Evolutionary algorithms to improve plasma confinement

Antonio Gómez-Iglesias, Francisco Castejón, Miguel Cárdenas-Montes, Enrique Morales-Ramos

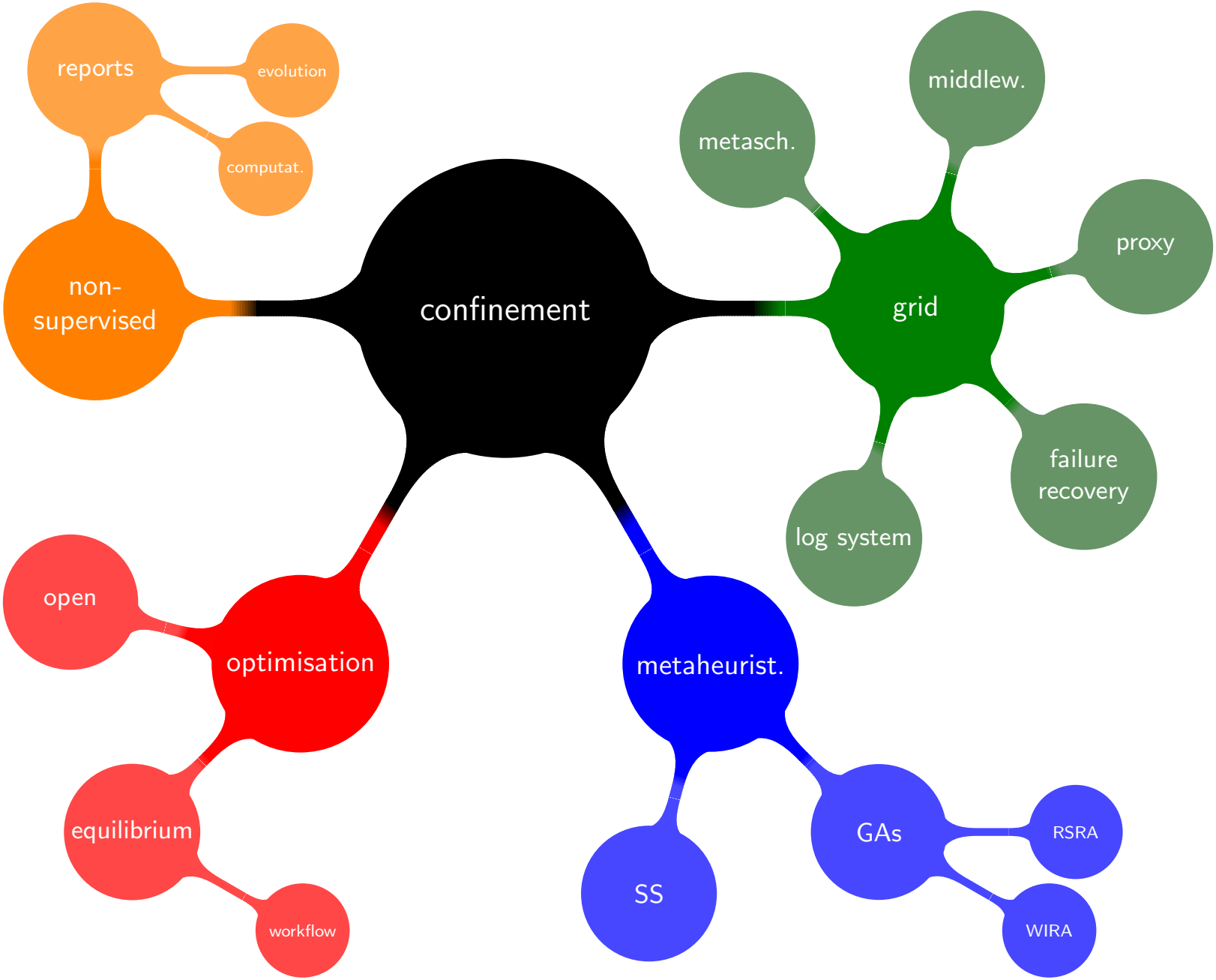
National Fusion Laboratory, CIEMAT

March, 2009

Laboratorio Nacional Fusión

Enabling Grids for E-sciencE

Outline

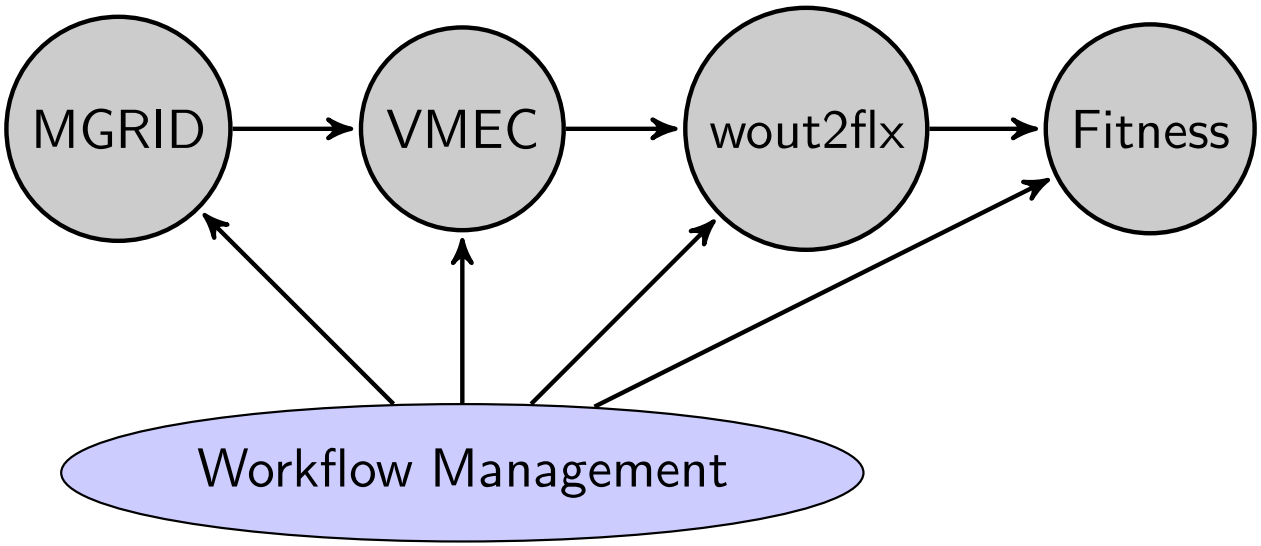

reports
evolution
computat.
non-
supervised
confinement
middlew.
metasch.
proxy
grid
failure
recovery
log system
open
optimisation
equilibrium
workflow
metaheurist.
SS
GAs
RSRA
WIRA

Measuring the equilibrium

