ECE 220: Computer Systems & Programming

Lecture 6: Control Structures & Basic I/O

Announcements:

Machine Problem	Submission due date
MP 01 - Printing histogram	09-04
MP 02 - Stack calculator	09-11
MP 03 - Pascal's triangle	09-18

Quiz	Date	Location	Topic(s)	Points
Mock	09/08 - 09/10	CBTF	Short Survey LC-3 practice (HW0)	25
Quiz 1	09/15 - 09/17	CBTF	LC-3 Programming (up to and including Lecture 4/Lab 1 /MP 1) See Lab1 and Lab2 programming exercise. **An LC-3 web simulator will be available during Quiz 1 - you should NOT use it for your MPs.**	100

Exam schedule

Exam	Date & Time	Location	Topic	Practice Questions	Conflict Exam Information
Midterm 1	Thursday 09/25 at 7.00pm - 8.20pm	ECEB	Lecture 1 to Lecture 06 Associated book chapters, labs,and MPs. (Programming & Concept)	Past exams Worksheets LC3 RefSheet	Sign-up Link **Deadline: 09/21**

Practice

```
int a = 6, b = 9;
```

Expression	Value of Expression
a | b	0b0110 | 0b1001 = 0b1111 = 15
a || b	true OR ture = 1
a & b	0b0110 & 0b1001 = 0
a && b	1
!(a + b)	0
a % b	6
b / a	9/6 = 1
a = b	9
a = b = 5	5
++a + b--	11

Input and Output (More details in Lec14)

- Must include `<stdio.h>` to use I/O functions.

```
printf("%d\n", counter);
```

- This call says to print the variable counter as a decimal integer, followed by a linefeed (\n).

```
scanf("%d", &startPoint);
```

- This call says to read a decimal integer and assign it to the variable startPoint.
- Must use ampersand (&) for variables being modified. (Explained in later lecture)

Format Specifier

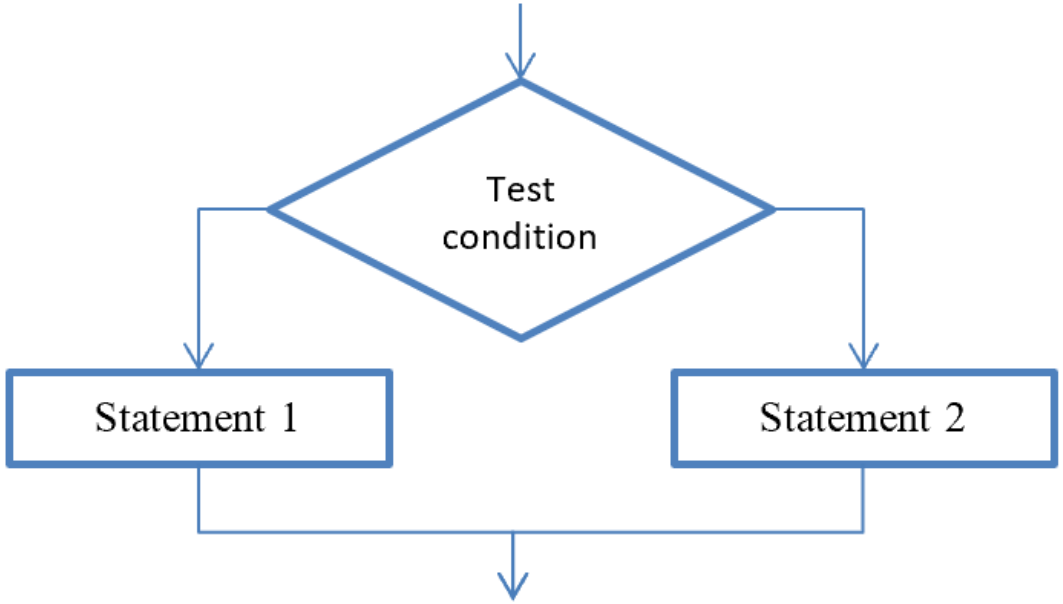
specifier	Output	Example
`d` *or* `i`	Signed decimal integer	`392`
`u`	Unsigned decimal integer	`7235`
`o`	Unsigned octal	`610`
`x`	Unsigned hexadecimal integer	`7fa`
`X`	Unsigned hexadecimal integer (uppercase)	`7FA`
`f`	Decimal floating point, lowercase	`392.65`
`F`	Decimal floating point, uppercase	`392.65`
`e`	Scientific notation (mantissa/exponent), lowercase	`3.9265e+2`
`E`	Scientific notation (mantissa/exponent), uppercase	`3.9265E+2`
`g`	Use the shortest representation: `%e` or `%f`	`392.65`
`G`	Use the shortest representation: `%E` or `%F`	`392.65`
`a`	Hexadecimal floating point, lowercase	`-0xc.90fep-2`
`A`	Hexadecimal floating point, uppercase	`-0XC.90FEP-2`
`c`	Character	`a`
`s`	String of characters	`sample`
`p`	Pointer address	`b8000000`
`n`	Nothing printed. The corresponding argument must be a pointer to a `signed int`. The number of characters written so far is stored in the pointed location.	
`%`	A `%` followed by another `%` character will write a single `%` to the stream.	`%`

