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- Grading:
  - Midterm exams & Assignments & Quizzes 60%
  - Final exam 40%

only individual submissions allowed!

PROBLEM SOLVING & ALGORITHM DEVELOPMENT

Introduction

- An algorithm is a systematic logical step-by-step procedure for solving a problem.
- When we solve a problem using a computer, we first need to design an algorithm concerning the problem.
- Generally, we use flowcharts or pseudocode in the development phase of an algorithm.

Why we need good algorithms?

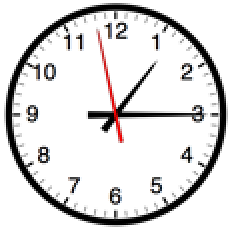
- Without efficient algorithms many simple problems can't be solved by the computer (running time is too large, or not enough memory)

Algorithms - Properties

- There is no ambiguity in any instruction
- There is no ambiguity about which instruction is to be executed next (steps are ordered well)
- The description of the algorithm is finite
- The execution of the algorithm concludes after a finite number of steps

How do we measure whether an algorithm is 'good'?

- **Time complexity**
  - The number of steps it takes to solve the problem as function of input size

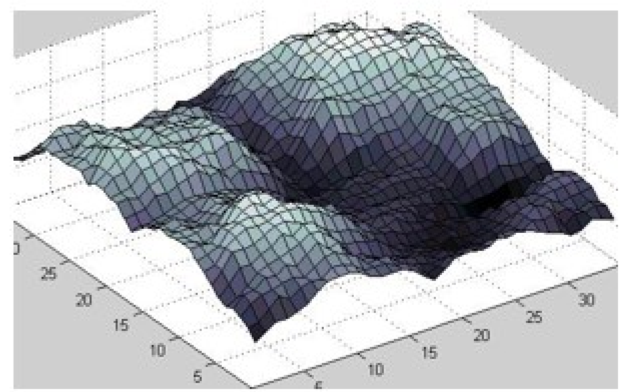


  - Examples:
    - Analogy: Mowing grass has linear time complexity because it takes double the time to mow double the area
    - What about looking up a name in a dictionary, what happens if we double the dictionary size?

How do we measure whether an algorithm is 'good'?

- Space complexity
  - The amount of memory required by the algorithm

- Optimal vs. suboptimal solutions

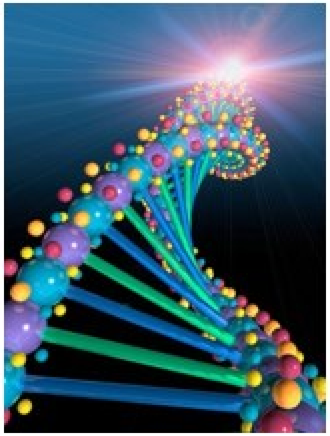


Examples of Problems that require efficient algorithms

- Find a person's name in a phone book

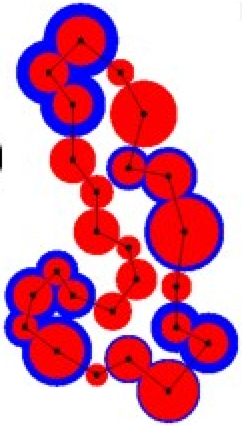
- Designing a web crawler

- The sequence alignment problem

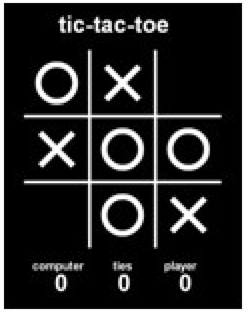


Examples of Problems that require efficient algorithms

- The traveling salesman problem (TSP)



- Teaching a computer to play Tic-Tac-Toe



- Teaching a computer to play Chess

Program Development Cycle

DEVELOP AN ALGORITHM!

MATLAB

1. Analyze: Define the problem
2. Design: Plan the solution to the problem.
3. Choose the interface: Select the objects (textboxes, command buttons, etc.)
4. Code: Translate the algorithm into a programming language.
5. Test & Debug: Locate and remove any errors in the program.
6. Document: Organize all the material that describes the program.

