A distance-based ranking estimation of distribution algorithm for the permutation flowshop scheduling problem

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April 2013

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The Background

Estimation of Distribution Algorithms

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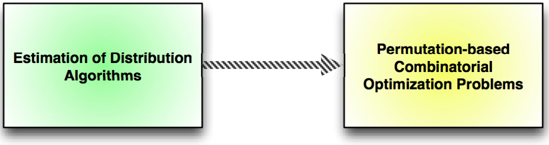
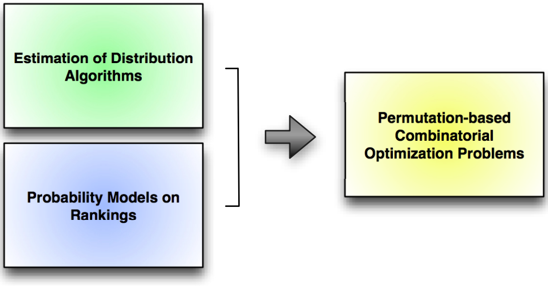


Poor performance

The Hypothesis

"Existing EDAs do not implement adequate probabilistic models for optimizing permutation domain problems."

The Contribution



Outline

Outline

1. Estimation of Distribution Algorithms
2. Permutation-based Optimization Problems
3. Distance-based Ranking Models
4. Our approach
5. Experiments
6. Conclusions & Future work

Estimation of Distribution Algorithms

Definition

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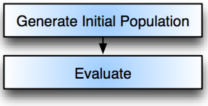

Estimation of Distribution Algorithms

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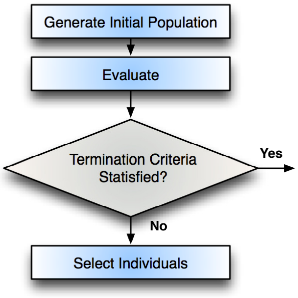

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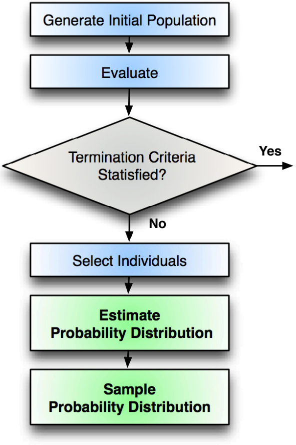

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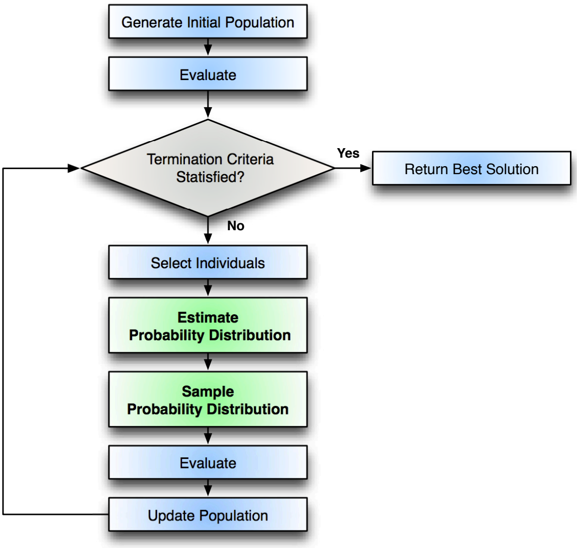

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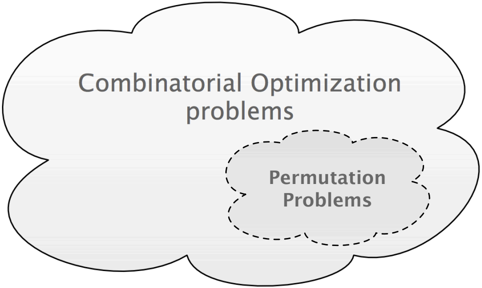
Permutation-based Optimization Problems

Definition



Permutation-based Optimization Problems

Definition

Problems whose solution can be naturally represented as a permutation.

Permutation-based Optimization Problems

Examples

Travelling Salesman Problem

Which permutation of cities provides the the shortest path?

Permutation-based Optimization Problems

Examples

Linear Ordering Problem

	1	2	3	4	5
1	0	16	11	15	7
2	21	0	14	15	9
3	26	23	0	26	12
4	22	22	11	0	13
5	30	28	25	24	0

	5	3	4	2	1
5	0	25	24	28	30
3	12	0	26	23	26
4	13	11	0	22	22
2	9	14	15	0	21
1	7	11	15	16	0

Which permutation of rows/columns optimizes this problem?

