Lecture 1 Introduction

CS101 Algorithms and Data Structures

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Outline

- What will we learn from this course?
- How we manage this course?

Definition of Data Structure

- A data structure is a scheme for organizing data in the memory of a computer.
- The way in which the data is organized affects the performance of an algorithm for different tasks.
- 数据结构（data structure）是计算机中存储、组织数据的方式。通常情况下，精心选择的数据结构可以带来最优效率的算法（algorithm）。

Ex1 How to arrange books on the bookshelf?

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- The following two operations are essential for efficiently arranging your books:
  - **Operation 1:** how to insert new books?
  - **Operation 2:** how to find/access an existing book?

Ex1 How to arrange books on the bookshelf?

- **Method 1:** randomly insert new books.
  - **Operation 1:** how to insert new books?

    Insert the book wherever there is an available space.

    Nice and easy!
  - **Operation 2:** how to find/access an existing book?

    It depends …

Ex1 How to arrange books on the bookshelf?

- **Method 2:** insert new books according to the alphabets order of the first letter.
  - **Operation 1:** how to insert new books?

    EX: we bought a new book “Algorithm”.
  - **Operation 2:** how to find/access an existing book?

    EX: Binary search!

Ex1 How to arrange books on the bookshelf?

- **Discussion 1:** is **Method 2** absolutely better/more efficient than **Method 1**?

Method 1: randomly insert new books.

Method 2: insert new books according to the alphabets order of the first letter.

- **Discussion 2:** how can we further improve **Method 2**?

Ex1 How to arrange books on the bookshelf?

- **Method 3: cluster books according to different topics** (computer science, economics, agriculture, politics…), then insert new books according to the alphabets order of the first letter.
  - **Operation 1:** how to insert new books?

    EX: we bought a new book “Algorithm”.
  - **Operation 2:** how to find/access an existing book?

    EX: Binary search for topic first, then binary search for book title.
- **Discussion 3:** how much space we should preserve for each topic? How many topics is an optimism option?

The efficiency of a method/algorithm highly depends on the organization&amount of the data.

Ex2 How to implement a function PrintN?

- Implement a function named PrintN, when input a positive integer N, print all the positive integer from 1 to N.

```
void PrintN ( int N )
{ int i;
  for ( i=1; i<=N; i++ ) {
        printf( "%d\n" , i);
}
return;
}
```

Loop implementation

```
void PrintN ( int N )
{ if (N);
   PrintN( N-1);
   printf( "%d\n" , N);
}
return;
}
```

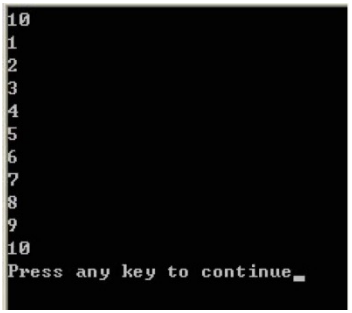
Recursive implementation

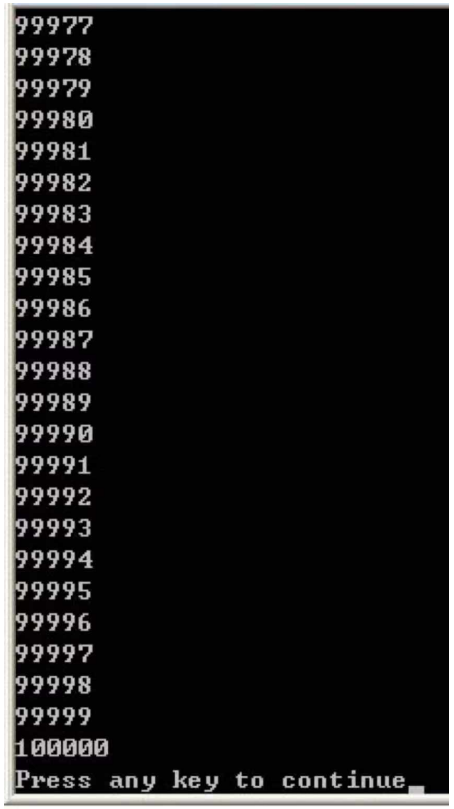
- Let N = 100, 1000, 10000, 100000, … …

Ex2 How to implement a function PrintN?

