Recursion

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Did you mean: ***recursion***

Recursion - Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/**Recursion**

Recursion is the process of repeating items in a self-similar way. For instance, when the surfaces of two mirrors are exactly parallel with each other the nested ...

Formal definitions of recursion - Recursion in language - Recursion in mathematics

Recursion (computer science) - Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/**Recursion**_(computer_science)

Recursion in computer engineering is a method where the solution to a ...

Recursive data types - Recursive algorithms - Structural versus generative ...

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Recursion -- from Wolfram MathWorld

mathworld.wolfram.com › ... › Algorithms › Recursion

5 days ago – A **recursive** process is one in which objects are defined in terms of other objects of the same type. Using some sort of recurrence relation, the ...

Recursion in C and C++ - Cprogramming.com

www.cprogramming.com/tutorial/lesson16.html

Learn how to use **recursion** in C and C++, with example **recursive** programs.

Java **Recursion** with examples

www.danzig.us/java_class/**recursion**.html

Simply put, **recursion** is when a function calls itself. That is, in the course of the function definition there is a call to that very same function. At first this may seem ...

2.3 **Recursion** - Introduction to Programming in Java

introcs.cs.princeton.edu/23**recursion**

Recursion is a powerful general-purpose programming technique, and is the key to ... The HelloWorld for **recursion** is to implement the factorial function, which is ...

Recursion

recursion (rɪˈkɜːʃən)
—***n***

1*. see "recursion"*

Recursion

Think of recursion as a function calling itself:

```
// a recursive function
void recursive_fn() {
    recursive_fn(); // calls itself
}
```

This particular recursive function never stops (infinite recursion)

- you'll probably never intentionally write a function like this!

Recursion

<u>Useful</u> recursive functions will consist of two parts:

The recursive step

- if the problem can be decomposed into a smaller version of the same task, the function should call itself on the smaller version

The base case

- when the problem is simple enough, it can be solved *without* further recursive calls
- this is called the "base case" or "stopping case"
- to prevent infinite recursion, a recursive function should <u>always</u> test for the base case <u>before</u> making the recursive call

Recursion

Recursive tasks are common

- a recursive task is one that can be broken into smaller versions of itself
- the smaller versions of the problem are much easier to solve than the entire larger problem (an idea called "divide and conquer")

Example: binary search

- searching for a value in a sorted array (think like using a phone book) can be thought of as a recursive task
- at each step, find the middle of the array, determine which half contains the target value, and then repeat the process on that half of the array (the recursive step)
- when the array consists of only one item, the problem is trivially easy; either the value is the one you're looking for, or it's not (the base case)

Recursion

Recursive structures are also common

- a recursive structure is one that can be broken into smaller versions of itself
- for any such structure, there is very likely a recursive approach to utilizing it (traversing, emptying, sorting, etc...)

Which of the following data structures can treated as recursive?

- linked lists
- strings
- arrays
- stacks
- queues
- trees

Recursion

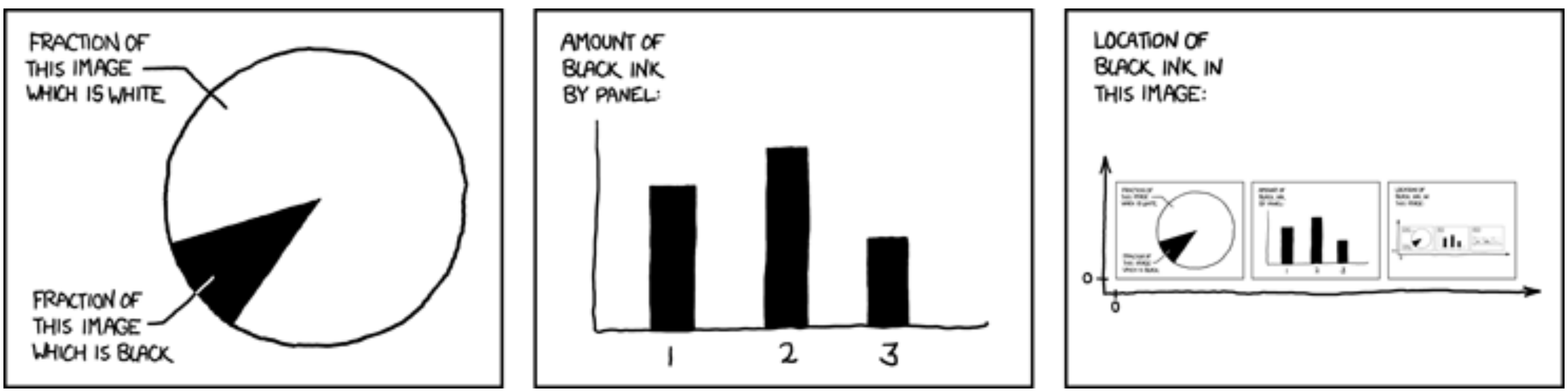
How about all of them?

- linked lists:
  - if you remove a node from a linked list, the result is a shorter linked list
- strings:
  - if you remove a character from a string, the result is a shorter string
- arrays:
  - if you consider only a subset of an array, that subset is essentially just a shorter array
- stacks:
  - remove an item, the result is just a smaller stack
- queues:
  - remove an item, the result is just a shorter queue
- trees:
  - the chapter on recursion proceeds the chapter on trees in your book for a good reason =)

Recursion

Recursion isn't magic, and it won't solve all your problems...