Permutation-based Optimization Problems

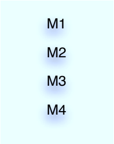
Examples

Permutation Flowshop Scheduling Problem

Permutation-based Optimization Problems

Examples

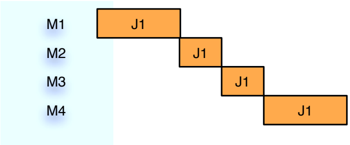
Permutation Flowshop Scheduling Problem



Permutation-based Optimization Problems

Examples

Permutation Flowshop Scheduling Problem



Permutation-based Optimization Problems

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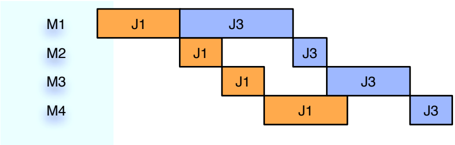
Permutation Flowshop Scheduling Problem



Permutation-based Optimization Problems

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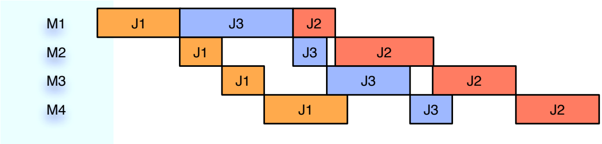
Permutation Flowshop Scheduling Problem



Permutation-based Optimization Problems

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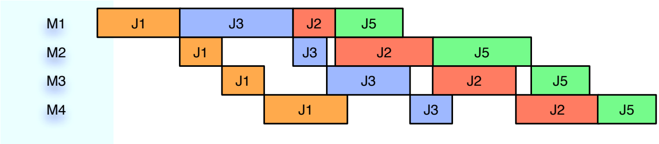

Permutation-based Optimization Problems

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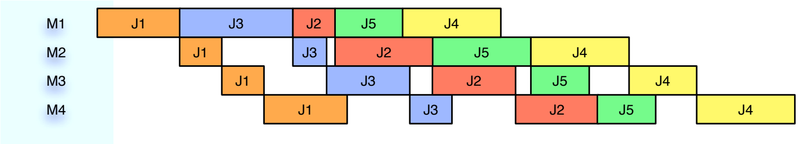
Permutation Flowshop Scheduling Problem



$$(1, 3, 2, 5, 4)$$

Standard representations are not effective due to the mutual exclusivity constraints associated with permutations.

Estimation of Distribution Algorithms

Existing approaches

Standard representations are not effective due to the mutual exclusivity constraints associated with permutations.

Integer encoding EDAs

UMDA EBNA MIMIC PBIL TREE EHBSA NHBSA	Learn a probability distribution over a set $\Omega = \Omega_1 \times \Omega_2 \times \cdots \times \Omega_n$ where $\Omega_i = \{1, \ldots, r_i\}$ and $r_i \in \mathbb{N}, i = 1, \ldots, n$.

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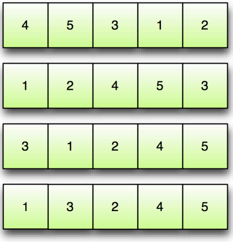
Integer encoding EDAs

Sample



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Integer encoding EDAs

Univariate model

Job	X1	X2	X3	X4	X5
1	0.5	0.25	-	0.25	-
2	-	0.25	0.5	-	0.25
3	0.25	0.25	0.25	-	0.25
4	0.25	-	0.25	0.5	-
5	-	0.25	-	0.25	0.5

Estimation of Distribution Algorithms

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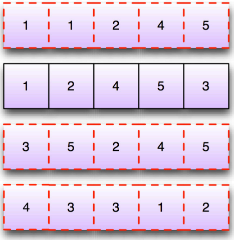
Integer encoding EDAs

New Sample



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Integer encoding EDAs

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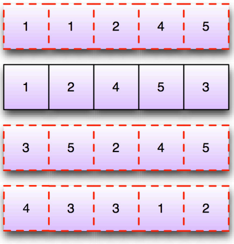

The sampling does not always provide an individual in $\mathbb{S}_n$, but an individual in Ω.

Standard representations are not effective due to the mutual exclusivity constraints associated with permutations.

Real-value encoding EDAs

UMDA$_c$
MIMIC$_c$
EGNA
IDEA
...

