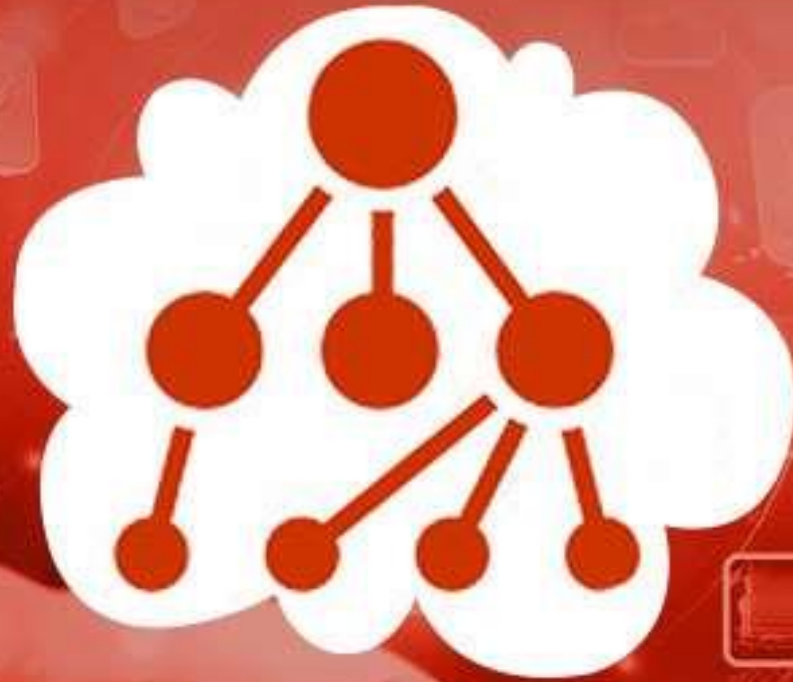




Data Structures & Algorithms



tutorialspoint

SIMPLY EASY LEARNING

www.tutorialspoint.com



<https://www.facebook.com/tutorialspointindia>



<https://twitter.com/tutorialspoint>

About the Tutorial

Data Structures are the programmatic way of storing data so that data can be used efficiently. Almost every enterprise application uses various types of data structures in one or the other way.

This tutorial will give you a great understanding on Data Structures needed to understand the complexity of enterprise level applications and need of algorithms, and data structures.

Audience

This tutorial is designed for Computer Science graduates as well as Software Professionals who are willing to learn data structures and algorithm programming in simple and easy steps.

After completing this tutorial you will be at intermediate level of expertise from where you can take yourself to higher level of expertise.

Prerequisites

Before proceeding with this tutorial, you should have a basic understanding of C programming language, text editor, and execution of programs, etc.

Copyright and Disclaimer

© Copyright 2016 by Tutorials Point (I) Pvt. Ltd.

All the content and graphics published in this e-book are the property of Tutorials Point (I) Pvt. Ltd. The user of this e-book is prohibited to reuse, retain, copy, distribute or republish any contents or a part of contents of this e-book in any manner without written consent of the publisher.

We strive to update the contents of our website and tutorials as timely and as precisely as possible, however, the contents may contain inaccuracies or errors. Tutorials Point (I) Pvt. Ltd. provides no guarantee regarding the accuracy, timeliness or completeness of our website or its contents including this tutorial. If you discover any errors on our website or in this tutorial, please notify us at contact@tutorialspoint.com

Compile & Execute Online

For most of the examples given in this tutorial you will find **Try it** option, so just make use of this option to execute your programs on the spot and enjoy your learning.

Try the following example using the Try it option available at the top right corner of the following sample code box –

```
#include <stdio.h>

int main(){
    /* My first program in C */
    printf("Hello, World! \n");

    return 0;
}
```

Table of Contents

About the Tutorial	i
Audience.....	i
Prerequisites.....	i
Copyright and Disclaimer	i
Compile & Execute Online.....	ii
Table of Contents	iii
BASICS.....	1
1. Overview	2
Characteristics of a Data Structure.....	2
Need for Data Structure	2
Execution Time Cases	3
Basic Terminology	3
2. Environment Setup	4
Try it Option Online	4
Local Environment Setup.....	4
Installation on UNIX/Linux.....	5
Installation on Mac OS.....	5
Installation on Windows.....	6
ALGORITHM.....	7
3. Algorithms – Basics	8
Characteristics of an Algorithm	8
How to Write an Algorithm?	9
Algorithm Analysis.....	10
Algorithm Complexity.....	11
Space Complexity	11
Time Complexity.....	11
4. Asymptotic Analysis.....	12
Asymptotic Notations.....	12
Common Asymptotic Notations	15
5. Greedy Algorithms	16
Counting Coins.....	16
6. Divide & Conquer.....	18
Divide/Break.....	18
Conquer/Solve.....	18
Merge/Combine	19
7. Dynamic Programming.....	20