- Implement a function named PrintN, when input a positive integer N, print all the positive integer from 1 to N.

```
# include <stdio.h>
void PrintN ( int N );
int main ()
{ int N;
  scanf ("%d", &N);
  PrintN(N);
  return 0;
}
```





Loop implementation

The efficiency of a method/algorithm depends on the occupation of RAM.

Ex3 compute the summation for a polynomial at a fixed value x.

$$f(x) = a_0 + a_1 x + a_2 x^2 + \cdots + a_{n-1} x^{n-1} + a_n x^n$$

```
double fpoly1 ( int n, double a[ ], double x )
{ int i;
  double p = a[0];
  for (i = 1; i <=n; i++)
      p += (a[i] * pow( x, i) );
  return p;
}
```

$$f(x) = a_0 + x(a_1 + x(a_2 + \cdots x(a_{n-1} + x(a_n)) \cdots))$$

```
double fpoly2 ( int n, double a[ ], double x )
{ int i;
  double p = a[n];
  for (i = n; i > 0; i-- )
      p = a[i-1]  + x* p;
  return p;
}
```

- clock(): capture consumed time for running a function. The unit of the captured time is ***clock tick***, which depends on the CPU.
- CLOCKS_PER_SEC is a constant that presents the number of ***clock ticks*** per second.

```
#include <stdio.h>
#include <time.h>

clock_t  start, stop;
/* Clock_t is the variable returned by function clock(). */
double duration;
/* Record the running time for a function. Time unit is second. */
int main ()
{
  start = clock ();  /* Start timing. */
  Myfunction();
  stop = clock ();   /* Stop timing. */
  duration = ((double) (stop - start))/CLOCKS_PER_SEC;

  return 0;
}
```

Ex3 compute the summation for a polynomial $f(x) = \sum_{i=0}^{9} i \cdot x^i$ at a fixed value $x = 1.1$, $f(1.1)$.

```
double fpoly1 ( int n, double a[ ], double x )
{ int i;
  double p = a[0];
  for (i = 1; i <=0; i++)
       p += (a[i] * pow( x, i) );
  return p;
}
```

```
double fpoly2 ( int n, double a[ ], double x )
{ int i;
  double p = a[n];
  for (i = n; i > 0; i-- )
       p = a[i-1]  + x* p;
  return p;
}
```

$$f(x) = \sum_{i=0}^{9} i \cdot x^i$$

```
#include <stdio.h> #include <time.h> #include <math.h>
clock_t start, stop;
double duration;
#define MAXN 10  /*maximum order of the polynomial */
double fpoly1 ( int n, double a[ ], double x )
double fpoly2 ( int n, double a[ ], double x )
int main ()
{  int i;
   double a[MAXN]; /*save the coefficient of the
polynomial*/
   for ( i=0; i<MAXN; i++) a[i] = (double) i;

   start = clock ();
   fpoly1(MAXN-1, a, 1.1);
   stop = clock ();
   duration = ((double) (stop - start))/CLOCKS_PER_SEC;
   prinft ("ticks1 = %f\n",(double) (stop - start));
   prinft ("duration1 = %6.2e\n", duration));

   start = clock ();
  fpoly2(MAXN-1, a, 1.1);
  stop = clock ();
  duration = ((double) (stop - start))/CLOCKS_PER_SEC;
  prinft ("ticks1 = %f",(double) (stop - start));
  prinft ("duration1 = %6.2e\n", duration));
 return 0;
}
```

```
ticks1  = 0.000000
duration1  = 0.00e+000
ticks2  = 0.000000
duration2  = 0.00e+000
Press any key to continue
```

```
#include <stdio.h>
#include <time.h>
#include <math.h>
……
#define MAXK 1e7
/*maximum repeat time of the test function */
……
int main ()
{  ……

  start = clock ();

  for ( i=0; i<MAXK; i++)
        fpoly1(MAXN-1, a, 1.1);  /* repeat the test function to get enough clock ticks*/

  stop = clock ();
  duration = ((double) (stop - start))/CLOCKS_PER_SEC/MAXK;
   /* compute running time for single function duration */
  prinft (“ticks1 = %f\n”,(double) (stop - start));
  prinft (“duration1 = %6.2e\n”, duration));

   ……

  return 0;
}
```

```
ticks1  = 10093.000000
duration1  = 1.01e-006
ticks2  = 1375.000000
duration2  = 1.38e-007
Press any key to continue
```

The efficiency of a method/algorithm depends on the design of the algorithm.

