
Optimization tools and applications developed during the OMD & OMD2 projects

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General context

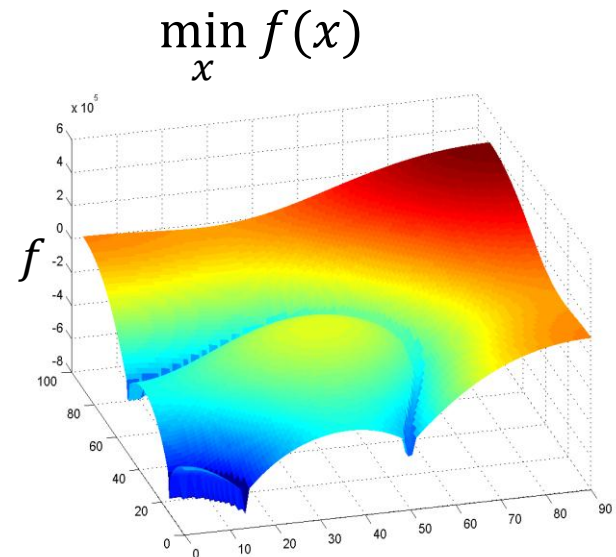
OMD = Optimisation MultiDisciplinaire (French) = MDO (English).
OMD2 = a continuation of OMD + Distributed.

- Numerical simulation has reached a high level of maturity and is increasingly turning to optimization.
- The encountered bottlenecks (see later) are not the ones mathematicians would spontaneously consider.

optimize a complex object

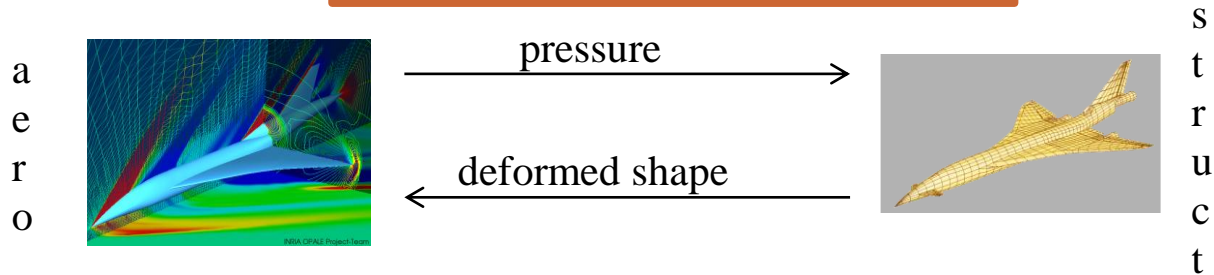


versus

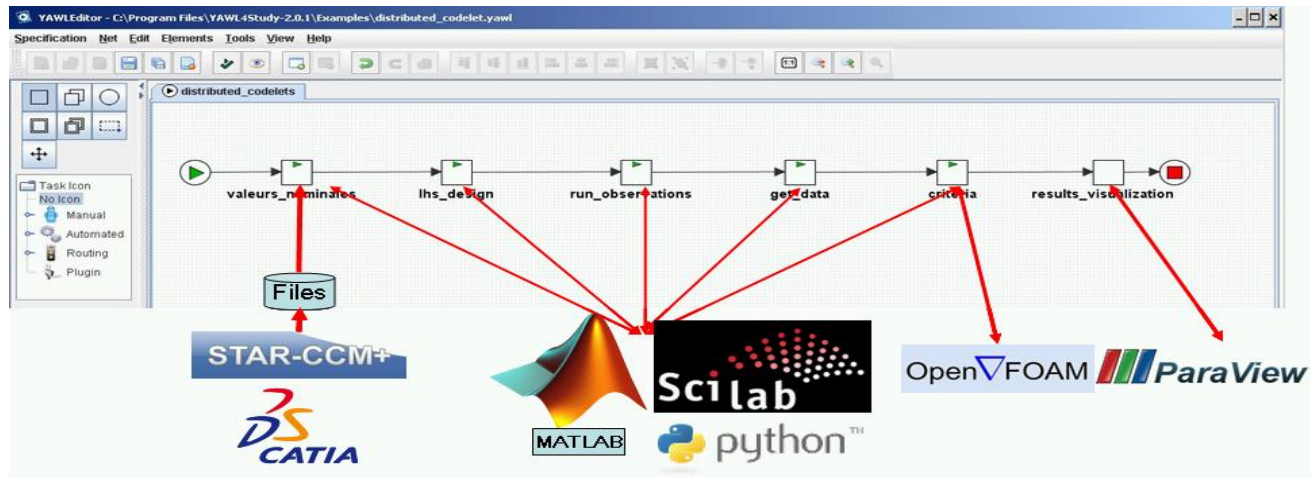


Context : uncertainties & multidiscipline

$f(x)$ is in fact $f(y(x, U))$ where
 y is the output of the multidisciplinary simulation

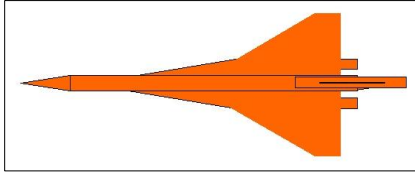


U are uncertain parameters
 $f(y(x, U))$ is calculated through a complex workflow

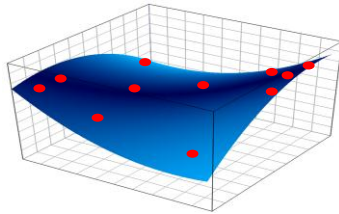


Context : computational time & multi-fidelity

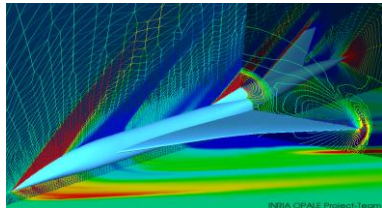
Many simulations are possible to describe the same object :



engineering model



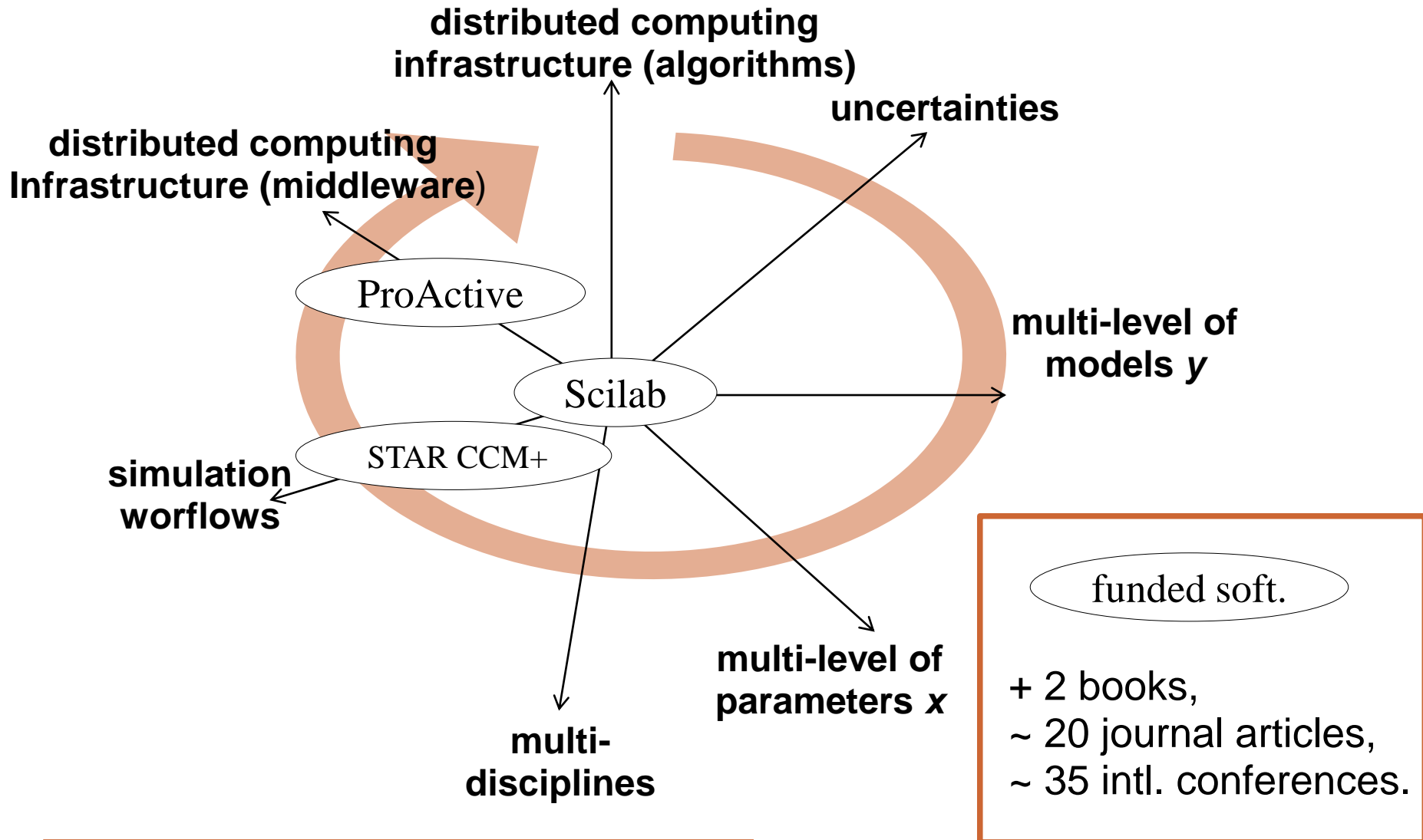
statistical model
(or metamodel)



