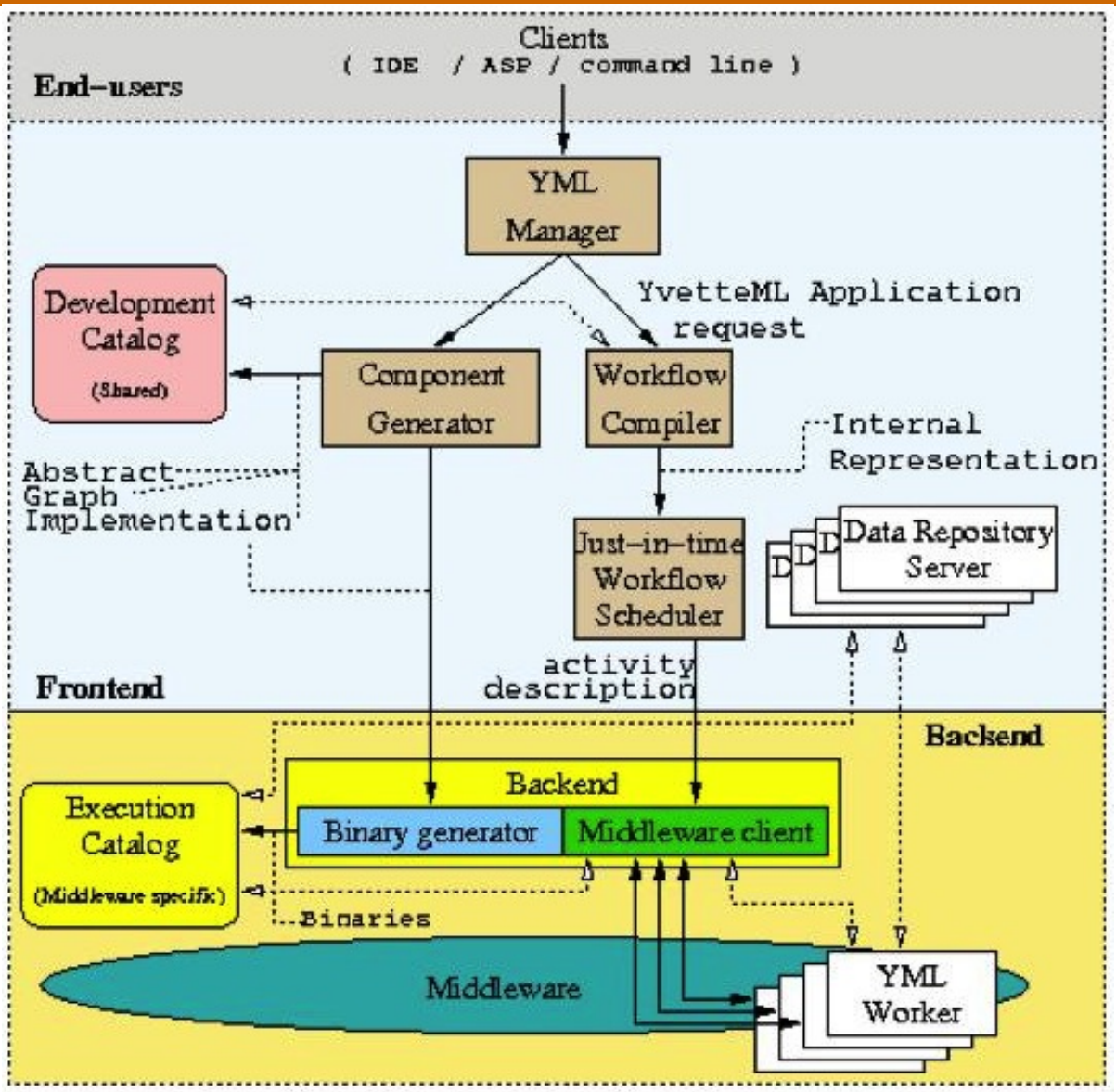

Figure : YML Architecture

Coupling between Backend and Middleware

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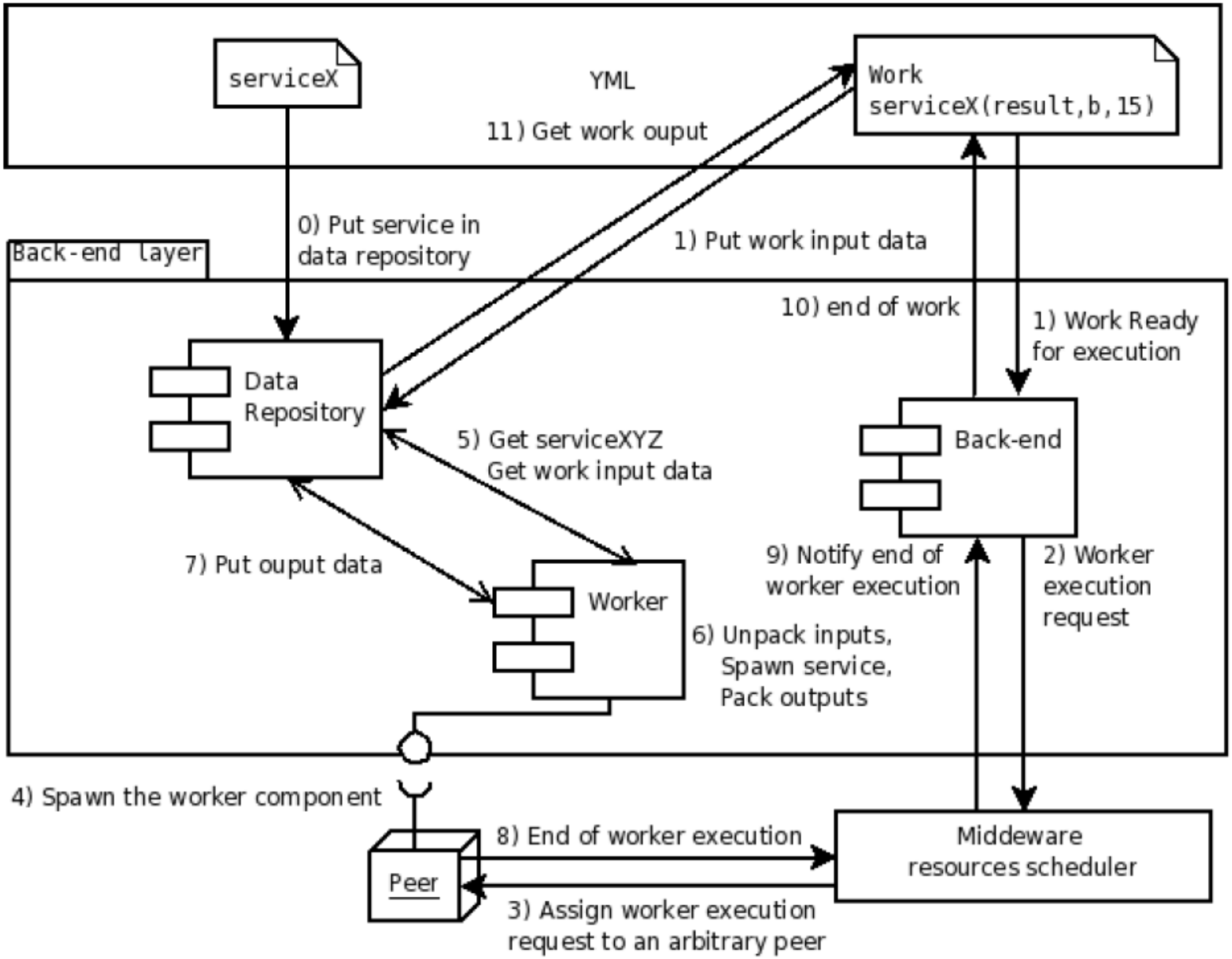

Figure : Backend Model - Structural Point of vue

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Note on backend interface

- Backend interface provides information from catalogs
- Middleware use this information
- **Separation of Data definition, computation and communication**

yml_scheduler

1. get information on application (graph, binaries)
2. Scheduling loop
   1. Scheduler schedule pending task (with BackendManager)
   2. BackendManager execute task (with Backend)
   3. Backend execute Implementation

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Eigenvalue problem: **M**ultiple **E**xplicit **R**estarted **A**rnoldi **M**ethod (MERAM)

- solution by ERAM by a component with possibly many implementation
  - expression of paralleslism
  - use of different libraries (Petsc/Slepc, Scalapak)
- Restarted Krylov Method: How to choose the good size of subspaces and restarting ?
- Restart combine multiple instances of ERAM with different parameter
  - coarse grain parallelism
  - asynchronous communication

Inverse of a matrix: **B**lock **G**auss **J**ordan

- each component perform parallel linear algebra operation
- coarse grain parallelism expressed by the graph of task (dependencies)

