CS101 - Compilers/Interpreters and Algorithms

Lecture 11

School of Computing
KAIST

Course Evaluation

Course Evaluation

- When: June 4 (Monday) – June 8 (Friday)
- Where: KAIST Portal System

Roadmap

In the first half of the semester we covered

- Why we learn programming
- Boolean values, conditionals, loops
- Objects, types, variables, methods, operators, expressions, tuples
- Functions with parameters and return values
- Local and global variables, modules, graphics
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In the second half of the semester we are covering

- String methods, set, dictionary, image processing
- File I/O
- Object creation and attributes
- Object constructors, user interface programming
- Interpreters vs. compilers and algorithms

Speed

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Machine language is just numbers in the memory:

```
21 37 158 228 255 10 49 26 88 250 12 ...
```

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++, Java, or Fortran are *compiled*. The input program (source code) is converted to a numeric format that contains machine instructions.

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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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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`:

```
def simple_sort(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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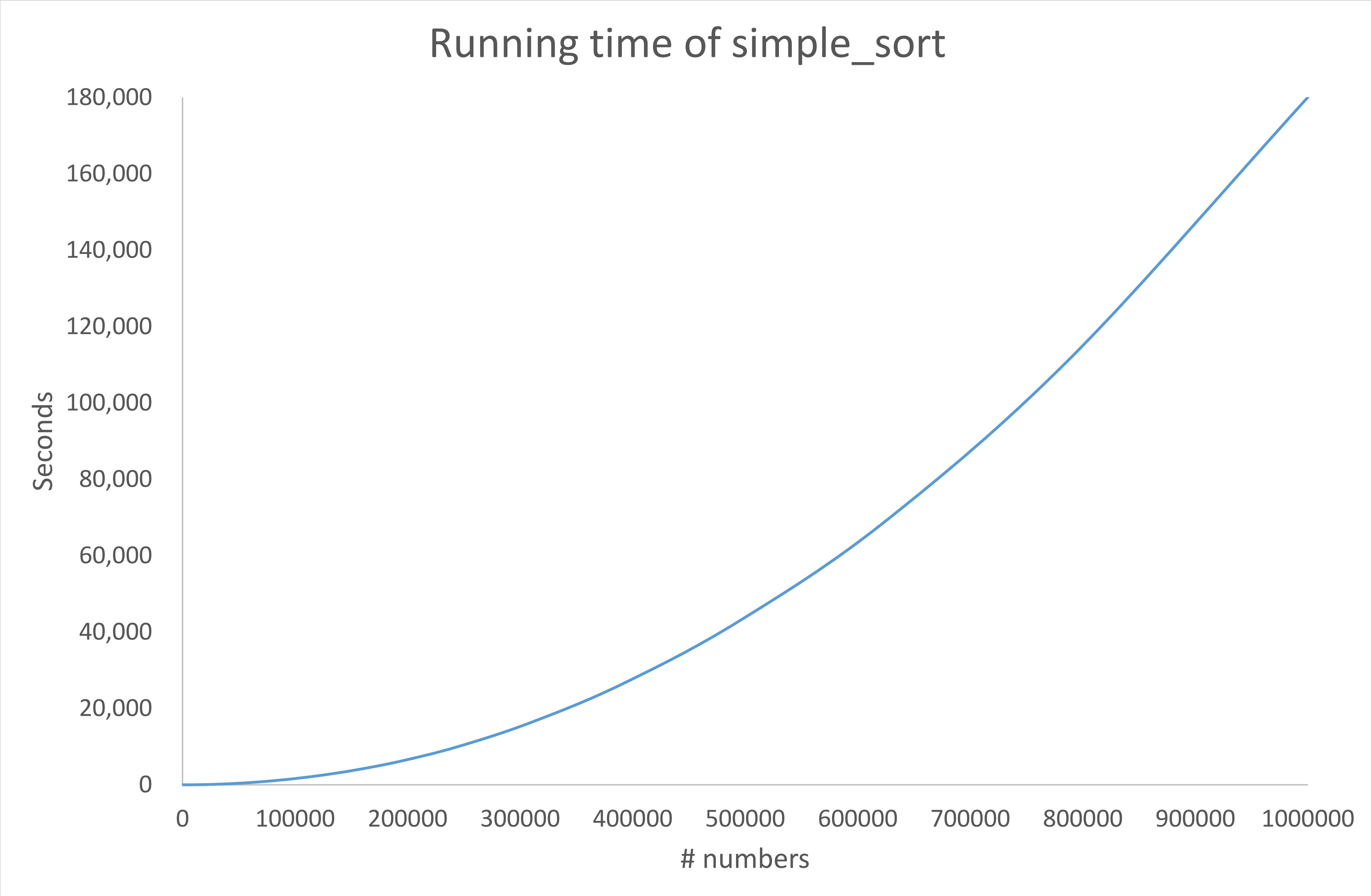
If the list `a` has `n` elements, then the **`if`** statement is executed $(n-1)^2$ times.

Test code:

```
import random
import time
large_list = list(range(200000))
random.shuffle(large_list)
st = time.time()
simple_sort(large_list)
print("Running time: %f sec" % (time.time() - st))
```

Example: Sorting

On a Intel i7 3.60GHz desktop, sorting 1M numbers takes 180,055 seconds.



Merge Sort: a smarter algorithm

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Test code:

```
import random
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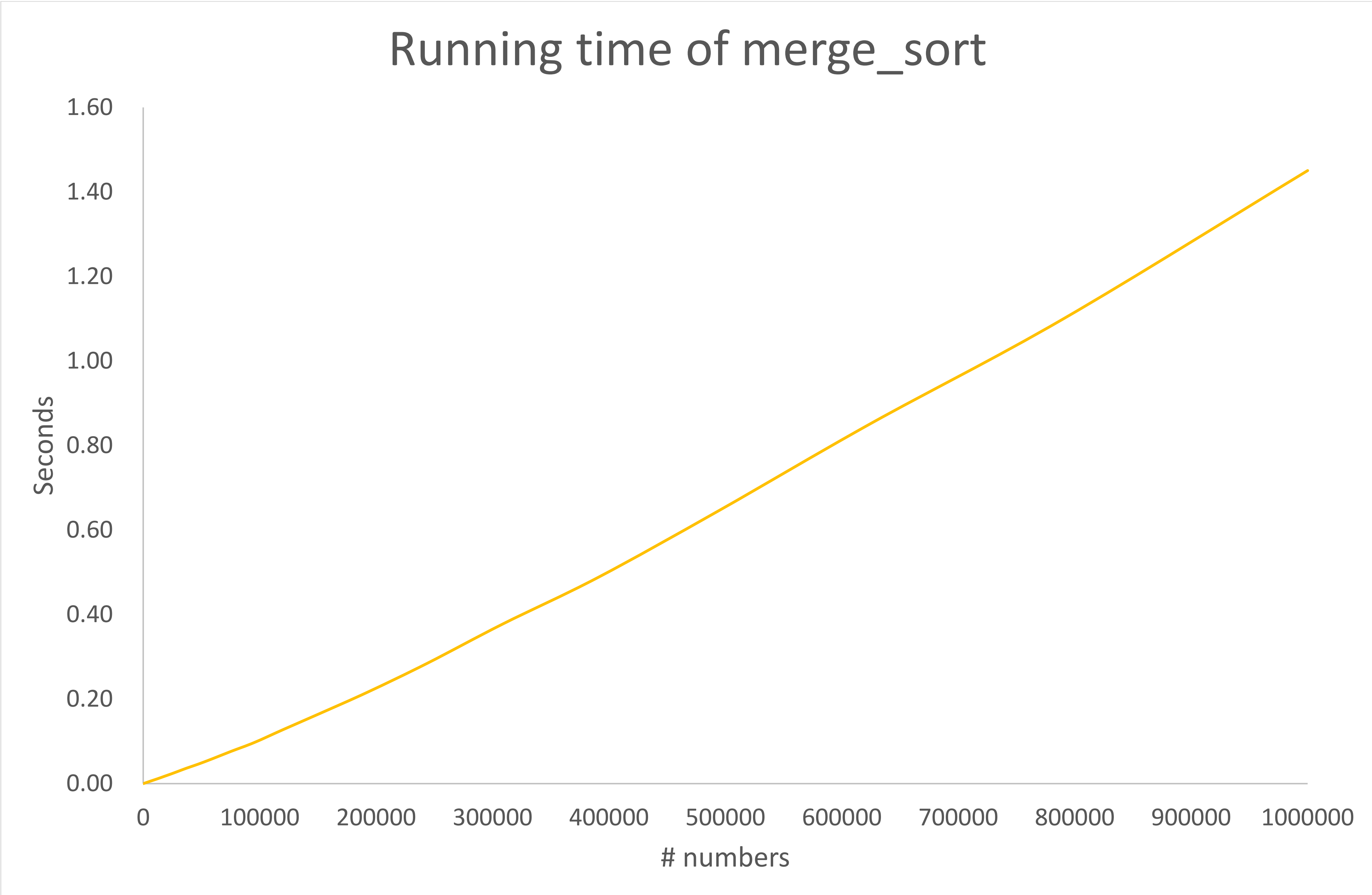
large_list = list(range(200000))
random.shuffle(large_list)