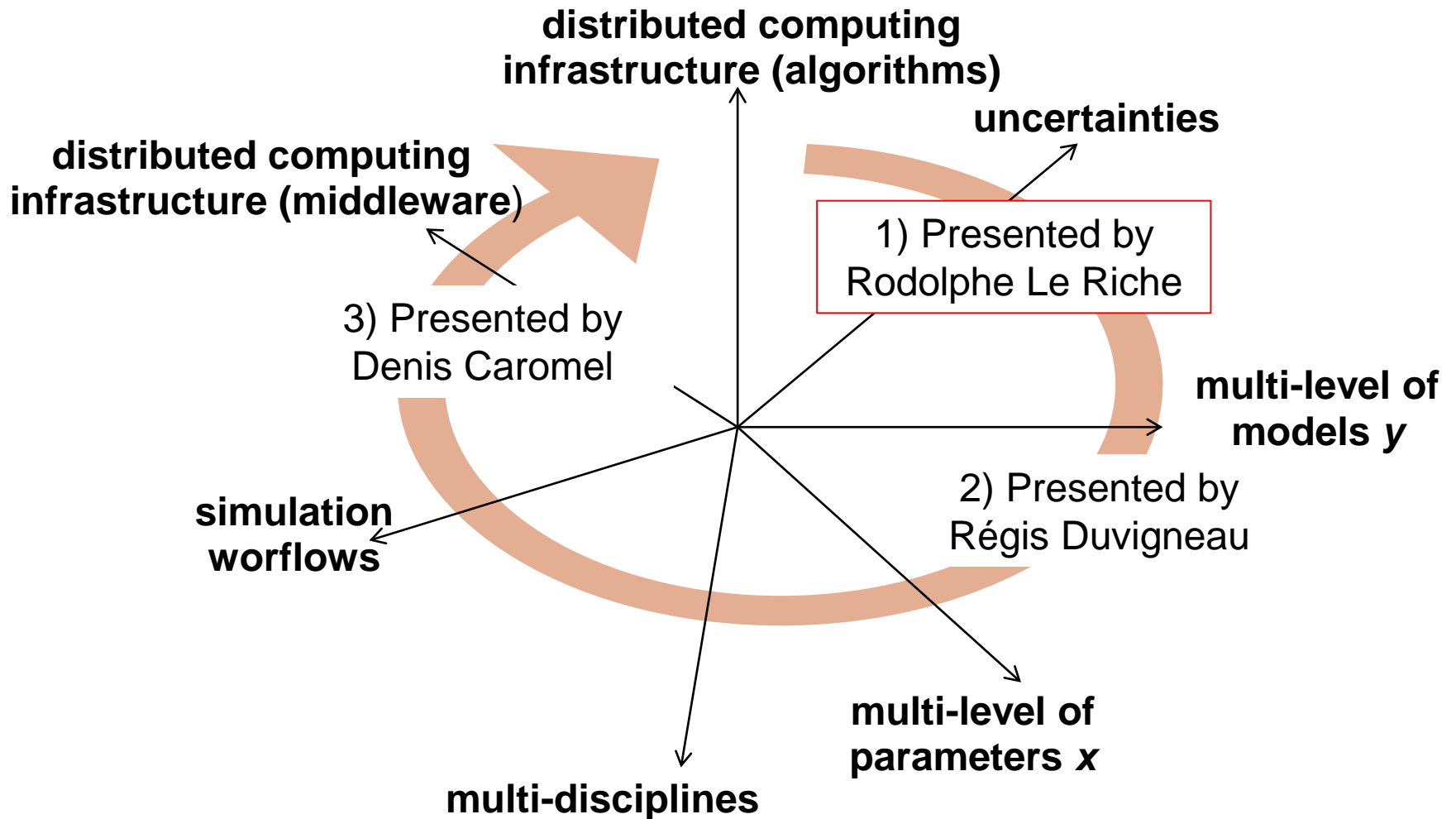
discretized PDEs

They represent various compromises between simulation fidelity and computational cost.

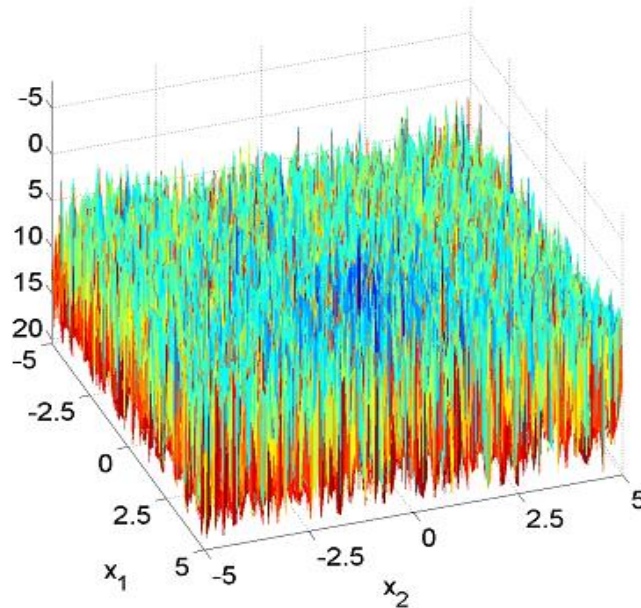
The OMD and OMD2 projects aim at solving realistic, simulation based OPTIMIZATION problems



Outline of the talk



Optimization with uncertainties (1)



$f(x)$ is noisy $\rightarrow f(x, U)$, where U is random.
 U used to represent uncertain environment, model error, noise.

How to « optimize » x ?
What does it mean ?

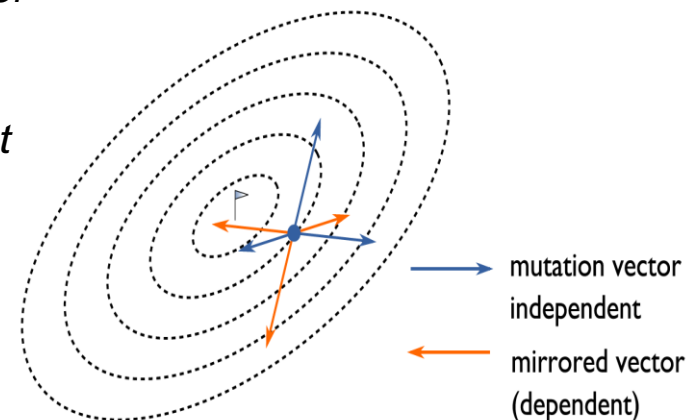
Optimization with uncertainties (2) : when noise cannot be controlled

Problem : $\min_x f(x)$ but evaluations of $f(x)$ are perturbed as $f(x,u)$, where u is not controlled.

Method : a stochastic optimization algorithm which strikes a good compromise between efficiency and robustness, **CMA-ES with mirrored sampling and sequential selection**. (CMA-ES available in Scilab)

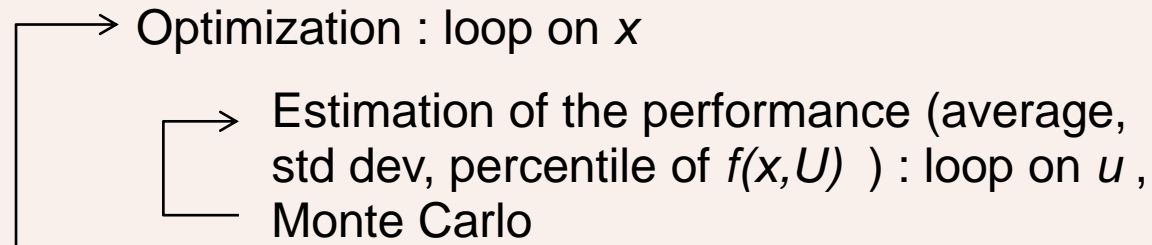
D. Brockhoff, A. Auger, N. Hansen, D. V. Arnold, and T. Hohm. *Mirrored Sampling and Sequential Selection for Evolution Strategies*, PPSN XI, Springer, 2010

A. Auger, D. Brockhoff, N. Hansen, *Analysing the impact of mirrored sampling and sequential selection in elitist Evolution Strategies*, FOGA 2011.