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Targeted Architecture

- **Grid'5000**: Cluster of clusters distributed over 10 distant sites and > 5000 cores.
- **Carver**: IBM iDataPlex System at NERSC/LBNL (9984 cores, 1120 nodes of 8 cores & 80 nodes of 12 cores).
- **K Computer**: 864 rack x 102 nodes x 1 CPU = 88,128 CPUs. Node: SPARC64 VIIIfx (8core) CPU 128GFLOPS/node

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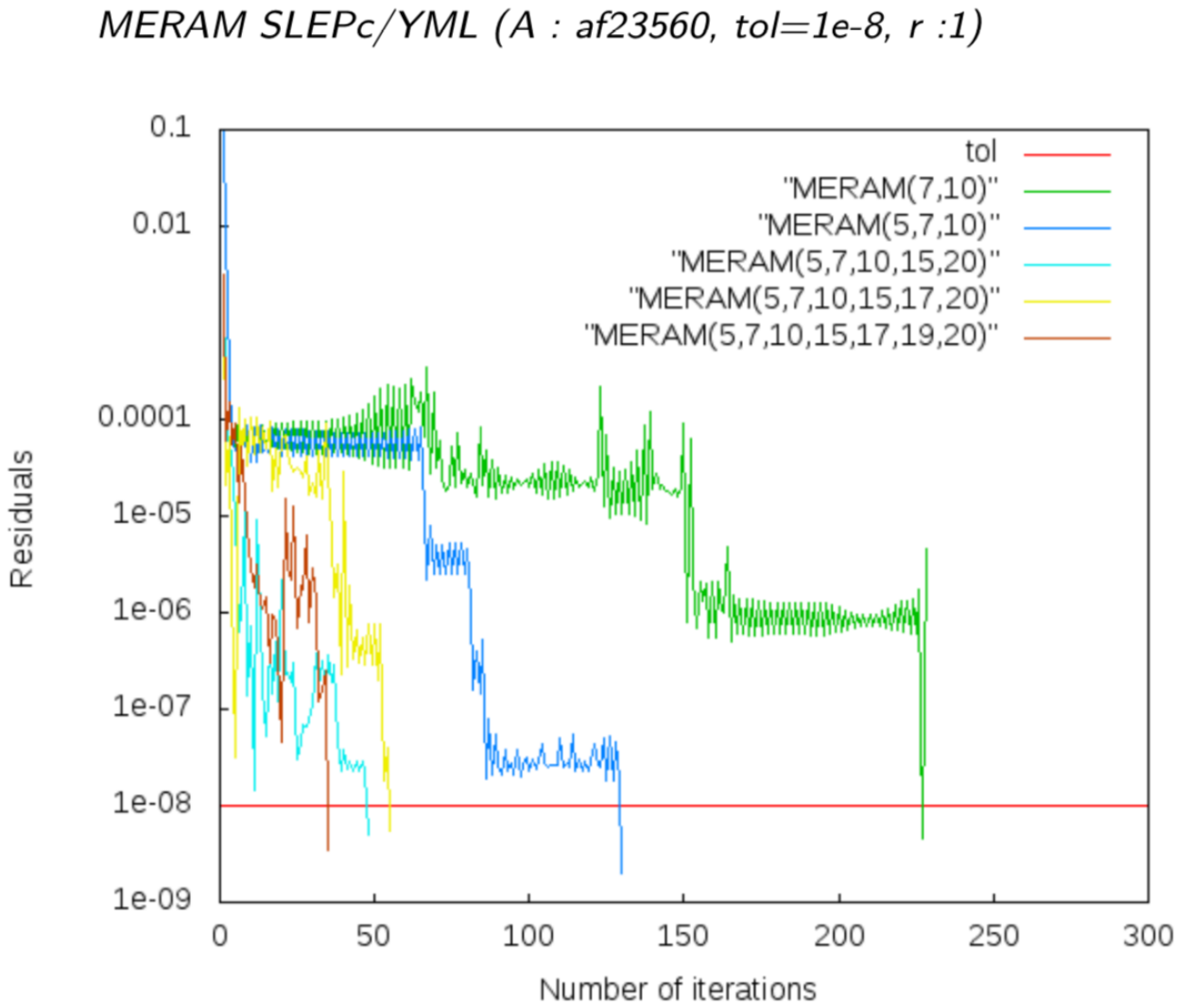

Figure : MERAM on Grid'5000

Results from M. Dandouna (Reusable numerical libraries for large scale distributed system, Ph.D. Thesis, 2012)