st = time.time()
merge_sort(large_list)
print("Running time: %f sec" % (time.time() - st))
```

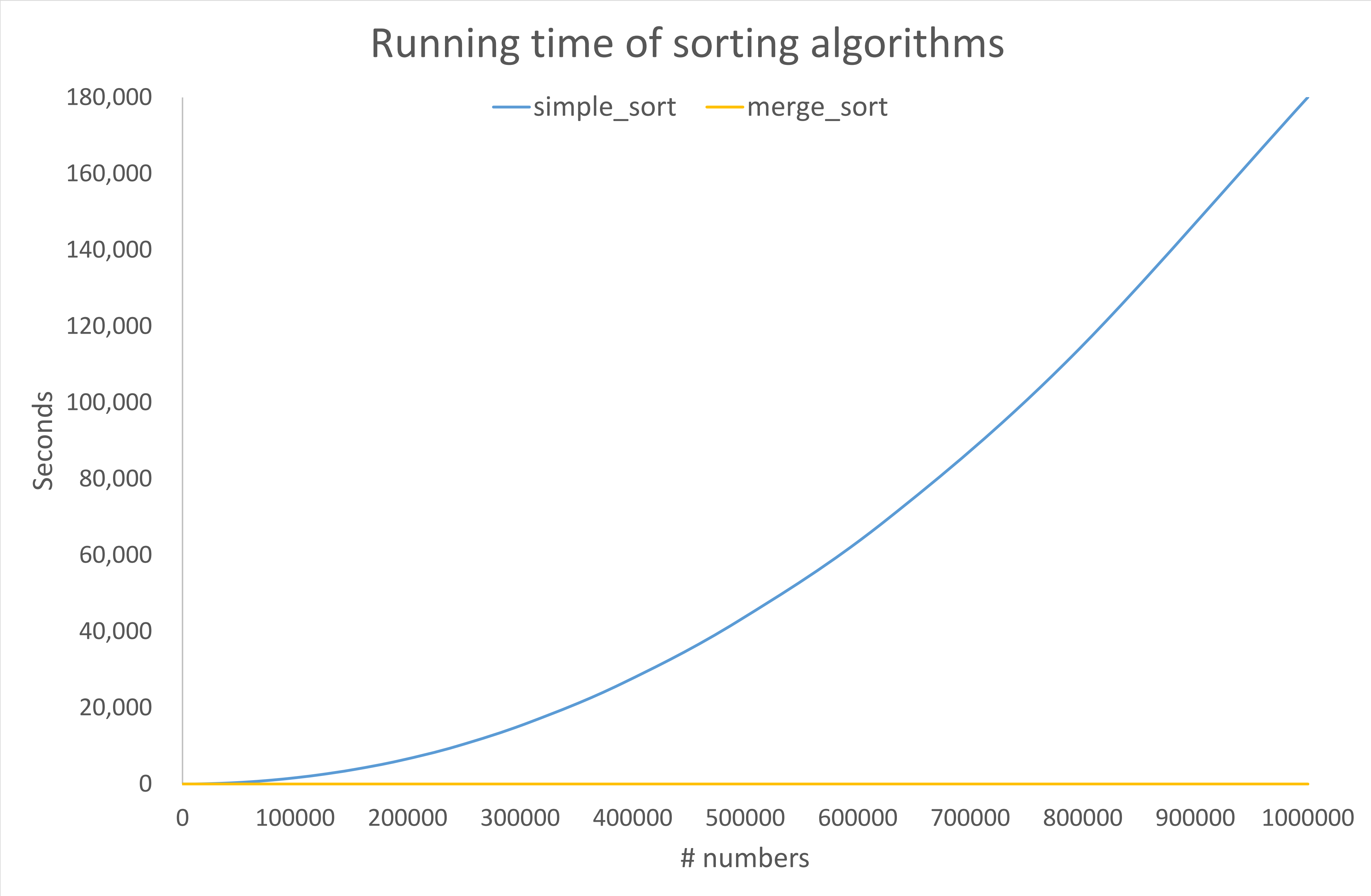
Merge Sort: a smarter algorithm

On a Intel i7 3.60GHz desktop, sorting 1M numbers takes 1.45 seconds.



Running time comparison

The comparison of `simple_sort` and `merge_sort` running time



Algorithm analysis

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An algorithm is *optimal* if we can prove that no algorithm can possibly solve the problem with a smaller number of operations (asymptotically).