Optimization with uncertainties (3) : when noise can be controlled

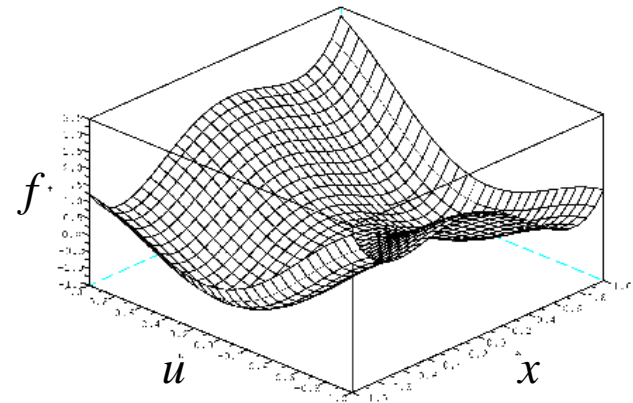
The optimization of a statistical measure of the performance is costly



Problem : $\min_x E_U f(x,U)$, U normal and calls to $f(x,u)$ are controlled, f calls expensive.

Method : approximate $E_U f(x,u)$ by a kriging process used to simultaneously sample U and optimize x . No double loop.
Scilab implementation.

J. Janusevskis and R. Le Riche, Simultaneous kriging-based sampling for optimization and uncertainty propagation, ROADEF 2011 and report hal-00506957 2010.



Optimization with uncertainties (4) : when noise can be controlled

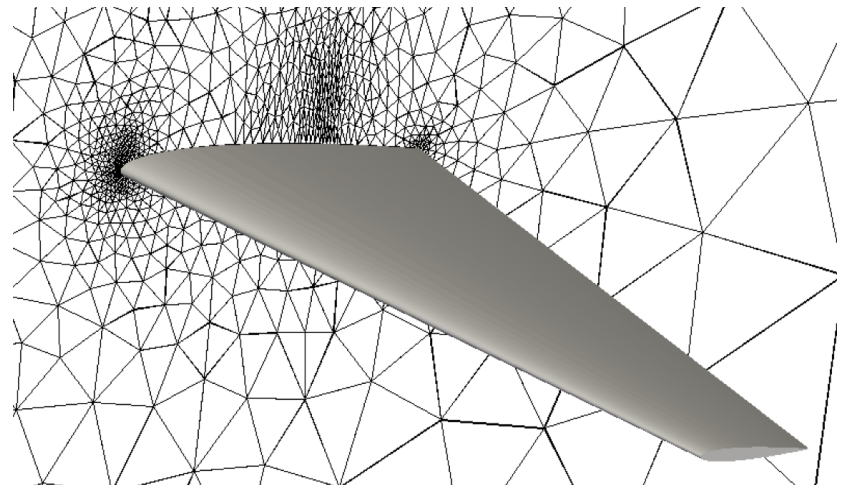
Problem : $\min_x E_U f(x,U)$ and / or $\min_x \text{VAR}_U f(x,U)$

Method 1 : The gradients and Hessian of f w.r.t. u are known (adjoint method, automatic differentiation) → **method of moments**, $E_U f(x,U)$, $\text{VAR}_U f(x,U)$ can be estimated from $\text{grad}_U f$, $\text{Hess}_U f$, $E(U)$ and $\text{VAR}(U)$.

Method 2 : Only f evaluations known → Monte Carlo and metamodels (radial basis functions, kriging). Scilab implementation.

• R. Duvigneau et al., *Uncertainty Quantification for Robust Design*, Multidisciplinary Design Optimization in Computational Mechanics, Wiley, 2010.

• G. Pujol et al., *L'incertitude en conception*, Optimisation multidisciplinaire en mécanique, Hermes, 2009.



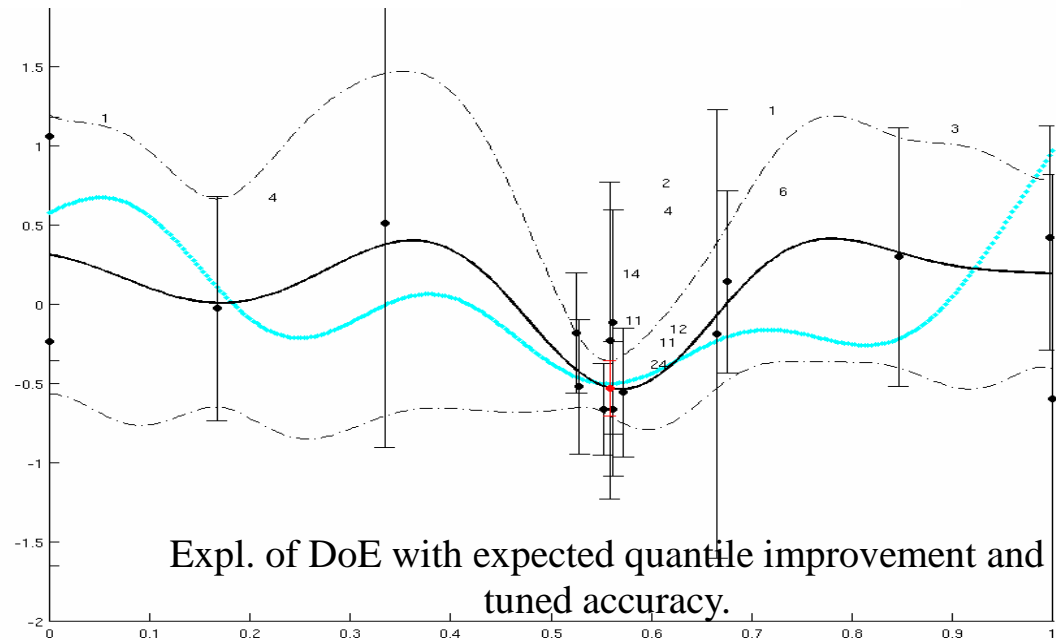
application to $f = \text{drag}$, Duvigneau et al. 2010.

Optimization with uncertainties (5) : adjustable fidelity

Adjustable fidelity = the noise of the simulations can be reduced at an increased computational cost, e.g., $t^2 \sim 1 / \text{time}$ (Monte Carlo).

Expected quantile improvement : a measure of potential improvement at unknown points accounting for the risk associated to noisy observations (based on kriging).

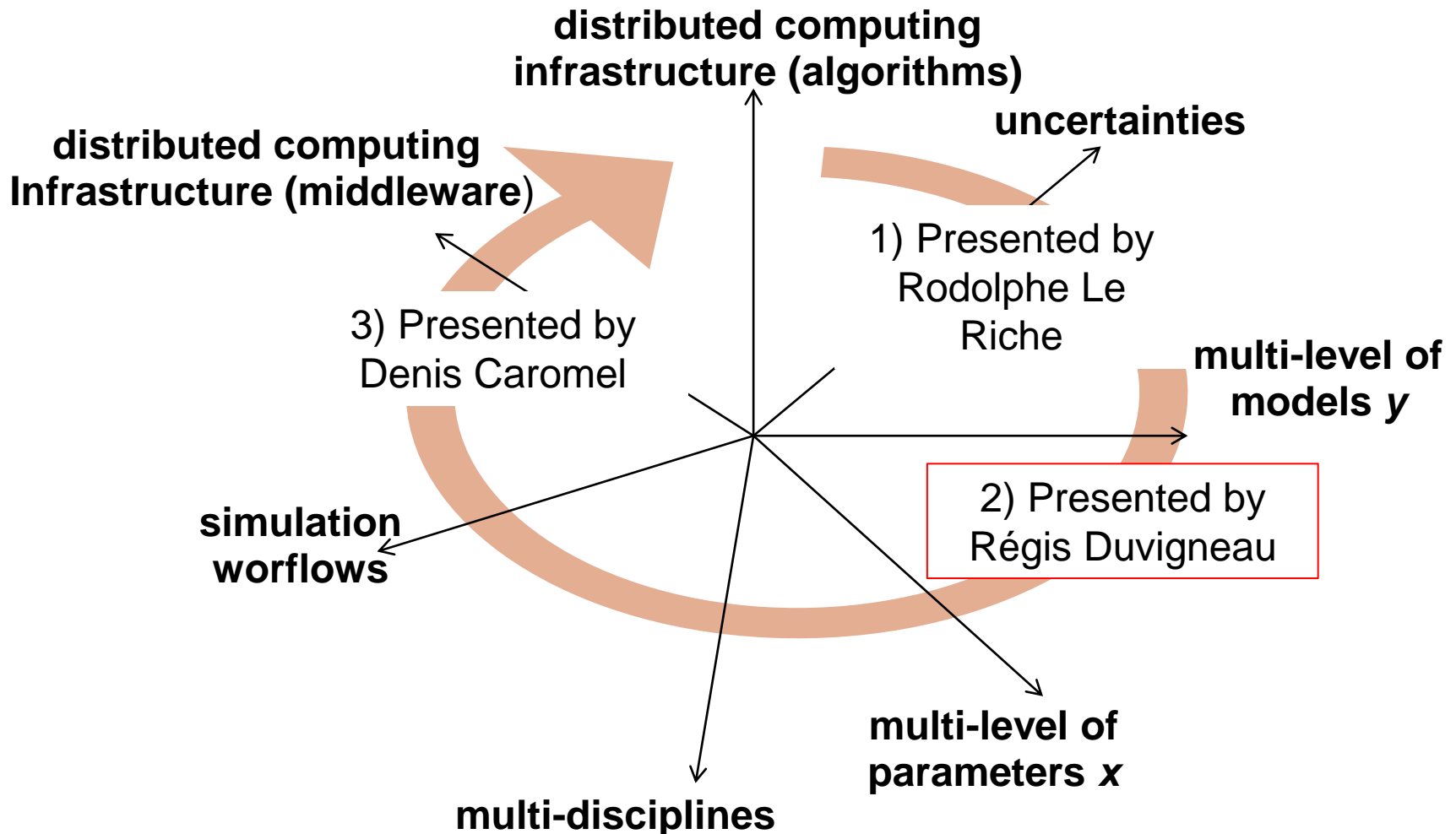
V. Picheny et al., *Optimization of noisy computer experiments with tunable precision*, Technometrics, 2011.