Definition of Data Structure

- ***Data structure***, way in which data are stored for efficient search and retrieval.
- Different data structures are suited for different ***operations***.
- ***Algorithm*** is a procedure for solving a mathematical pro blem in a finite number of steps that frequently involves repetition of an operation.

Abstract Data Type (ADT 抽象数据类型)

- Abstract: The method that we describe the data type, does not depend on the implementations.
  - Not related to the computer that stores the data.
  - Not related to the physical structure that stores the data.
  - Not related to the algorithm and language that implements the operation.

- We only care about "*how to design*" the objective data sets and related operations, not how to "*implement*" a data structure.

EX4 Abstract data type of a $\boldsymbol{matrix}$

Array?
Structural array? Orthogonal list?

- Data type: $Matrix$
- Objects: a $M\times N$ matrix $\mathrm{A}_{\mathrm{M}\times N} = (a_{ij})\ (i = 1,\cdots,M; j = 1,\cdots,N)$ is composed by a number of $M\times N$ array of $< a, i, j >$, where a present the value of the matrix element, i present the no. of row, and j present the no. of column.
- Operations: for an arbitrary matrix $\mathrm{A}, \mathrm{B}, \mathrm{C} \in Matrix$, and integers i, j, M, N
- $Matrix\ create\ (int\ M, int\ N)$: return an empty matrix of $M\times N$;
- $int\ GetMaxRow(\ Matrix\ A\ )$: return the number of rows;
- $int\ GetMaxCol(\ Matrix\ A\ )$: return the number of columns;
- $ElementType\ GetEntry(\ Matrix\ A, int\ i, int\ j)$: return the element of matrix A in row i, column j;
- $Matrix\ Add\ (Matrix\ A,\ Matrix\ B)$: if the dimension of matrix A and B are the same, return matrix $C = A + B$, otherwise error;
- $Matrix\ multiply\ (Matrix\ A,\ Matrix\ B)$: if the number of columns of matrix A is equals to the number of rows of matrix B, return matrix $C = AB$, otherwise return error;
- ……

The elements are added in order of rows or columns? C,C++,Python,…?

Outline

- What will we learn from this course?
- How we manage this course?

Course info

- **Instructors**
  - Yuyao Zhang zhangyy8@shanghaitech.edu.cn SIST 2-302F
  - Dengji Zhao zhaodj@shanghaitech.edu.cn SIST 1A304E
  - Zhihao Jiang jiangzhh@shanghaitech.edu.cn SIST 2-302E

Course info

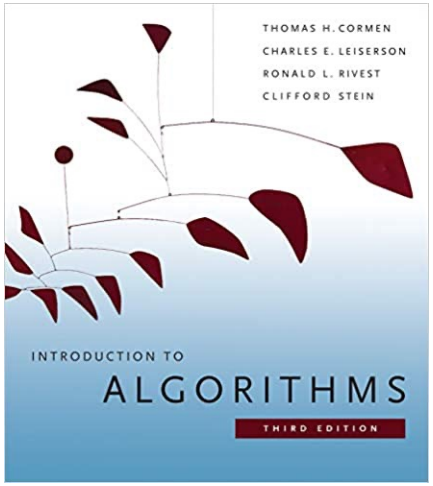
- **Classes**
  - Mon 8:15-9:55; Wed 8:15-9:55
- **Review/Quizzes/Discussions**
  - Format: 5 groups, 40 students each (Week 3-16 Weekly)
  - Length: 60mins each time
  - Location: TBA
  - Time: TBA
  - Instructors: all TAs
  - Contents: quizzes, and homework solutions

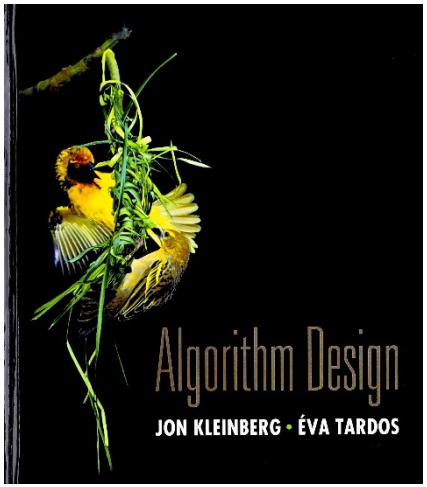
Course info

- Piazza Course Forum
  - piazza.com/shanghaitech.edu.cn/fall2021/cs101 You are encouraged to ask questions and participate in discussions
  - Course schedule, slides, office hour etc. are published on the forum
  - Invitation has be sent to your ShanghaiTech email (haven't received it?)
- Office Hours
  - Location and Time: see course forum
- Homework
  - Submit to gradescope : see course forum

Course info

- Reference Book
  - Introduction to Algorithms (3rd ed.). Cormen, Thomas H., Leiserson, Charles E., Rivest, Ronald L., Stein, Clifford. MIT Press. ISBN，9780262033848.
  - Algorithm design. Jon Kleinberg, Éva Tardos. Pearson. ISBN, 978-0321295354.