The sampled real vectors are transformed into permutations with the Random Keys strategy.

$$\begin{array}{c} (0.30, 0.10, 0.40, 0.20) \\ (0.25, 0.14, 0.35, 0.16) \\ (0.60, 0.20, 0.80, 0.40) \end{array} \quad \rightarrow \quad (3, 1, 4, 2)$$

High redundancy in the codification.

Outline

Distance-based Ranking Models

The Mallows model

A distance-based unimodal exponential model.

Distance-based Ranking Models

The Mallows model

A distance-based unimodal exponential model.

Two parameters:

- Consensus ranking σ_0
- Spread parameter θ

A distance-based unimodal exponential model.

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Probability distribution:

$$P(\sigma) = \frac{1}{\psi(\theta)} e^{-\theta D_\tau(\sigma, \sigma_0)}$$

Distance-based Ranking Models

The Mallows model

A distance-based unimodal exponential model.

Two parameters:

- Consensus ranking σ_0
- Spread parameter θ

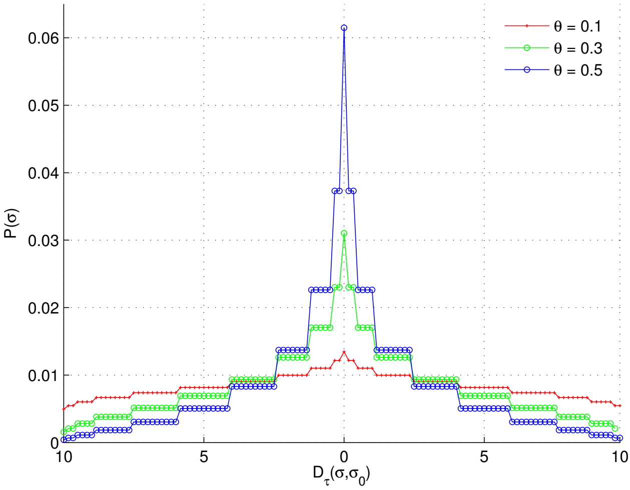
Probability distribution:

$$P(\sigma) = \frac{1}{\psi(\theta)} e^{-\theta D_\tau(\sigma,\sigma_0)}$$

Analogous over permutations to the Gaussian distribution.

Distance-based Ranking Models

The Mallows model



Kendall's$-\tau$ distance

Counts the number of pairwise disagreements.

σ_A	4	2	1	5	3
σ_B	2	4	3	5	1

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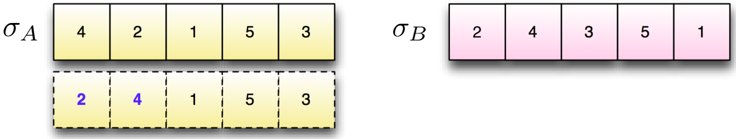

Kendall's$-\tau$ distance

Counts the number of pairwise disagreements.

σ_A	4	2	1	5	3		σ_B	2	4	3	5	1
	2	**4**	1	5	3							
	2	4	**5**	**1**	3							

Kendall's$-\tau$ distance

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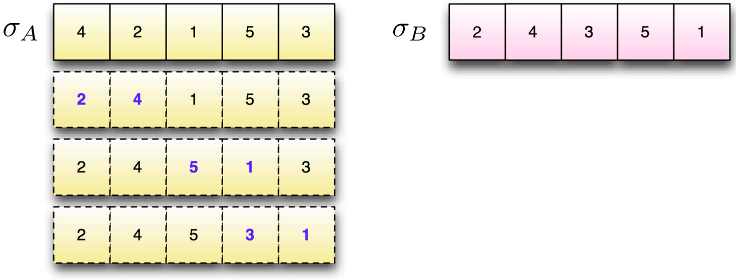

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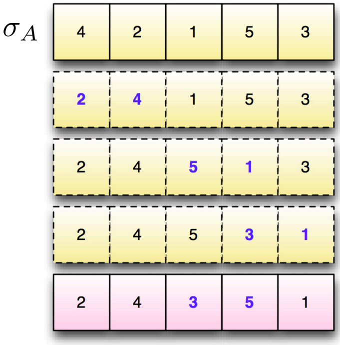
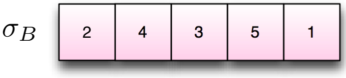




$$D_\tau(\sigma_A, \sigma_B) = 4$$

Distance-based Ranking Models

The Generalized Mallows model

If the D can be decomposed as... $D_\tau(\sigma, \sigma_0) = \sum_{j=1}^{n-1} V_j(\sigma, \sigma_0)$