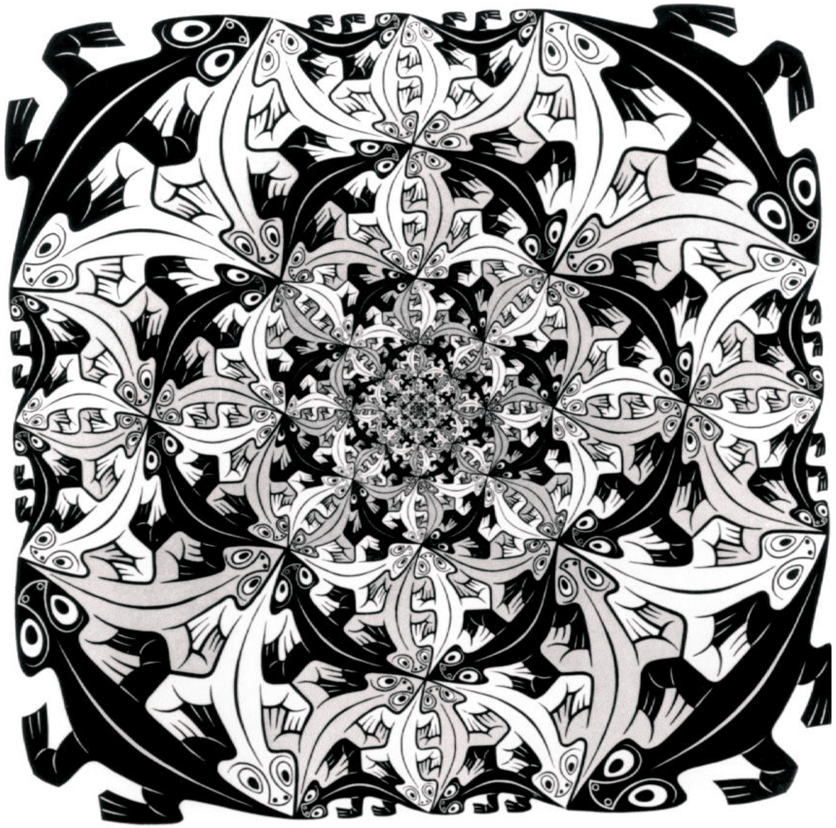
We can prove that it is impossible to sort n numbers with less than $n \log_2 n$ comparisons, and therefore Merge Sort is optimal.

Recursion

"Recursion" means to define something in terms of itself.

A folder is a collection of files and folders.

Words in dictionaries are defined in terms of other words.



A recursive function

Factorial

$$n! = \begin{cases} 1 & \text{if } n = 0 \\ (n-1)! \times n & \text{if } n > 0 \end{cases}$$

A recursive function

How would you implement this function?