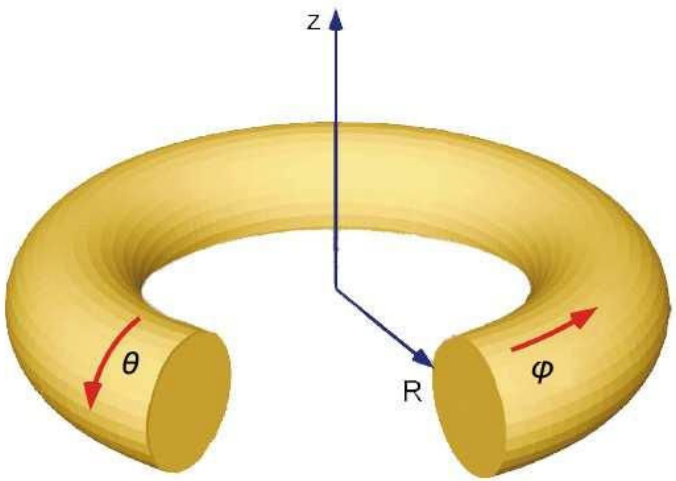
Function

$$F_{target\_function} = \sum_{i=1}^{N} \left\langle \left| \frac{\vec{B} \times \vec{\nabla} |B|}{B^3} \right| \right\rangle_i$$

Workflow



VMEC



What VMEC solves

$$R(\rho,\theta,\phi) = \sum_{mn} R_{mn}(\rho)\cos(m\theta - n\phi)$$

$$Z(\rho,\theta,\phi) = \sum_{mn} Z_{mn}(\rho)\sin(m\theta - n\phi)$$

$$B(\rho,\theta,\phi) = \sum_{mn} B_{mn}(\rho)\cos(m\theta - n\phi)$$

Measuring the equilibrium

Problems of the workflow

- Required time for optimal configurations: 45 min.
- Huge solution space.