Control Structures

- **Conditional**

one or another statement will be executed, but not both, depending on some condition:

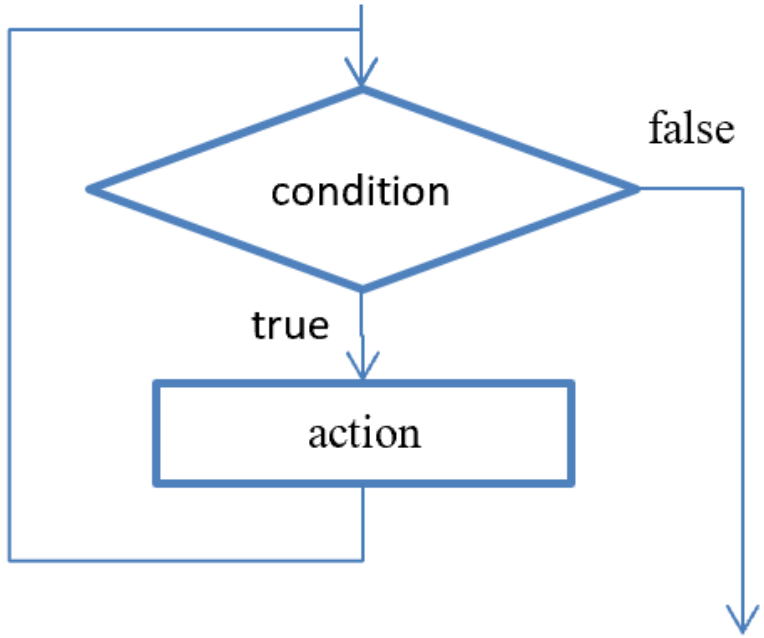
  - `if`
  - `if-else`
  - `switch`



- **Iteration**

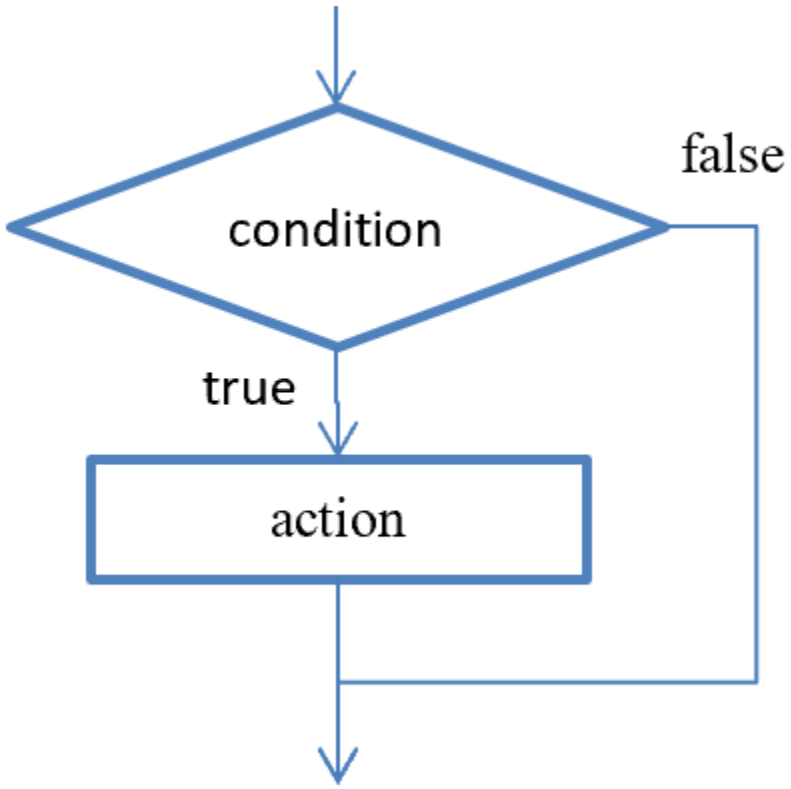
some statements will be executed multiple times until some condition is met:

  - `while`
  - `for`
  - `do-while`



if statement

- `if (condition)`
  `action;`




```
; LC-3 assembly
;
; generate condition code
;
BR(nzp) FALSE
;
; action
;
FALSE
;
```

example

```
if (x < 0)
     x  = -x;                    /* simple statement */

if (x > 5)
if (x< 25) {
     y = x * x +5;          /* compound statement */
     printf("y=%d\n", y);
}
```

- action statement can be simple, as in first example, or compound, as in second example

example

```
if (x < 0)
    x  = -x;                    /* simple statement */

if (x > 5 && x< 25) {
    y = x * x +5;          /* compound statement */
    printf("y=%d\n", y);
}
```

- action statement can be simple, as in first example, or compound, as in second example