$P(\sigma) = \frac{1}{\psi(\theta)} e^{-\theta D_\tau(\sigma, \sigma_0)}$

Mallows

Distance-based Ranking Models

The Generalized Mallows model

If the D can be decomposed as... $D_\tau(\sigma, \sigma_0) = \sum_{j=1}^{n-1} V_j(\sigma, \sigma_0)$

$$P(\sigma) = \frac{1}{\psi(\theta)} e^{-\theta D_\tau(\sigma,\sigma_0)} \quad \rightarrow \quad P(\sigma) = \frac{1}{\psi(\boldsymbol{\theta})} e^{-\sum_{j=1}^{n-1} \theta_j V_j(\sigma,\sigma_0))}$$

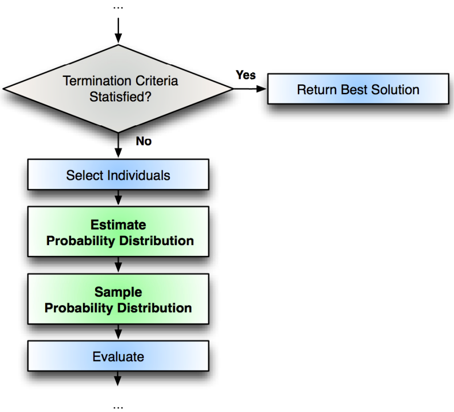
Mallows

Generalized Mallows

Outline

Generalized Mallows EDA

Scheme



Generalized Mallows EDA

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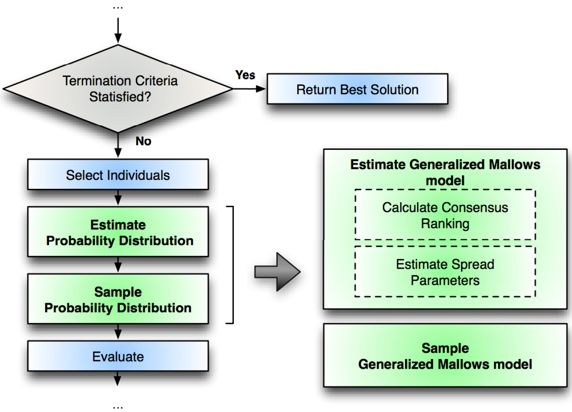

Generalized Mallows EDA

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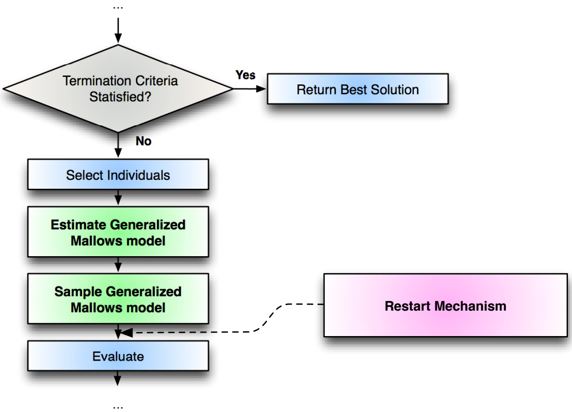

Generalized Mallows EDA

Preliminary Experiments - Comparing to NHBSA and EHBSA

Algorithms

- Edge Histogram-based Sampling Algorithm (EHBSA)
- Node Histogram-based Sampling Algorithm (NHBSA).
- Generalized Mallows EDA (GMEDA).

Instances

- Taillard's Benchmark: 120 instances.

Other

- Best solution of 20 repetitions.
- Max. number of evaluations.

Generalized Mallows EDA

Preliminary Experiments - Comparing to NHBSA and EHBSA

Results

120 instances

Generalized Mallows EDA

Preliminary Experiments - Comparing to NHBSA and EHBSA

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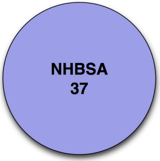

120 instances

Generalized Mallows EDA

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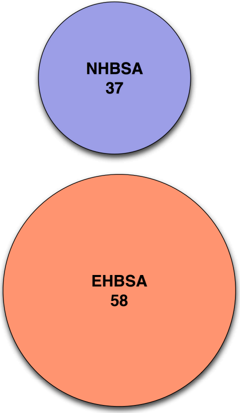

