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Selecting Simulation Algorithm Portfolios by Genetic Algorithms

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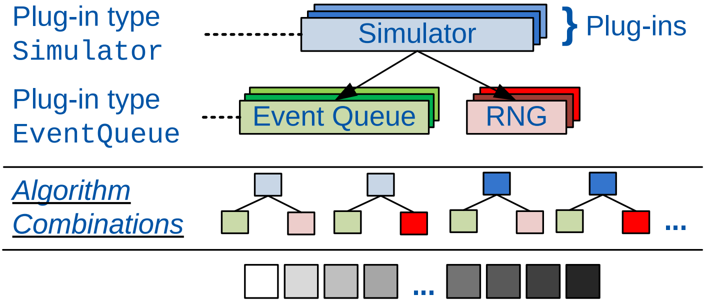
JAMES II

- Java framework for modeling & simulation
- Open source (`http://www.jamesii.org`)
- Focus on **extensibility** and **flexibility**
- Over **500** plug-ins, **combinable**

Simulation Algorithms in JAMES II



In the following: ***algorithms****.*

Simulation Algorithm Selection in JAMES II

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Which simulation algorithm to select for a given problem?

$\Rightarrow$ Algorithm Selection Problem [Rice, 1976]

Simulation Algorithm Selection in JAMES II

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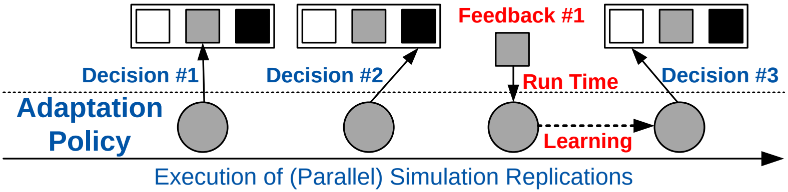
Dozens to **hundreds** of ”algorithms” available!

Adaptive Replication



- Restricted to Stochastic Simulation
- *Policies* to solve the Multi-Armed Bandit Problem
- Requires **sufficiently many replications** [Ewald *et al.*, 2009]

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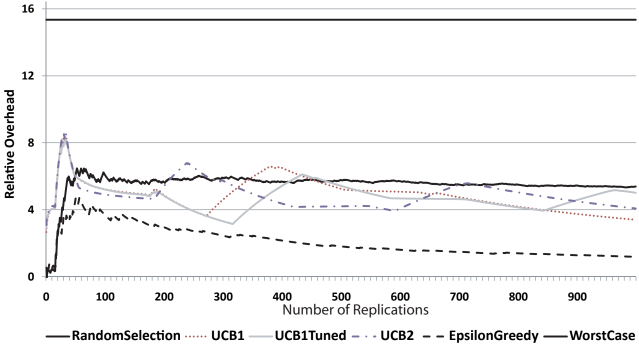
How many replications are 'sufficient'?



- Previous study: **1.000** replications
- More options ⇒ slower convergence

Improving Convergence Speed

Solution Strategies:

- Better policies $\rightarrow$ *exploration vs. exploitation*
- **Reduce number of options**

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Portfolio Selection

- Given some assets $\mathbb{A} = \{a_1, \ldots, a_n\}$
- What *subset* $A \subseteq \mathbb{A}$ of assets is the most beneficial?
- Requires **additional data**

Portfolio Theory

Finance

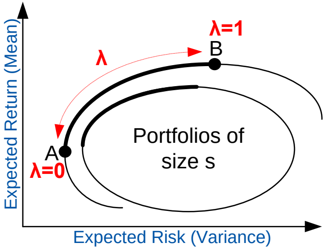
- Asset Price $\rightarrow$ Random Variable
- Portfolios for capital allocation: $\alpha = (\alpha_1, \ldots, \alpha_n) \in [0, 1]^n$
- $\sum \alpha_i = 1$
- Additional constraints: size, zero-risk assets

