The Traveling Salesman Problem (TSP)

**Roughly Speaking:** Find a shortest tour of N cities by visiting each city exactly once and returning to the starting city.

**Traveling Salesman Problem (TSP)**

4. Infeasibility can be a big problem in many combinatorial problems. But such situations are not always obvious.

3. Crossers can be particularly tricky to design because we want to incorporate the possibility of producing better offspring.

2. A good representation should

1. L. Unlike numerical function optimization, a proper representation of combinatorial structures can be very difficult to find.

Representation in Combinatorial Optimization

2. We can have different representations and adapt our tools.

1. Search step size and bias are important in determining EAs.

Review of the Last Lecture

4. Summary

3. EAs for cutting stock problems

2. EAs for Traveling Salesman problems

1. Review of the last lecture

Lecture 08: EAs for Combinatorial Optimization
where \( x_i \) is the current city and \( x_{i+1}p \) and \( x_{i+2}p \)

\[
\frac{\left( x_{i+1}p/1 \right)^{\frac{1}{k}}}{x_{i+2}p/1} = x_d
\]

that is, city \( x \) will be chosen according to probability

The edge that has the lowest distance from the current city.

The next city is not chosen according to the number of cities in

**First Variation of the Recombination**

Let's start by randomly selecting the initial city and perform the crossover.

1. Construct an edge map from 2 parented tours.
2. Construct a child tour from the edge map.
3. Choose the initial city at random as the current city.
4. Determine which of the cities in the edge that has the lowest distance from the current city.
5. The lowest cities become the current city. The next city.

An Example

Recombination (crossover)

Tour Representation

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...
where \( \ell = 1, 2, \ldots \) and

\[
(1 + \gamma - d)^{1+\gamma} \leq \frac{1}{1 + \ell - d} = (\ell + 1)^{\gamma/d}.
\]

is selected with probability

sort each route and numbered as \( 0, 1, \ldots, \ell - 1 \). Then the \( \ell \)th route

determines the order according to their lengths. Let the

2. Rank the routes in a population and then select in a

1. Fitness proportional selection

Selection

Definition of Selection:

\[ f(x) \neq f(y) \] where \( x \) is the current city and \( y \) is the distance between \( x \) and

\[
\frac{(x, y) + p/1}{x, y + p/1} = f_x d
\]

according to probability \( p \). Each city \( y \) will be chosen

number of times in that edge, then city \( x \) will be chosen

or the same

Second Variational of the Recombination

10

6
### Comparison of Recombination Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA1 (best)</td>
<td>12.105</td>
<td>1.358</td>
<td>0.045</td>
</tr>
<tr>
<td>EA2 (best)</td>
<td>11.981</td>
<td>0.938</td>
<td>0.028</td>
</tr>
<tr>
<td>EA3 (best)</td>
<td>11.148</td>
<td>0.450</td>
<td>0.015</td>
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<tr>
<td>EA4 (best)</td>
<td>11.015</td>
<td>0.435</td>
<td>0.015</td>
</tr>
<tr>
<td>EA5 (best)</td>
<td>10.915</td>
<td>0.350</td>
<td>0.015</td>
</tr>
<tr>
<td>EA6 (best)</td>
<td>10.939</td>
<td>0.280</td>
<td>0.015</td>
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### Performance Metrics

\[
\text{H} = \frac{\sum_{i=1}^{N} N[i]}{N}
\]

where \( N \) is the number of switching and \( N[i] \) is the number of edges connecting city \( i \) and city \( j \) in the population.

3. **Population**: The mean (in a population):

1. Best (found so far).

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**Experimental Setup**

- The expected minimum tour length is 100.
- Ten randomly generated TSPs with 100 cities.
- Six operators:
  1. EA1
  2. EA2
  3. EA3
  4. EA4
  5. EA5
  6. EA6

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**Evolutionary Algorithms**

- EA1: Randomized selection.
- EA2: Tournament selection.
- EA3: Tournament selection.
- EA4: Competition.
- EA5: Tournament selection.
- EA6: Tournament selection.
- EA7: TSP is broken in favor of a nearest neighbor.
- EA8: Tournament selection.
- EA9: TSP is broken in favor of a nearest neighbor.
- EA10: As described before.

Before but no recombination:

1. EA1, EA2, and EA3 use a genetic algorithm as described.
2. EA4, EA5, and EA6 use the mutation operator described.
3. EA7, EA8, and EA9 use a combination of operators described.
The number of generations is 300.

| Experiment | Average Results of EA3 and EA4 over ten TSP instances. | The number of generations is 300.
<table>
<thead>
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<tbody>
<tr>
<td></td>
<td>Ev (Average)</td>
</tr>
<tr>
<td></td>
<td>0.073</td>
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<td></td>
<td>0.082</td>
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<td></td>
<td>0.084</td>
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<td>0.086</td>
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<td>0.088</td>
</tr>
<tr>
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<td>0.090</td>
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</tbody>
</table>
The stock length is 12. Four stock lengths are needed here. The total wastage
from the representation is 6.8 in.

Here is an example of order-based representation and the mapping.
were used in each mutation.

where w is the weight of the fitness function, then in the selected

\[ f_{m} \] = \frac{f}{T} = \frac{f_{m}}{T} = (f) \]

\[ 0 \neq f_{m} \]

random according to the following probability of being the first selected in two stage. First, a stock is selected at

and then swapped the best item with the second one and then swaps the

3 Point Swap (3PS) Mutation

3 PS Swap Mutation

1. Insert the removed stock right behind the first such found stock.

2. Remove the tool that could be selected the

3. Search throughout the list to find the tool that could be removed.

4. Insert the removed tool right behind the first such found tool.

The idea of this mutation comes from the concept of distance

Dealing With Contiguity

For CSPs with contiguity, another mutation operator, the stock

References

Summary