VL01 Algorithms - the Basics

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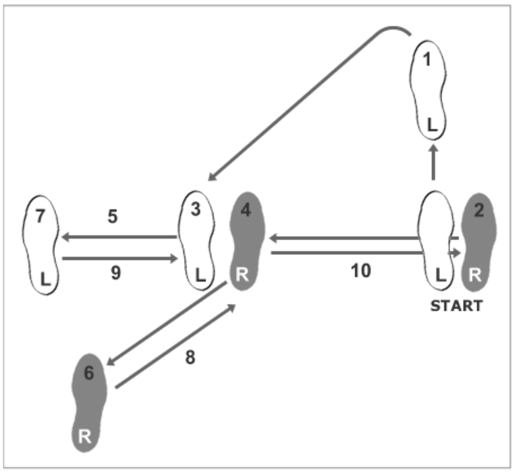
Agenda

- https://github.com/ondrah/algo/
- Definition
- Algorithm Types
- Notation and Interpretation
- Complexity
- Output Domain
- Code Review
- Example Algorithm: Digital Root
- Excercises

Definition

An algorithm is a sequence of steps that describes an approach to a solution of a given problem. Every computer program that ends with a result is basically based on a set of algorithms. Algorithms, however, are not just confined for use in computers and can be used to solve generic tasks.



Algorithm Types

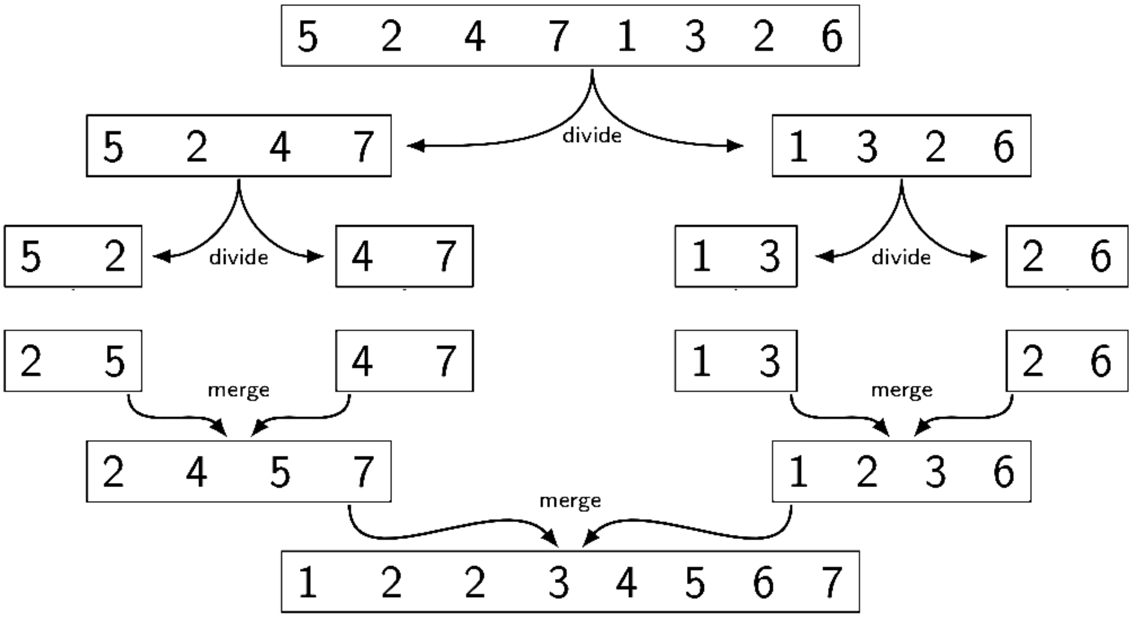
- Divide and Conquer
- Dynamic
- Recursive
- Greedy
- Backtracking
- Randomized
- Brute Force
- and many others...