DATA STRUCTURES	21
8. Basic Concepts	22
Data Definition	22
Data Object.....	22
Data Type.....	22
Basic Operations.....	23
9. Arrays	24
Array Representation	24
Basic Operations.....	25
Insertion Operation	25
Array Insertions	27
Insertion at the Beginning of an Array	28
Insertion at the Given Index of an Array	30
Insertion After the Given Index of an Array	32
Insertion Before the Given Index of an Array.....	34
Deletion Operation.....	36
Search Operation.....	37
Update Operation.....	39
LINKED LIST	41
10. Linked List – Basics	42
Linked List Representation	42
Types of Linked List	42
Basic Operations.....	43
Insertion Operation	43
Deletion Operation.....	44
Reverse Operation.....	45
Linked List Program in C	46
11. Doubly Linked List	55
Doubly Linked List Representation	55
Basic Operations.....	55
Insertion Operation	56
Deletion Operation.....	57
Insertion at the End of an Operation.....	57
Doubly Linked List Program in C.....	58
12. Circular Linked List	67
Singly Linked List as Circular	67
Doubly Linked List as Circular	67
Basic Operations.....	67
Insertion Operation	68
Deletion Operation.....	68
Display List Operation.....	69
Circular Linked List Program in C.....	69

STACK & QUEUE.....	74
13. Stack	75
Stack Representation.....	75
Basic Operations.....	76
peek().....	76
isfull().....	77
isempty().....	77
Push Operation.....	78
Pop Operation	79
Stack Program in C.....	81
14. Expression Parsing	84
Infix Notation.....	84
Prefix Notation	84
Postfix Notation.....	84
Parsing Expressions	85
Postfix Evaluation Algorithm	86
Expression Parsing Using Stack.....	86
15. Queue	92
Queue Representation	92
Basic Operations.....	92
peek().....	93
isfull().....	93
isempty().....	94
Enqueue Operation	95
Dequeue Operation	96
Queue Program in C	98
SEARCHING TECHNIQUES.....	102
16. Linear Search	103
Linear Search Program in C	104
17. Binary Search	107
How Binary Search Works?	107
Binary Search Program in C	110
18. Interpolation Search	113
Positioning in Binary Search	113
Position Probing in Interpolation Search.....	114
Interpolation Search Program in C	116
19. Hash Table	118
Hashing.....	118
Linear Probing.....	119
Basic Operations.....	120
Data Item.....	120

Hash Method	120
Search Operation.....	120
Insert Operation	121
Delete Operation	122
Hash Table Program in C	123
 SORTING TECHNIQUES.....	 128
20. Sorting Algorithm.....	129
In-place Sorting and Not-in-place Sorting	129
Stable and Not Stable Sorting.....	129
Adaptive and Non-Adaptive Sorting Algorithm	130
Important Terms.....	130
21. Bubble Sort Algorithm	132
How Bubble Sort Works?.....	132
Bubble Sort Program in C	136
22. Insertion Sort	140
How Insertion Sort Works?	140
Insertion Sort Program in C	143
23. Selection Sort.....	147
How Selection Sort Works?	147
Selection Sort Program in C.....	150
24. Merge Sort Algorithm	153
How Merge Sort Works?	153
Merge Sort Program in C	156
25. Shell Sort	158
How Shell Sort Works?	158
Shell Sort Program in C.....	162
26. Quick Sort	166
Partition in Quick Sort	166
Quick Sort Pivot Algorithm	166
Quick Sort Pivot Pseudocode	167
Quick Sort Algorithm	167
Quick Sort Pseudocode.....	168
Quick Sort Program in C	168
 GRAPH DATA STRUCTURE	 172
27. Graphs	173
Graph Data Structure	173
Basic Operations.....	175

