AI and Decision Sciences

Genetic Algorithms

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What does survival of the fittest mean

Summary of biology

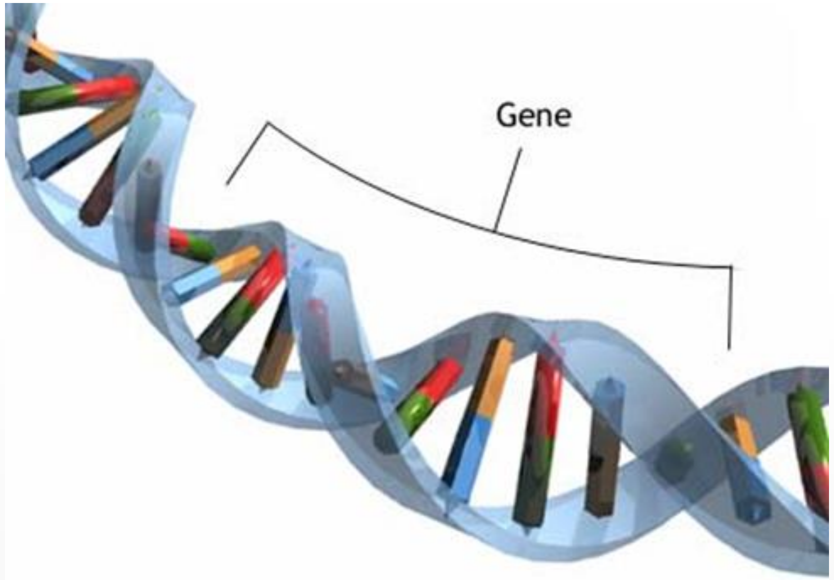
- Not all members survive until reproduction. Only a few learn to earn lunch. Others are lunch!
- The strong ones then need to attract and mate other members of the species that survived.
- The offspring generation hence is normally better than the parents generation
- Over generations, species develop

Can a similar theory be applied to optimization

- Start with random solutions
- Kill the weak ones
- Reproduce from the good ones
- Will the newer set be more optimal than its parents?