Note: larger algorithms usually combine multiple algorithm types

Divide and Conquer

Divide the algorithm into multiple parts, that contain a sub-problem ideally of the same type. The combination of sub-solutions leads to the global solution.

Example: merge sort



Dynamic

These algorithms use values computed in the past to compute future results, boosting efficiency.

Example: Fibonacci numbers

```
$a = 1; $b = 2;

print "$a, $b, ";

for($i = 0; $i < 10; $i++) {
        $c = $b;
        $b = $b + $a;
        $a = $c;

        print $b, ", ";
}
```

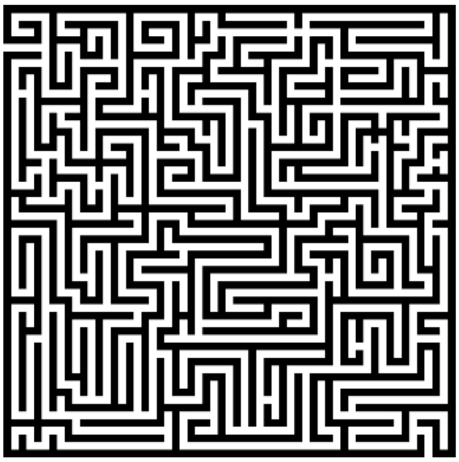
Recursive

A special type of algorithm using a method of simplification that divides the problem into sub-problems of the same nature. The result of one recursion is the input for the next recursion. Recursion works in environments where the algorithm is able to call itself.

Backtracking

Class of algorithms for optimization tasks. The algorithm finds a partial solution candidate on local level with hope that this candidate is a part of the solution at the global level. Backtracking algorithms typically use recursion.

Example: routing algorithms



Greedy, Randomized

Greedy

Greedy algorithm usually solve optimization tasks without the guarantee of finding a solution. The result should be a solution candidate which matches the requirement of being *good enough*.

Example: genetic algorithms

Randomized

Is a type of algorithm that uses random values in its decisions.

Example: genetic algorithms

Brute Force

Brute force is the hard way of finding a solution by generating solution candidates in all possible combinations. Technically, the method always finds a solution, the real problem is the duration.

Example: password guessing

```
foreach $l0 ( 'a' ... 'z' ) {
    foreach $l1 ( 'a' ... 'z' ) {
        foreach $l2 ( 'a' ... 'z' ) {
            foreach $l3 ( 'a' ... 'z' ) {
                print $l0, $l1, $l2, $l3, "\n";
            }
        }
    }
}
```

Notation and Interpretation

- What you essentially do
  - Data transformation
  - Data comparison
  - **Jump** or transition to the next **instruction**
- Plain text preferably with clear instructions
- Usually a pseudocode of a C-like language
  - C, Perl, Java, Python, Basic, and many others