Mean-Variance Portfolios

Finance

- Asset Price $\rightarrow$ Random Variable
- Portfolios for capital allocation: $\alpha = (\alpha_1, \ldots, \alpha_n) \in [0,1]^n$
- $\sum \alpha_i = 1$

Efficient Frontier



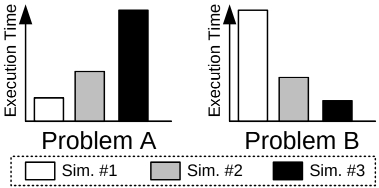
Optimization Problem
(cf. [Markowitz, 1952]):

$$f(\alpha) = \lambda \left(\sum_{i=1}^{n} \alpha_i \cdot \hat{R}_i \right) - (1-\lambda) \left(\sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i \cdot \alpha_j \cdot \hat{\sigma}_{i,j} \right)$$

Portfolio Theory → Algorithm Portfolios

Computer Science

- Asset Prices ⇒ Algorithm Performances
- α_i allocate CPU time (e.g. $\in \{0.0, 0.1, \ldots, 1\}$)
- Additional constraints: size, execution scheme



Simulation Algorithm Portfolios

Differences to other applications (e.g. [Gomes & Selman, 2001]):

- Problems easier than NP
- No phase transitions or search heuristics
- Specific requirements: time constraints, replications, etc.

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Applications:

- **Adaptive Replication**
- Brute-force parallelization
- Performance analysis

Requirements

- Constraints: portfolio size, permissible values for the α_i
- Multiple performance metrics (accuracy, execution time)
- Speed: portfolio selection at runtime
- Objective function may depend on application

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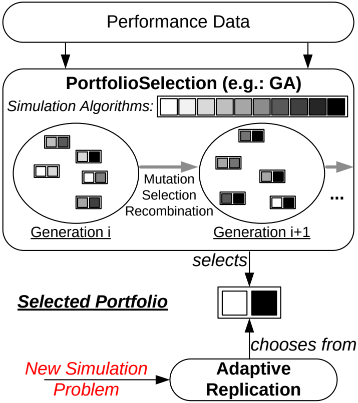
- Constraints: portfolio size, permissible values for the α_i
- Multiple performance metrics (accuracy, execution time)
- Speed: portfolio selection at runtime
- Objective function may depend on application
- **Constraints make optimization problem hard!**
  $\Rightarrow$ **Use meta-heuristics!** (e.g. [Wilding, 2003])

Portfolio Selection with GA

General Procedure:

1. Retrieve performance data
2. Select portfolio
3. Start adaptive replication



Portfolio Selection with GA

- **Return**: average execution time (minimization!)
- **Risk**: adaptation fails

Portfolio Selection with GA

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Fitness Function for Adaptive Replication

$$f(\alpha) = \lambda \frac{\sum_{i=1}^{n} \min\{p_{i,j} | \alpha_j \neq 0\}}{n} + (1 - \lambda)\bar{p}(\alpha)$$

$p_{i,j}$ – performance of algorithm j on problem i

$\bar{p}(\alpha)$ – average performance of portfolio on all problems

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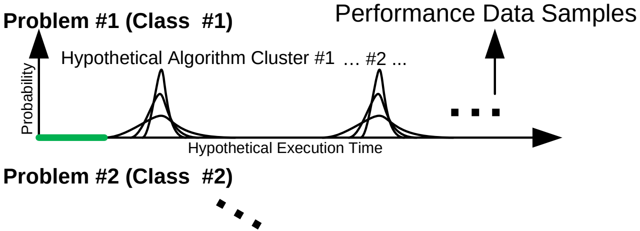
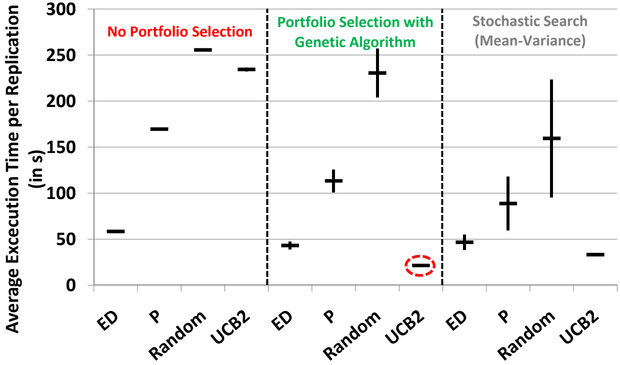
Evaluation with Hypothetical Setups