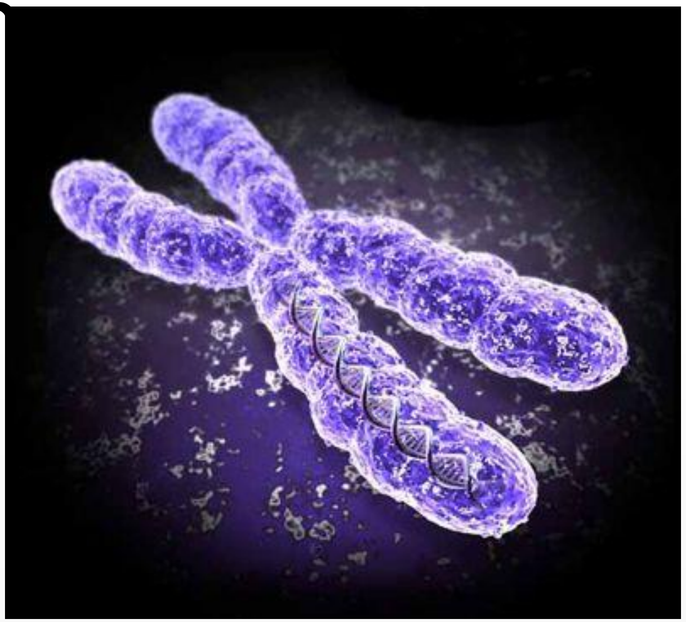
Gene

Gene: The reproducible building block of chromosome



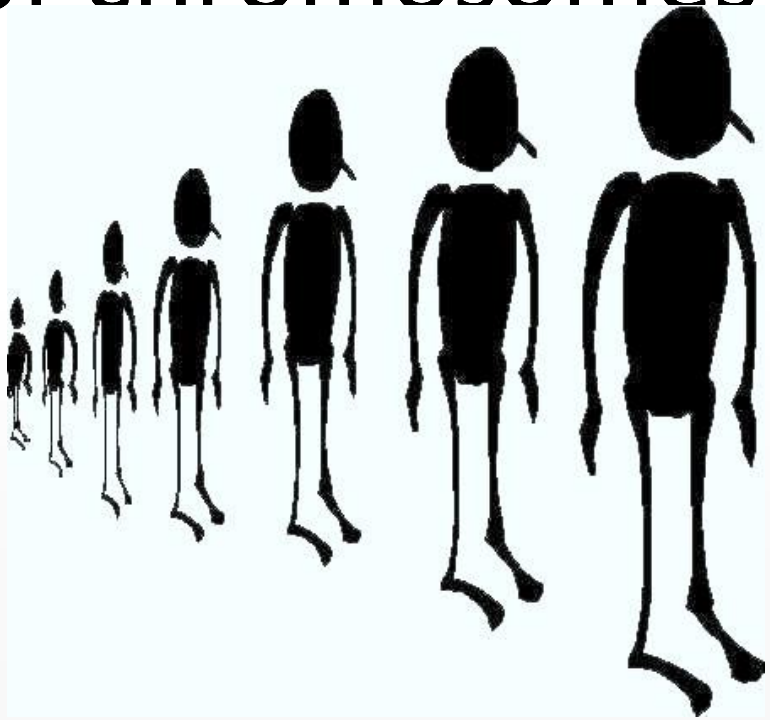
Beg, Borrow or Steel

- Chromosome: A possible solution



Population

- A set of chromosomes



Generation

- A population derived from the fittest chromosomes of the previou

Reproduction, Mating and Mutation

- Create a new solution from the old fitter solu

```
{
    initialize population;
    evaluate population;
    while TerminationCriteriaNotSatisfied
    {
        select parents for reproduction;
        perform recombination and mutation;
        evaluate population;
    }
}
```

So, GA at a snapshot

- Create a schema to create possible solutions in a bit/byte format
- Start with a number of random solutions
- Identify the best ones
- Create new ones from them using some exchange mechanism
- Continue with the last two steps until a solution is found

Some unique differentiators

- GAs work with a coding of the parameters and not the parameters themselves
- GAs search from a population of points and not a single point
- GAs work with the objective function and not the derivatives
- GAs transition based on random rules and not on deterministic rules

OPERATIONAL ASPECTS

Population

Chromosomes could be:

- Bit strings (0101 ... 1100)
- Real numbers (43.2 -33.1 ... 0.0 89.2)
- Permutations of element (E11 E3 E7 ... E1 E15)
- Lists of rules (R1 R2 R3 ... R22 R23)
- Program elements (genetic programming)
- ... any data structure ...

Innovations: Creating a coding scheme

- Password retrieval
- Knap Sack
- Polynomial fit
- TSP
- Portfolio allocation

How do we decide mating pool

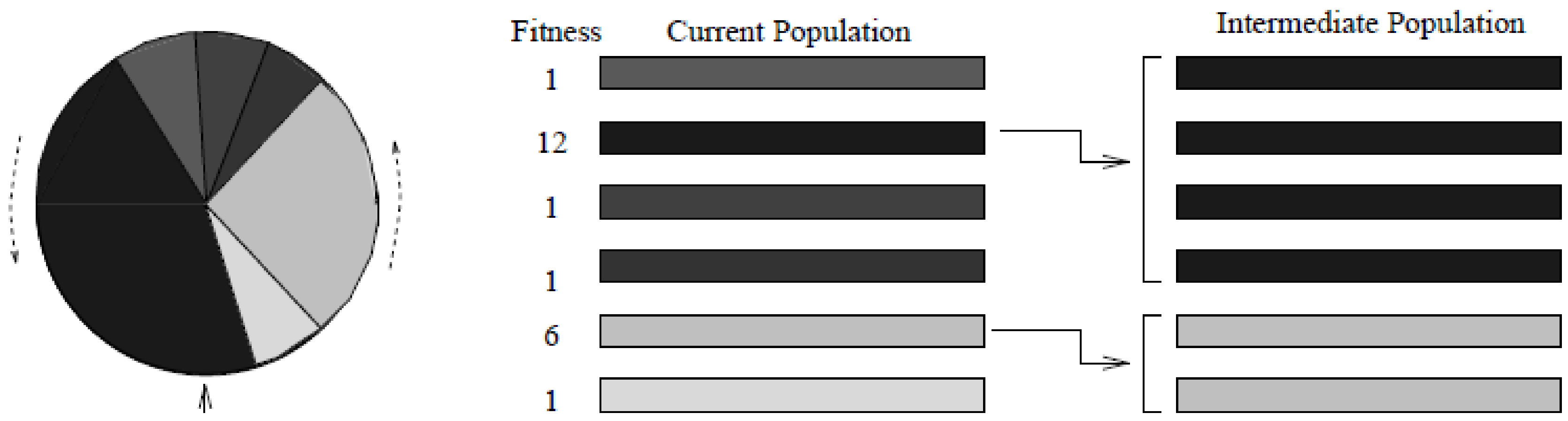


Figure 2. Selection application

How do we determine reproduction

- Most common: Cross over
  - npoint crossover: n crossover points are randomly selected and the segments of the parents, defined by them, are exchanged for generating the offspring.
  - uniform crossover: the values of each gene in the offspring are determined by the uniform random choice of the values of this gene in the parents.

For real coding

Arithmetical crossover (Michalewicz, 1992)

Two offspring, $H_k = (h_1^k, ..., h_i^k, ..., h_n^k)$ $k = 1, 2$, are generated, where $h_i^1 = \lambda c_i^1 + (1 - \lambda)c_i^2$ and $h_i^2 = \lambda c_i^2 + (1 - \lambda)c_i^1$. λ is a constant (uniform arithmetical crossover) or varies with regard to the number of generations made (non-uniform arithmetical crossover).

