Fundamentals of Algorithms

ESC108A Elements of Computer Science and Engineering
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Course Leaders:

Roopa G.

Ami Rai E.

Chaitra S.

Objectives

- At the end of this lecture, student will be able to
  - Explain the process of arriving at a computer solution
  - Describe the nature of a computer algorithm
  - Explain the role of memory in a computer program and hence the use of variable in algorithms

Contents

- A Problem
- Computable Algorithms
- Role of Memory and its impact on computer algorithms
- Algorithms
- Problem Solving Approach
- Some Examples of Problem Solving

A Problem

Multiply

129837382

with

914147324

Given:

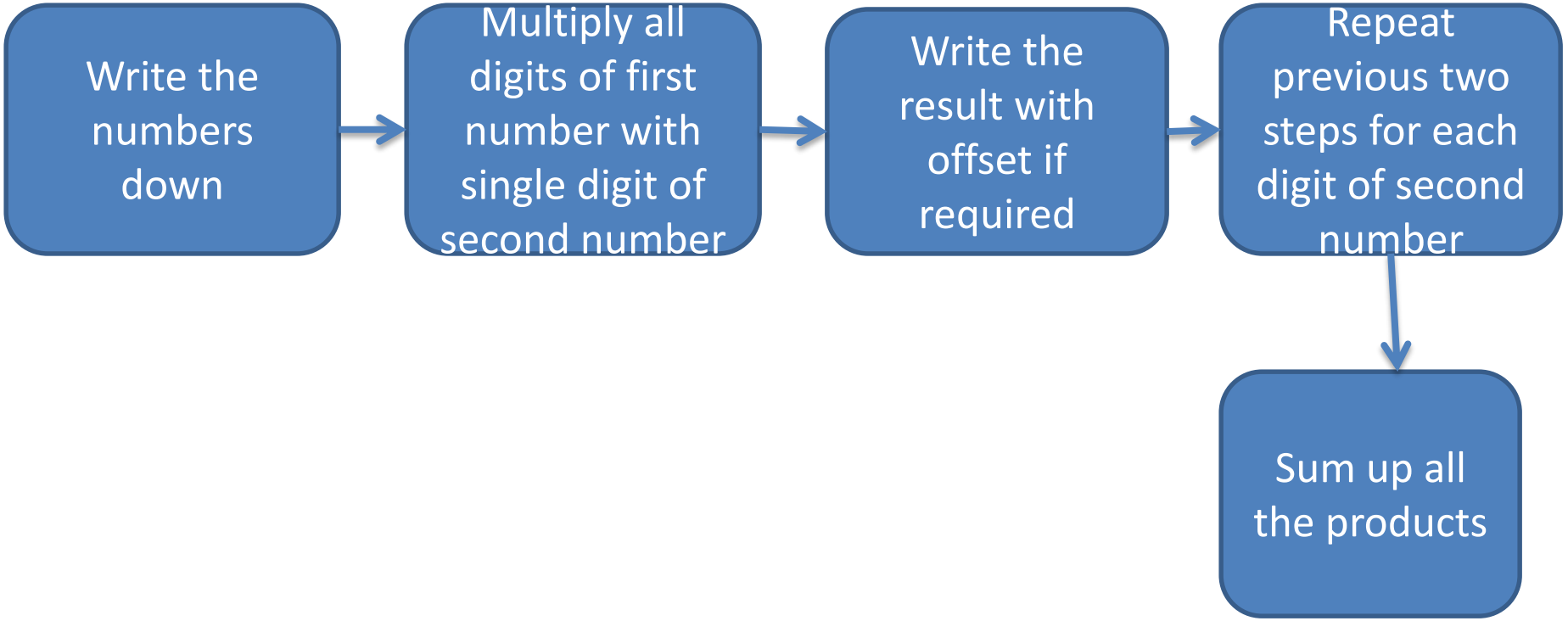
129837382

X 914147324

??????????

129837382
X 914147324
519349528
259674764
389512146
908861674
519349528
129837382
519349528
129837382
1168536438
11869049531046576 8

What Did You Do?