Example if statements

```
if (x <= 10)
  y = x * x + 5;
```

same

```
if (x <= 10){
  y = x * x + 5;
}
```

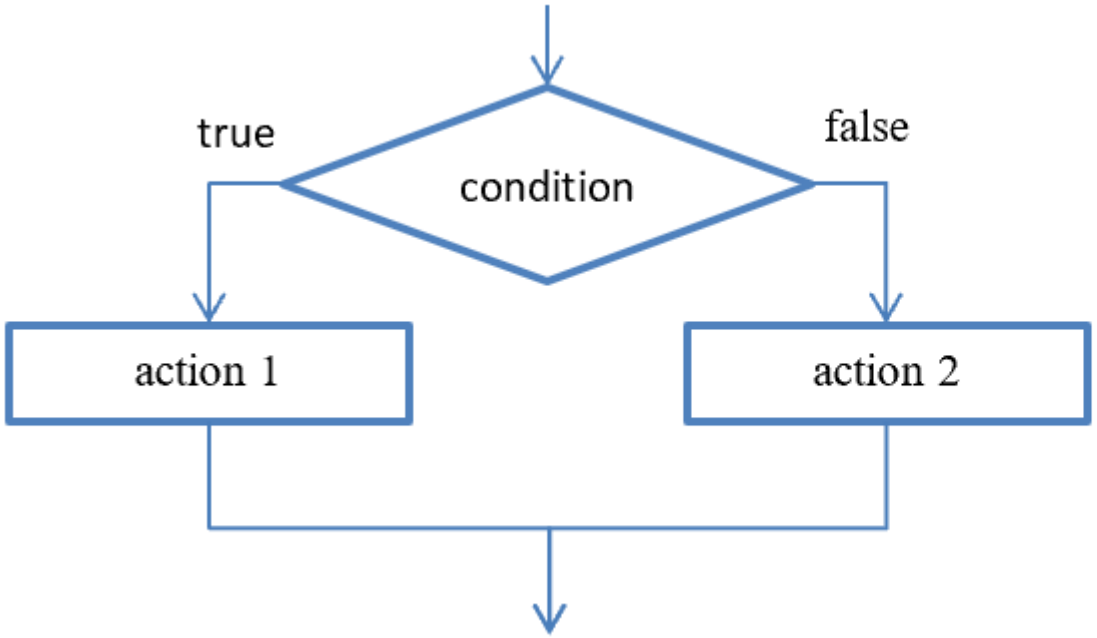
```
if (x <= 10) {
  y = x * x + 5;
  z = (2 * y) / 3;
}
```

NOT same

```
if (x <= 10)
  y = x * x + 5;
  z = (2 * y) / 3;
```

if-else statement

```
if (condition)
    action_when_condition_is_true;
else
    action_when_condition_is_false;
```




```
; LC-3 assembly
;
; generate condition code
;
BR(nzp) FALSE
;
; action 1
BRnzp DONE
;
FALSE
; action 2
;
DONE
```

Example

```
if (x < 0)
     x  = -x;
else
     x = x * 2;
```

```
if (x > 5 && x< 25) {
     y = x * x +5;
     printf("y=%d\n", y);
}
else
     printf("x=%f\n", x);
```

common programming errors

- if (x = 2) using assignment operator instead of ==

Associating **if**s with **else**s

- in a cascaded **if-else** statement, an **else** is associated with the closest **if**
  - that is, when not using braces, which is not a good practice

`if (x != 0)` `  if (y > 3)` `  z = z / 2;` `  else` `  z = z + 2;`	same as	`if (x != 0) {` `  if (y > 3)` `  z = z / 2;` `  else` `  z = z + 2;` `}`

"else" is associated with the closest unassociated if. How do you associate "else" with the outer if?

if we really want to associate **else** with the first **if**, then we should use braces:

```
if (x != 0) {
    if (y > 3)
        z = z / 2;
}
else
    z = z + 2;
```

use braces to write clear and readable code!

Floating Number Comparison (Caution)

```
float myFloat = 3.14;

if(myFloat == 3.14)
    printf("My float is PI.\n");
else
    printf("My float is not PI.\n");
```

```
My float is not PI.
```

```
double myDouble = 3.14;

if(myDouble == 3.14)
    printf("My double is PI.\n");
else
    printf("My double is not PI.\n");
```

```
My double is PI.
```