Our idea

- Use GAs to look for improved configurations.
- Use grid computing.
- Highly customizable system.

Some problems still remain

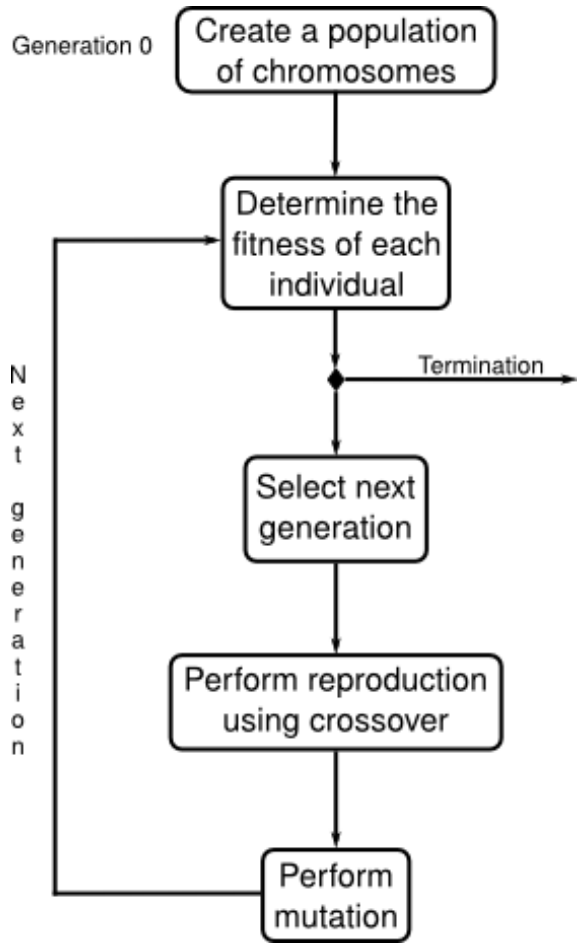
- Time required to find optimal configurations is still high.
- The number of iterations we can evaluate will be low.