MERAM on Carver

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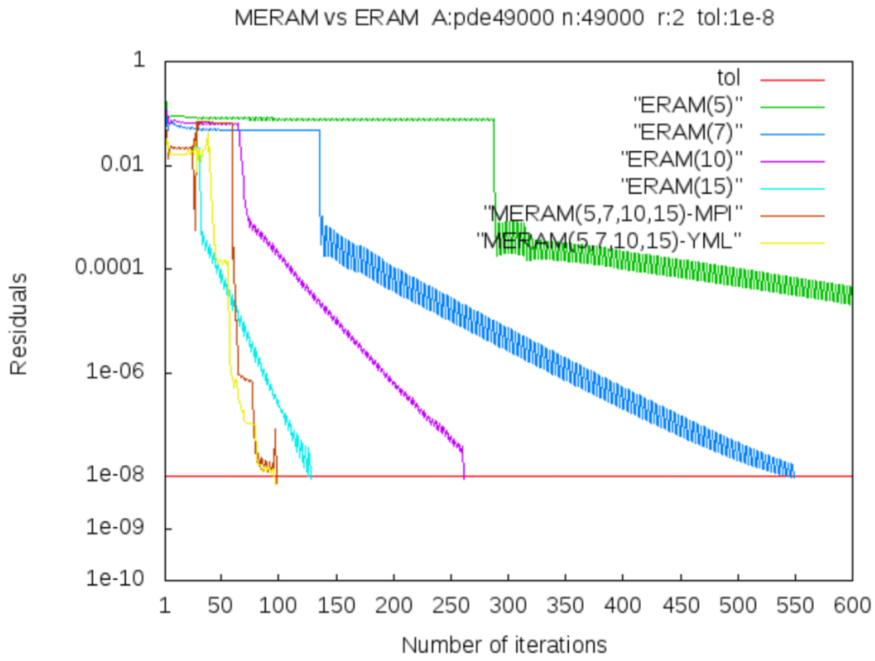