- Flat crossover: An offspring, H is generated, where hi is a randomly (uniformly) chosen value of the interval [c1i; c2i]

Cross over

- Hello World
- Knap Sack
- Polynomial fit
- TSP
- Portfolio allocation

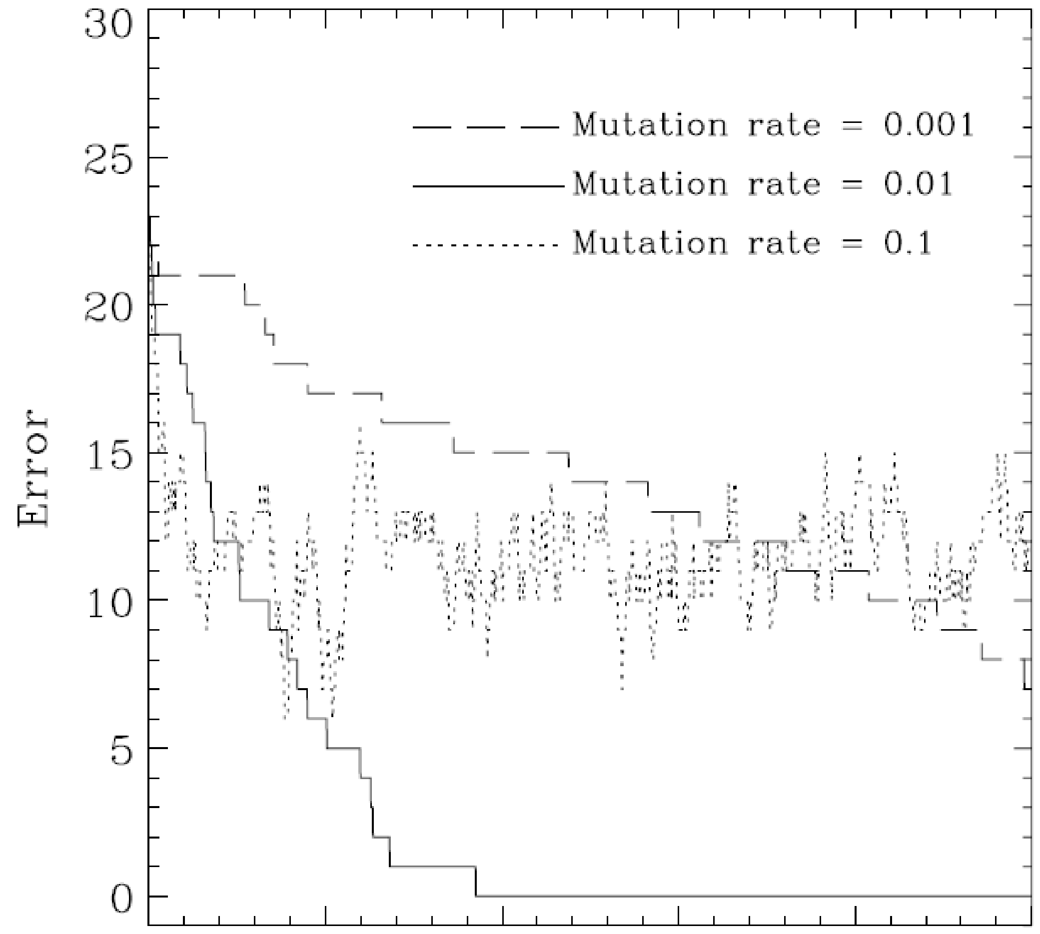
Inversion or Mutation

- Flip
- Random generation
- An unexpected operation

Non uniform mutation

- Initially mutate heavily
- As the number of generations increase mutate less

What about mutation?