Complexity

Table 1. A small overview

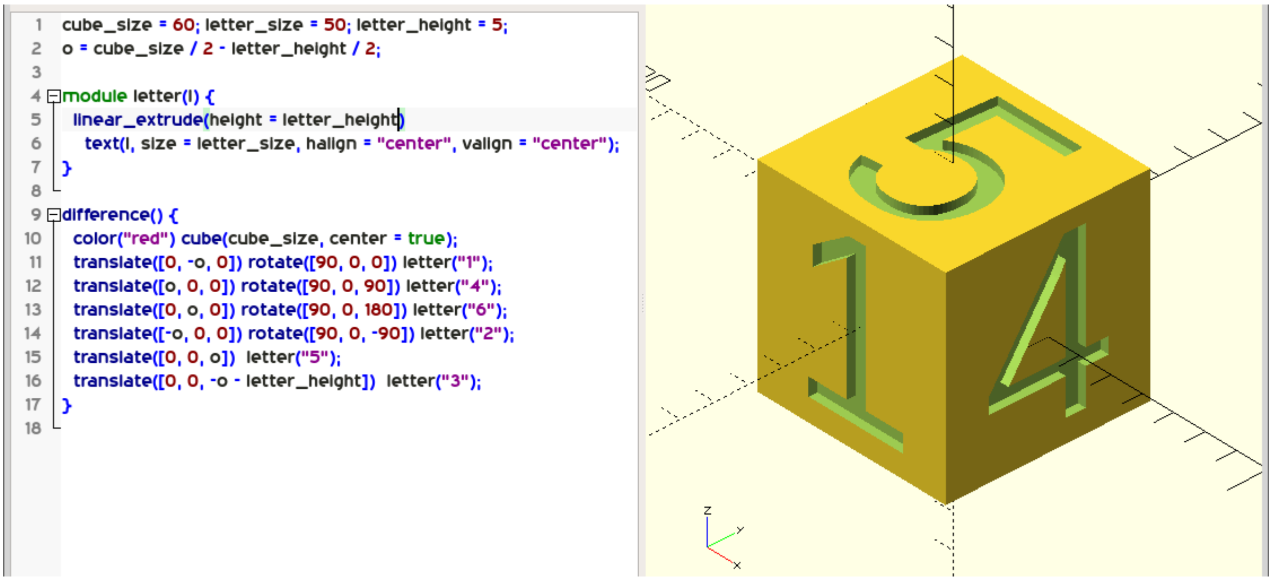
Complexity	n = 10	n = 100	n = 1000	n = 10000
log(n)	1 ns	2 ns	3 ns	4 ns
n*log(n)	10 ns	100 ns	1 us	10 us
n^2	100 ns	10 us	1 ms	100 ms
n^3	1 us	1 ms	1 s	16.7 min
2^n	1 us	10^{24} years	10^{302} years	10^{3011} years

Output Domain

With the same principles and similar logic, you can work in a completely different domain.

Try programming 3D models on https://openjscad.org

Hint: search for *openscad cheat sheet*



```
cube_size = 60; letter_size = 50; letter_height = 5;
o = cube_size / 2 - letter_height / 2;

module letter(l) {
  linear_extrude(height = letter_height)
    text(l, size = letter_size, halign = "center", valign = "center");
}

difference() {
  color("red") cube(cube_size, center = true);
  translate([0, -o, 0]) rotate([90, 0, 0]) letter("1");
  translate([o, 0, 0]) rotate([90, 0, 90]) letter("4");
  translate([0, o, 0]) rotate([90, 0, 180]) letter("6");
  translate([-o, 0, 0]) rotate([90, 0, -90]) letter("2");
  translate([0, 0, o])  letter("5");
  translate([0, 0, -o - letter_height])  letter("3");
}
```

If something can go wrong, it will.

- Robustness
- Consistency
- Determinism
- Testing
- Dual Programming
- Code Reviews

Code Review I

```c
int evaluate_pivot(int adj, char *my_string)
{
    int b = adj - 1;
    int idx = b * b;

    if(idx == 0)
    {
        return forward_direction(0, my_string);
    }

    if(idx > 0)
    {
        return forward_direction(+1, my_string);
    }

    return forward_direction(-1, my_string);
}
```

Code Review II

```c
/*
 * Generate a random value between a and b, a < b.
 */
int rand_between(int a, int b)
{
    int r;

    do
    {
        r = rand();
    }
    while(r < a || r > b);

    return r;
}
```

Example: Factorial

```
int factorial(int n)
{
    if(n <= 1)
        return 1;

    return n * factorial(n - 1);
}
```

Example: Digital Root

The digital root (also repeated digital sum) of a natural number in a given number base is the (single digit) value obtained by an iterative process of summing digits, on each iteration using the result from the previous iteration to compute a digit sum. The process continues until a single-digit number is reached. (source: Wikipedia)

Fixed assumption: base = 10

Example:

Input 11111, Output 5

Input 999, Output 9

Input 68, Output 5

Exercises

- Factorial as a dynamic algorithm
- Lucas Numbers as a recursive algorithm
- Tower of Hanoi
- Integer subsequence with the highest sum
- Bug on a string