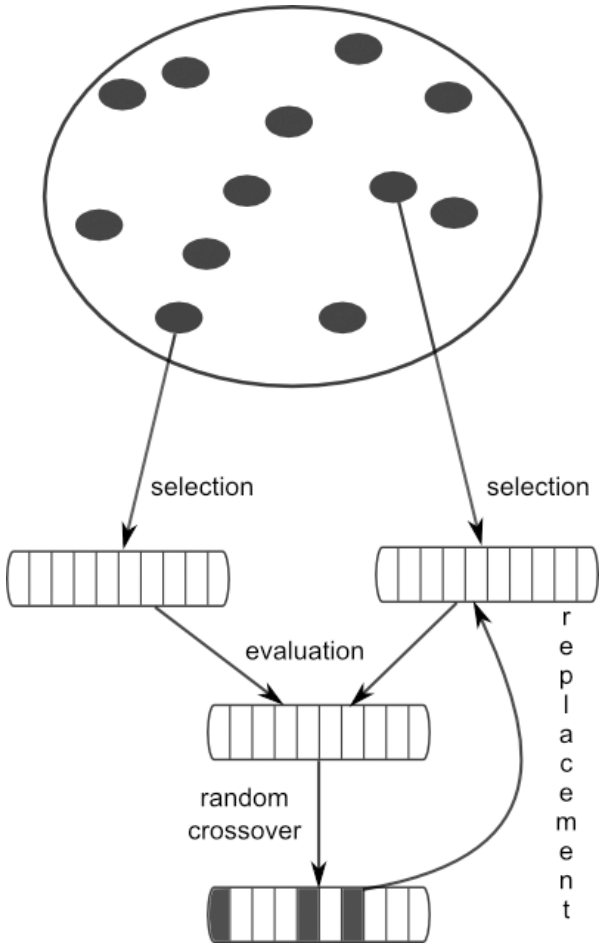
Crossover GA

Considerations

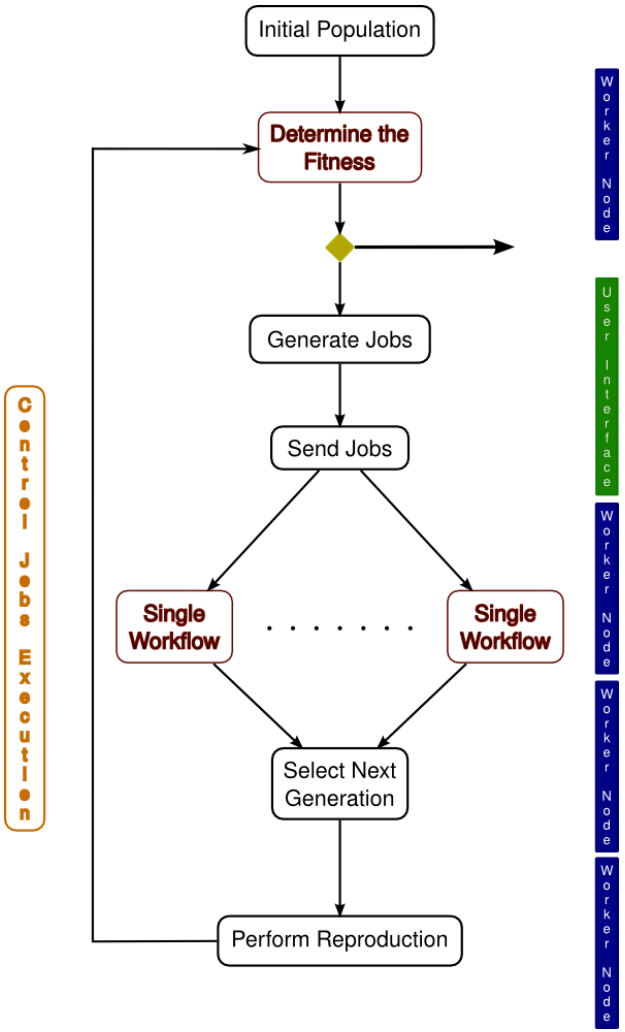
- Long time for a single function.
- Each individual within a generation can be calculated independent from the others.
- Parallel and distributed processing appears to be the best option.
- Master node managing the different slaves.
- Fully configurable via XML files.
  - Number of individuals.
  - Chromosomes.
  - Stop conditions.
  - Selection method.
  - Replacement method.

Crossover GA





Overview of the GA using the Grid



Grid implementation

Features

- Set of Python scripts interacting with grid infrastructure.
- Backup system.
- Error recovering.
- Proxy management.
- Log system.
- Highly configurable system through XML files.

Jog management

Solution to job failures

- Our system manages all submitted jobs by querying the metascheduler.
- Due to failures in the infrastructure, jobs can fail.
- Some configurations can be wrong.
- Failed jobs are resubmitted one time.
- Jobs taking extra-time are killed and resubmitted once.

Mutation-based GA

Features

- Floating point representation.
- Tournament selection.
- Use the sample standard deviation for mutation.
  - Each selected chromosome is added or subtracted with a value in the range $(0 - \sigma]$.
- Random number of chromosomes to mutate ($[1 - number\_of\_chromosomes]$).
- Based on experience:
  - Some binary chromosomes.
  - These chromosomes are randomly selected and crossed.