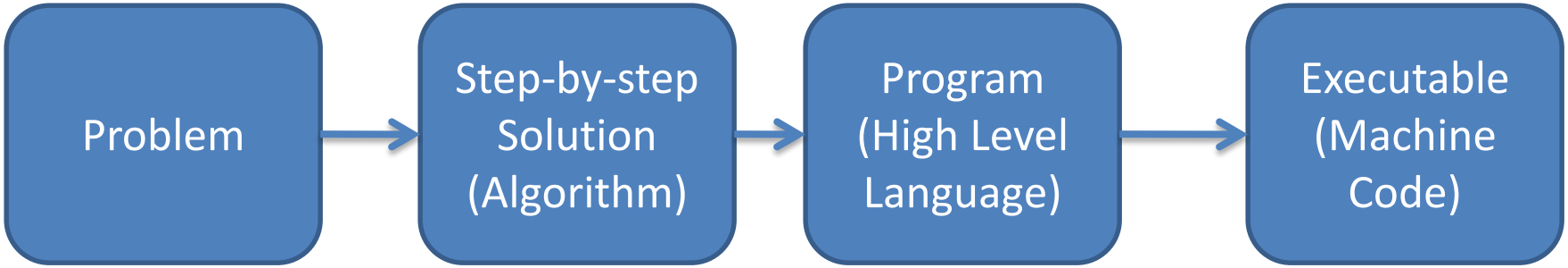


Why Do You Follow These Steps?

- General solution
  - Works for any 2 numbers
- Guarantee of solution
- Any one who has never done multiplication can also follow these steps and find the result
  - Clear, precise steps

- Computers do not know anything
  - You must tell the steps
  - It will do the job for you

Program Development



Example: Problem

Q. Design and Develop a program to find factorial of a number

$$n! = 1 \times 2 \times 3 \times \ldots \times (n-1) \times n$$

Example: Algorithm

```
function fact(var n:integer);
var     i { loop variable},
        ret{holds the return value}: integer;
begin {check n and calculate factorial}
        {assert : n>= 0}
        ret := 1;
        for i := 2  to n do
        begin
                ret: = ret * i;
        end
end
```

Example: C Program

```c
/*
 * File:   Factorial.c
 * Author: vsarma
 * Created on 18 July, 2014, 12:11 PM
 */

#include <stdio.h>
#include <stdlib.h>
#define NUMBER 4/*The number for calculating factorial*/
/* Function fact:
 * Calculates factorial of a given number.
 * Input: A positive Integer number
 * Output: The factorial of the number or -1 in case of an error
 */
int fact(int n){
    int i;
    int ret = 1;
    if(n<0){
        return -1;
    }
    for(i=2;i<=n;i++)
    {
        ret = ret * i;
    }
    return ret;
}
```