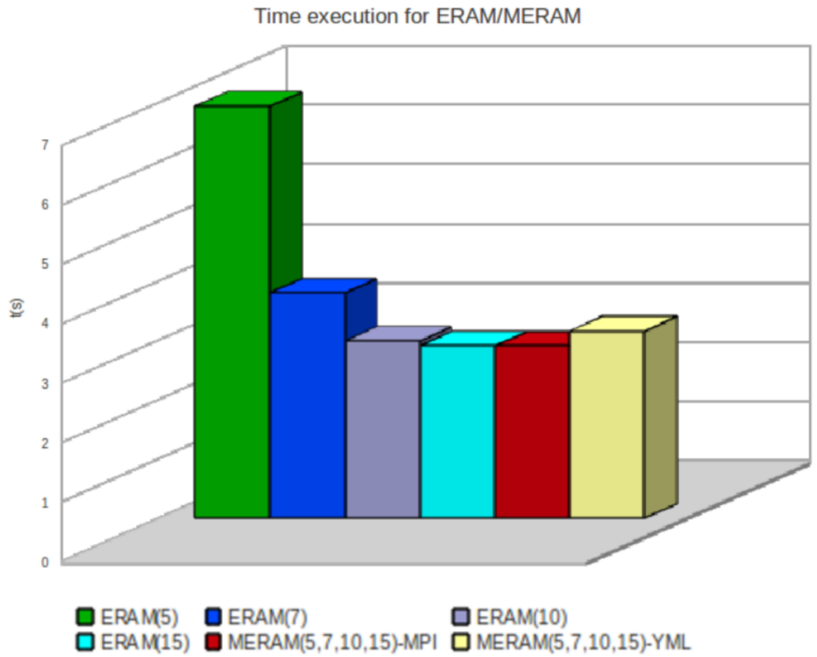

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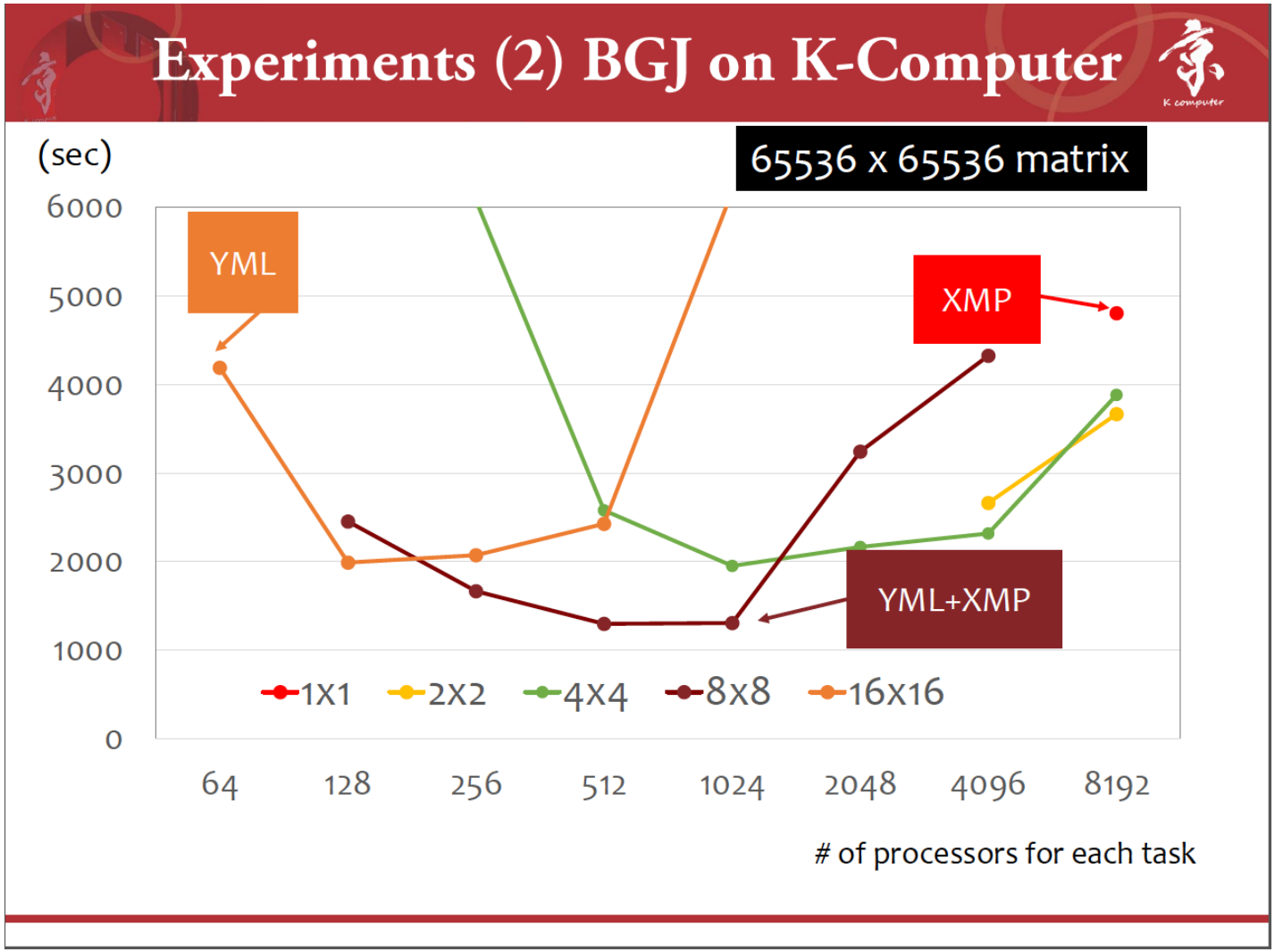

Figure : A^{-1} computation with Gauss-Jordan Block (YML-XMP on K computer (Japan)

Results from Miwako Tsuji (FP3C project, S. Petiton, M. Sato et.al.)

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Target algorithm

- Current algorithms: BGJ, MERAM
- YML-XMP for direct solution method (see talk J. Gurhem)
- New algorithms: Padé Rayleigh Ritz (PRR), Multiple PRR (2018 internship)

Expertise on current design

- Internships on languages integration and interoperability in YML (Master CHPS 2014, 2016)
- study on data managment in YML (First SPPEXA Workshop)
- Yvette language specification (MYX Project (ANR-15-SPPE-0003))
- creation of a YML development comitee (2018)

Dissemination and support

- yml.prism.uvsq.fr
- **Virtual Machine (Workshop JDev 2015, CNRS) Available on yml.prism.uvsq.fr**
- Various virtual machine environment with container (Docker (Debian, CentOs), Singularity) (Undergraduate student project, 2017-2018)
- with tutorial: add, sort, BGJ

Thanks for your attention!

University of Tsukuba
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3rd Workshop on Parallel Programming Models - Productivity and Applications

March 15th 2018

RWTH Aachen university, Aachen

References (Selection)

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