28. Depth First Traversal	176
Depth First Traversal in C	179
29. Breadth First Traversal	184
Breadth First Traversal in C	186
 TREE DATA STRUCTURE	 192
30. Tree	193
Important Terms.....	193
Binary Search Tree Representation	194
Tree Node	194
BST Basic Operations	195
Insert Operation	195
Search Operation.....	197
Tree Traversal in C	198
31. Tree Traversal	204
In-order Traversal	204
Pre-order Traversal.....	205
Post-order Traversal	206
Tree Traversal in C	207
32. Binary Search Tree	213
Representation	213
Basic Operations.....	214
Node	214
Search Operation.....	214
Insert Operation	215
33. AVL Trees	217
AVL Rotations	218
34. Spanning Tree	222
General Properties of Spanning Tree	222
Mathematical Properties of Spanning Tree.....	223
Application of Spanning Tree	223
Minimum Spanning Tree (MST).....	223
Minimum Spanning-Tree Algorithm	223
Kruskal's Spanning Tree Algorithm	224
Prim's Spanning Tree Algorithm	227
35. Heaps	231
Max Heap Construction Algorithm	232
Max Heap Deletion Algorithm	233
 RECURSION	 234

36. Recursion – Basics	235
Properties	235
Implementation	236
Analysis of Recursion	236
Time Complexity	236
Space Complexity	237
37. Tower of Hanoi	238
Rules	238
Algorithm	242
Tower of Hanoi in C	245
38. Fibonacci Series	249
Fibonacci Iterative Algorithm	250
Fibonacci Interactive Program in C	250
Fibonacci Recursive Algorithm	252
Fibonacci Recursive Program in C	252

Basics

1. Overview

Data Structure is a systematic way to organize data in order to use it efficiently. Following terms are the foundation terms of a data structure.

- **Interface** – Each data structure has an interface. Interface represents the set of operations that a data structure supports. An interface only provides the list of supported operations, type of parameters they can accept and return type of these operations.
- **Implementation** – Implementation provides the internal representation of a data structure. Implementation also provides the definition of the algorithms used in the operations of the data structure.

Characteristics of a Data Structure

- **Correctness** – Data structure implementation should implement its interface correctly.
- **Time Complexity** – Running time or the execution time of operations of data structure must be as small as possible.
- **Space Complexity** – Memory usage of a data structure operation should be as little as possible.

Need for Data Structure

As applications are getting complex and data rich, there are three common problems that applications face now-a-days.

- **Data Search** – Consider an inventory of 1 million(10^6) items of a store. If the application is to search an item, it has to search an item in 1 million(10^6) items every time slowing down the search. As data grows, search will become slower.
- **Processor Speed** – Processor speed although being very high, falls limited if the data grows to billion records.
- **Multiple Requests** – As thousands of users can search data simultaneously on a web server, even the fast server fails while searching the data.

To solve the above-mentioned problems, data structures come to rescue. Data can be organized in a data structure in such a way that all items may not be required to be searched, and the required data can be searched almost instantly.

Execution Time Cases

There are three cases which are usually used to compare various data structure's execution time in a relative manner.

- **Worst Case** – This is the scenario where a particular data structure operation takes maximum time it can take. If an operation's worst case time is $f(n)$ then this operation will not take more than $f(n)$ time, where $f(n)$ represents function of n .
- **Average Case** – This is the scenario depicting the average execution time of an operation of a data structure. If an operation takes $f(n)$ time in execution, then m operations will take $mf(n)$ time.
- **Best Case** – This is the scenario depicting the least possible execution time of an operation of a data structure. If an operation takes $f(n)$ time in execution, then the actual operation may take time as the random number which would be maximum as $f(n)$.

Basic Terminology

- **Data** – Data are values or set of values.
- **Data Item** – Data item refers to single unit of values.
- **Group Items** – Data items that are divided into sub items are called as Group Items.
- **Elementary Items** – Data items that cannot be divided are called as Elementary Items.
- **Attribute and Entity** – An entity is that which contains certain attributes or properties, which may be assigned values.
- **Entity Set** – Entities of similar attributes form an entity set.
- **Field** – Field is a single elementary unit of information representing an attribute of an entity.
- **Record** – Record is a collection of field values of a given entity.
- **File** – File is a collection of records of the entities in a given entity set.

2. Environment Setup

Try it Option Online

You really do not need to set up your own environment to start learning C programming language. Reason is very simple, we already have set up C Programming environment online, so that you can compile and execute all the available examples online at the same time when you are doing your theory work. This gives you confidence in what you are reading and to check the result with different options. Feel free to modify any example and execute it online.

Try the following example using the **Try it** option available at the top right corner of the sample code box –

```
#include <stdio.h>

int main(){
    /* My first program in C */
    printf("Hello, World! \n");

    return 0;
}
```

For most of the examples given in this tutorial, you will find Try it option, so just make use of it and enjoy your learning.

Local Environment Setup

If you are still willing to set up your environment for C programming language, you need the following two tools available on your computer, (a) Text Editor and (b) The C Compiler.