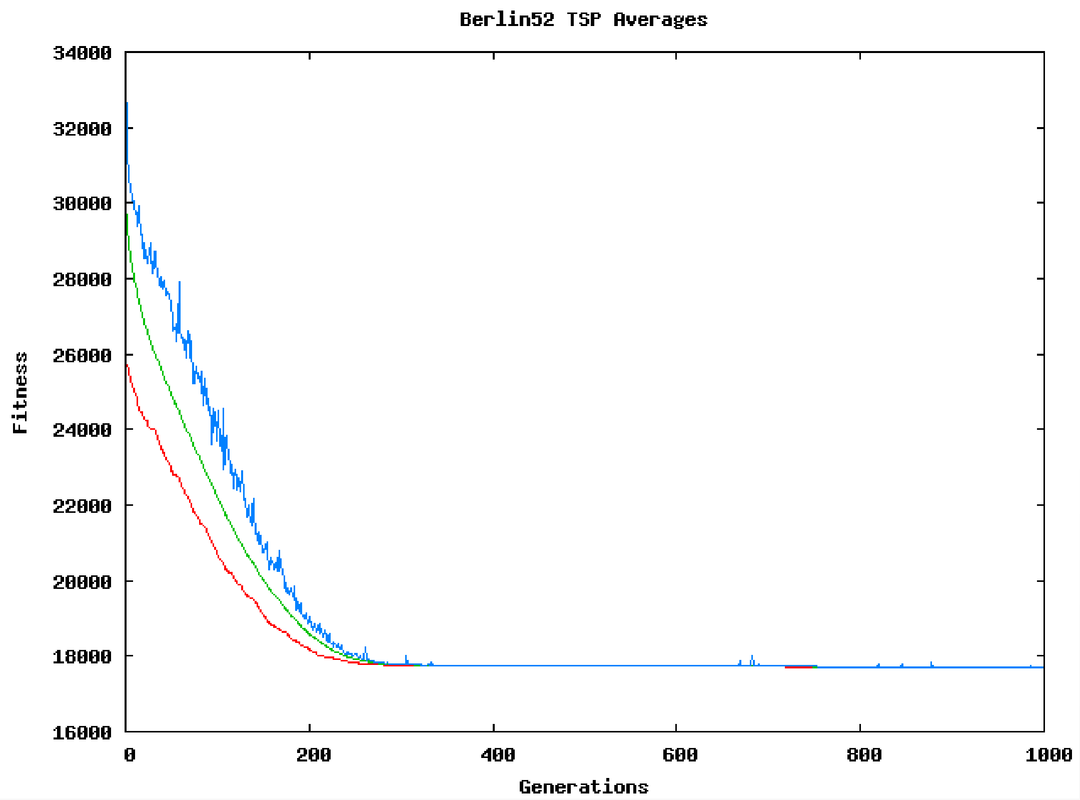


Mutation scheme

- Hello World
- Knap Sack
- Polynomial fit
- TSP
- Portfolio allocation

Convergence of a GA

When to stop?



EXAMPLES

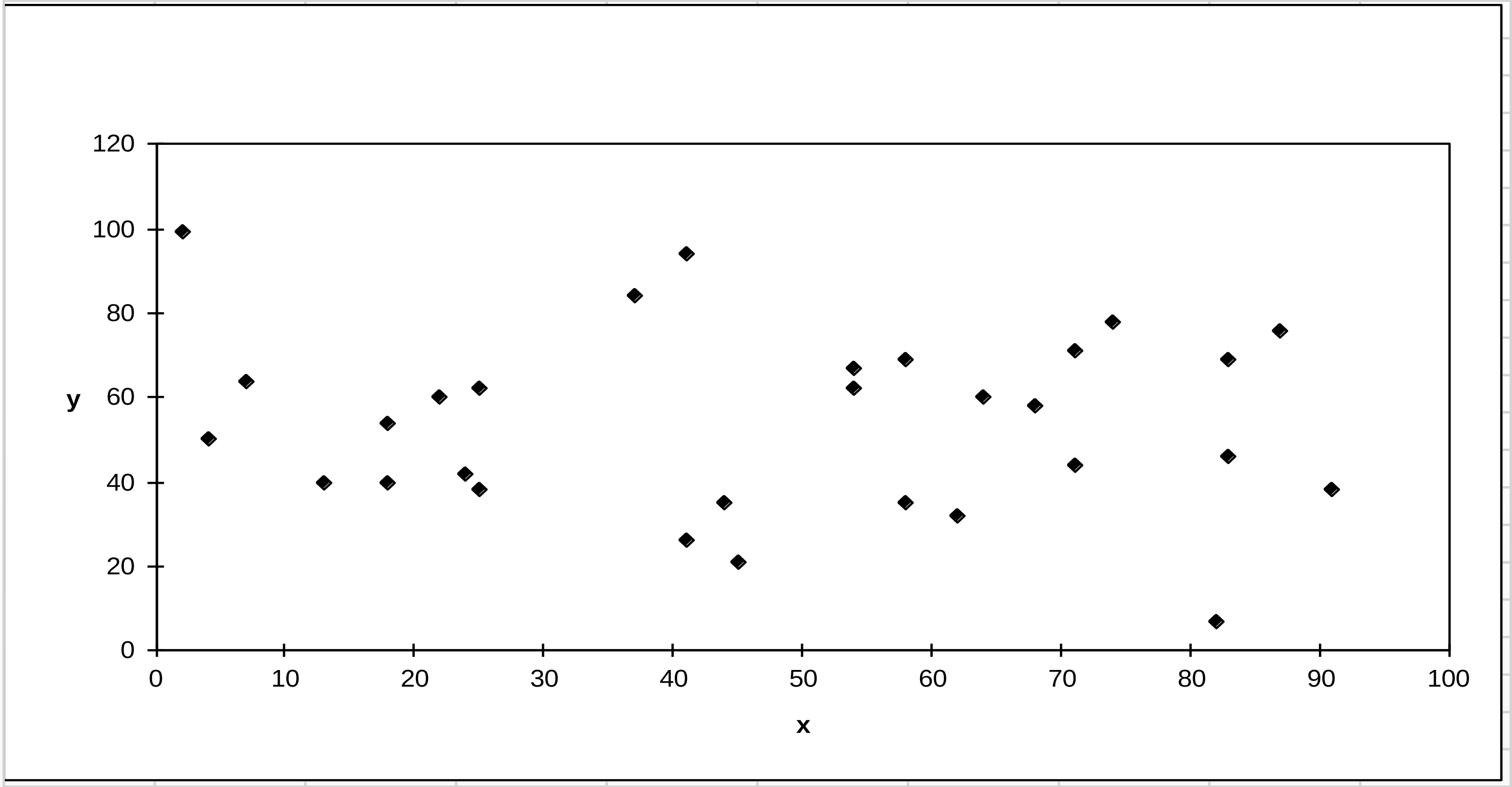
A Simple Example

The Traveling Salesman Problem:

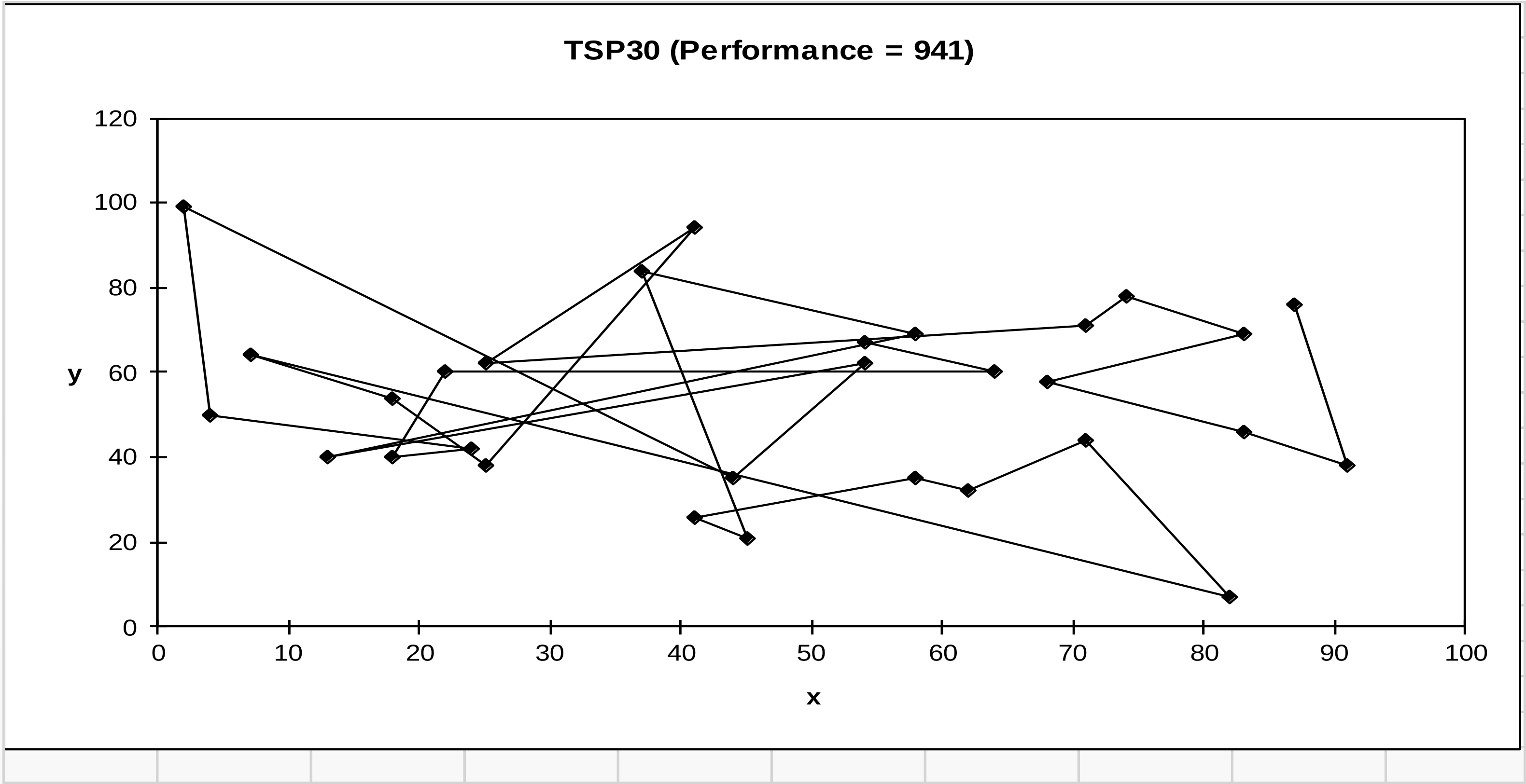
Find a tour of a given set of cities so that