- it can be an extremely powerful tool, though
- many experienced programmers start expecting to find simpler versions of a larger problem during the design process
- in such a case, recursion can potentially be used for a solution (one which tends to be both simple and elegant)



A Simple Example

Recursion Examples

Here's a recursive function for printing numbers, one digit per line:

```
void print_number(int num) {
    if (num < 10) {
        cout << num << endl;
    } else {
        print_number(num / 10);
        cout << (num % 10) << endl;
    }
}
```

What is the recursive step? How is it a smaller problem?

```
print_number(num / 10); // number with 1 fewer digit
```

Recursion Examples

Here's a recursive function for printing numbers, one digit per line:

```
void print_number(int num) {
    if (num < 10) {
        cout << num << endl;
    } else {
        print_number(num / 10);
        cout << (num % 10) << endl;
    }
}
```

What is the base case and why was it chosen?

```
if (num < 10) { ... } // only 1 digit
```

Recursion Examples

Here's a recursive function for printing numbers, one digit per line:

```
void print_number(int num) {
    if (num < 10) {
        cout << num << endl;
    } else {
        print_number(num / 10);
        cout << (num % 10) << endl;
    }
}
```

What output does this function call generate?

```
print_number(12345);
```

Recursion Examples

Here's a recursive function for printing numbers, one digit per line:

```
void print_number(int num) {
    if (num < 10) {
        cout << num << endl;
    } else {
        print_number(num / 10);
        cout << (num % 10) << endl;
    }
}
```

How could you reverse the order in which the digits are printed?

Recursion Examples

Printing the digits in the reverse order:

```
void print_number(int num) {
    if (num < 10) {
        cout << num << endl;
    } else {
        cout << (num % 10) << endl;
        print_number(num / 10);
    }
}
```

How could you reverse the order in which the digits are printed?

- just do the recursive call *after* printing `(num % 10)`

Another Example

Recursion Examples

What is the recursive step here? How is it a smaller problem?

```
void recurse_to_zero(size_t num) {
    cout << num << endl;

    if (num == 0) {
        cout << "Zero!" << endl;
    } else {
        recurse_to_zero(num - 1);
    }

    cout << num << endl;
}
```

Recursion Examples

What is the base case?

```
void recurse_to_zero(size_t num) {
    cout << num << endl;

    if (num == 0) {
        cout << "Zero!" << endl;
    } else {
        recurse_to_zero(num - 1);
    }

    cout << num << endl;
}
```

Recursion Examples

What does this function output when called with 3 as the input?

```
void recurse_to_zero(size_t num) {
    cout << num << endl;

    if (num == 0) {
        cout << "Zero!" << endl;
    } else {
        recurse_to_zero(num - 1);
    }

    cout << num << endl;
}
```

How Recursion Works

A closer look

The Call Stack

Computers keep track of function calls using a stack (the “call stack”)

- every time a function is called, an entry (called an activation record) gets added onto the call stack
- execution immediately stops in the original function and jumps to the start of the called function

Each activation record contains:

- the location to which execution should return when the function has finished
- the current value of arguments
- the current value of local variables

The Call Stack

Here's a simple program. We're going to trace it. =)

```
int recurse_to_zero(int n) {
    cout << num << endl;
    if (num != 0) {
        recurse_to_zero(num - 1);
    }
    cout << num << endl;
}

int main() {
    recurse_to_zero(3);
    return 0;
}
```

Recursion Pitfalls

Recursion Pitfalls

What is wrong with this recursive function?

```
void print_number(int n) {
    print_number(n / 10);
    cout << n % 10 << endl;
}
```

No base case!

- infinite recursion =(

Recursion Pitfalls

What is wrong with this recursive function?

```
void print_again(int n) {
    if (n < 10) {
        cout << n << endl;
    } else {
        print_number(n);
        cout << n % 10 << endl;
    }
}
```

Recursive step doesn't use a smaller problem (uses SAME problem)

- infinite recursion =(

Recursion Pitfalls

What is wrong with this recursive setup?

```
bool fn_1() {
    return fn_2();
}

bool fn_2() {
    return fn_1();
}
```

Crazy cyclic recursion!

- infinite recursion =(

Recursion Pitfalls

When writing recursive functions:

- always test for the base case
- make sure the recursive step works on a smaller problem (or on a problem that is somehow closer to the base case)

Recursion Practice!

Recursion Practice

Write a recursive function to test if an input string is a palindrome

- what is the recursive step?
- what is the base case?

Recursion Practice

An example implementation:

```
bool is_palindrome(const string& s, int beg, int end) {
    if (beg >= end) {
        return true;
    } else if (s[beg] == s[end]) {
        return is_palindrome(s, beg+1, end-1);
    }

    return false;
}
```

Recursion Practice

Write a recursive function to calculate n-factorial

- what is the recursive step?
- what is the base case?

Recursion Practice

An example implementation:

```
// returns n-factorial (n!)
int factorial(int n) {
    if (n == 1) {
        return 1;
    }

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

Recursion Practice

Write a recursive function to calculate the nth Fibonacci number

- what is the recursive step?
- what is the base case?

Recursion Practice

An example implementation:

```
// returns the nth fibonacci number (n > 0)
unsigned fibonacci(unsigned n) {
    if (n <= 2) {
        return 1;
    }

    return fibonacci(n - 1) + fibonacci(n - 2);
}
```

This last function is hugely inefficient...

Make sure you understand why!