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21 37 158 228 255 10 49 26 88 250 12 ...
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21 37 158 228 255 10 49 26 88 250 12 ...
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Each number means some instruction: load value from memory to CPU register. Add two register values. Store register value to memory. Compare two numbers. Jump to a new memory address.

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Languages such as C, C++, or FORTRAN are compiled. The input program (source code) is converted to a numeric format that contains machine instructions.

Interpreters & Compilers

Using an interpreter is like making a dish using a cooking book in a foreign language that you cannot read well. You need to look up many words, and you execute the recipe slowly.

Fondant au chocolat

par Crevette

Pour 6 personnes :
Préparation : 20 min
Cuisson : 30 min

Ingrédients :

- 200 g de chocolat pâtissier
- 60 g de beurre
- 4 cuillerées à soupe de farine
- 4 œufs
- 150 g de sucre

Préparation :

Faire fondre le chocolat au bain-marie. Séparer les jaunes d'œufs des blancs.
Ajouter le beurre ramolli au chocolat fondu, ensuite les jaunes d'œufs, le sucre et la farine.

Montez les blancs d'œufs en neige bien ferme. Incorporez-les délicatement au mélange.
Cuire au four à 180°C (th.6) pendant environ 30 minutes.

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It takes time and effort to do the translation and to write it down. It is not worth doing that if we only cook the dish once. But now we can cook the dish many times quickly.

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Memory-management is done automatically by the interpreter.

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Smarter algorithms

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A smart algorithm in an interpreted language can easily beat a simple algorithm in a compiled language.

Example: Sorting

Here is a simple algorithm to sort a list a:

```
for i in range(len(a) - 1):
  for j in range(len(a) - 1):
    if a[j] > a[j+1]:
      a[j], a[j+1] = a[j+1], a[j]
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On a 2.8 GHz desktop, sorting 10000 numbers takes 20 seconds.

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Sorting 10000 numbers on the same desktop computer takes 0.1 seconds. One million numbers can be sorted in 11 seconds.

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We can prove that it is impossible to sort n numbers with less than $n \log_2 n$ comparisons, and therefore Merge Sort is optimal.

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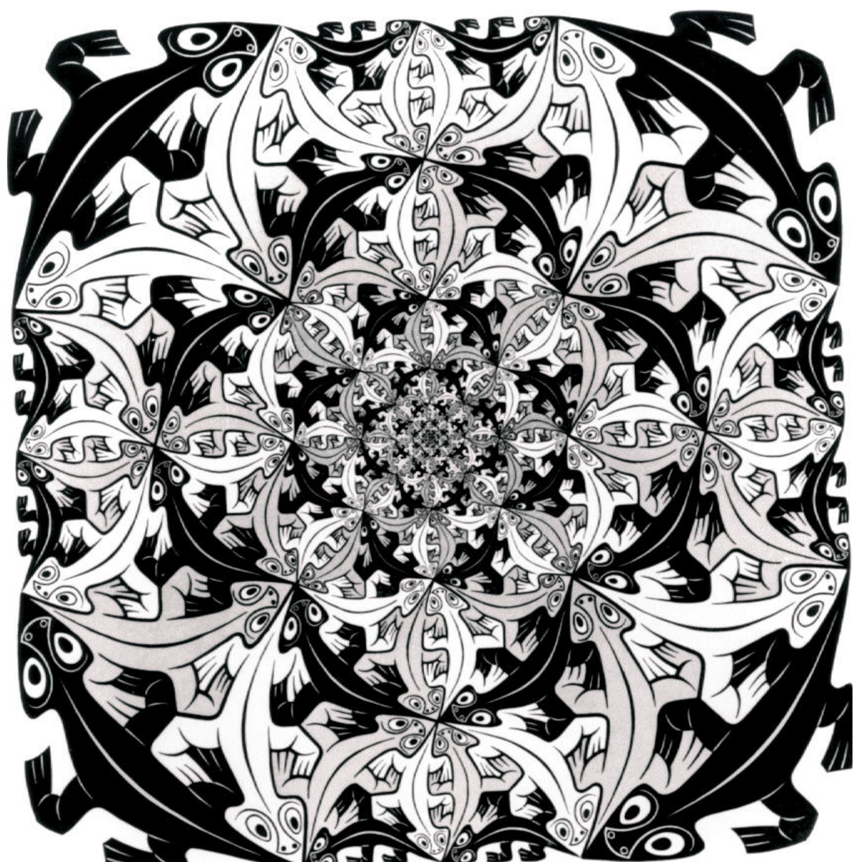

A recursive function

How would you implement this function?