- each city is visited only once
- the total distance traveled is minimized

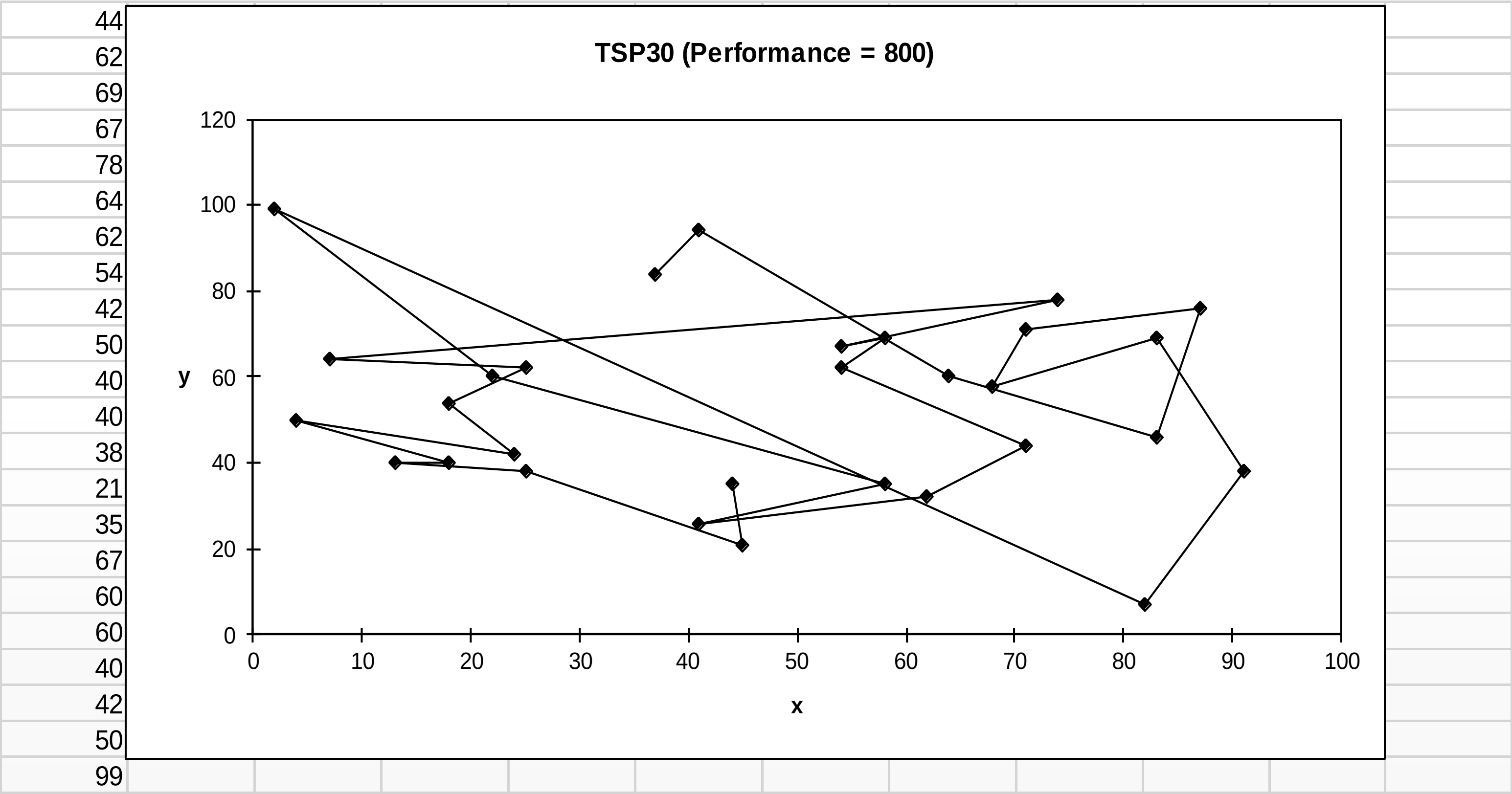
TSP Example: 30 Cities