Example: Executable

```
00000000  7f 45 4c 46 01 01 01 00  00 00 00 00 00 00 00 00  |.ELF............|
00000010  02 00 03 00 01 00 00 00  30 83 04 08 34 00 00 00  |........0...4...|
00000020  b8 0b 00 00 00 00 00 00  34 00 20 00 08 00 28 00  |........4. ...(.|
00000030  25 00 22 00 06 00 00 00  34 00 00 00 34 80 04 08  |%."....4...4...|
00000040  34 80 04 08 00 01 00 00  00 01 00 00 05 00 00 00  |4...............|
00000050  04 00 00 00 03 00 00 00  34 01 00 00 34 81 04 08  |........4...4...|
00000060  34 81 04 08 13 00 00 00  13 00 00 00 04 00 00 00  |4...............|
00000070  01 00 00 00 01 00 00 00  00 00 00 00 00 80 04 08  |................|
00000080  00 80 04 08 dc 05 00 00  dc 05 00 00 05 00 00 00  |................|
00000090  00 10 00 00 01 00 00 00  dc 05 00 00 dc 95 04 08  |................|
000000a0  dc 95 04 08 20 01 00 00  24 01 00 00 06 00 00 00  |.... ...$.......|
000000b0  00 10 00 00 02 00 00 00  e8 05 00 00 e8 95 04 08  |................|
000000c0  e8 95 04 08 f0 00 00 00  f0 00 00 00 06 00 00 00  |................|
000000d0  04 00 00 00 04 00 00 00  48 01 00 00 48 81 04 08  |........H...H...|
000000e0  48 81 04 08 44 00 00 00  44 00 00 00 04 00 00 00  |H...D...D.......|
000000f0  04 00 00 00 50 e5 74 64  38 05 00 00 38 85 04 08  |....P.td8...8...|
00000100  38 85 04 08 24 00 00 00  24 00 00 00 04 00 00 00  |8...$...$.......|
00000110  04 00 00 00 51 e5 74 64  00 00 00 00 00 00 00 00  |....Q.td........|
00000120  00 00 00 00 00 00 00 00  00 00 00 00 06 00 00 00  |................|
00000130  04 00 00 00 2f 6c 69 62  2f 6c 64 2d 6c 69 6e 75  |..../lib/ld-linu|
00000140  78 2e 73 6f 2e 32 00 00  04 00 00 00 10 00 00 00  |x.so.2..........|
00000150  01 00 00 00 47 4e 55 00  00 00 00 00 02 00 00 00  |....GNU.........|
00000160  06 00 00 00 1a 00 00 00  04 00 00 00 14 00 00 00  |................|
00000170  03 00 00 00 47 4e 55 00  6f 05 cc 96 62 0c 6e 10  |....GNU.o...b.n.|
00000180  20 7f eb c3 d8 c0 3a 7d  f4 7d be b3 03 00 00 00  | .....:}.}......|
00000190  05 00 00 00 02 00 00 00  03 00 00 00 04 00 00 00  |................|
000001a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001b0  01 00 00 00 02 00 00 00  04 00 00 00 01 00 00 00  |................|
000001c0  05 00 00 00 00 20 00 20  00 00 00 00 04 00 00 00  |..... . ........|
000001d0  ad 4b e3 c0 00 00 00 00  00 00 00 00 00 00 00 00  |.K..............|
000001e0  00 00 00 00 29 00 00 00  00 00 00 00 00 00 00 00  |....)...........|
000001f0  12 00 00 00 01 00 00 00  00 00 00 00 00 00 00 00  |................|
00000200  20 00 00 00 30 00 00 00  00 00 00 00 00 00 00 00  | ...0...........|
00000210  12 00 00 00 1a 00 00 00  1c 85 04 08 04 00 00 00  |................|
00000220  11 00 10 00 00 5f 5f 67  6d 6f 6e 5f 73 74 61 72  |....._gmon_star|
00000230  74 5f 5f 00 6c 69 62 63  2e 73 6f 2e 36 00 5f 49  |t__.libc.so.6._I|
00000240  4f 5f 73 74 64 69 6e 5f  75 73 65 64 00 70 72 69  |O_stdin_used.pri|
```

Algorithms and Programs

An Algorithm

- Set of *finite steps* that *give the solution* to a problem
- a sequence of computational steps that transform the input into the output
- A procedure for solving a problem consists of
  - actions to be executed, and
  - order in which these actions are to be executed

A Computer Program

- It is the algorithm to solve a problem, expressed in a programming language

Why is it called an Algorithm?

Named after Abū Abdallāh Muḥammad ibn Mūsā al-Khwārizmī (عَبْدَالله مُحَمَّد بِن مُوسَى اَلْخَوَارِزْمِي)

- around *825*
- *On the Calculation with Hindu Numerals*
- *Algoritmi de numero Indorum*
- ‘Algorism’
  - rules of performing arithmetic
- ‘Algorithm’
  - Steps to solve problems in Mathematics and Computer Science

Characteristics of an Algorithm

- Input
  - may accept zero or more inputs
- Output
  - should produce at least one output
- Precise
  - each step should be clear and precise. No ambiguity
- Finiteness
  - should end after a fixed time. No infinite loop
- Effectiveness
  - steps must be simple and can be done exactly and in a finite length of time, by person using pencil and paper