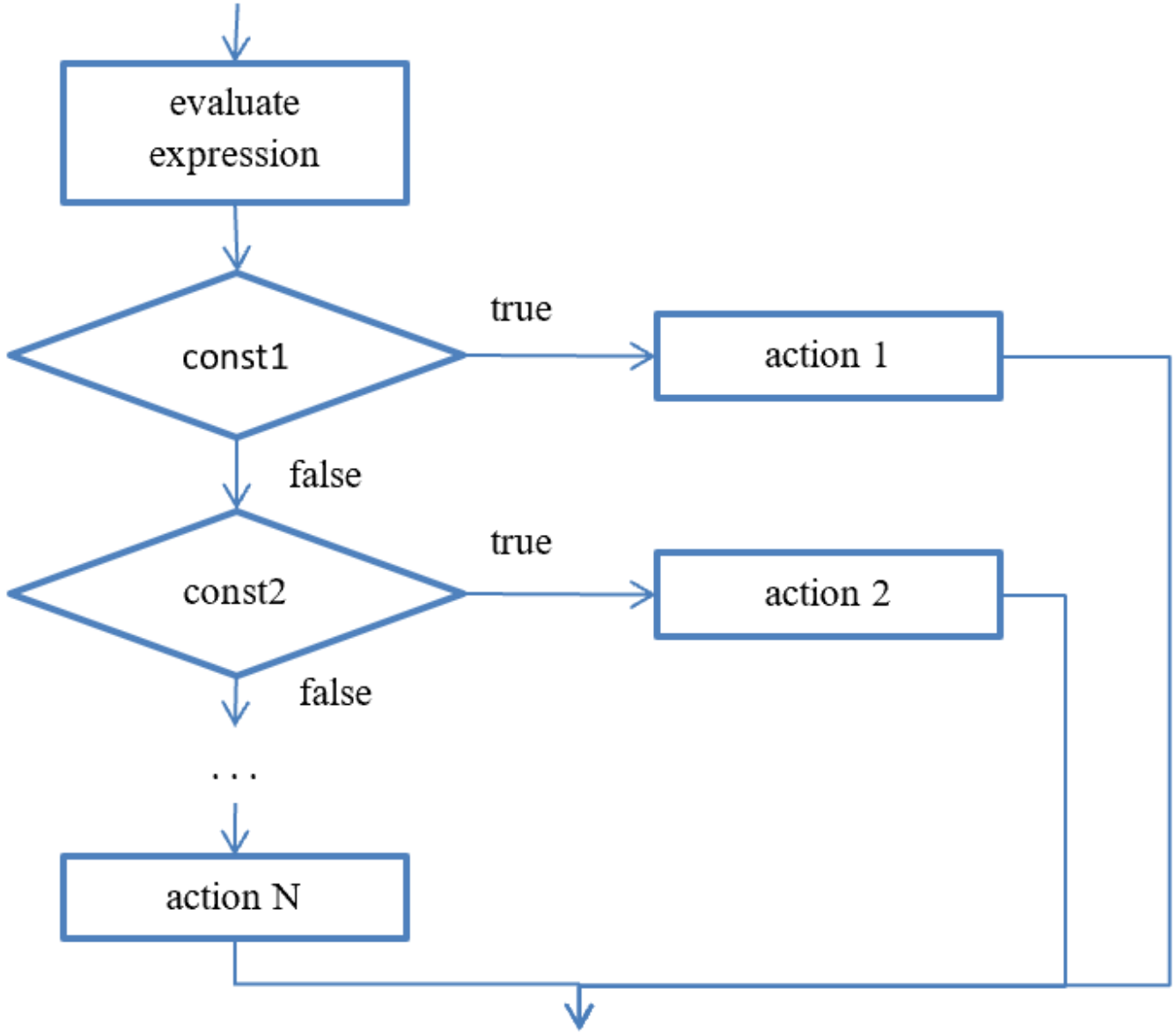
```
printf("%d, %d, %d\n", sizeof(3.14), sizeof(3.14f),  sizeof(myFloat));

8, 4, 4
```

switch statement

- consider example shown in the left column; it also can be implemented as shown on the right:

Using cascaded **if-else** statements	Using **switch** statement
if (expression == const1) *action1;* **else if** (expression == const2) *action2;* **else if** (expression == const3) *action3;* ... **else** *actionN;*	**switch** (expression) { **case** const1: *action1;* **break;** **case** const2: *action2;* **break;** **case** const3: *action3;* **break;** ... **default:** *actionN;* }



this only works when we consider some discrete values to which `expression` is evaluated, `const1, const2, …`

Break Example

```
a = 5;
switch(a){
    case 5:
        printf("E");
        break;
    case 2:
        printf("C");
        break;
    default:
        printf("G");
        break;
}
```