Solving problems with MATLAB

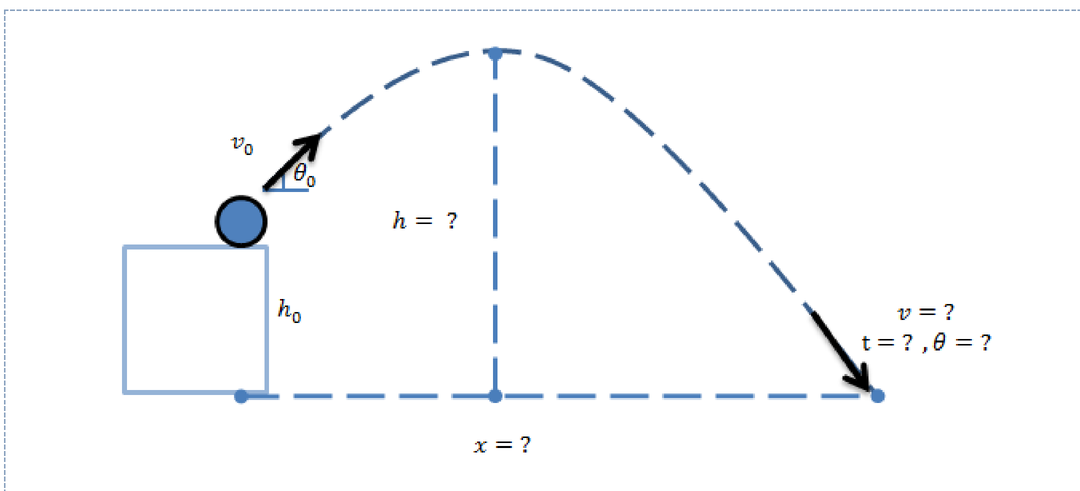
To solve a problem, use the following problem solving methodology

1. State the Problem
2. Describe the Input and Output
3. Develop a Hand Example
4. Develop a MATLAB Solution
   - First, clear the screen and memory: `clear, clc`
   - Now perform the following calculations in the command window or in the editor window
5. Test the solution

Solving problems with MATLAB Example

- **<u>Problem</u>**: For the initially given parameters
  - v_0: the magnitude of initial velocity vector,
  - h_0: initial height,
  - θ_0: the angle of the velocity vector with the horizontal axis,
  - g: gravity;

  calculate the final velocity vector (its magnitude as well as its angle with the horizontal axis (v,θ)), the time passes during this travel (t), the horizontal distance it travels (x), and the maximum height it reaches to (h).



Solving problems with MATLAB Example ctd.

1) **State the Problem:**

For the initially given parameters

- v_0: the magnitude of initial velocity vector,
- h_0: initial height,
- θ_0: the angle of the velocity vector with the horizontal axis,
- g: gravity;

calculate the

- final velocity vector (its magnitude as well as its angle with the horizontal axis (v,θ)),
- the time passes during this travel (t),
- the horizontal distance it travels (x),
- the maximum height it reaches to (h).

Solving problems with MATLAB Example ctd.

2) Describe the Input and Output:

In this example

- v_0, h_0, θ_0 and g are the inputs.
- (v,θ), t, x, and h are the outputs.

3) Develop a Hand Example (use mathematical expressions):

Let, $\pi = 3.141592$, $g = 9.8$, $v_0 = 20$, $\theta_0 = 75$ (in degrees), $h_0 = 30$.

Then,

$v_{0y} = v_0 \sin(\pi\theta_0 / 180)$ and $v_{0x} = v_0 \cos(\pi\theta_0 / 180)$.

$t_{rise} = (v_{0y} - 0) / g$

$m.g.h_{rise} = 0.5m(v_{0y})^2$ □ $h_{rise} = 0.5(v_{0y})^2 / g$

$h_{fall} = h_{rise} + h_0$ and $m.g.h_{fall} = 0.5m(v_y)^2$ □ $v_y = (2gh_{fall})^0.5$

$t_{fall} = (v_y – 0) / g$, $d = v_{0x}(t_{rise} + t_{fall})$, $v_x = v_{0x}$

$\theta_0 = 180*(\arctan(-v_y / v_x)) / \pi$

Solving problems with MATLAB Example ctd.