- Stochastic elements (portfolio selection, policies, algorithms)
- Evaluation under various (controlled) circumstances
- More details: see paper



Results



"On average, a single simulation run takes $\approx$ 21.5 *s when using the* UCB2 *policy to execute 200 replications, choosing from 250 algorithms with GA-selected portfolio."*

$\Rightarrow$ Portfolio selection parameters: size $\in [3, 6]$, $\lambda = 1$ (risky)

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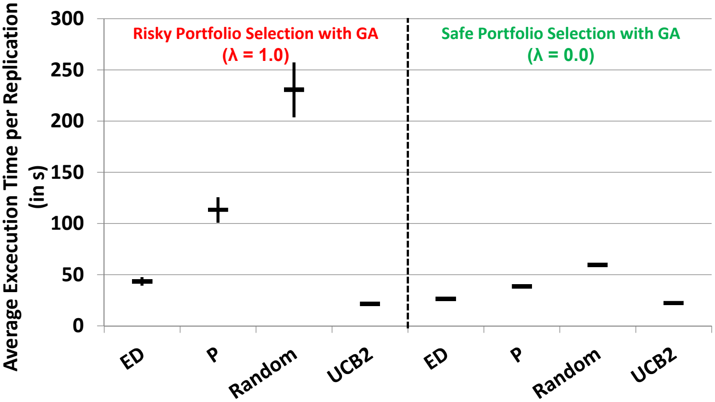
Results



Further Results

- Heavy-tailed runtime distributions do not affect results
- Speed-up in small yet realistic scenario
- Less replications suffice (not in paper)

Bottom Line?

Overview: Algorithm Selection in JAMES II

-	Data	Features + Data
Stochastic Simulation		
Multi-Armed Bandit Policies	*+ Portfolios*	*Prediction (e.g. Data Mining)*
Simulation Algorithm Selection		

Summary & Outlook

- **Simulation Algorithm Portfolios**
- **Useful** for adaptive replication
- **Interdependence**:
  Portfolio Approach $\Longleftrightarrow$ Replication Policy $\Longleftrightarrow$ Problem

- *How to collect enough performance data?*
- *How does GA-based selection compare to other techniques*?
- *How to integrate portfolio selection into the* JAMES II *GUI*?

Thank you.

Questions?

Download JAMES II from
`http://www.jamesii.org`

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References

Ewald, Roland, Leye, Stefan, & Uhrmacher, Adelinde M. 2009.
An Efficient and Adaptive Mechanism for Parallel Simulation Replication.
Pages 104–113 of: Proc. of the 23rd Workshop on Principles of Advanced and Distributed Simulation.
IEEE Computer Society.

Gomes, Carla P., & Selman, Bart. 2001.
Algorithm portfolios.
Artificial Intelligence, **126**(1-2), 43–62.

Markowitz, Harry. 1952.
Portfolio Selection.
The Journal of Finance, **7**(1), 77–91.

Rice, John R. 1976.
The Algorithm Selection Problem.
Advances in Computers, **15**, 65–118.

Wilding, T. 2003.
Using genetic algorithms to construct portfolios.
Chap. 6, pages 135–160 of: Satchell, Stephen, & Scowcroft, Alan (eds), *Advances in Portfolio Construction and Implementation*.
Quantitative Finance Series.
Butterwoth-Heinemann.