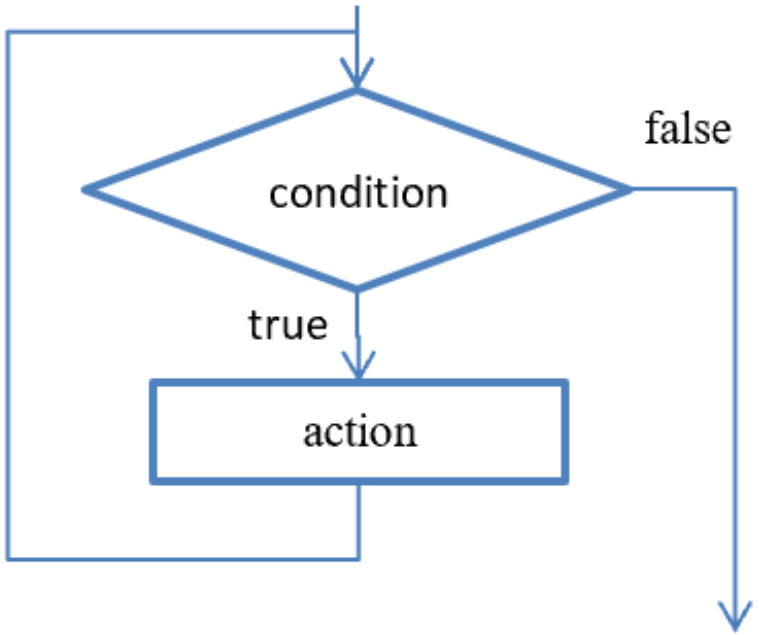
E

```
a = 5;
switch(a){
    case 5:
        printf("E");
    case 2:
        printf("C");
    default:
        printf("G");
}
```

ECG

Iterative constructs

Iterative construct means that some statements will be executed multiple times until some condition is met:



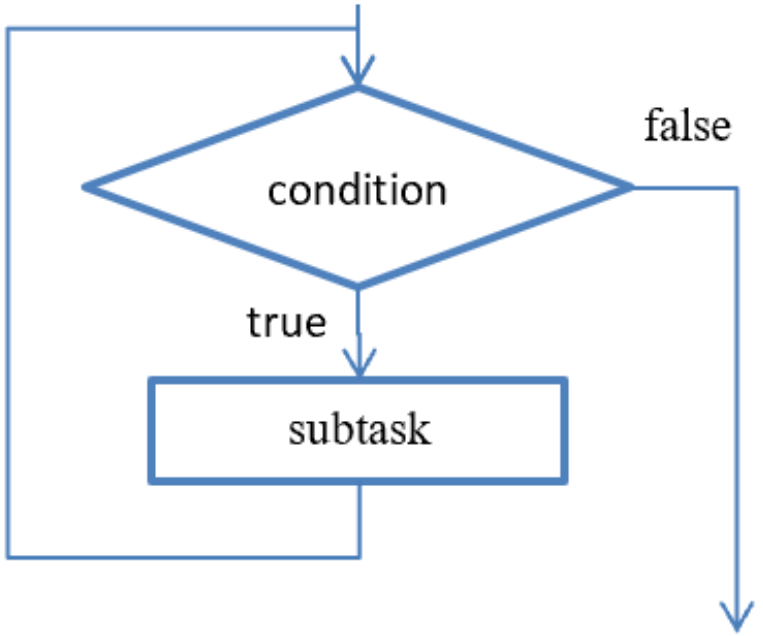

```
; LC-3 implementation
LOOP
; generate condition code
BR(nzp) FALSE
;
; action
;
BRnzp LOOP
;
FALSE
;
```

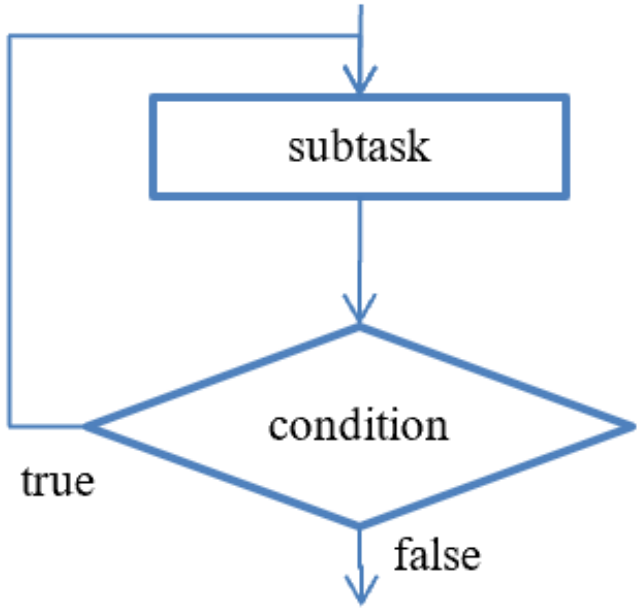
Such construct implements a loop structure in which *action* is executed multiple times, as long as some *condition* is true

- *action* is also called *loop body*

while and do-while statements

- ```
  while (condition) {
      subtask;
  }
  ```
- ```
  do {
      subtask
  } while (condition);
  ```
- For while loop, loop body may or may not be executed even once
- For do-while loop, loop body will be executed at least once