```
>>> downup("Hello")
Hello
Hell
Hel
He
H
He
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My solution:

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def downup(w):
  print w
  if len(w) <= 1:
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  downup(w[:-1])
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recursive call

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The remaining digits are the representation of `n / b` in base `b`:

```
def to_radix(n, b):
  if n < b:
    return str(n)
  s = to_radix(n / b, b)
  return s + str(n % b)
```

Merge Sort is an example of a more interesting recursive algorithm: it uses two recursive calls:

```
def merge_sort(a):
  if len(a) <= 1:
    return
  m = len(a)/2
  a1 = a[:m]
  a2 = a[m:]
  merge_sort(a1)
  merge_sort(a2)
  merge(a, a1, a2)
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Merge Sort is recursive

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Divide & Conquer: Divide a problem into two smaller problems. Solve the smaller problems, and combine the solutions.

Efficient algorithms for everything?

Travelling Salesman: Given n points in the plan, find the shortest tour that visits all the points.

CS101

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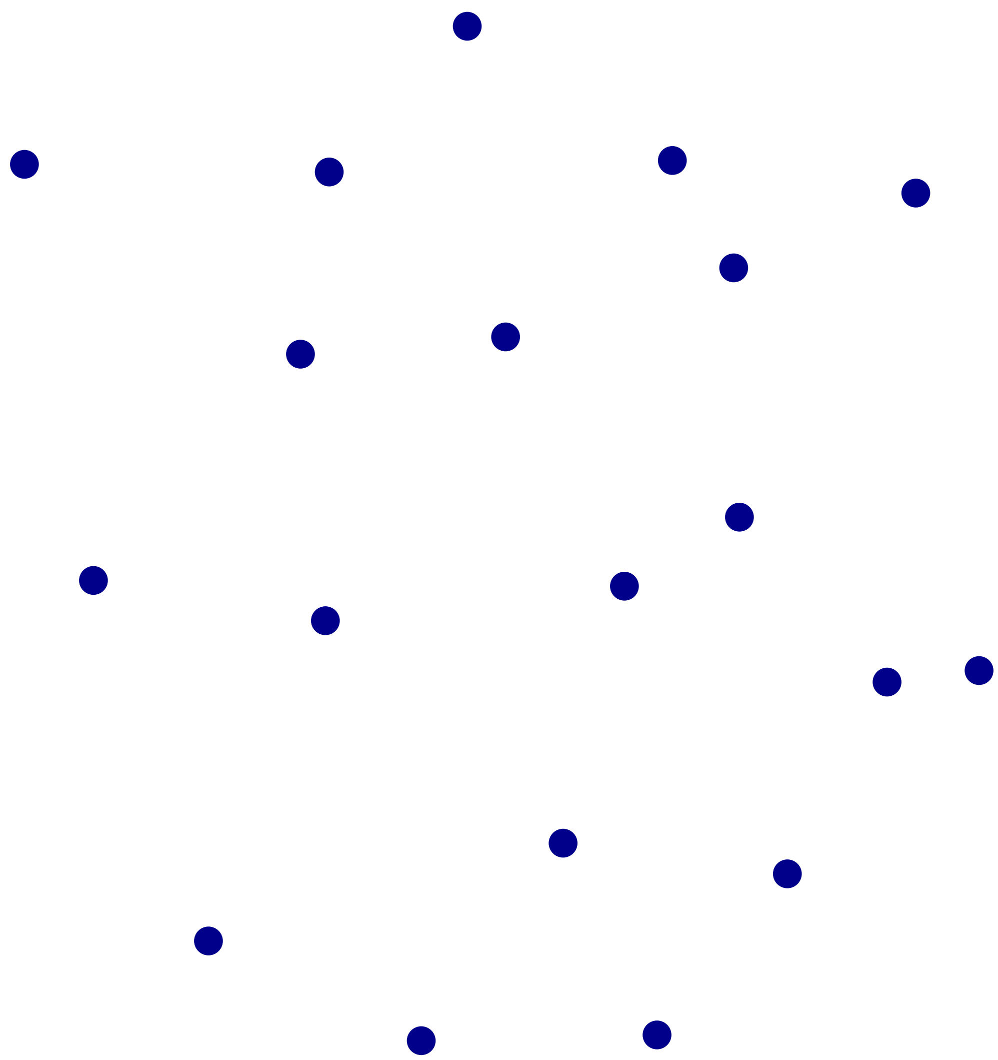

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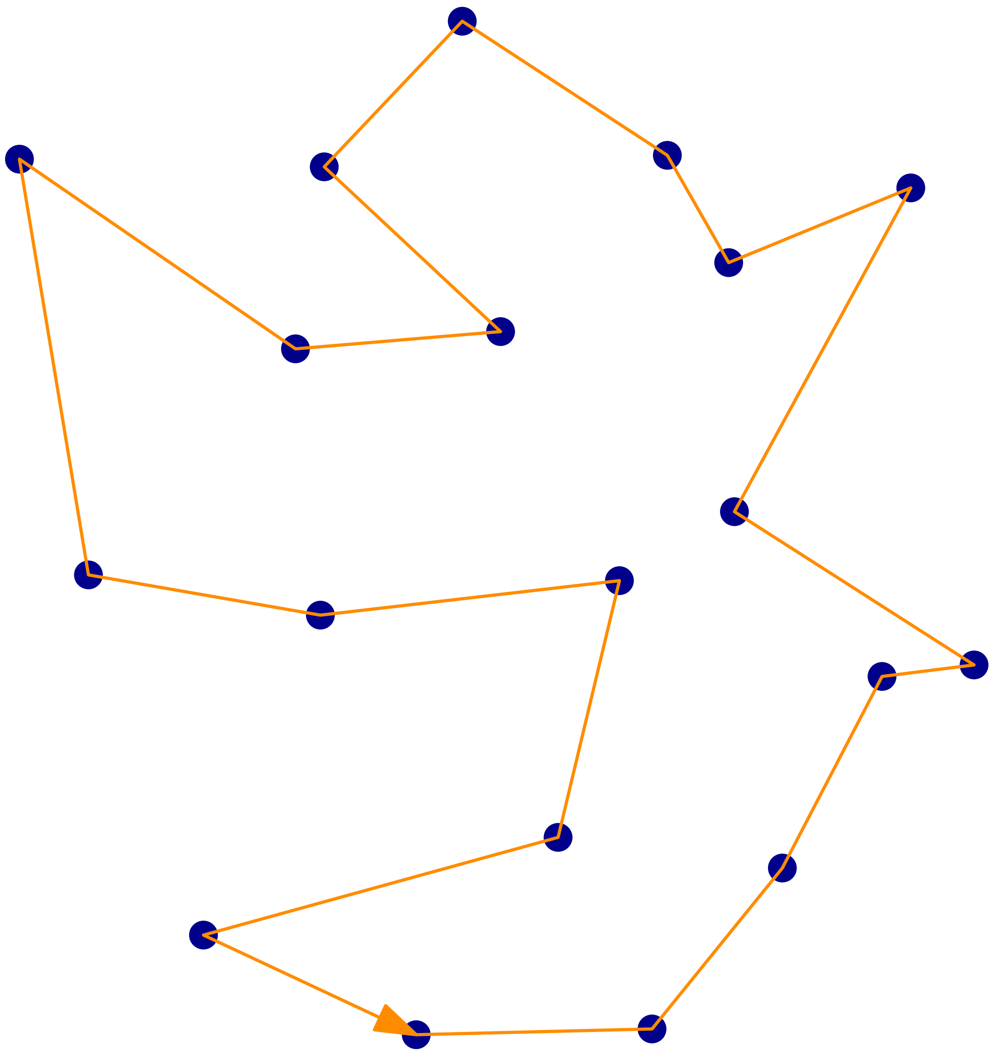

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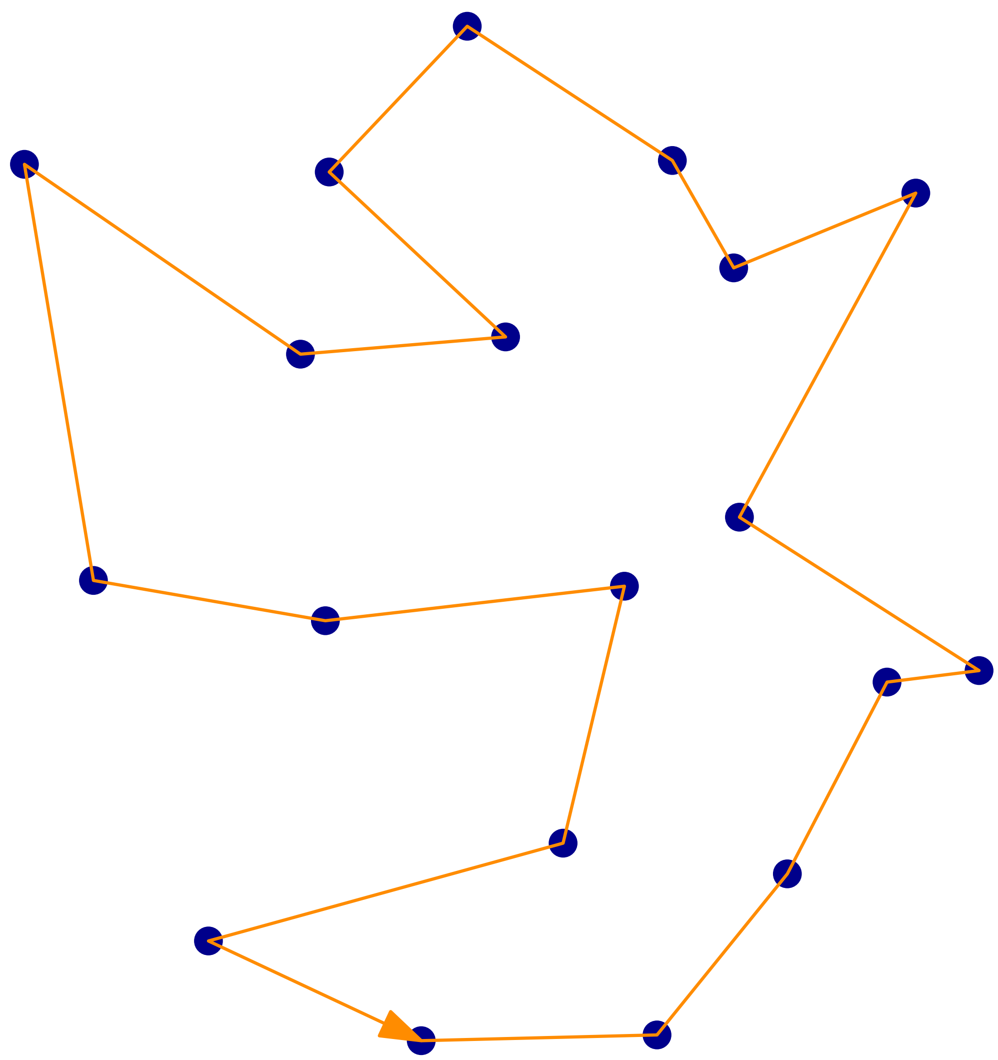

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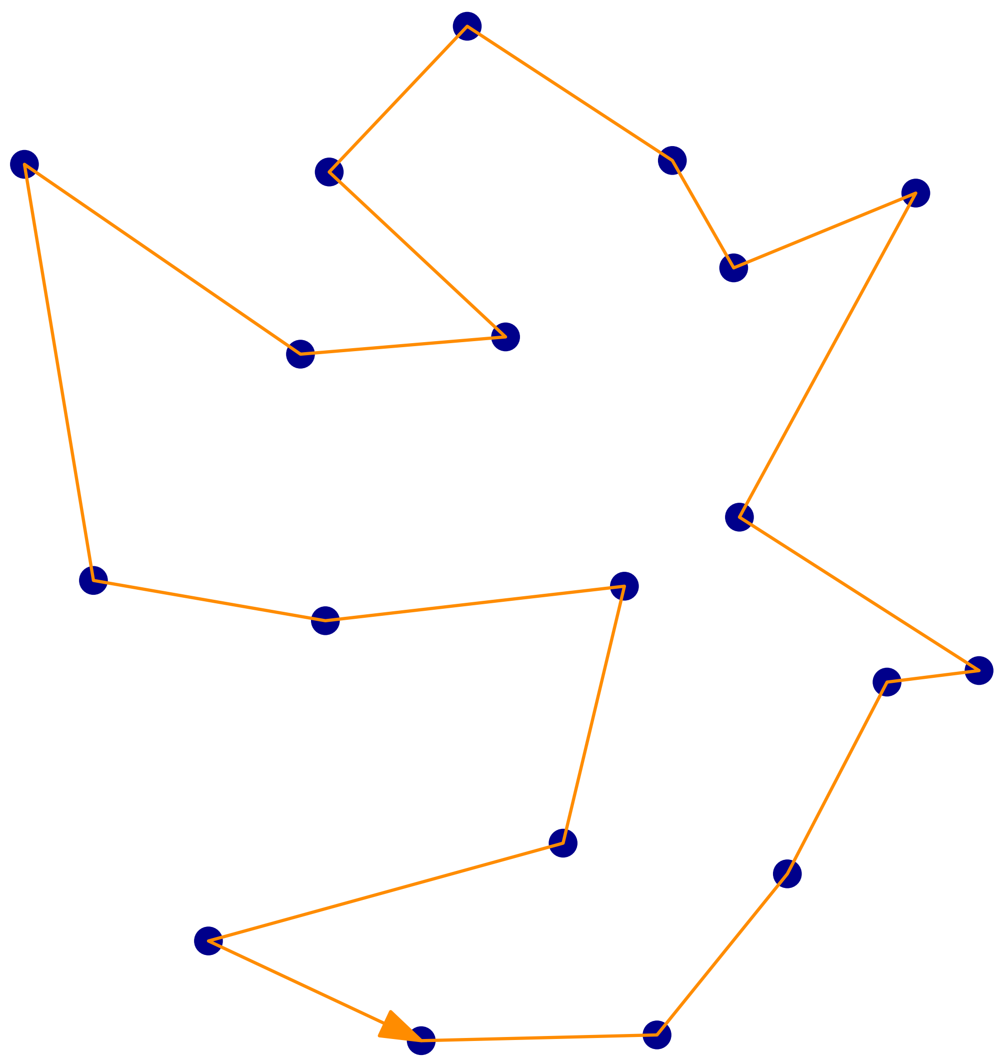