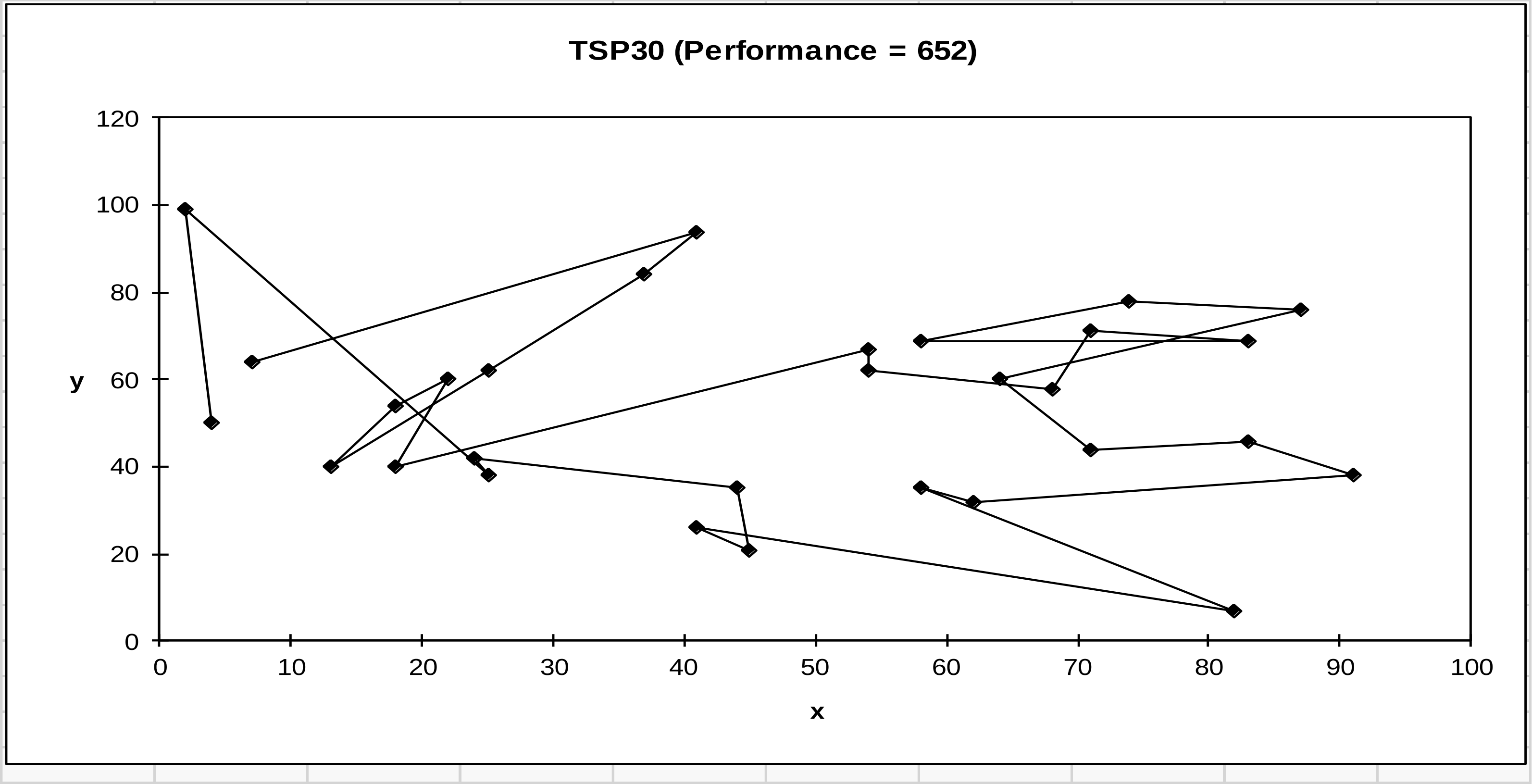
Solution ¡ (Distance = 941)



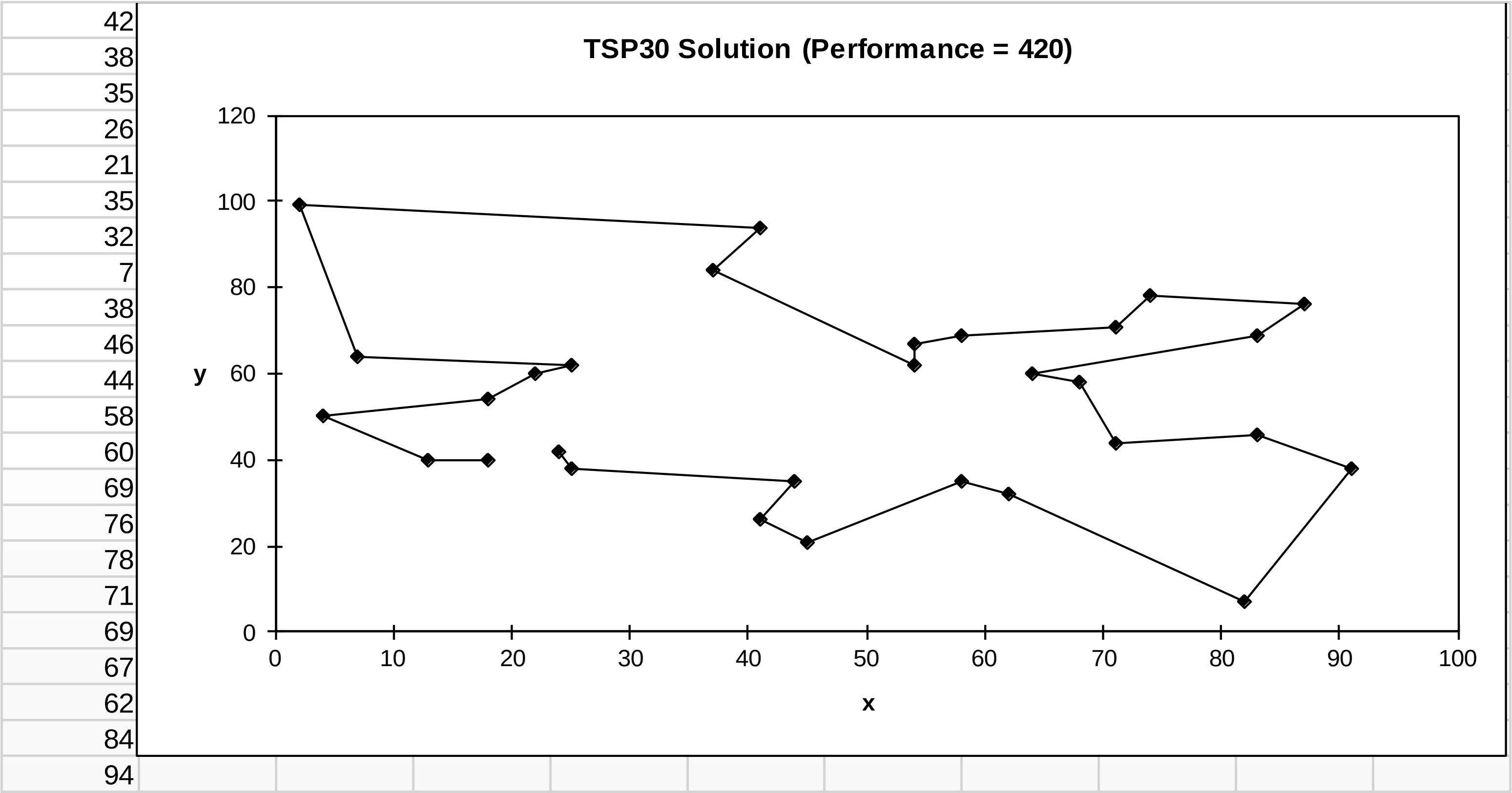
Solution $_j$(Distance = 800)