```
>>> downup("Hello")
Hello
Hell
Hel
He
H
He
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```

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>>> downup("Hello")
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```

One solution

```
def downup(w):
  print(w)
  if len(w) <= 1:
    return
  downup(w[:-1])   # Recursive call
  print(w)
```

Printing in any base

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```
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 recursive

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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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 plane, find the shortest tour that visits all the points.

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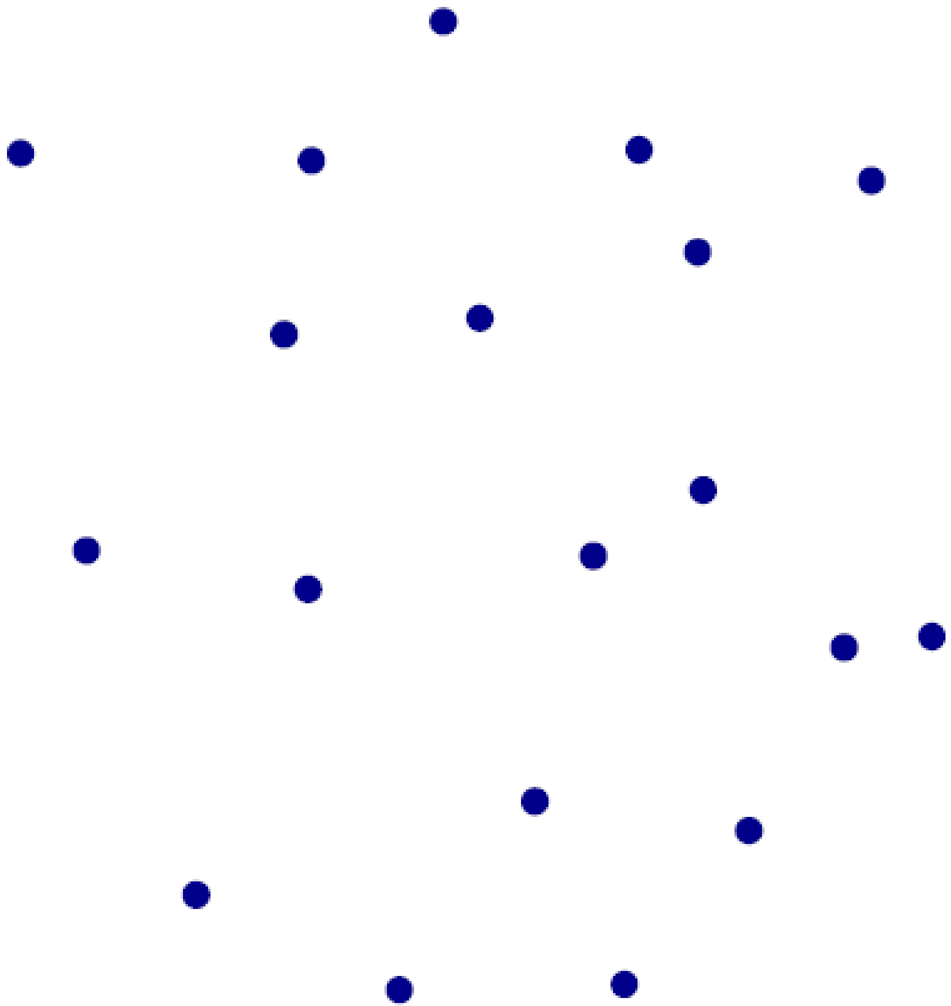

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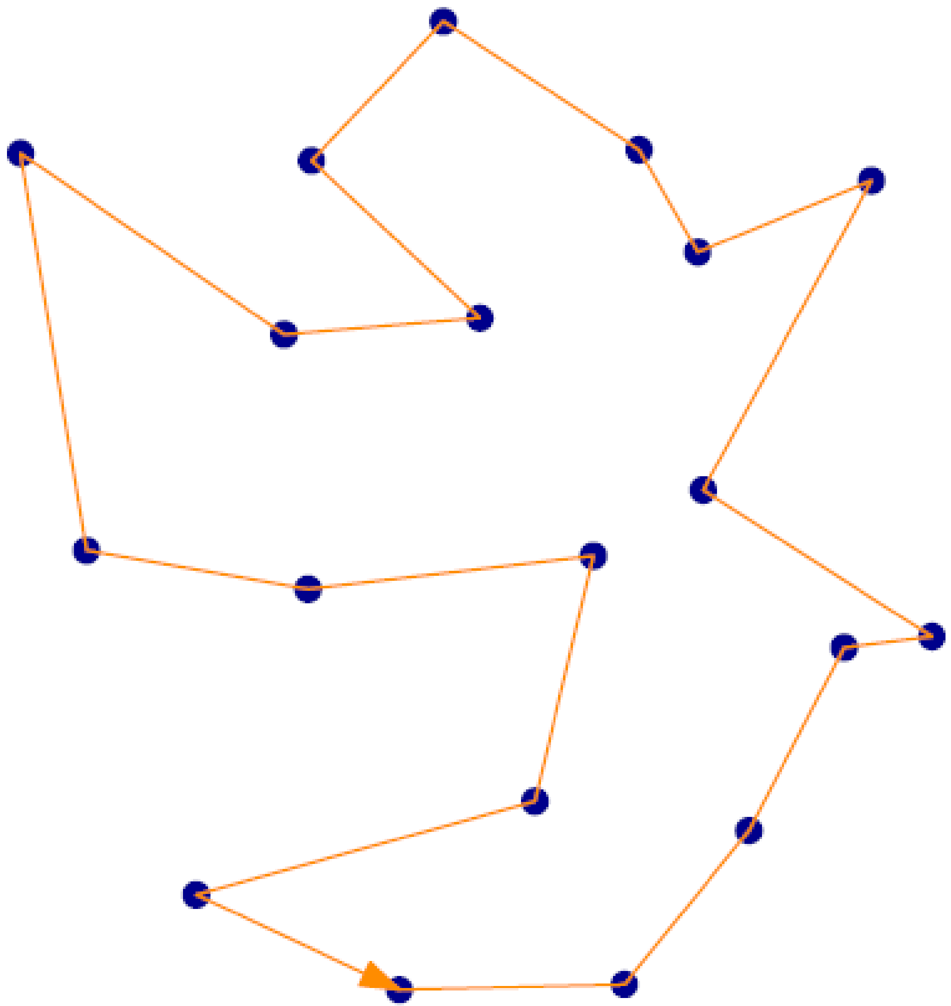