Fidelity accounted for in the optimization algorithm : Scilab implementation.

D. Salazar et al., *An empirical study of the use of confidence levels in RBDO with Monte Carlo simulations*, Multidisciplinary Design Optimization in Computational Mechanics, Wiley, 2010.

Outline of the talk



Multilevel Algorithms : Motivations

Simulation-based optimization in industrial context is limited by the CPU time required, originating from :

- Complex physical systems → expensive simulations
- Presence of several local minima → large number of simulations
- Anisotropy of objective functions → slow convergence
- Large number of design parameters → slow convergence

To address these issues, hierarchical approaches are proposed :

- **Multilevel modelling**
 - **Multi-fidelity simulation**
 - **Multilevel parameterization**
-

Multilevel Modelling : Principles

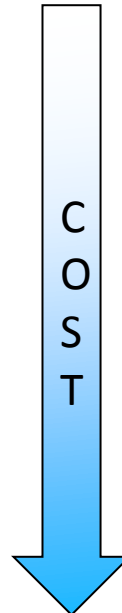
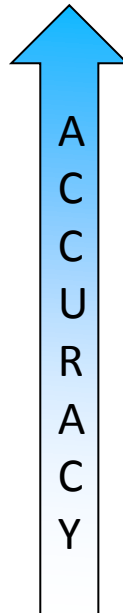
Physical systems can be represented by models of various accuracy levels:

Non-linear PDEs
(ex: Navier-Stokes)

Linear PDEs
(ex: Laplace)

Reduced-order models
(ex: POD)

Metamodels
(Polynomial fitting,
Kriging)



Some hours on a cluster

Some minutes on
workstations

Some seconds on
workstations

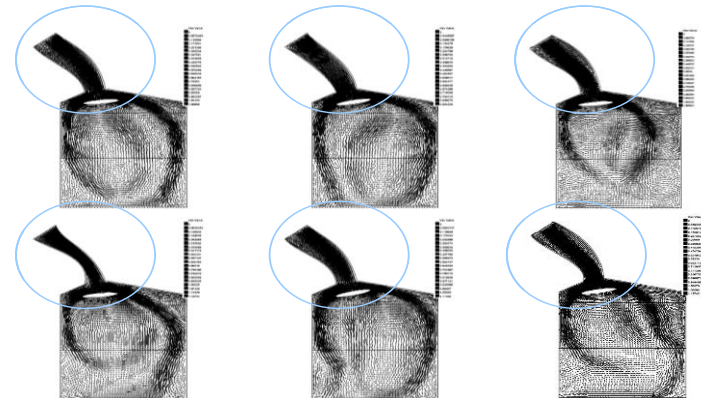
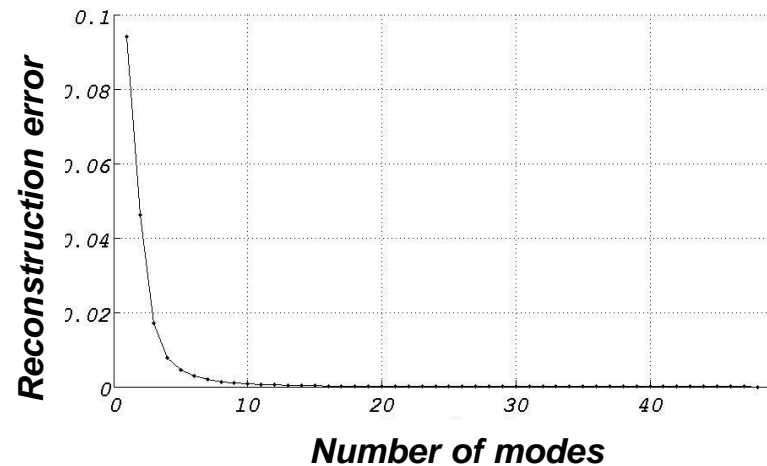
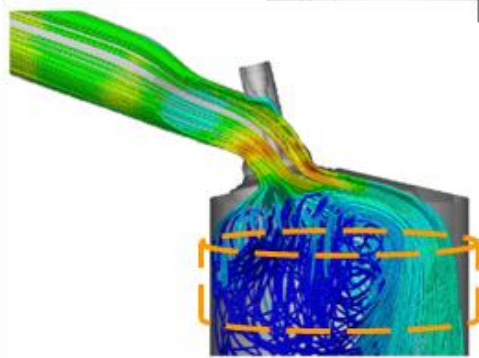
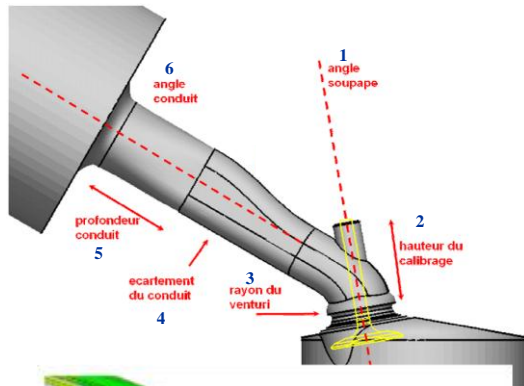
Less than one second

Multilevel modelling optimization : use **as much as possible low-level modelling**, but reach **high efficiency for high-level modelling**

Example : POD

Proper Orthogonal Decomposition (POD) consists of constructing a reduced-order model based on a **small number of eigenmodes** using some high-level modelling simulations

Ex : Admission duct design



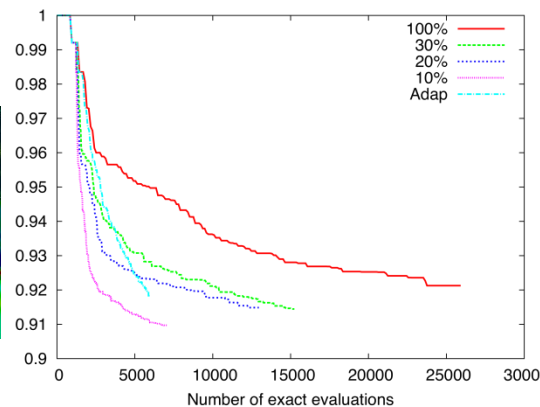
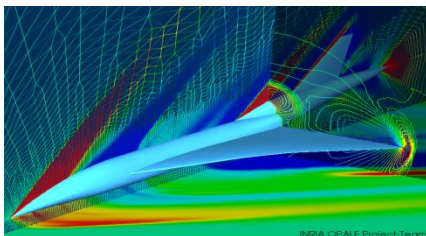
Example : Metamodels

Replace some expensive simulations by a **mathematical model** that interpolates data previously computed

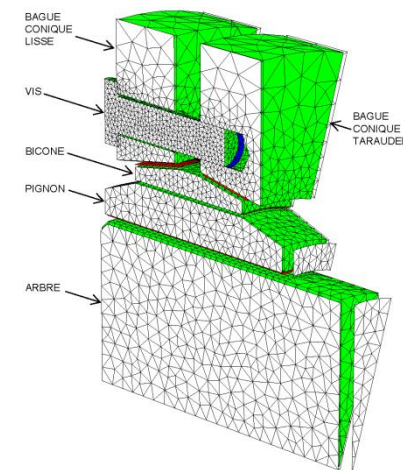
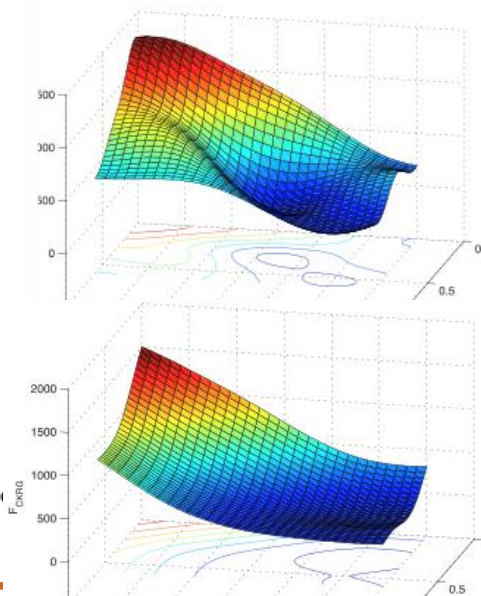
Two examples of strategy:

- Use metamodels only to **select promising simulations** that will be carried out with high-level modelling (inexact pre-evaluation method)
- Use metamodels to completely drive the search by determining **designs with highest probability of improvement** (EGO method)

Ex 1 : aerodynamic wing design



Ex 2 : structural design



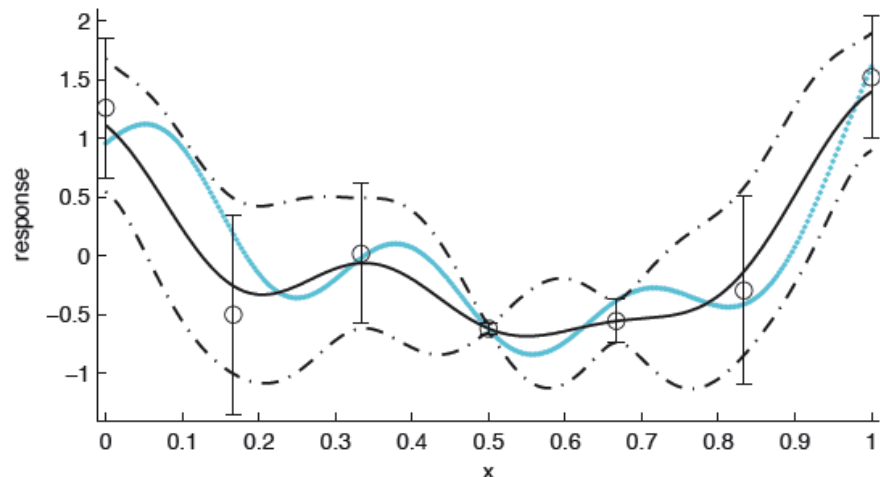
Multi-fidelity simulation : Principle

Reduce the computational cost by **degrading the numerical accuracy** of the simulations used during the optimization :

- Use **coarser grids**
- Use **incomplete convergence**
- Use **low-order discretization** schemes

Optimization algorithms have to take into account the errors !

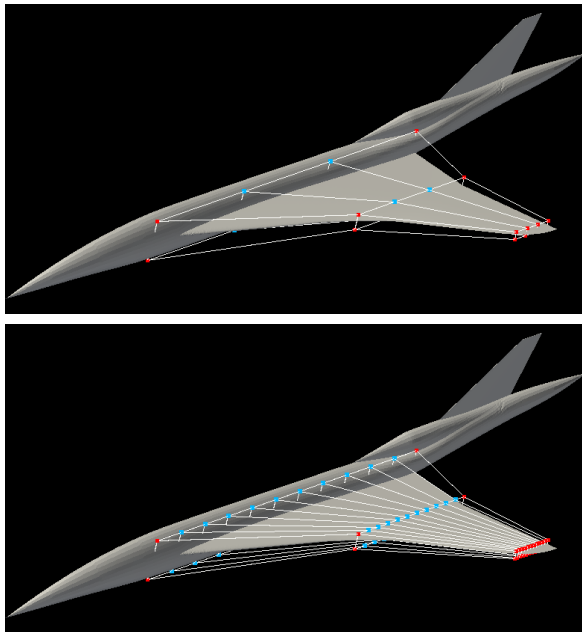
Ex : construction of metamodels taking into account confidence intervals



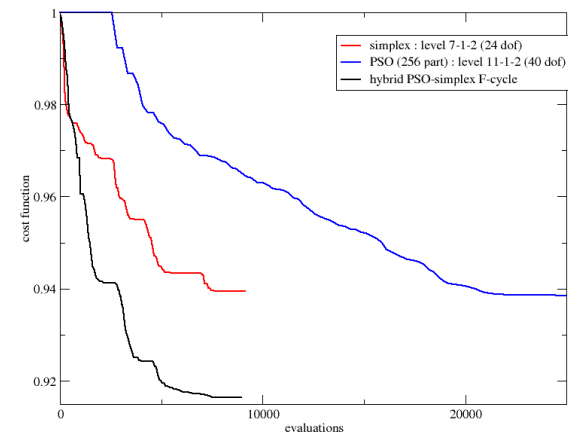
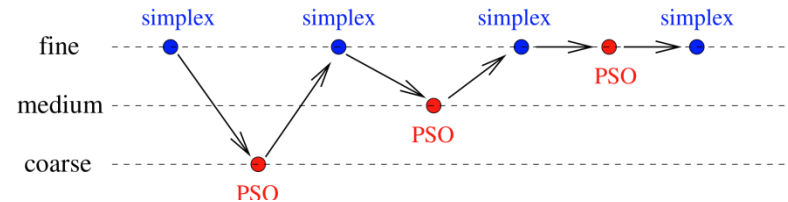
Multilevel parameterization : Principle

Accelerate the convergence (anisotropy and multimodality) by **conducting the search in nested design spaces**

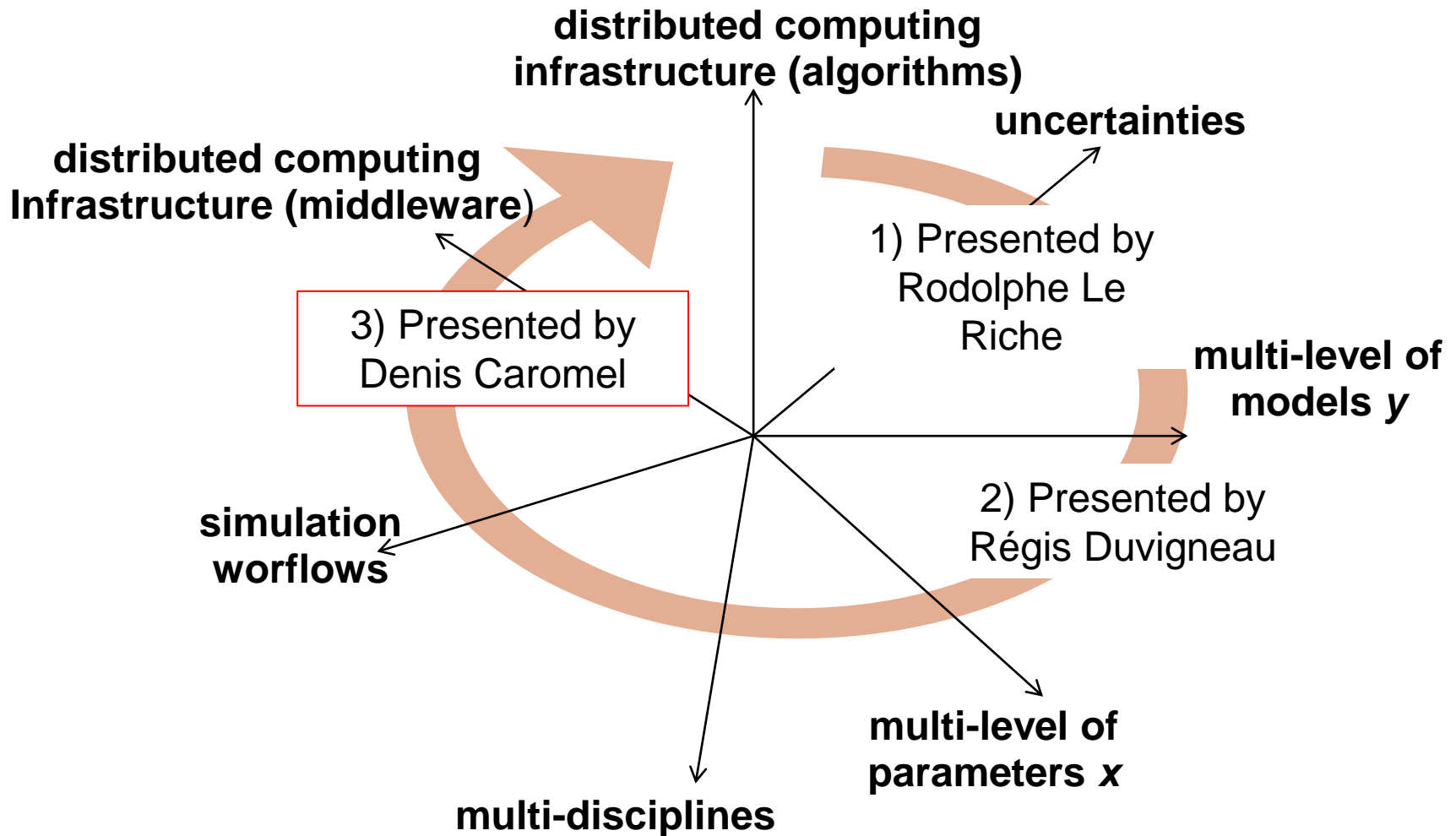
- Construct some parameterization levels (**coarse level** with small number of parameters to **fine level** with large number of parameters)
- Define hierarchical optimization strategy



Ex : aerodynamic design with three levels and hybridization



Outline of the talk



Distributed optimization : middleware, workflows and integration with Scilab

Workflow analysis : for complex applications, evolve over time, distributed environnement, resilient. (INRIA Opale)

T. Nguyễn, et al. A Distributed Workflow Platform for Simulation, Intl. Journal on Advances in Intelligent Computing Systems, 2011.