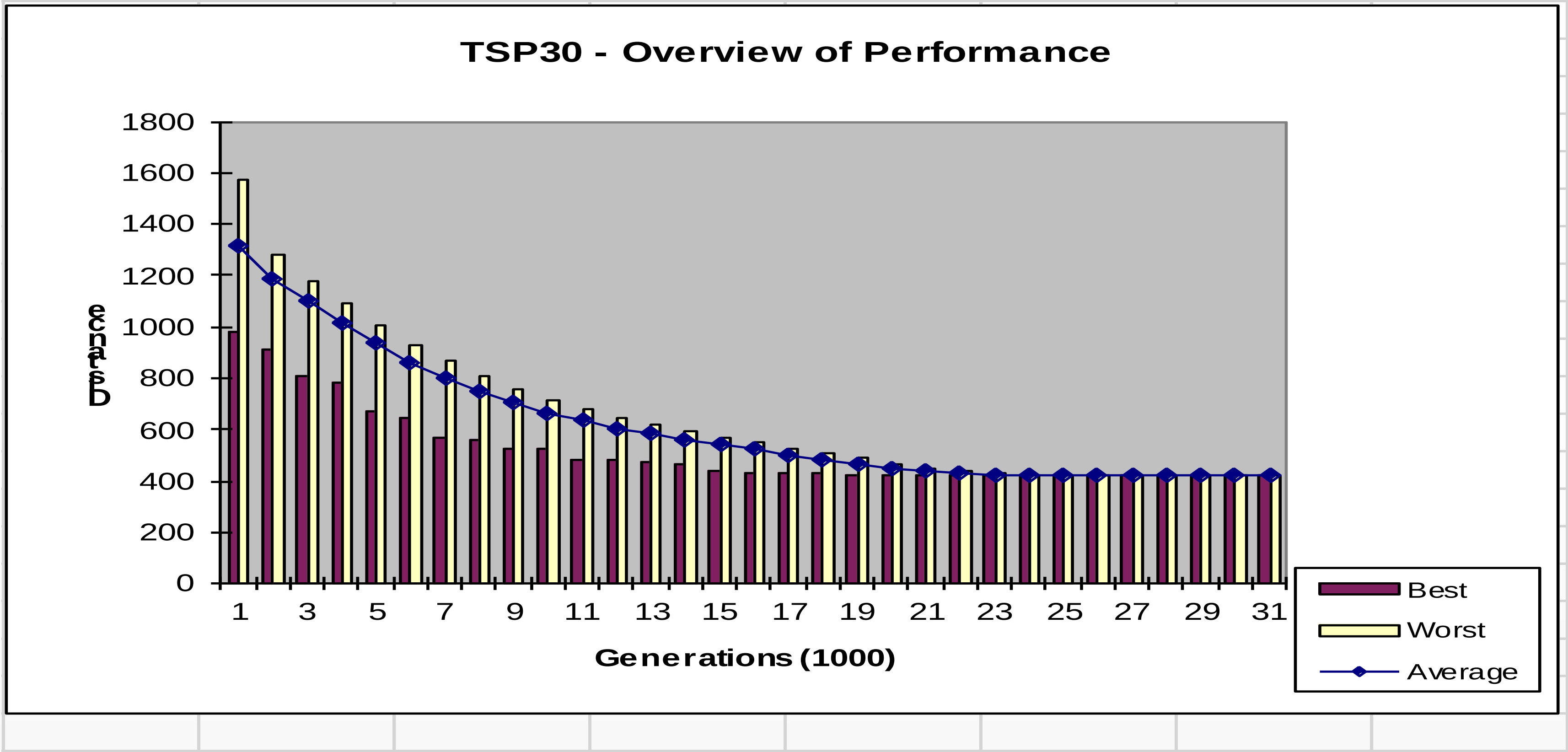
Solution $_k$(Distance = 652)



Best Solution (Distance = 420)



Overview of Performance



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