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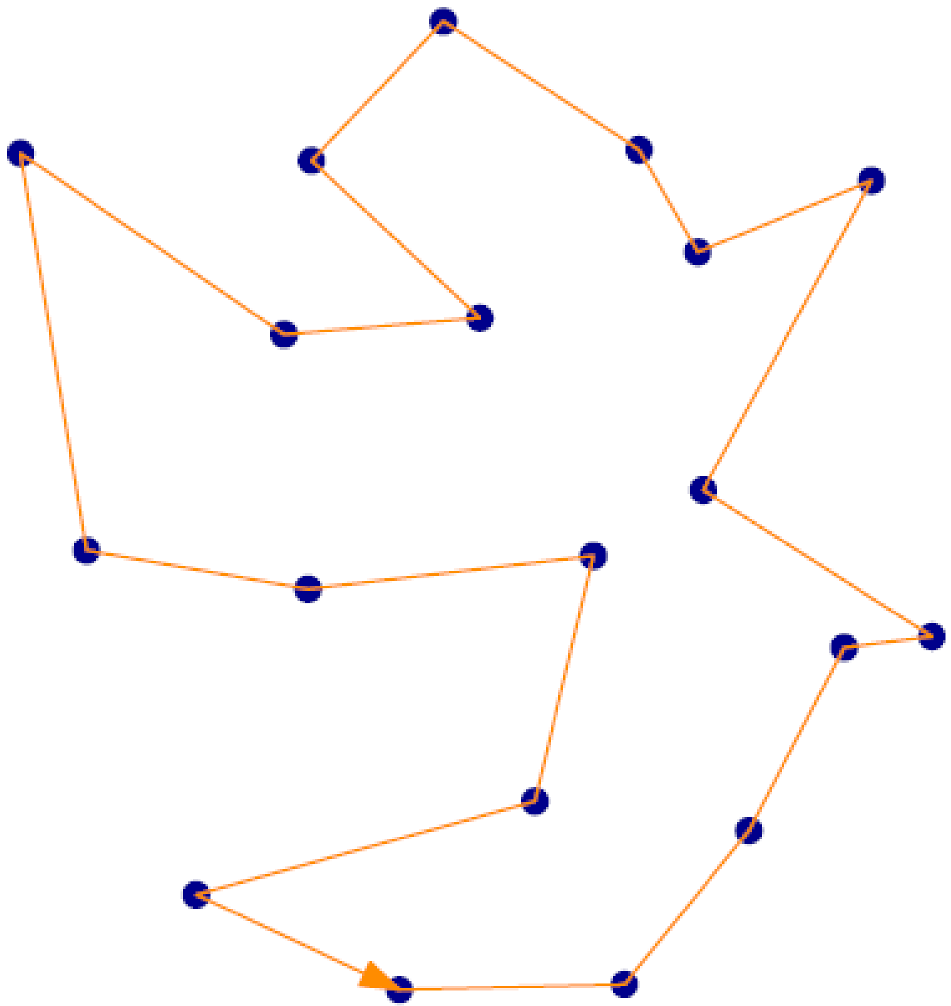