Replacement

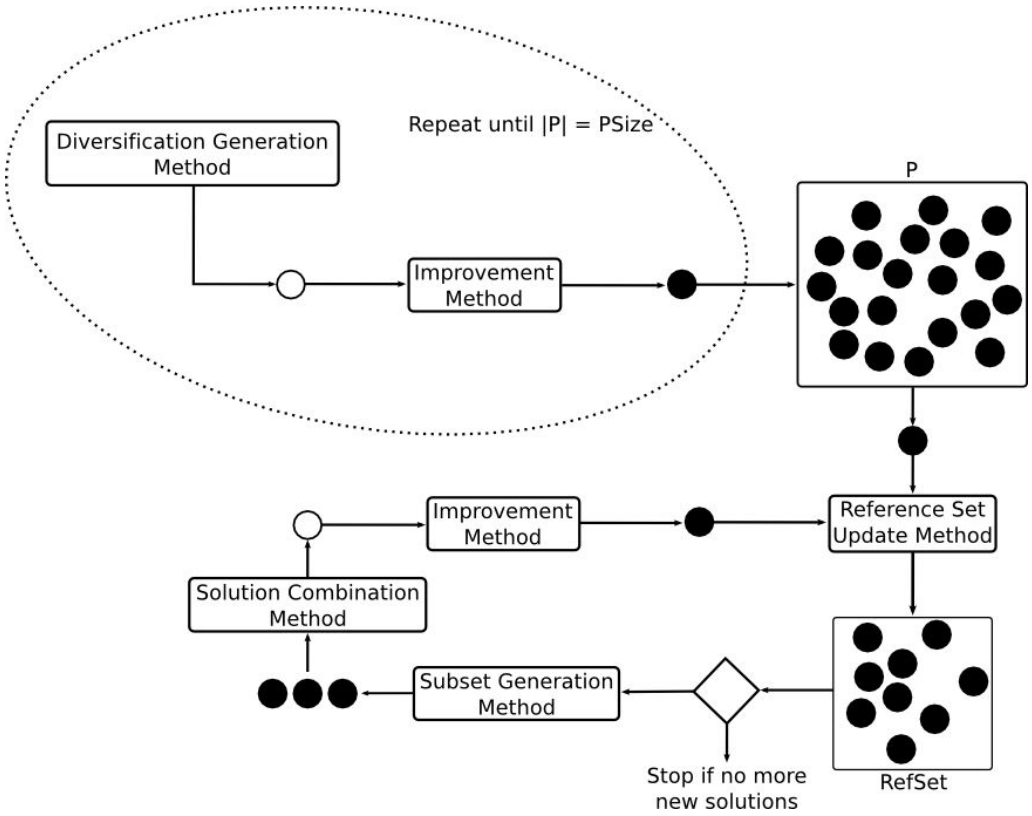
RSRA

- This version of the algorithm replaces one element within the population randomly.
- High dispersion.
- Poor evolution.

WIRA

- This version uses a sorted list of the individuals.
- The worst individual previously evaluated is selected for replacement.

Scatter Search



Crossover GA after 50 generations

Parameter	Value
Number of Fitness Evaluations	48,158
Aggregated Execution Time	74,551:15:34
Average Execution Time	01:32:53
Execution Time	1,834:57:31