4) Develop a MATLAB solution:

```
PI=3.141592; % or use pi
G=9.8; v0=20; theta0=75; h0=30;
%assuming theta0 is given in degrees not in radians
v0y=( v0 * sin(PI*theta0/180.0) );
v0x=( v0 * cos(PI*theta0/180.0) );

t_rise=v0y/G;
h_rise=0.5*(v0y*v0y)/G; % 0.5mv^2=mgh
h_fall=h_rise+h0;
vy=sqrt(2*G*h_fall); %0.5mv^2=mgh
t_fall=vy/G;
d=v0x*(t_rise+t_fall);
vx=v0x;
theta=180*atan(-vy/vx)/PI;
t = t_rise + t_fall;
v_mag = sqrt(vx^2 + vy^2);
```

Solving problems with MATLAB Example ctd.

5) **Test the solution:**

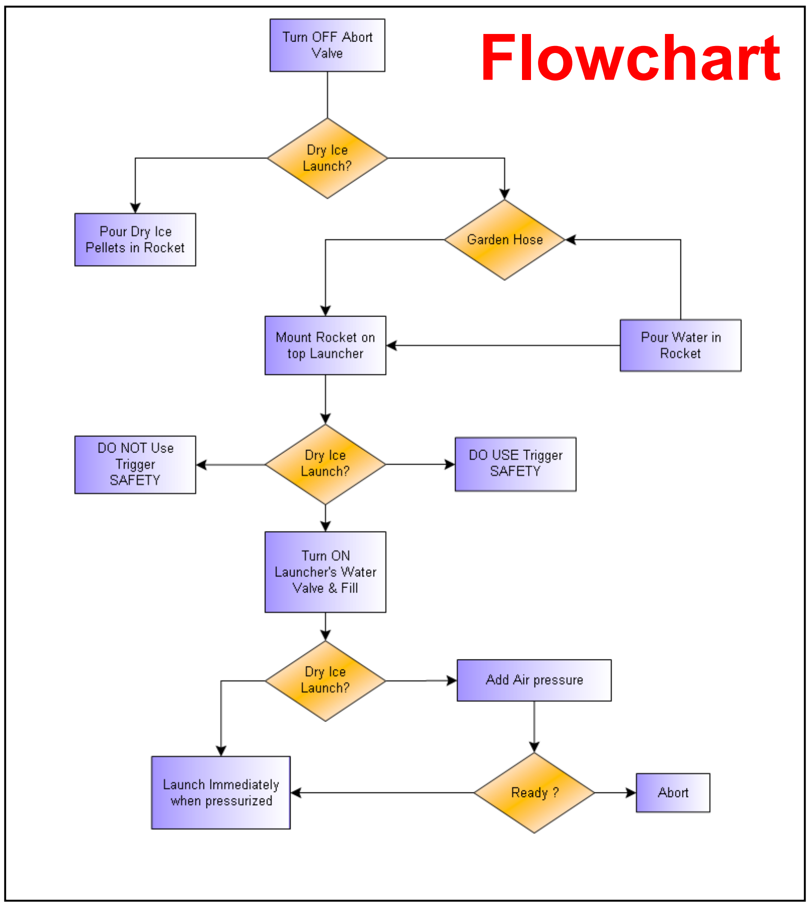
We can run the commands and output the solution as:

```
For a given set of initial values:
Initial Velocity Magnitude: 20[m/s]
Initial Velocity Angle with the horizontal: 75[degrees]
Initial height: 30[m]
Gravity: 9.8[m/(s^2)]

Final parameter set is:
Velocity Magnitude: 31.4325[m/s]
Velocity Angle with the horizontal: -80.5212
Travel time: 5.1349[s]
Maximum height it reaches to: 49.0411[m]
The horizontal distance it travels: 26.5801[m]
```

Methods to represent algorithms (Algorithm Design Techniques)