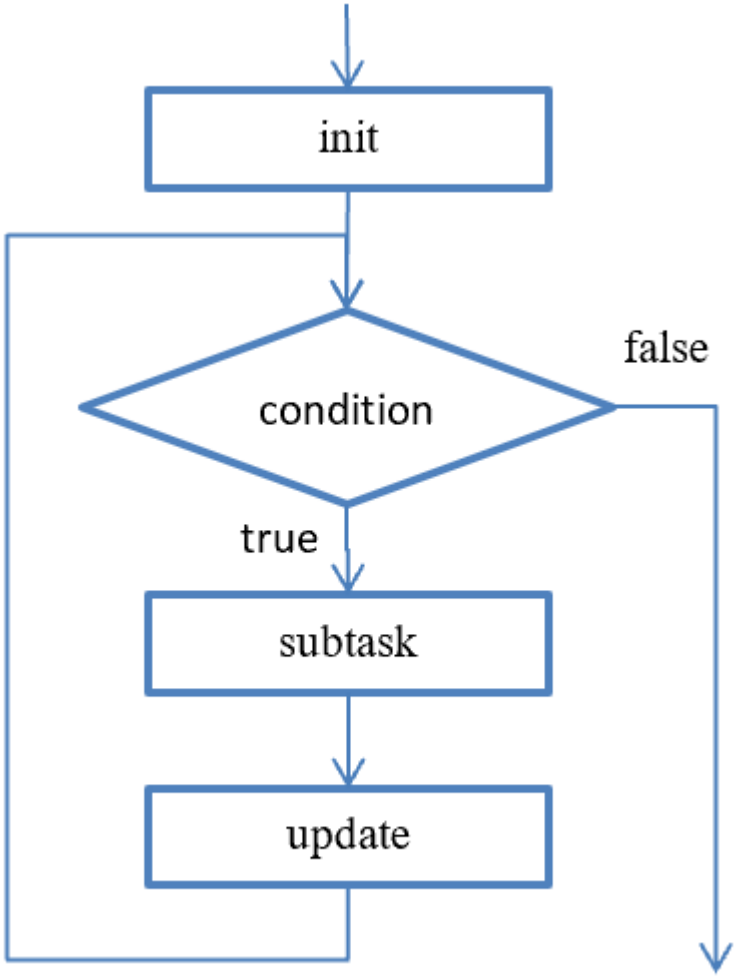


Example

while	do-while
x = 0; while (x < 10) { printf("x=%d\n", x); x = x + 1; }	x = 0; do { printf("x=%d\n", x); x = x + 1;} while (x < 10);

for statement

- **for** (init; test; update) {
  subtask;
  }



Example

While	for
x = 0; while (x < 10) { printf("x=%d\n", x); x = x + 1; }	for (x = 0; x < 10; x++) printf("x=%d\n", x);

break and continue

- `break`

  used only in switch or iteration statement

  break will cause the loop to be terminated

- `continue`
  - used only in iteration statement
  - end the current iteration and start the next

```
for (i = 1; i < 10; i++){
    if(i == 5)
        break;
    printf("%d ",i);
}
```

```
1 2 3 4
```

```
for (i = 1; i < 10; i++){
    if(i == 5)
        continue;
    printf("%d ",i);
}
```

```
1 2 3 4 6 7 8 9
```

Problem: Print nxn Identity Matrix

- 3-by-3 identity matrix :

$$\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{matrix}$$

- Can we stop printing after the second “1” on the main diagonal such as

$$\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & \end{matrix}$$

Example:

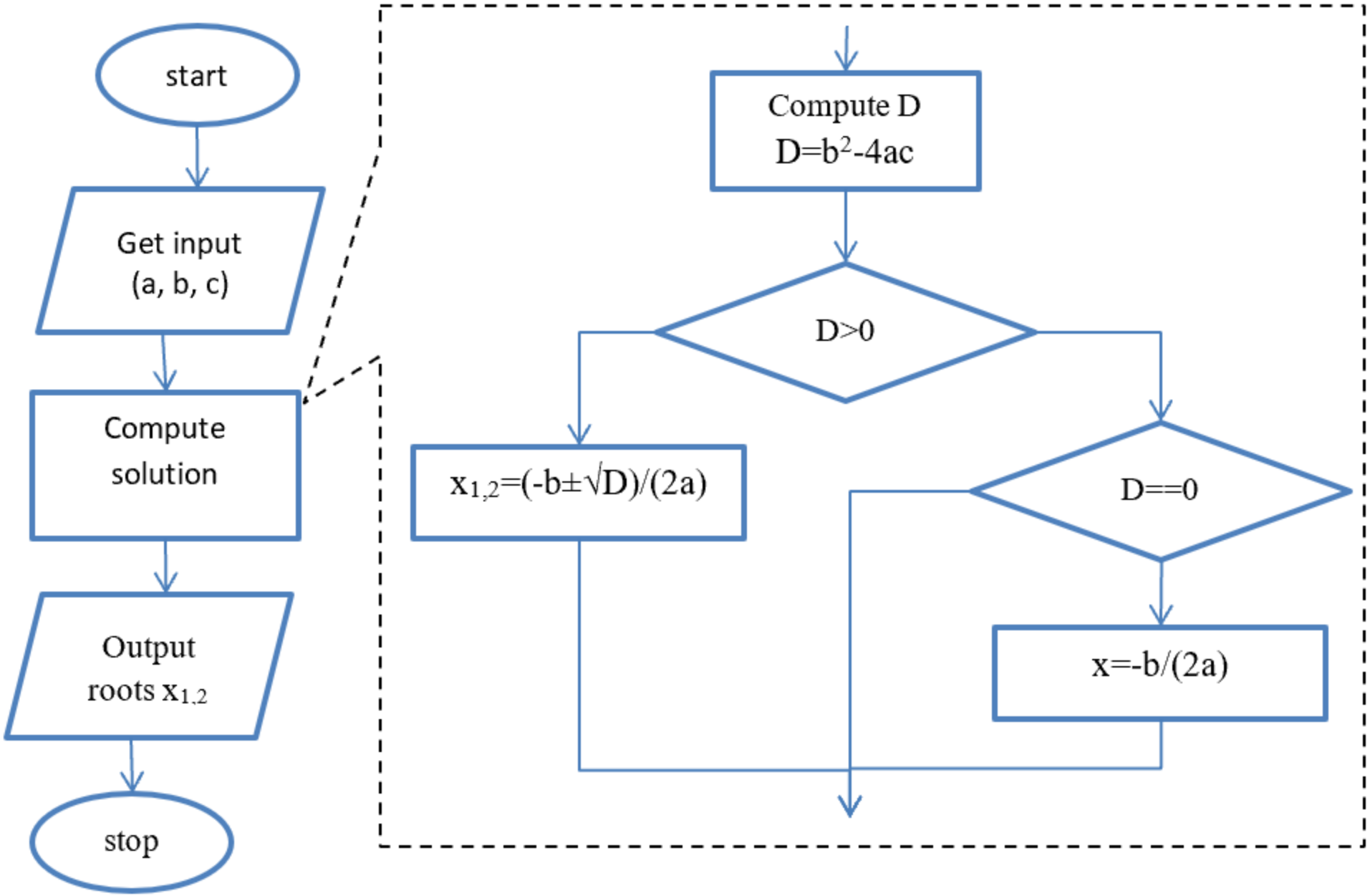
Computing solution of a quadratic equation $ax^2+bx+c=0$

Algorithm:

- $D = b^2 - 4ac$
- If D equals 0, there is one real root: $x = -b/(2a)$
- If D is positive, there are two roots: $x_{1,2} = (-b \pm \sqrt{D})/(2a)$
- If D is negative, no real roots exist

Problem decomposition into separate steps using a flowchart

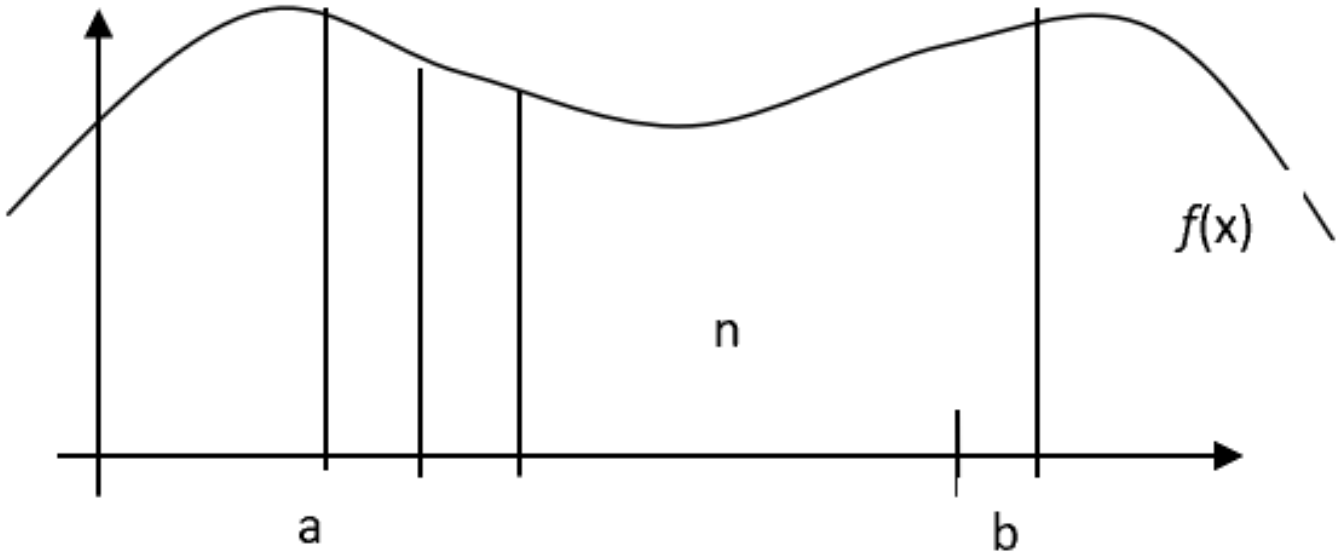
- Get input
- Compute solution according to the above algorithm
- Print output


start
Get input
(a, b, c)
Compute
solution
Output
roots x1,2
stop
Compute D
D=b2-4ac
D>0
x1,2=(-b±√D)/(2a)
D==0
x=-b/(2a)