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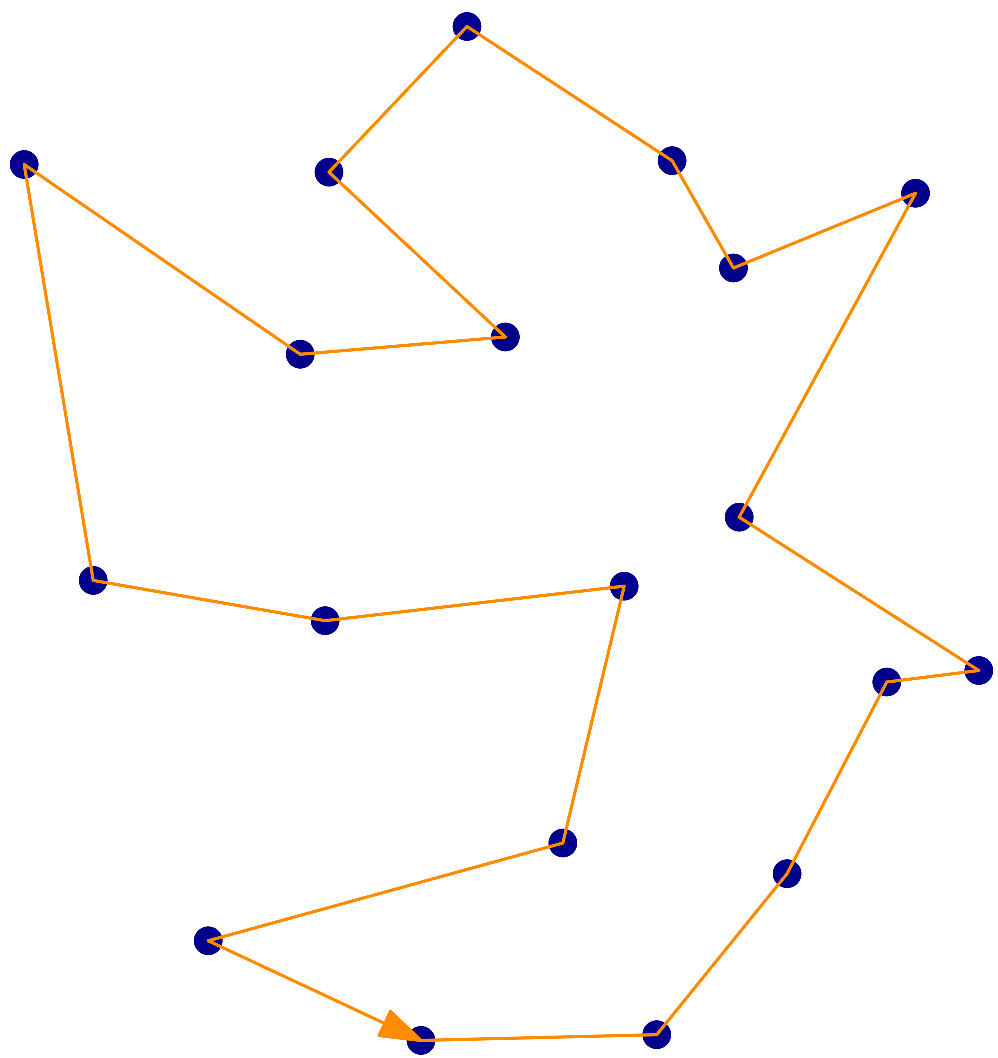

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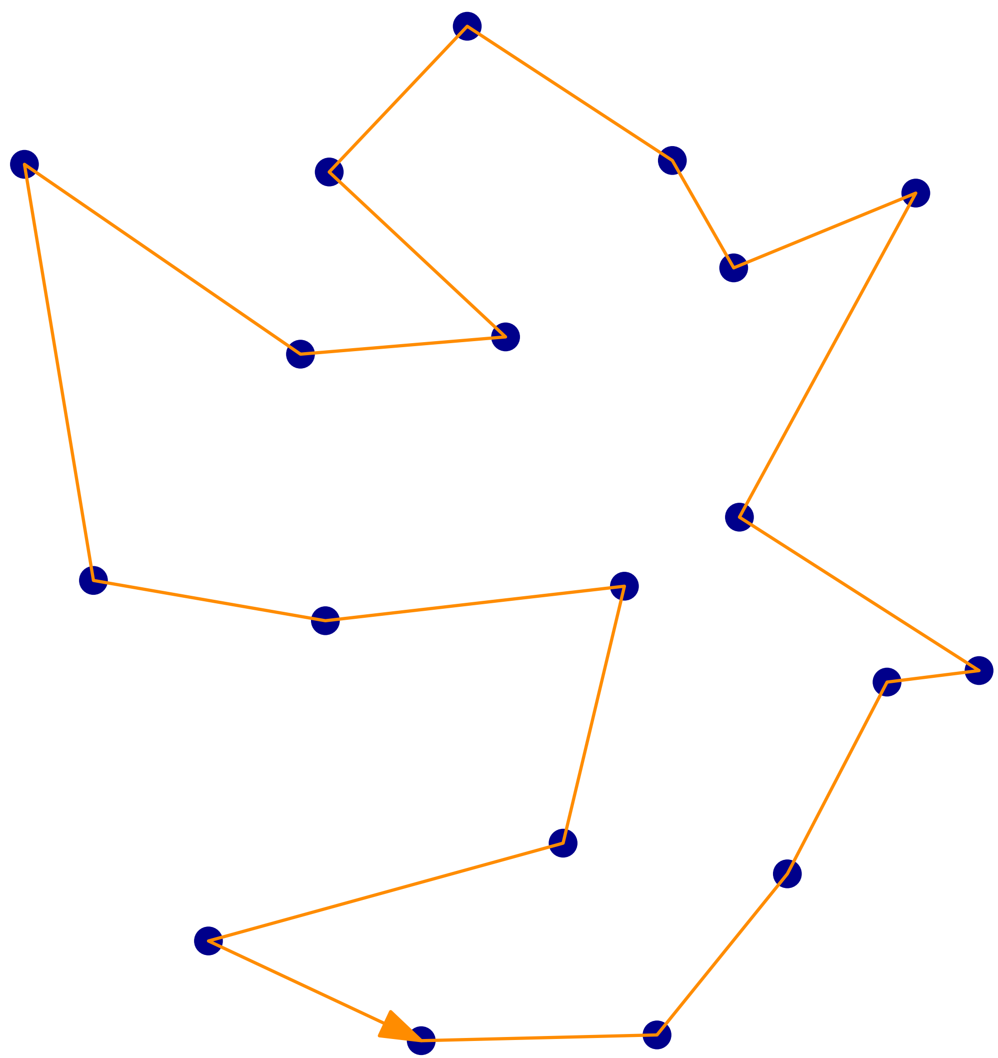

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There are problems for which we can prove that no algorithm exists.

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