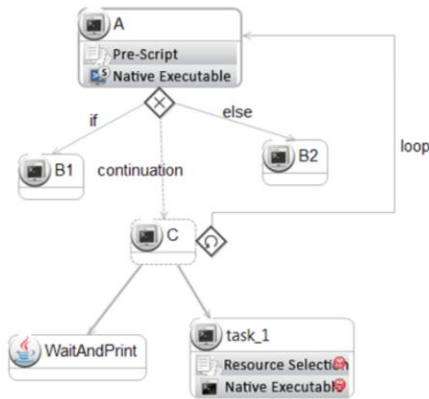


Distribution on heterogeneous infrastructures, workflow visualization (Activeon)

Interface with the Scilab opensource scientific calculation platform.



Workflow Execution Studio Editor and Visualization Parallel Programming in Java



Portal, Multi-Application & Multi-Tenant Enterprise Orchestration

ProActive Scheduler Portal

ID	State	User	Progress	Priority
2002	Running	border	1/3	Normal
2001	Running	border	1/3	Normal
2000	Running	border	1/3	Normal
1999	Running	border	1/3	Normal
1998	Killed	border	1/3	Normal
1997	Running	madman	3/4	Normal
1996	Killed	madman	3/4	Normal
1995	Finished	rampeur	3/3	Normal

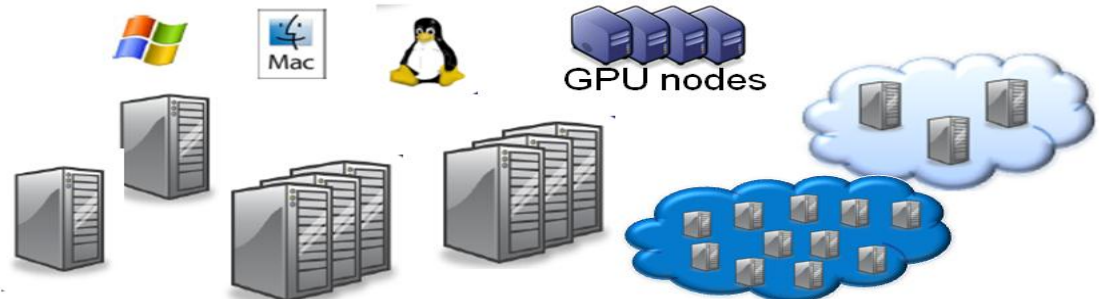
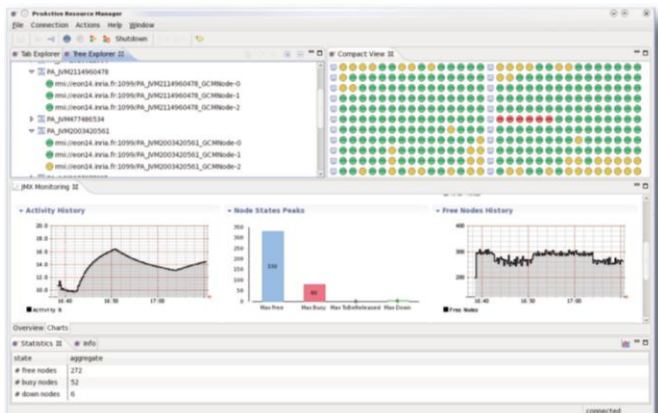
Details

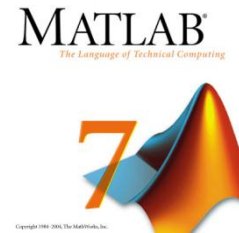
User	Jobs	Connected at	Last submit	Hostname
garen	0	03/16 11:17:25		4640
madman	29	03/16 12:59:30	03/16 05:38:23	4650
border	66	03/16 04:55:39	03/16 04:17:22	4690
colibri	1	03/17 11:35:02	03/17 11:36:11	4722
border	0	03/17 01:54:45		4729
watcher	0	03/16 02:47:14		4876
demo	0	03/16 08:33:57		4876

Job Info

Job id: 2009
State: Running
Name: TEST_CV_0029
Priority: Normal
User: border
Pending tasks: 1
Running tasks: 1
Finished tasks: 1
Total tasks: 3

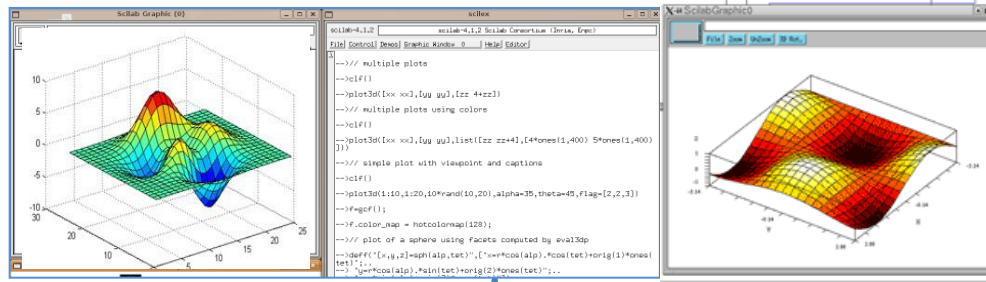
Physical and Virtual Machines Management





Integration with Scilab and Matlab

Integration with Scilab and Matlab



MATLAB
The Language of Technical Computing



Static Policy

LSF

Timing Policy
12/24

Desktops

Dynamic Workload
Policy

EC2



Dedicated resources



Desktops



Amazon EC2

Interface ProActive ↔ Scilab

Console

```

-->PAconnect('rmi://shainese.inria.fr:6608');
Connection successful to rmi://shainese.inria.fr:6608

-->res1 = PAsolve( 'cosh', list(1,2,3,4,5,6,7,8,9,10));

-->res1
res1 =

    res1(1)
1.5430806
    res1(2)
3.7621957
    res1(3)
10.067662
    res1(4)
27.308233
    res1(5)
74.209949
    res1(6)
201.71564
    res1(7)
548.31704
    res1(8)
1490.4792
    res1(9)
4051.542
        
```

Scheduler

Pending (8)

Id	Priority	Name	Description
78	Normal	job_2_tasks	2 tasks with variable durations
79	Normal	job_2_tasks	2 tasks with variable durations
80	Normal	job_2_tasks	2 tasks with variable durations
81	Normal	job_2_tasks	2 tasks with variable durations
82	Normal	job_2_tasks	2 tasks with variable durations
83	Normal	job_2_tasks	2 tasks with variable durations
84	Normal	job_2_tasks	2 tasks with variable durations
85	Normal	job_2_tasks	2 tasks with variable durations

Running (10)

Id	Task	Priority	Name	Description
68	7/8	Normal	job_8_tasks	Simple test of 8 tasks with
69	7/8	Normal	job_8_tasks	Simple test of 8 tasks with
70	6/8	Normal	job_8_tasks	Simple test of 8 tasks with
71	0/1	Normal	job_PI	Calcul de Pi, methode de l
72	0/1	Normal	job_PI	Calcul de Pi, methode de l
73	0/1	Normal	job_PI	Calcul de Pi, methode de l
74	0/1	Normal	job_PI	Calcul de Pi, methode de l
75	0/1	Normal	job_PI	Calcul de Pi, methode de l
76	1/2	Normal	job_2_tasks	2 tasks with variable durat
77	0/2	Normal	job_2_tasks	2 tasks with variable durat

Finished (7)

Id	Priority	Name	Description
61	Normal	job_8_tasks	Simple test of 8 tasks with variat
62	Normal	job_8_tasks	Simple test of 8 tasks with variat
63	Normal	job_8_tasks	Simple test of 8 tasks with variat
64	Normal	job_8_tasks	Simple test of 8 tasks with variat
65	Normal	job_8_tasks	Simple test of 8 tasks with variat
66	Normal	job_8_tasks	Simple test of 8 tasks with variat
67	Normal	job_8_tasks	Simple test of 8 tasks with variat

Tasks

Job 65 has 8 tasks

Id	State	Name	Start time	finished time	Run time limit	ReRunnable	Description
65001	Finished	task6	08:55:11 07/05/07	08:55:16 07/05/07			
65002	Finished	task5	08:55:13 07/05/07	08:55:21 07/05/07			
65003	Finished	task4	08:55:14 07/05/07	08:55:20 07/05/07			
65004	Finished	task2	08:55:14 07/05/07	08:55:21 07/05/07			
65005	Finished	task8	08:55:15 07/05/07	08:55:35 07/05/07			
65006	Finished	task1	08:55:15 07/05/07	08:55:23 07/05/07			
65007	Finished	task3	08:55:16 07/05/07	08:55:24 07/05/07			
65008	Finished	task7	08:55:17 07/05/07	08:55:22 07/05/07			

Jobs info

Property	Value
Id	65
Name	job_8_tasks
Priority	Normal
Pending tasks number	0
Running tasks number	0
Finished tasks number	8
Total tasks number	8
Submitted time	08:54:55 07/05/07
Started time	08:55:11 07/05/07
Finished time	08:55:35 07/05/07
Pending duration	16s 25ms
Execution duration	24s 622ms