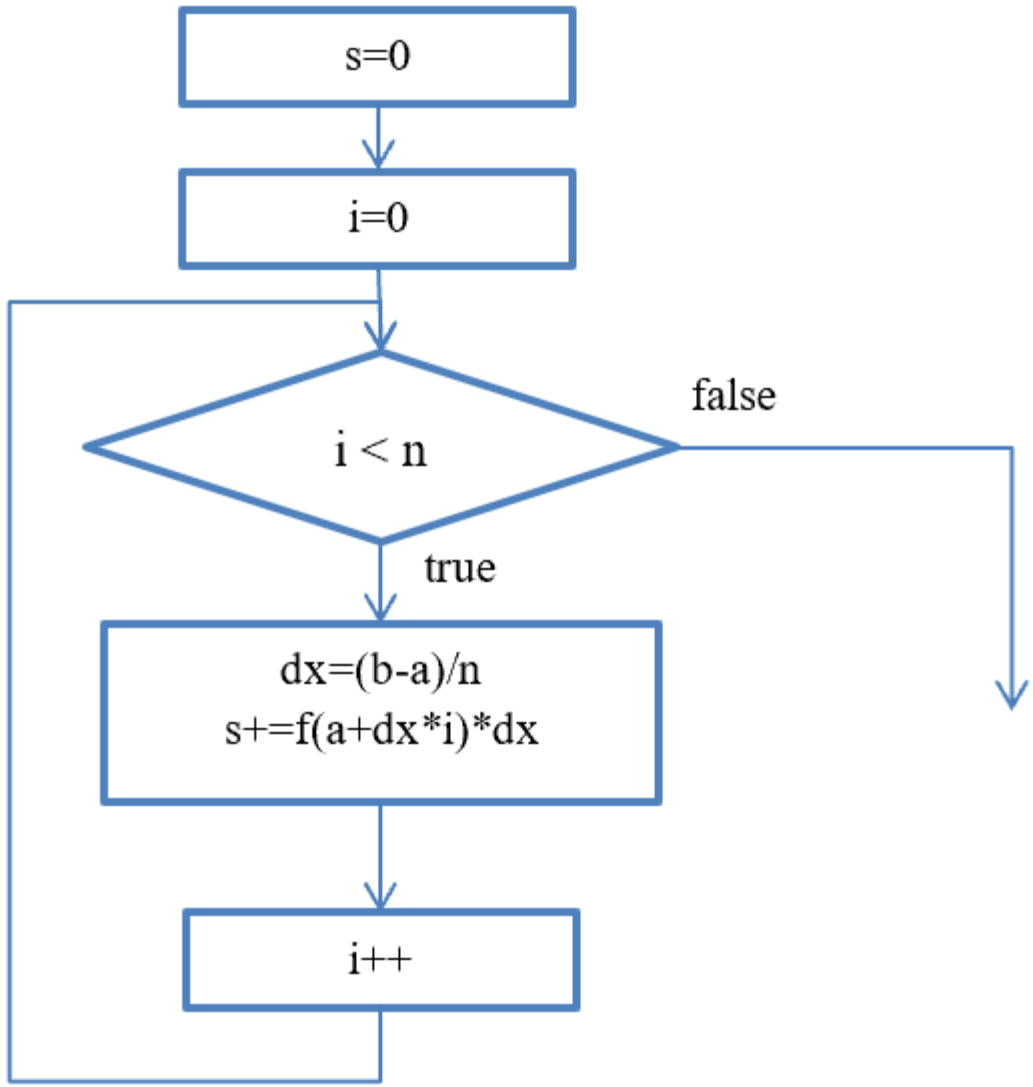
Riemann integral

Problem statement: write a program to compute integral of a function f(x) on an interval [a,b].

Algorithm: use integral definition as an area under a function *f*(x) on an interval [a,b]



$$\int_a^b f(x)dx = \lim_{n\to\infty} \sum_{i=0}^{n-1} f\left(a + \frac{b-a}{n} i\right) \frac{b-a}{n}$$


s=0
i=0
i < n
false
true
dx=(b-a)/n
s+=f(a+dx*i)*dx
i++

```c
/* compute integral of f(x) = x*x+2x+3 on [a,b] */
#include <stdio.h>

int main()
{
    int n = 100;        /* hardcoded number of Reimann sum terms */
    float a = -1.0f;    /* hardcoded [a,b] */
    float b = 1.0f;
    float s = 0.0f;             /* computed integral value */
    int i;                      /* loop counter */
    float x, y;                 /* x and y=f(x) */
    float dx = (b - a) / n;     /* width of rectangles */

    for (i = 0; i < n; i++)
    {
        x = a + dx * i;
        y = x * x + 2 * x + 3;
        s += y * dx;
    }

    printf("%f\n", s);

    return 0;
}
```