Basic Concepts

Overview & Algorithm Specification

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Outline

1. System Life Cycle

2. Algorithm Specification
   - Recursive Algorithms

3. Data Abstraction

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System Life Cycle

- Requirements.
- Analysis.
  - Bottom-up vs. top-down.
- Design.
  - Data objects.
  - Operations.
- Refinement and coding.
- Verification.
  - Correctness **proofs**.
  - Testing.
  - Error removal (debugging).

Requirement

- Purpose of the project.
- We should rigorously define the input and the output.

Analysis

- Bottom-up:
  - Older and unstructured.
  - Due to not having a master plan for the project, the resulting program frequently has many loosely connected, error-ridden segments.
- Top-down:
  - Begin with the purpose.
  - Use the end (purpose) to divide the program into manageable segments.
  - Generate diagrams that are used to design the system.

Design

- The designer starts to approach the system...
- The data objects that the program needs and the operations performed on them.
- For example, consider a scheduling system for a university.
  - Data objects: students, courses, assistants, professors, etc.
  - Operations: inserting, removing, searching within each object or between them.
- We postpone the implementation decisions because the abstract data types and the algorithms specifications are language-independent.

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Algorithm Specification

Algorithm

An algorithm is a finite set of instructions that accomplishes a particular task.

Criteria of an algorithm

- Input.
- Output.
- Definiteness (clear & unambiguous).
- Finiteness* (terminate after a finite number of steps).
- Effectiveness (each instruction must be basic enough to be carried out).

Example: Selection Sort

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- A solution: Find the smallest and place it next in the sorted list.

What's the issue/problem here?

- How the integers are **initially stored**?
- **Where** should we place **the result**?

Selection Sort

- Assume that the integers are stored in an array ‘`list`’, such that the *i*th integer is stored in the *i*th position `list[i]`.

```
for (i = 0; i<n; i++) {
    Examine list[i] to list[n-1] and suppose that the smallest
    integer is at list[min];
    Interchange list[i] and list[min];
}
```

⇒ sample code.

```c
#include <stdio.h>
#include <stdlib.h>
#define MAX_SIZE 101

void SWAP(int *x, int *y) {
    *x = *x^*y; *y = *x^*y; *x = *x^*y;
}
void sort(int [], int ); /* 選擇排序 */

int main() {
    int i, n;
    int list[MAX_SIZE];
    scanf("%d", &n); /* 多少輸入值? */
    for (i = 0; i < n; i++) { /* 隨機產
        list[i] = rand() % 1000;
        printf("%d ", list[i]);
    }
    printf("\n");
    sort(list, n);
    for (i = 0; i < n; i++) printf("%d ", list[i]);
    return 0;
}
```

```c
void sort(int list[], int n) {
    int i, j, min, temp;
    for (i = 0; i < n; i++) {
        min = i;
        for (j = i+1; j < n; j++) {
            if (list[j] < list[min])
                min = j;
        }
        if (i != min) {
            SWAP(&list[i], &list[min]);
        }
    }
}
```

Example: Binary Search

- **Goal:** Searching in a sorted list.

```
while (there are more integers to check) {
    middle = (left + right) / 2;
    if (searchnum < list[middle])
        right = middle - 1;
    else if (searchnum == list[middle])
        return middle;
    else
        left = middle + 1;
}
```

Example

i	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
	3	11	15	20	23	29	31	35	36	43	47	49	50	53	56
	3	11	15	20	23	29	31	35	36	43	47	49	50	53	56
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sample code

```c
int binSearch(int list[], int target, int left, int right) {
/* return its position if found. Otherwise return -1 */
    int middle;
    while (left <= right) {
        middle = (left + right)/2;
        if (list[middle] < target) {
            left = middle + 1;
        } else if (list[middle] == target)
            return middle;
        else
            right = middle - 1;
    }
    return -1;
}
```

Outline


遞迴是蝦毀…

Recursion

- Direction recursion.
  - Functions can call themselves.
- Indirect recursion.
  - Functions may call other functions that invoke the calling function again.

```
void recurse() {
    ...
    recurse();
    ...
}
int main() {
    ...
    recurse();
    ...
}
```

Benefits of using recursion

- Extremely powerful/elegant
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Example: $\binom{n}{m} = \binom{n}{m-1} + \binom{n-1}{m-1}$.

Another Example: Fibonacci Sequence

- $F(n) = F(n-1) + F(n-2)$, for $n \geq 2$.
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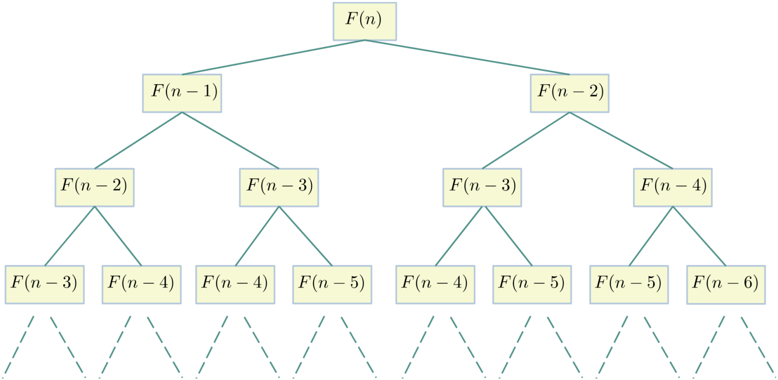
- $F(n) = F(n-1) + F(n-2)$, for $n \geq 2$.
  $F(0) = 0, F(1) = 1$: boundary conditions.
- However, a recursive algorithm for computing $F(n)$ given an arbitrary n is NOT a good idea. ☹


$F(n)$
$F(n-1)$
$F(n-2)$
$F(n-2)$
$F(n-3)$
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$F(n-4)$
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$F(n-5)$
$F(n-6)$

Recursive Binary Search

```
int binSearch(int list[], int target, int left, int right) {
/* return its position if found. Otherwise return -1 */
    int middle;
    while (left <= right) {
        middle = (left + right)/2;
        if (list[middle] < target) {
            return binSearch(list, target, middle+1, right);
        } else if (list[middle] == target)
            return middle;
        else
            return binSearch(list, target, left, middle-1);
    }
    return -1;
}
```

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- The data types in C:
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- The data types in C:
  - Basic types: `char`, `int`, `float`, `double`, ...
  - Group data types: `array`, `struct`, ..., Pointer data types.
  - User-defined types.

Example

```c
struct student {
    char last_name;
    int student_id;
    float grade;
};
```

Abstract Data Type

Abstract Data Type (ADT):

A data type that is organized in such a way that

the specification of the objects and the operations on the objects

is separated from

the representation of the objects and the implementation of the operations.

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- Example in C++: class.
- The nature of an ADT argues that we avoid implementation details. Therefore, we will usually use a form of structured English to explain the meaning of the functions.

ADT in C

- struct.
- the functions that operate on the ADT defined separately from the struct.

```c
struct Triangle {
    double a;
    double b;
    double c;
};

int main() {
    Triangle t1 = { 3, 4, 5 };
    Triangle t2 = { 3, 3, 3 };
}
```

ADT in C

```
double perimeter(const Triangle *tri) {
    return tri->a + tri->b + tri->c;
}

void scale(Triangle *tri, double s) {
    tri->a *= s;
    tri->b *= s;
    tri->c *= s;
}
int main() {
    Triangle t1 = { 3, 4, 5 };
    scale(&t1, 2);
    cout << perimeter(&t1) << endl;  // 6+8+10 = 24
}
```

Discussions