Demonstration

The ProActive PACA Grid Platform (4)

Use Cases and Demonstration on a Production Platform

Total:

- ❑ 1 368 Cores
- ❑ 480 CUDA Cores
- ❑ 30TB Storage

Publically Available Today



Workflow Studio

Resource - myWorkFlow/OMD2_modified/job_static_workflow_kepsilon.job_diagram - Eclipse Platform

File Edit Diagram Navigate Search Project Run Window Help

Project Explorer

- myWorkFlow
 - OMD2
 - OMD2_modified
 - img
 - cas2_template_geom_and_mesh_distant.job.c
 - cas2_template_geom_and_mesh_distant.xml
 - cas2_template_geom_distant.job_diagram
 - cas2_template_geom_distant.xml
 - job_static_workflow_kepsilon.job_diagram
 - job_static_workflow_kepsilon.xml
 - workflow
 - default.job_diagram
 - default.xml
 - default.taipan
 - default.taipan_diagram

Job Properties

Job

Rulers & Grid

Appearance

Project Name

Job Name

Job Description

Input Space URL:

Output Space URL:

Log File

Max number of executions for tasks

Cancel Job On Error Policy

If an error occurs restart task

Job Priority

generic information

job classpath

job variables

Palette

- Task
 - Java Task
 - Native Task
 - pre/post/clean
 - InputFiles
 - Output Files
 - Resource Selection
- Flow Controls
 - if
 - loop
 - replicate
- Flow Connectors
 - Flow Connection
 - if-then branch
 - if-else branch
 - if-join branch
 - loop connection

ProActive Orchestration Portal

File Edit View Favorites Tools Help

★ Favorites | ★ Suggested Sites | Web Slice Gallery

ProActive Scheduler Portal

Home RSS Mail Print Page Safety Tools ? >>

Portal Admin Help Submit job Logout demo

ProActive
Parallel Suite

Jobs list

My jobs

Finished

Pending

Running

< Previous

1 - 50

Next >

Id	State	User	Progress	Priority
2602	Running	lbordier	1 / 3	Normal
2601	Running	lbordier	1 / 3	Normal
2600	Running	lbordier	1 / 3	Normal
2599	Running	lbordier	1 / 3	Normal
2562	Killed	lbordier	1 / 3	Normal
2610	Running	madelain	3 / 4	Normal
2608	Killed	madelain	3 / 4	Normal
2595	Finished	rameur	3 / 3	Normal

Use filters to restrict the number of jobs currently displayed.

Filters apply only to the current page.

Use The <Previous and Next> controls to view more results.

☒ Match All ☐ Match Any ☐ Match None

> - Id contains

Clear

Apply

Details

Tasks Users Statistics

User	Jobs	Connected at	Last submit	Hostname
gperetti	0	03/16 11:17:25		4649
madelain	29	03/16 12:59:30	03/18 05:38:23	4659
lbordier	66	03/16 04:55:39	03/18 04:17:22	4690
cdeibe	1	03/17 11:35:02	03/17 11:38:11	4722
lbordier	0	03/17 01:54:45		4729
watcher	0	03/18 02:47:14		4876
demo	0	03/18 08:33:57		4876

Job Info Output Result Preview

Job Id: 2599

State: Running

Name: TEST_CY_0029

Priority: Normal

User: lbordier

Pending tasks: 1

Running tasks: 1

Finished tasks: 1

Total tasks: 3

Done

Internet | Protected Mode: On

100%

Graphical Visualization of Workflow Execution

ProActive Scheduler Portal x Paris Air Show - The Show ... x 066006 avenue des alpes - ... x P

inria.fr https://node0.cloud.sophia.inria.fr:8888/portal/

Most Visited Getting Started Latest Headlines XE - Universal Currency ... ProActive Scheduler

Portal Admin Help Submit job Logout dcaromel

Jobs list

Id	State	User	Progress	Priority	Duration	Name
67	Running	dcaromel	36 / 37	Normal		PA_Workfl