Text Editor

This will be used to type your program. Examples of few editors include Windows Notepad, OS Edit command, Brief, Epsilon, EMACS, and vim or vi.

The name and the version of the text editor can vary on different operating systems. For example, Notepad will be used on Windows, and vim or vi can be used on Windows as well as Linux or UNIX.

The files you create with your editor are called source files and contain program source code. The source files for C programs are typically named with the extension ".c".

Before starting your programming, make sure you have one text editor in place and you have enough experience to write a computer program, save it in a file, compile it, and finally execute it.

The C Compiler

The source code written in the source file is the human readable source for your program. It needs to be "compiled", to turn into machine language so that your CPU can actually execute the program as per the given instructions.

This C programming language compiler will be used to compile your source code into a final executable program. We assume you have the basic knowledge about a programming language compiler.

Most frequently used and free available compiler is GNU C/C++ compiler. Otherwise, you can have compilers either from HP or Solaris if you have respective Operating Systems (OS).

The following section guides you on how to install GNU C/C++ compiler on various OS. We are mentioning C/C++ together because GNU GCC compiler works for both C and C++ programming languages.

Installation on UNIX/Linux

If you are using **Linux or UNIX**, then check whether GCC is installed on your system by entering the following command from the command line –

```
$ gcc -v
```

If you have GNU compiler installed on your machine, then it should print a message such as the following –

```
Using built-in specs.
Target: i386-redhat-linux
Configured with: ../configure --prefix=/usr .....
Thread model: posix
gcc version 4.1.2 20080704 (Red Hat 4.1.2-46)
```

If GCC is not installed, then you will have to install it yourself using the detailed instructions available at <http://gcc.gnu.org/install/>

This tutorial has been written based on Linux and all the given examples have been compiled on Cent OS flavor of Linux system.

Installation on Mac OS

If you use Mac OS X, the easiest way to obtain GCC is to download the Xcode development environment from Apple's website and follow the simple installation instructions. Once you have Xcode setup, you will be able to use GNU compiler for C/C++.

Xcode is currently available at developer.apple.com/technologies/tools/

Installation on Windows

To install GCC on Windows, you need to install MinGW. To install MinGW, go to the MinGW homepage, www.mingw.org, and follow the link to the MinGW download page. Download the latest version of the MinGW installation program, which should be named MinGW-<version>.exe.

While installing MinGW, at a minimum, you must install gcc-core, gcc-g++, binutils, and the MinGW runtime, but you may wish to install more.

Add the bin subdirectory of your MinGW installation to your **PATH** environment variable, so that you can specify these tools on the command line by their simple names.

When the installation is complete, you will be able to run gcc, g++, ar, ranlib, dlltool, and several other GNU tools from the Windows command line.

Algorithm

3. Algorithms – Basics

Algorithm is a step-by-step procedure, which defines a set of instructions to be executed in a certain order to get the desired output. Algorithms are generally created independent of underlying languages, i.e. an algorithm can be implemented in more than one programming language.

From the data structure point of view, following are some important categories of algorithms –

- **Search** – Algorithm to search an item in a data structure.
- **Sort** – Algorithm to sort items in a certain order.
- **Insert** – Algorithm to insert item in a data structure.
- **Update** – Algorithm to update an existing item in a data structure.
- **Delete** – Algorithm to delete an existing item from a data structure.

Characteristics of an Algorithm

Not all procedures can be called an algorithm. An algorithm should have the following characteristics –

- **Unambiguous** – Algorithm should be clear and unambiguous. Each of its steps (or phases), and their inputs/outputs should be clear and must lead to only one meaning.
- **Input** – An algorithm should have 0 or more well-defined inputs.
- **Output** – An algorithm should have 1 or more well-defined outputs, and should match the desired output.
- **Finiteness** – Algorithms must terminate after a finite number of steps.
- **Feasibility** – Should be feasible with the available resources.
- **Independent** – An algorithm should have step-by-step directions, which should be independent of any programming code.

How to Write an Algorithm?

There are no well-defined standards for writing algorithms. Rather, it is problem and resource dependent. Algorithms are never written to support a particular programming code.

As we know that all programming languages share basic code constructs like loops (do, for, while), flow-control (if-else), etc. These common constructs can be used to write an algorithm.

We write algorithms in a step-by-step manner, but it is not always the case. Algorithm writing is a process and is executed after the problem domain is well-defined. That is, we should know the problem domain, for which we are designing a solution.

End of ebook preview
If you liked what you saw...
Buy it from our store @ <https://store.tutorialspoint.com>