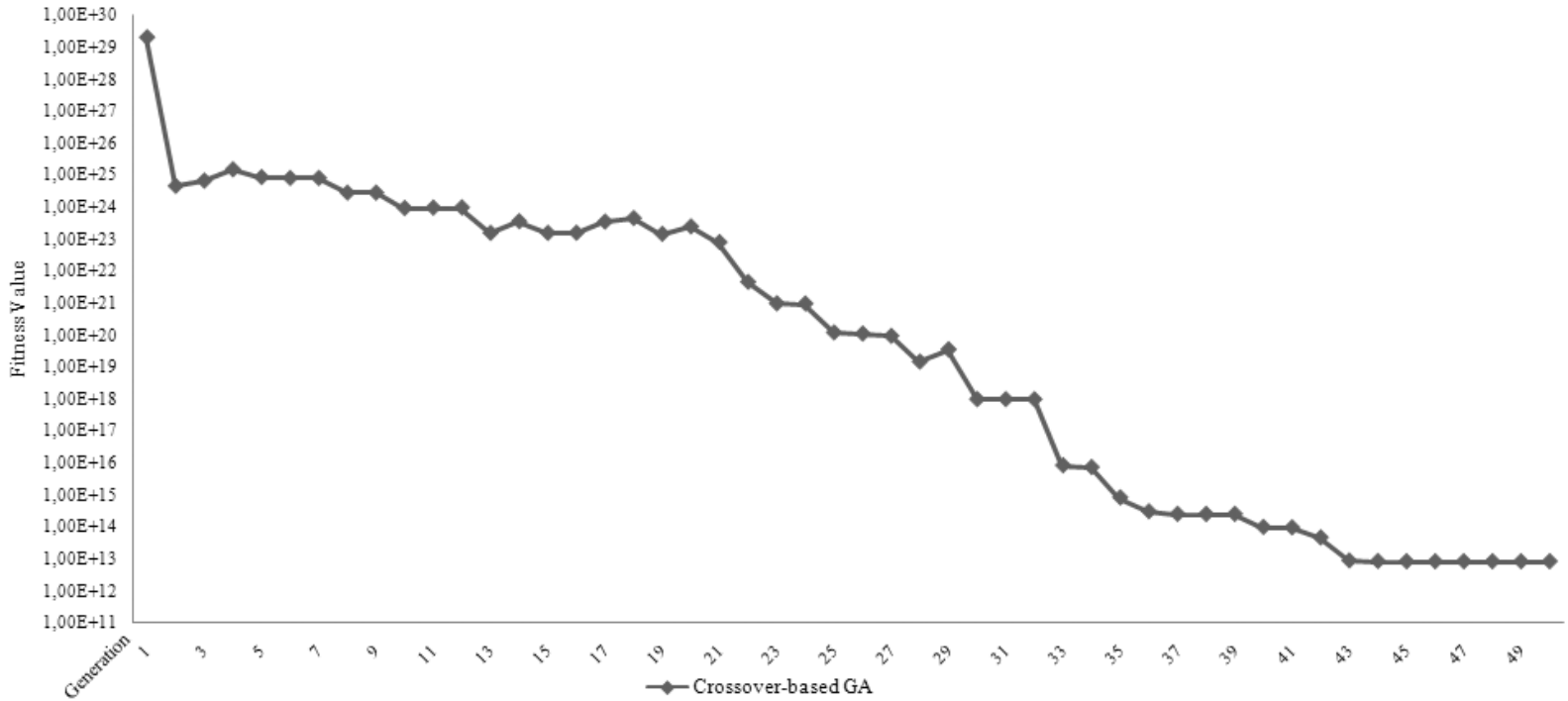
Mutation-based GA after 50 generations

Parameter	RSRA	WIRA
Number of evaluations	5,245	5,845
Cumulative CPU time	7,823:09:52	8,102:31:44
Average execution time	01:29:49	01:23:17
Speedup	12.80	16.56
Efficiency	0.20	0.26