Pseudocode

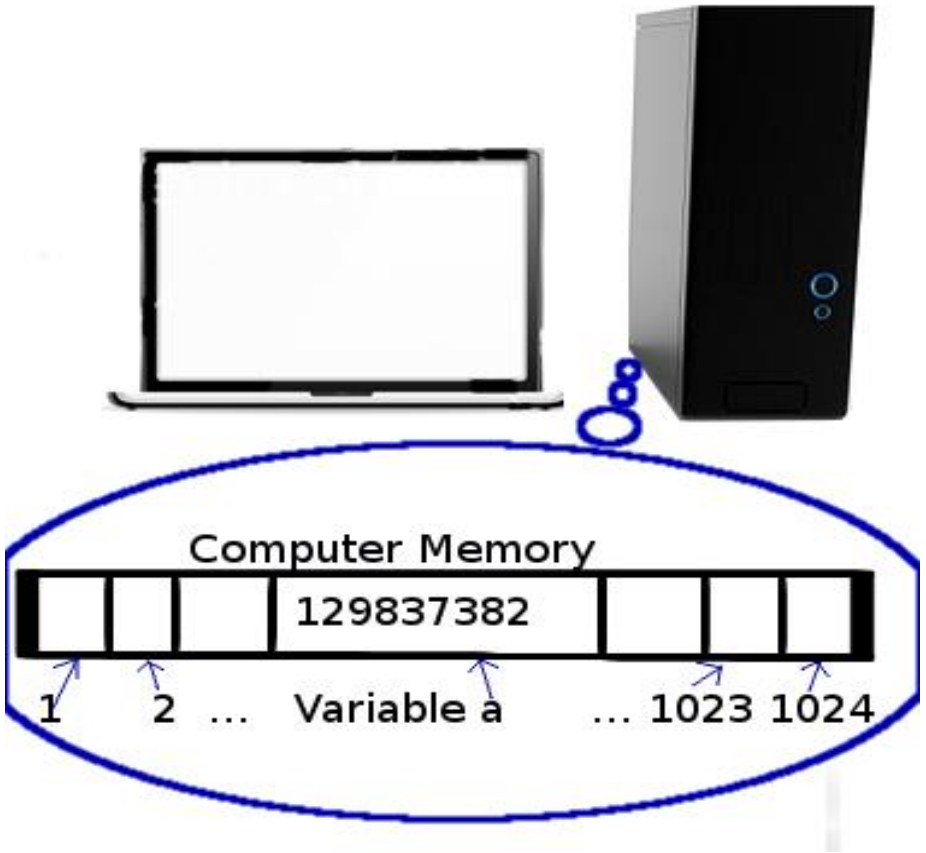
- A pseudocode is neither an algorithm nor a program
- An abstract form of a program
- Consists of English like statements which perform the specific operations
- Syntax of a program is not strictly followed
- Pseudocode programs are not executed on computers

Memory, Storage and Variable

- Computers store values in its memory

- A value is associated
  - Name (Variable)
  - Address

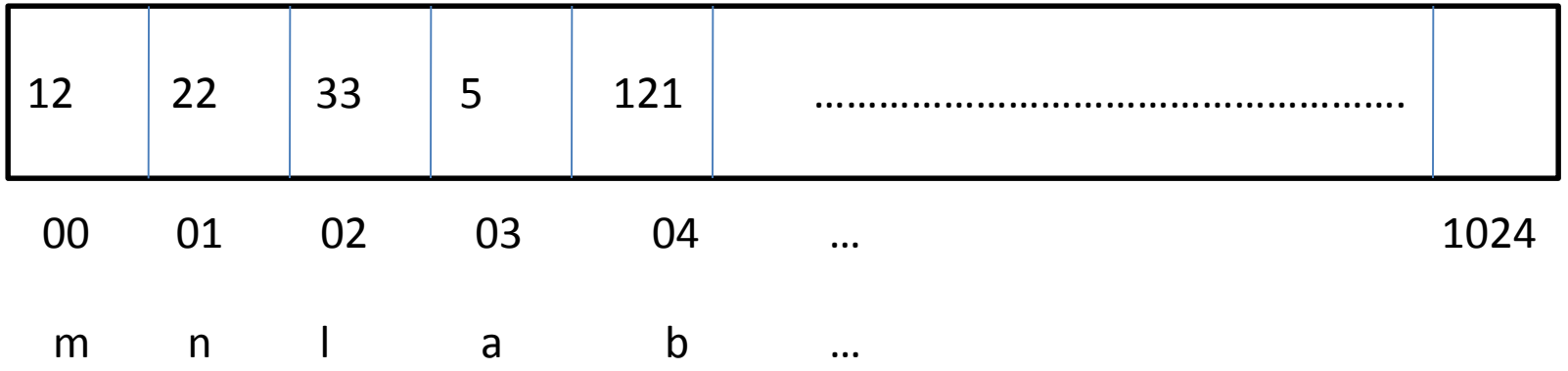
- Hence in Computer algorithms
  - Variables are used
  - Variables are associated with type