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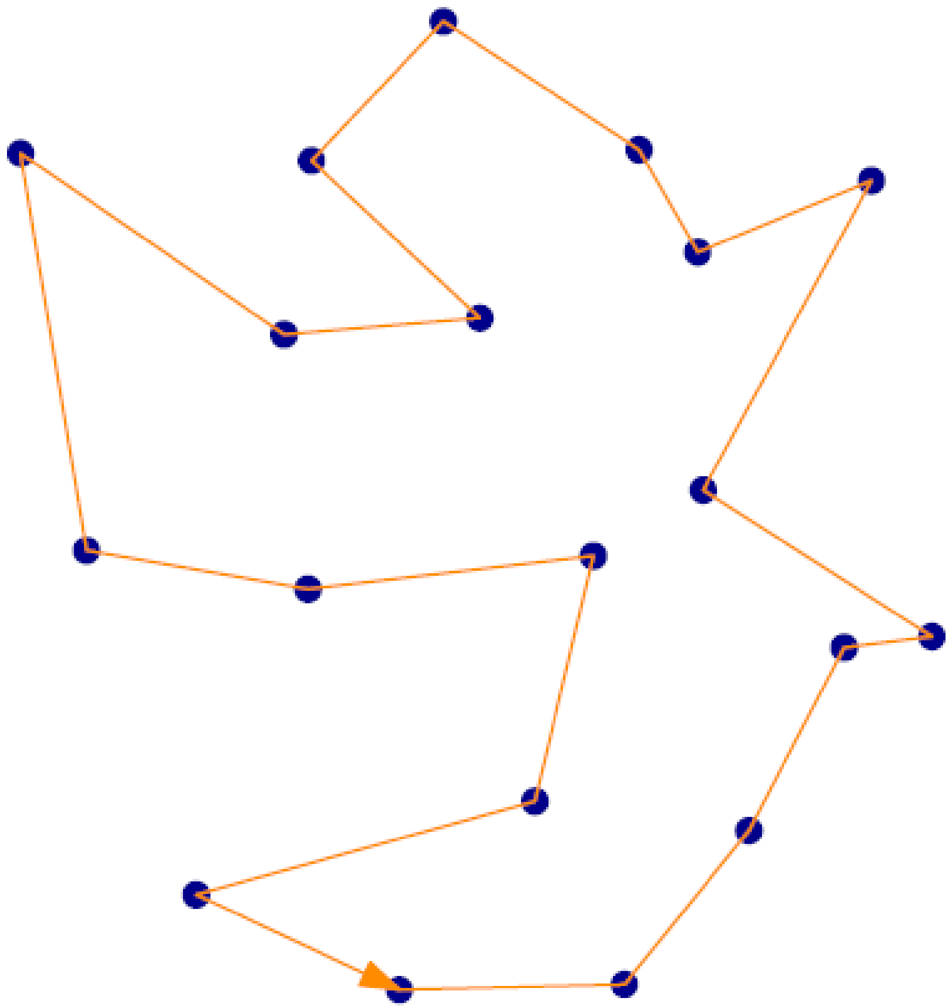

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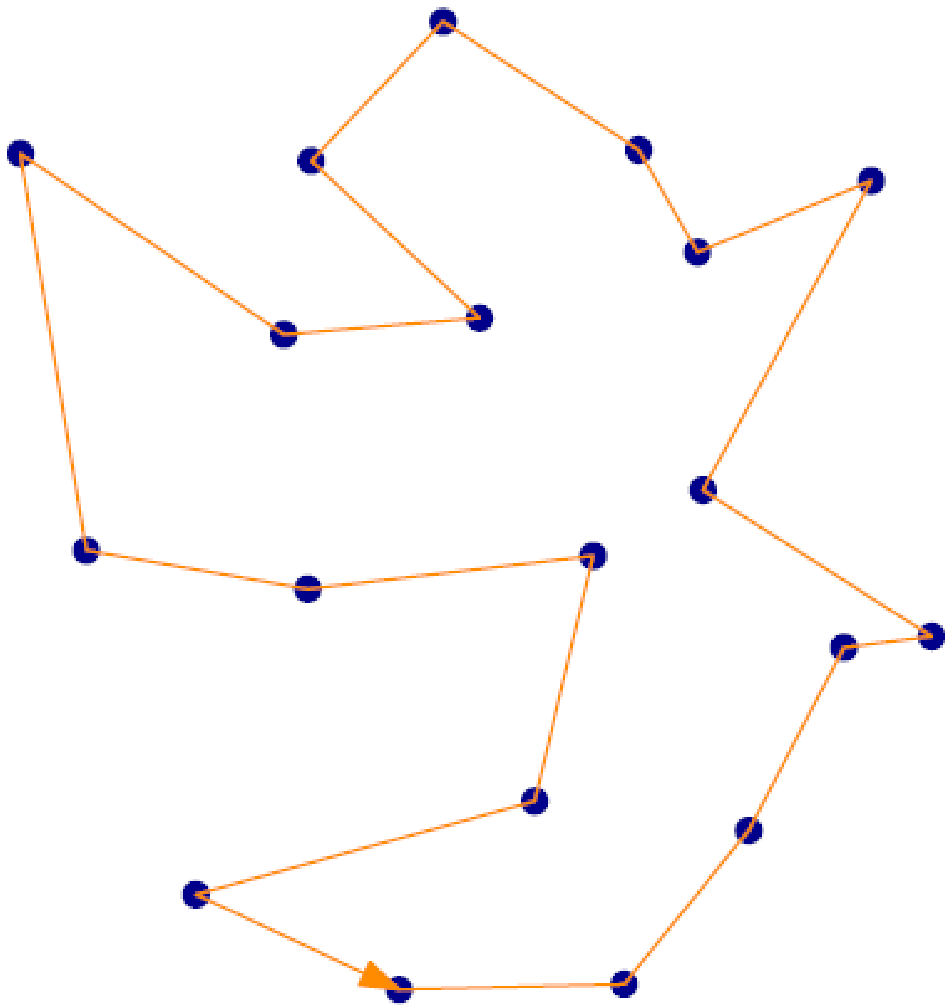