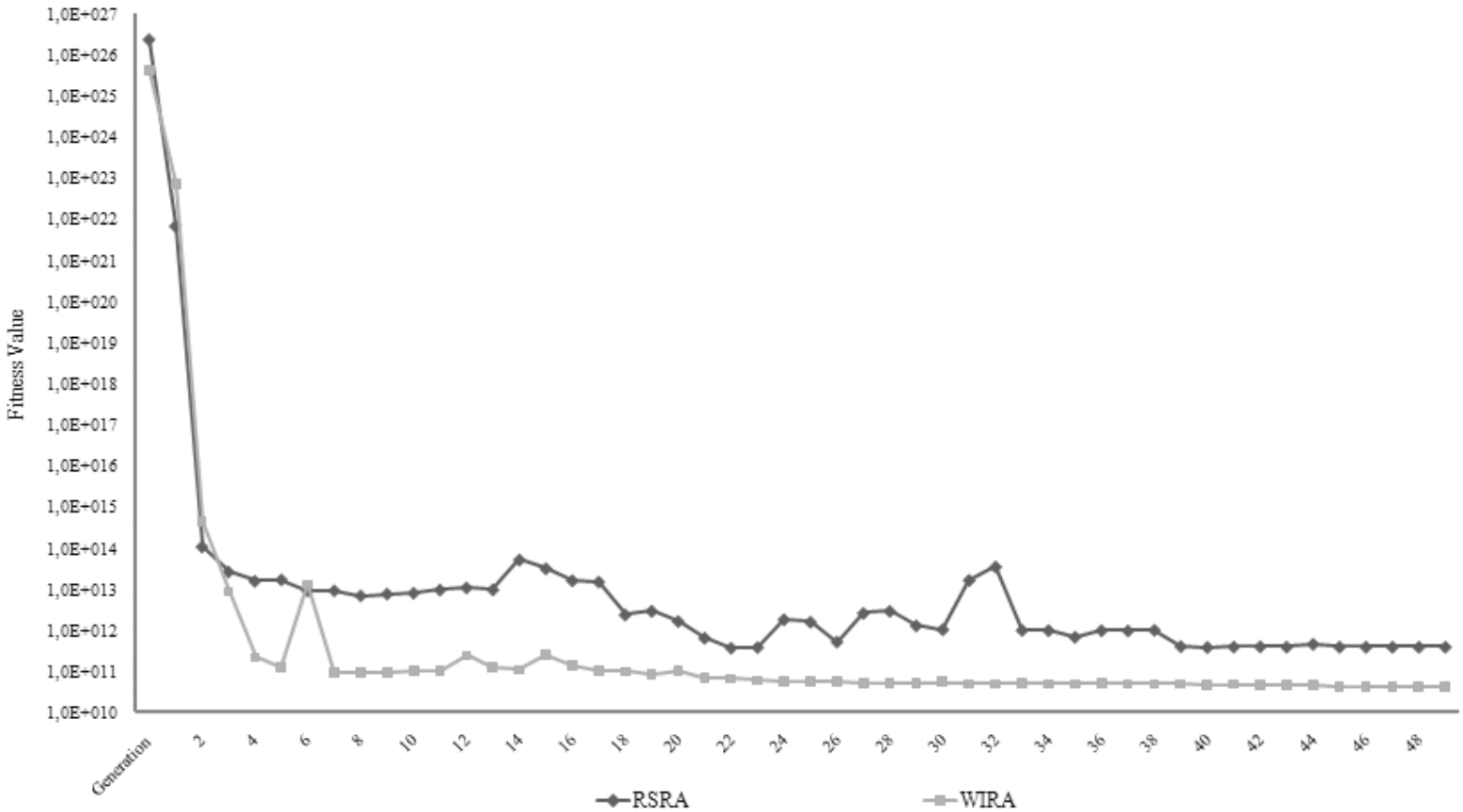
Scatter Search Results

Parameter	Test1	Test2	Test3	Test4
Chromosomes	100	100	100	100
Population size	100	100	100	50
RefSet size	10	10	10	5
Local search	Deactivated	Deactivated	Activated	Activated
Iterations	2	50	2	50
Evaluations	574	12,361	11,427	6,781
Execution time	36:10:19	535:36:25	495:12:51	310:12:53
Cumulative CPU time	783:07:21	9,095:41:07	8,727:29:07	5,321:03:57

Evolution of crossover GA



Evolution of mutation-based GA



Scatter Search best results

Test	Best Value
2 Iterations - Local Search Deactivated	1.76781E+05
50 Iterations - Local Search Deactivated	7.056280E+03
2 Iterations - Local Search Activated	1.47256E+04
50 Iterations - Local Search Activated - Smaller Population	1.02314E+04

Summary

- Workflow to optimise nuclear fusion devices.
- Crossover GA.
- Two implementations of a mutation-based GA.
- Grid-oriented Scatter Search.
- Non-supervised distributed GAs and EA using grid computing:
  - Master-slave model.
  - Failure recovery.
  - Job management.

Open problems

- We have to wait for the entire generation to be evaluated to get a new one $\Rightarrow$ asynchronous methods.
- Add more optimisation criteria.

Thank you for your attention!!

antonio.gomez@ciemat.es

Evolutionary algorithms to improve plasma confinement

Antonio Gómez-Iglesias, Francisco Castejón, Miguel Cárdenas-Montes, Enrique Morales-Ramos

National Fusion Laboratory, CIEMAT

March, 2009

Laboratorio Nacional Fusión

Enabling Grids for E-sciencE