Variable

- A name given to a location that stores a value

```
var a: integer;
{This is how a variable is declared with its type}
a := 5;
{This is called assignment operation. 5 is stored in the location that 'a' represents in the memory}
```

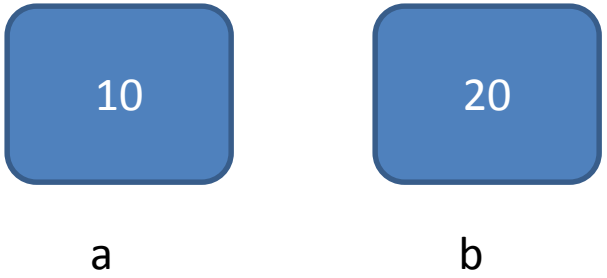


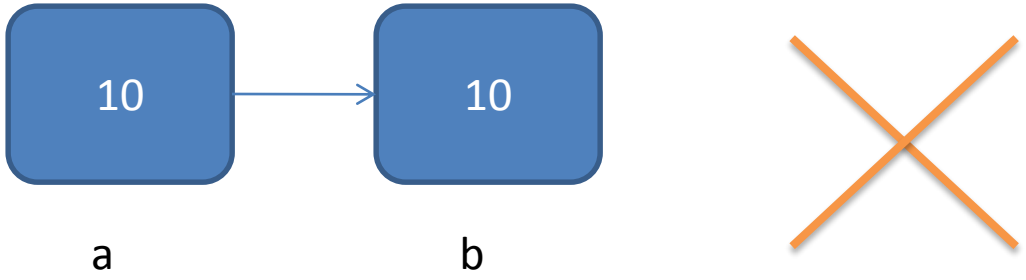
Example: Swap 2 Variables

- Swap values in two integer variables
  - Problem definition:
    - x has an integer value ‘k’
    - y has an integer value ‘l’
    - At end of execution
      - x must have integer value ‘l’
      - y must have integer value ‘k’

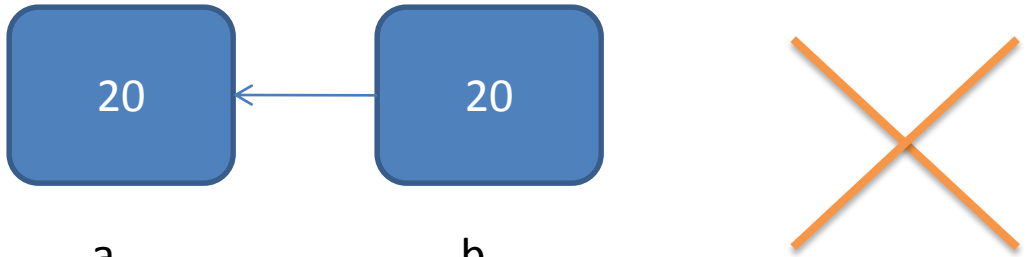
- APPROACH
  - No initial checks are required
  - To Swap values of variables, we need a third variable
    - Take an example: a := 10 and b :=20

Example: Swap 2 Variables contd.