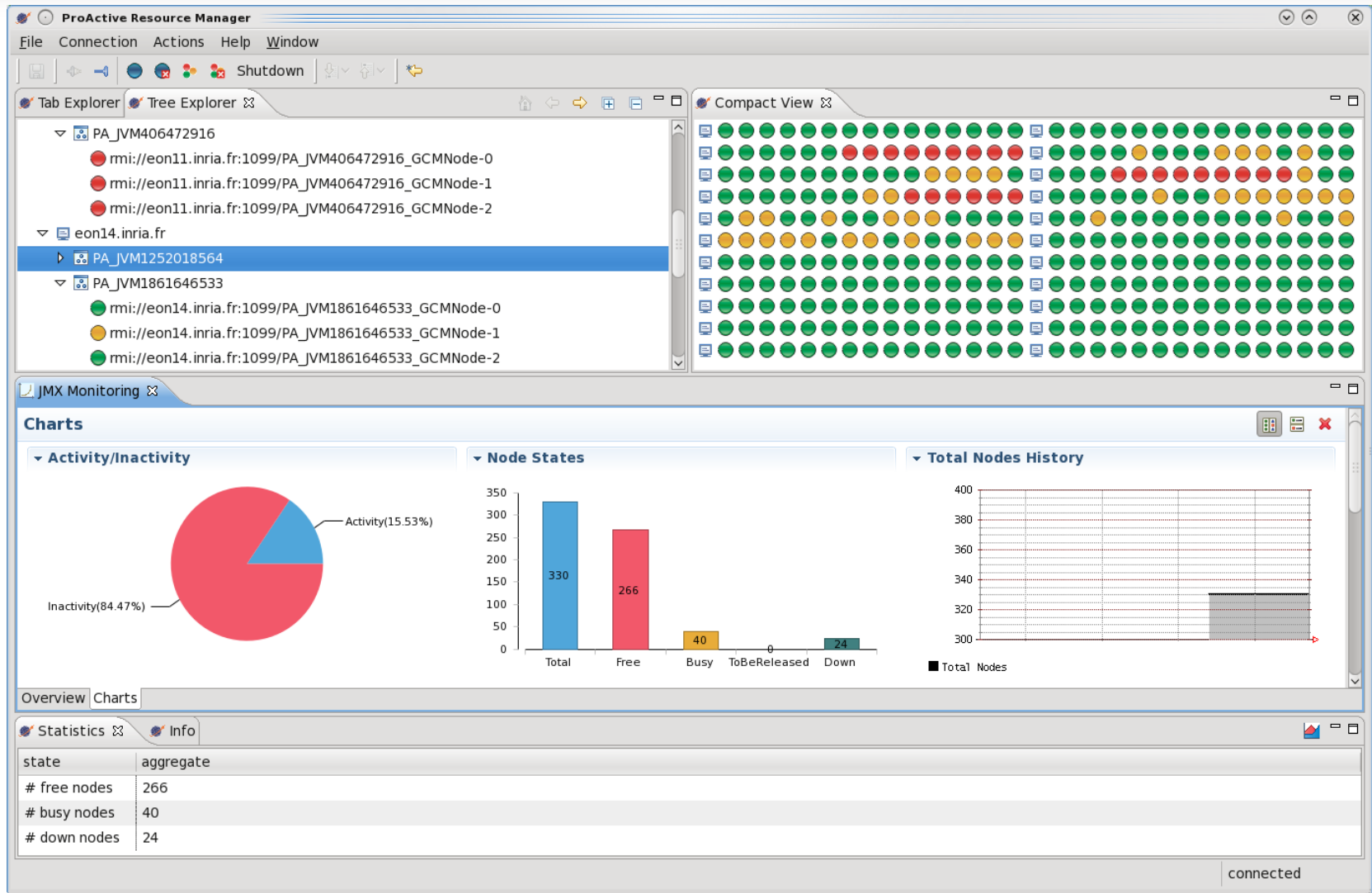
Details

Tasks Visualization Users Statistics

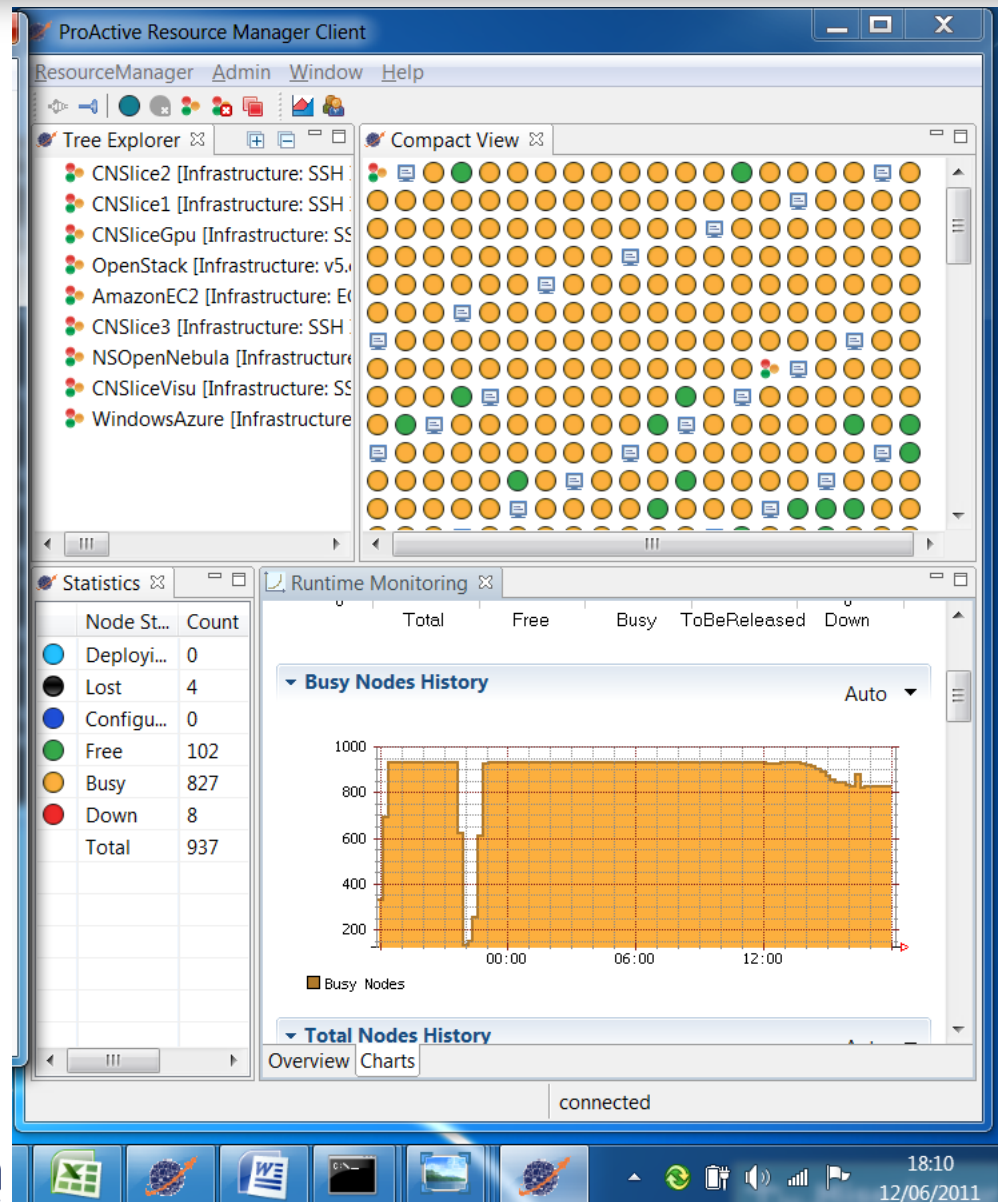
```
graph TD
    split[split 0/6 ✓] -- if --> worker[worker 0/6 ✓]
    split -- else --> else_split[else_split 0/6 ✓]
    else_split --> else_rep[else_rep 3/1 ✗ 5/5 ✓]
    else_rep --> else_merge[else_merge 0/5 ✓]
    else_merge -- loop --> split
    worker -- continuation --> merge[merge 1/0 ✗ 4/4 ✓]
    merge --> end[end 0/5 ✓]
```

The diagram illustrates a workflow execution process. It starts with a 'split' node (0/6, green checkmark). The flow branches into two paths: 'if' and 'else'. The 'if' path leads to a 'worker' node (0/6, green checkmark), which then connects to a 'merge' node (1/0, red X, 4/4, green checkmark). The 'else' path leads to an 'else_split' node (0/6, green checkmark), which connects to an 'else_rep' node (3/1, red X, 5/5, green checkmark). The 'else_rep' node connects to an 'else_merge' node (0/5, green checkmark), which loops back to the 'split' node. The 'merge' node connects to an 'end' node (0/5, green checkmark). A 'continuation' label is placed between the 'worker' and 'merge' nodes.

Heterogeneous Resource Management



Sustained Load of 99 % over Long Periods



ProActive OMD2 Demo



1000 Cores
Production
Cloud Portal



ProActive
Parallel Suite

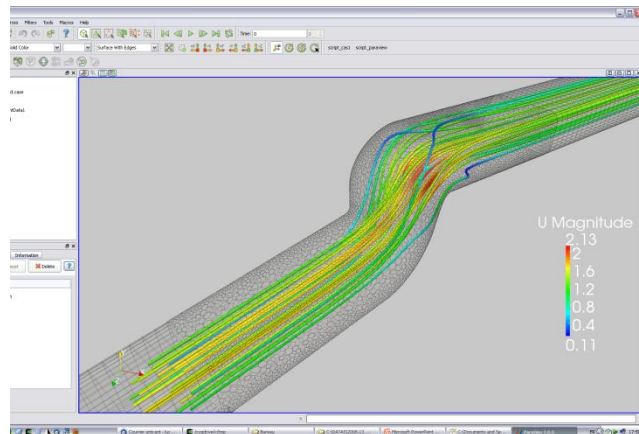
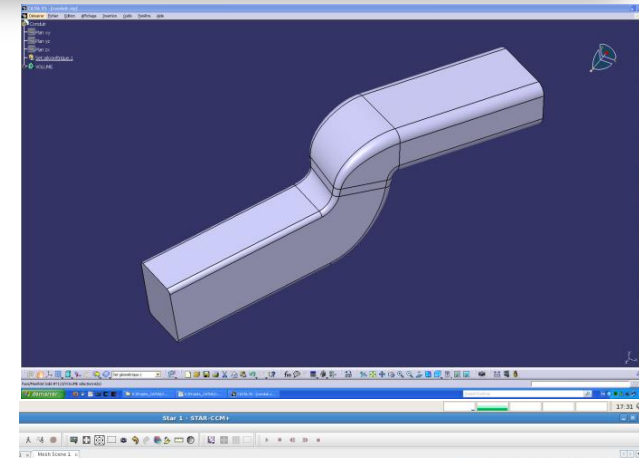
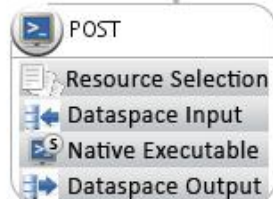
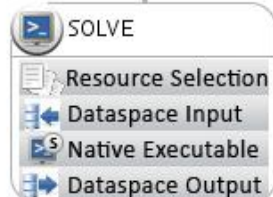
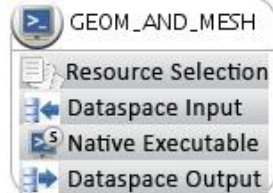
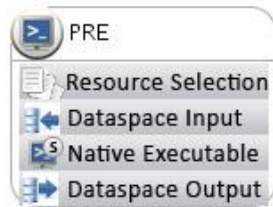
Remote Visualization Directly from Portal

The screenshot displays a desktop environment with several open windows. The primary window is a Mozilla Firefox browser titled "ProActive Scheduler Portal", showing a web interface with a "Jobs list" table and a "Details" section. The "Jobs list" table contains the following data:

Id	State
35	Running
31	Running
30	Running
29	Running
24	Running
23	Running
22	Running
21	Running
19	Running
12	Running

The "Details" section shows a table with "Id" and "Status" columns, listing tasks 350001 (Finished) and 350002 (Running). Overlaid on the browser is a ParaView 3.8.1 64-bit window, which displays a 3D visualization of a complex, intertwined structure rendered in green and yellow. The ParaView window includes a menu bar, a toolbar, and a sidebar with a "scytale:1" label. In the bottom right corner of the desktop, a "ProActive Resource Manager Client" window is visible, showing a "Busy Nodes History" section with "Overview" and "Charts" tabs, and a status indicator that reads "connected". The Windows taskbar at the bottom features icons for various applications, including Firefox, File Explorer, and several instances of the ProActive Scheduler Portal.

Engineering Optimizations: Renault UC



End Of Demonstration

Optimization algorithms for distributed computing infrastructures

CMA-ES (Covariance Matrix Adaptation Evolution Strategy) :
a state-of-the-art stochastic optimizer. λ calls to f are distributed on λ computing nodes at each iteration. What is the best parents population size ? (INRIA / TAO)

- Default choice of CMA: $\mu=\lambda/2$ not optimal
- $\mu=\min(d,\lambda/4)$ close from optimal , $\ln(\mu) \approx \ln^2(\ln(\lambda))$
- Optimal convergence rate prop to $\log(\lambda)$

M. Jebalia, A. Auger, Log-linear convergence of the scale-invariant $(\mu/\mu_w, \lambda)$ -ES and optimal m for intermediate recombination and large population sizes, PPSN XI, 2010.

Distributed optimization based on kriging : use a kriging metamodel to summarize past and currently running simulations, decide new simulations based on multi-points expected improvements

D. Ginsbourger, et al., *Dealing with asynchronicity in kriging-based parallel global optimization*, WCGO-2011.

The OMD and OMD2 projects aim at solving realistic, simulation based OPTIMIZATION problems