Flowchart



Pseudocode

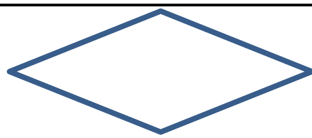
```
Algorithm 3.1: DFS(graph)

 procedure VISIT(node)
  if not node.VISITED
         { node.VISITED ← true
    then { for each edge ← EDGES(node)
         {   do VISIT(TARGET(edge))

 main
  for each node ← NODES(graph)
    do VISIT(node)
```

Flowcharts

- Flowchart is a tool to distinguish the problem into smaller problems and to order them sufficiently to obtain the solution.
- We use shapes such as boxes, diamonds, etc. and arrows to build flowcharts.
- Mostly used shapes are given as follows:

Shape	Name	Description
	Flow line	
	Terminal	Start or stop
	Decision	Yes (true) or no (false) question. Ex. Is *k* equal to 10? Or *k*=10?
	Input / Output	Recieve and display data. Ex. get input from keyboard; display it.
	Process	Perform something. Ex. add *a* to *b*.

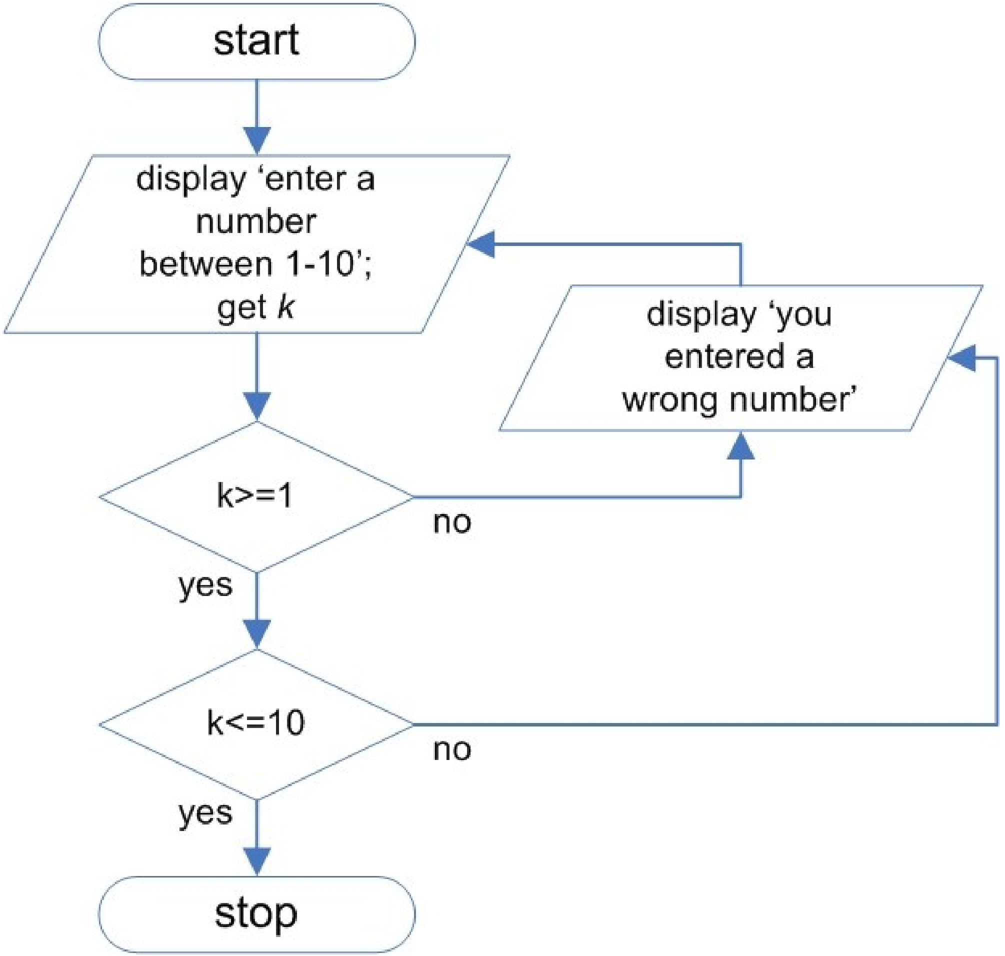
Example - 1

- Ask user to input a number between 1-10.

Example - 1

- Ask user to input a number between 1-10.