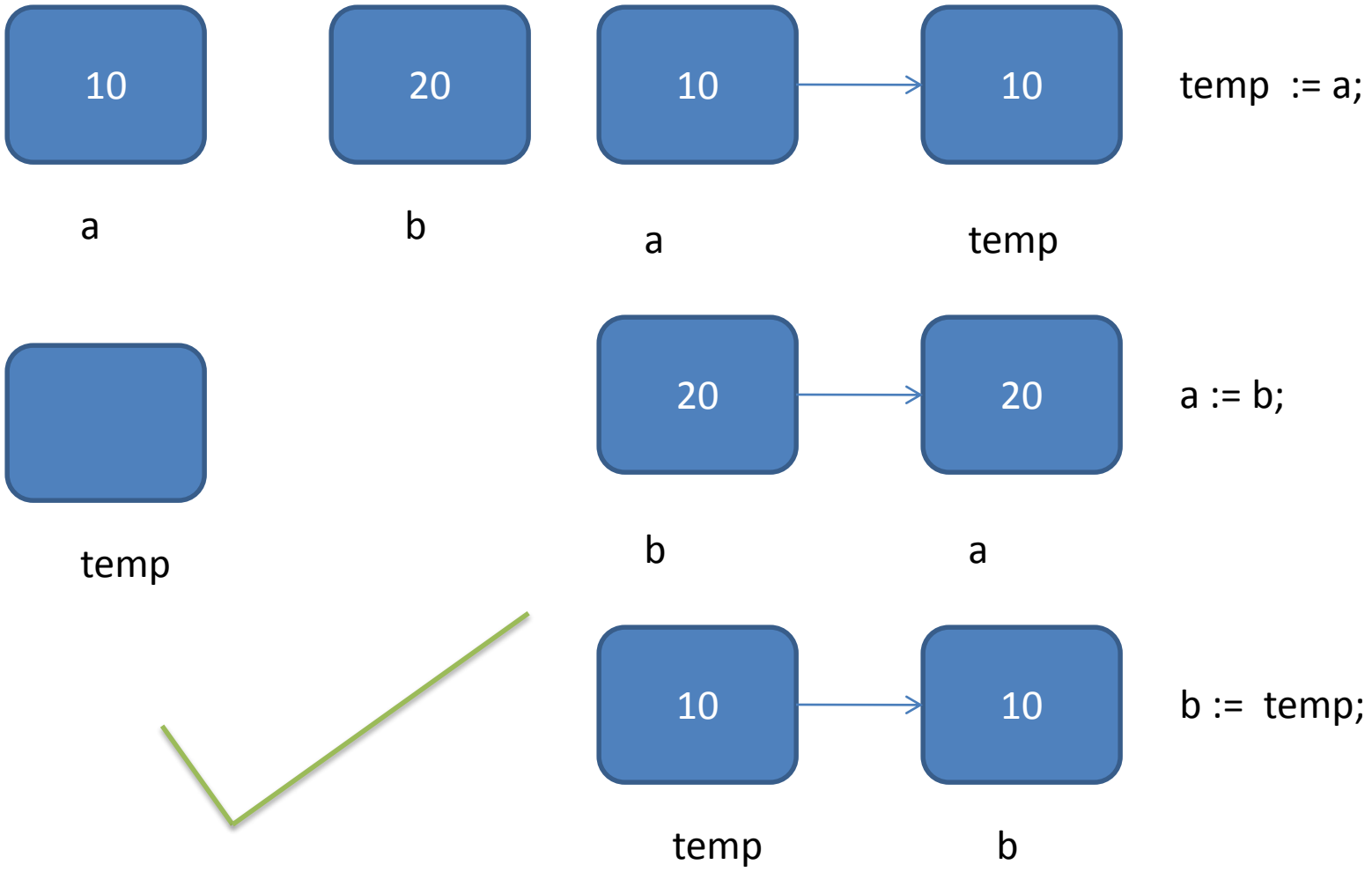


b := a;



a := b;

Example: Swap 2 Variables contd.



Example: Swap 2 Variables contd.

- Final Algorithm: Swapping two variables

```
Algorithm swap
var a,b,temp :integer; {The temporary variable}
begin
        temp := a ;
         a := b ;
         b := temp ;
end
```

Practice Problems

- Write an algorithm to
  - Calculate the sum of two numbers
  - Calculate the area of a circle
  - Find the largest of three numbers

Summary

- An algorithm is a set of explicit and unambiguous finite steps which when carried out for a given set of initial conditions, produce the corresponding output and terminate in a finite time
- Computers programs work with memory and hence computer algorithms are written to work with variables
- Computer solutions are called programs
- A Program is a set of explicit and unambiguous instructions expressed in a programming language
- Programming is application of problem solving using a computer

References

Dromey, R. (1982) *How To Solve it By Computer.* Noida: Pearson Education Inc.

Further Reading

Dijkstra, E. (1970). On Understanding Programs. *EWD249: notes on structured programming (1969a), available at http://www. cs. utexas. edu/users/EWD/ewd02xx/EWD249. PDF (accessed 22 July 2014).*