120 instances

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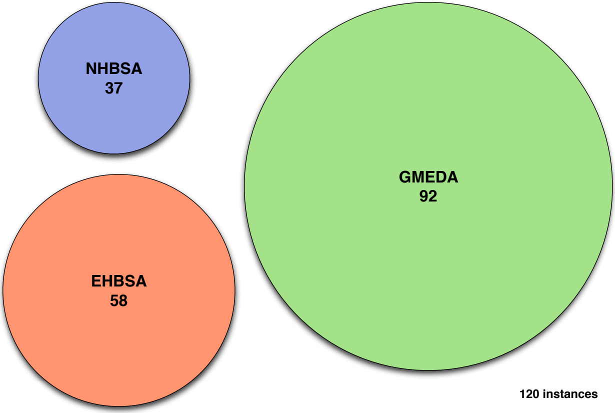


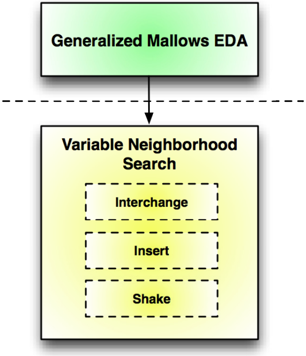
The challenge is to outperform the state-of-the-art algorithms of the PFSP.

Hybrid Generalized Mallows EDA

The challenge: State-of-the-art algorithms

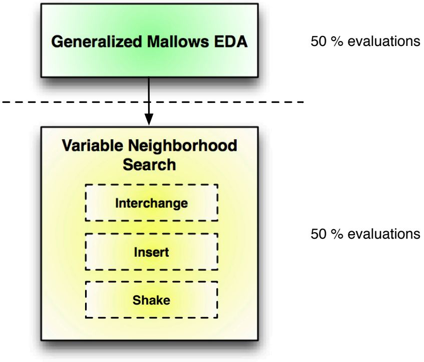
Hybrid Generalized Mallows EDA

The challenge: State-of-the-art algorithms



Hybrid Generalized Mallows EDA

The challenge: State-of-the-art algorithms



Outline

Algorithms

- Asynchronous Genetic Algorithm (AGA).
- Variable Neighborhood Search 4 (VNS_4).
- Generalized Mallows EDA (GMEDA).
- Hybrid Generalized Mallows EDA (HGMEDA).
- Variable Neighborhood Search (VSN) - own design.

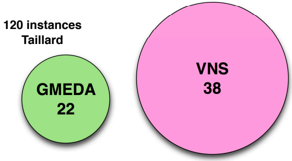
Instances

- Taillard's Benchmark: 120 instances.
- Random Benchmark: 100 instances.

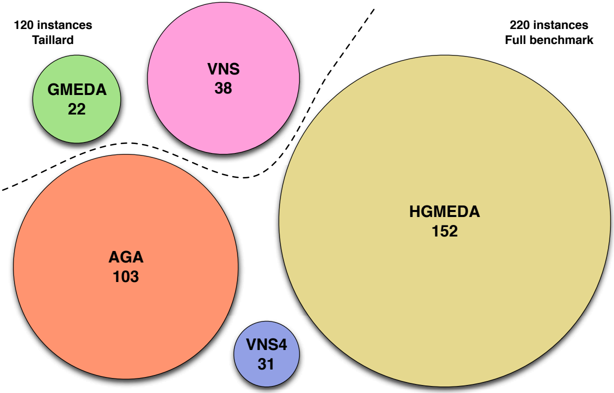
Other

- Best solution of 20 repetitions.
- Max. number of evaluations.

Results



Results


120 instances
Taillard
GMEDA
22
VNS
38
220 instances
Full benchmark
AGA
103
HGMEDA
152
VNS4
31

Outline

Conclusions

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1

We propose a novel algorithm for permutation problems: Generalized Mallows EDA

2

3

4

Conclusions

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It introduces an explicit probability model for permutations

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Generalized Mallows EDA outperforms existing EDAs for the PFSP

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Conclusions

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Generalized Mallows EDA outperforms existing EDAs for the PFSP

4

The hybrid GMEDA is the new state-of-the-art algorithm for the PFSP

Open Questions

About the model

- Accurate consensus ranking σ_0
- Self-adaptive spread parameters θ

Open Questions

About the EDA

- Initialization methods.
- Tunning the parameters of the EDA.
- Restart techniques.
- Advanced hybridizations.

Open Questions

Future Work

- Mallows + Cayley distance
- Mallows + Ulam distance
- Plackett-Luce
- Bradley-Terry

- Travelling Salesman Problem
- Linear Ordering Problem
- Quadratic Assignment Problem

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Parameters Settings

Population size	$10n$
Selection size	n
Offspring size	$10n - 1$
Max. Evaluations	$1000n^2$

n denotes the size of the problem.