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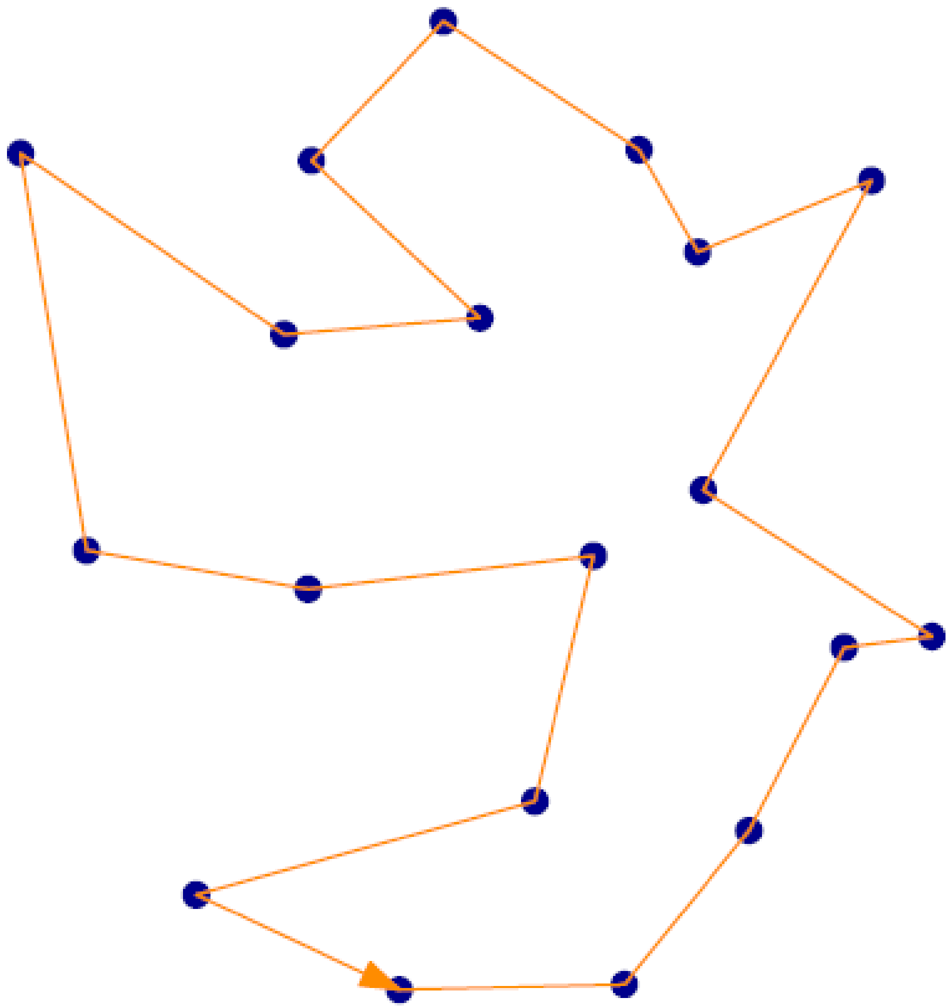

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There are problems for which we can prove that no algorithm exists.

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Remember that you can program to find answers to questions.

Other CS Courses

CS109: Programming Practice Gain experience programming with some fun projects

CS202 Problem Solving Learn about methods for problem solving and algorithm development.

CS204 Discrete Mathematics Cover mathematical concepts frequently employed in computer science: sets, relations, propositional logic, etc.

CS206: Data Structures (Separate sections for CS / non-CS in Spring) Improve programming skills; learn to design, use, and implement abstract data types; and learn about a number of fundamental standard data structures and algorithms.