Course Schedule

Week	Date	Content
1	9/13 Mon	Introduction
	9/15 Wed	Elementary Data Structures: Array and Lists
2	9/18 Sat	Stack and Queue
	9/22 Wed	Big O/Theta/Omega
3	9/27 Mon	Hash Table
	9/29 Wed	Sorting: Insertion, Bubble
4	Public Holiday	
	Public Holiday	
5	10/11 Mon	Sorting: Merge
	10/13 Wed	Sorting: Quick
6	10/18 Mon	Divide and Conquer
	10/20 Wed	Trees: Introduction, DFS, BFS
7	10/25 Mon	Binary Trees
	10/27 Wed	Heap and Heap Sort
8	11/01 Mon	Binary Search Trees + Huffman Coding
	11/13 Wed	Balanced Binary Search Trees: AVL

Course Schedule

Week	Date	Content
9	11/8 Mon	Red-Black Tree + Disjoint sets 1
	11/10 Wed	Middle Term Exam
10	11/15 Mon	Disjoint sets 2+ Graphs: Introduction, Traversal
	11/17 Wed	Graphs: Traversal
11	11/22 Mon	Minimum Spanning Trees
	11/24 Wed	Greedy
12	11/29 Mon	Topological Sorts
	12/01 Wed	Shortest Path Algorithm: Dijkstra
13	12/06 Mon	A*
	12/08 Wed	Floyd-Warshall Algorithm
14	12/13 Mon	Dynamic Programming
	12/15 Wed	Knapsack Problem
15	12/20 Mon	P+NP
	12/22 Wed	NPC
16	12/27 Mon	Median of Medians
	12/29 Wed	Review

Course Policy

- Plagiarism
  - All assignments must be done individually
    - You cannot copy directly from any other source
    - You cannot share solutions with any other students
    - Plagiarism detection software will be used on all the assignments
  - Ways of collaboration
    - You may discuss together or help another student such as debuging his or her code; however, you cannot dictate or give the exact solutions.

Course Policy

- Plagiarism
  - Punishment
    - When one student copied from another student, both students are responsible.
    - Zero point on the assignment or exam in question.
    - Disqualified from receiving any awards recommended by the school and from any competitive studying opportunities (e.g., international exchange).
    - Repeated violation will result in a F grade for this course as well as further punishment at the school/university level.

Plagiarism: Example 1

- Alex and Bob were roommates.
- Bob let Alex use his laptop to complete an assignment.
- Alex copied Bob’s solution for the assignment.

Plagiarism: Example 2

- Leslie asked if Morgan could send her his code so that she could look at it (promising, of course, not to copy it).
- Morgan sent the code.
- Leslie copied it and handed it in.

Plagiarism: Example 3

- Garry and Harry worked together on a single source file initially and then worked separately to finish off the details.
- The result was still noticeably similar with finger-print-like characteristics which left no doubt that some of the code had a common source.

Plagiarism: Example 4

- Jordan uploaded the projects to GITHUB.com without setting appropriate permissions. Kasey found this site, downloaded the projects and submitted them. Both are guilty.
  - This applies to any public forum, news group, etc., not just gitub.com…

Real Plagiarism Examples

- Copied a peace of the codes from others or online repositories.
- Copied someone's solution from his/her USB drive.
- Copied a peace of others' codes and change all the variable/function names.
- Unusual solutions appeared in different submissions.

Course Policy

- **Grading**
  - Exams (45%): middle term: 20%; final: 25%
  - Weekly Homework (20%): non-programming questions
  - Programming Tasks (20%): 4 programming tasks (each lasts 3 weeks)
  - In-Class Quizzes (15%): in lectures and discussions

Take Home Message

- Algorithms and Data Structure is ~~one of~~ the most important course during your undergraduate.

- You will sometimes feel it very tuff, but please always keep on going, we are here to help.