1. start
2. get the value (k)
3. if k is smaller than 1, go to step-4, otherwise go to step-5
4. display ‘you entered a wrong number’ and go to step-2
5. if k is larger than 10, go to step-4
6. stop



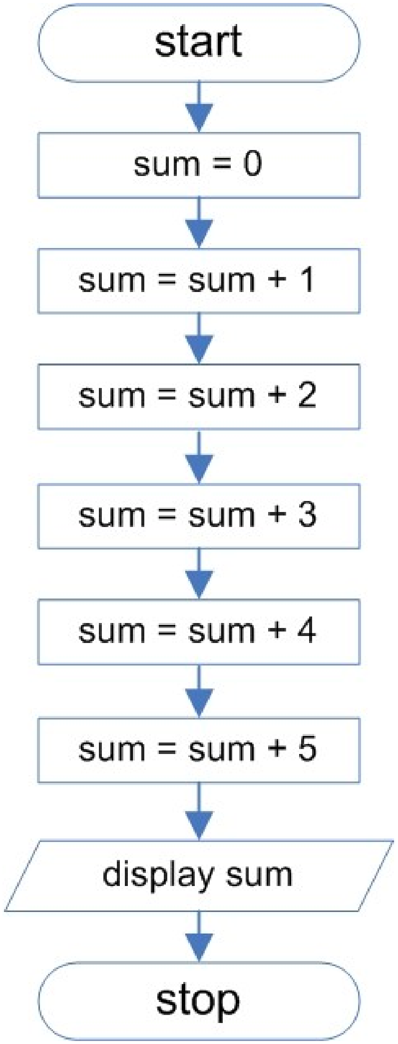
Example - 2

- Sum up numbers from 1 to 5

Example - 2

- Sum up numbers from 1 to 5

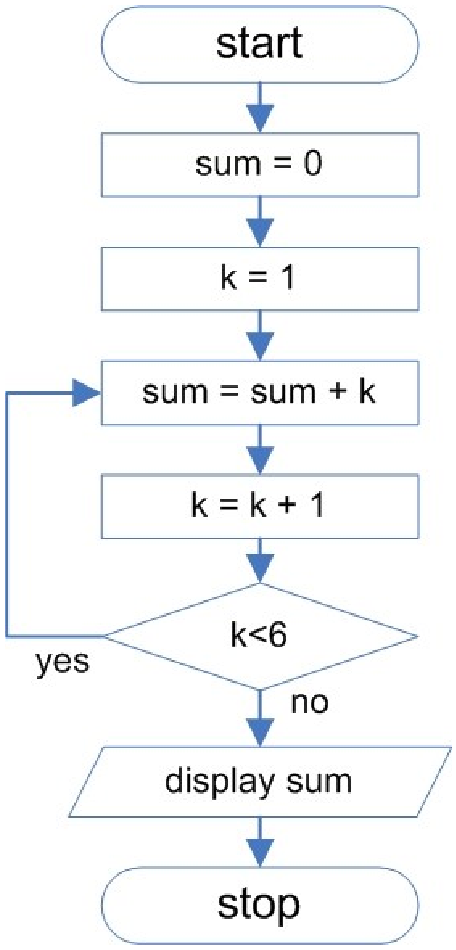
  1. start
  2. sum = 0
  3. sum = sum + 1
  4. sum = sum + 2
  5. sum = sum + 3
  6. sum = sum + 4
  7. sum = sum + 5
  8. output the sum
  9. stop



Example - 2

- Sum up numbers from 1 to 5

1. start
2. sum = 0
3. k = 1
4. sum = sum + k
5. k = k + 1
6. if k<6 go to step-4
7. output the sum
8. stop



Example - 3

- Ask user to input a non-negative integer and compute its factorial.

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- Ask user to input a non-negative integer and compute its factorial.

1. start
2. display ‘enter a non-negative integer’, get the value (k)
3. if k is negative or it is not an integer, go to step-2
4. fact = 1
5. if k is less than or equal to 1, go to step-9
6. fact = fact * k
7. k = k – 1
8. if k is larger than 1, go to step-6
9. output fact
10. stop