Computer Programming: Skills & Concepts (CP)
arithmetic, `if` and booleans (cont)

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Last Lecture

- Arithmetic
- Quadratic equation problem: $ax^2 + bx + c = 0$
- Floating point data

Today's lecture

- Solving quadratic with `if`-statements
- General form of the `if`-statement
- Boolean tests (using relational operators)
- What about degenerate quadratics?
- Refining `quadratic.c`

Choice of variables for `quadratic.c`

- We will need to compute the square-root of $b^2 - 4ac$.
- The `sqrt` function available in the `math` library for C is of the type `double sqrt (double x);`
- For this simple reason we use `double` variables for our real roots.
- Precision is not really important to *us*, at least not now.

C program to Solve Quadratic Equations

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

Steps of our program:

- Take in the inputs a, b and c from the user (`scanf`).
  Need three `int` variables to store these values: `a, b, c` **say**;
- *test whether $b^2 - 4ac$ is non-negative*.
  What we do will depend on the result of the test
  - If negative, output a message about "No real roots".
  - If exactly 0, a repeated root.
  - Otherwise, two differing roots as per formula.
- Get the square root of $b^2 - 4ac$ (if non-negative).
- Output both roots (or one if repeated).
- `return EXIT_SUCCESS;`

body of `quadratic.c`

```
int s = (b*b - 4*a*c);

if (s < 0) {
  printf("No real roots to this quadratic.\n");
} else if (s == 0) {
  printf("Eq. has the repeated root %f.\n", -(double)b/(2.0
} else {
  x1 = (-(double)b - sqrt(s))/(2.0*a);
  x2 = (-(double)b + sqrt(s))/(2.0*a);

  printf("The sols to %dx^2 +%dx +%d = 0 are ", a, b, c);
  printf("%lf and %lf.\n", x1, x2 );
}
```

Note: `sqrt()` takes a `double` argument, so the `int` expression `s` is automatically promoted to a `double` in `sqrt(s)`.
Question: is the cast `(double)b` necessary?

Running `quadratic.c`

`quadratic.c` (and the refinements of this program) uses the `sqrt` function from the `math` library.

note: Not *enough* to include `<math.h>` in the code.

- `<math.h>` is just a header file for the `math` library (it explains the "shape" of the `sqrt` function, and other `math` functions).
- To run our program, we need to *link* to *executable* code for the `math` functions.
- Link by adding `-lm` to `gcc` command when compiling:
  `gcc -Wall quadratic.c -lm`
- `-lm` is 'minus ell m', NOT 'minus one m'.

Assumptions :-(

We made some assumptions for `quadratic.c`

- By solving a quadratic, we (implicitly) assumed a is non-zero.
- Same for b.
- We might have had a linear or constant equation.

SOLUTION - use the (general) `if` statement.

if statement – general form

```
if ( condition1 ) {
  statement-sequence1
}
else if ( condition2 ) {
  statement-sequence2
}
...
else {
  statement-sequencen
}
```

- *condition*$_1$, ..., *condition*$_{n-1}$ are all *boolean expressions*: either true or false.
- *statement-sequence*$_1$, ..., *statement-sequence*$_n$ are all sequences of C-programming statements.
- Note that it is possible to use `if` alone without *any* `else` branch.

Warning about if

If you look in the textbooks, you will see that when the *statement-sequence* has only one statement, you can miss out the curly brackets round it:

```
if ( t > 0 )
  x = x + 1;
else
  x = x - 1;
```

We **recommend** that you **don't** do this (at least until you're experienced enough to understand when you can ignore our advice!).

You will see it in other people's programs though.

Actually, we lied about the general form of the `if` statement. In truth, the general form is
`if (` *condition* `)` *statement*$_1$ `else` *statement*$_2$
and a *statement* can have the form `{` *statement-sequence* `}`
or can be an `if`-statement itself. However, the form on the previous slide is the way we typically use it, so best to 'learn' that.

Relational operators

What kind of conditions can we use in `if` statements?
Assume e_1 and e_2 are (usually arithmetic) expressions ...
We can apply *relational operators* to form a boolean expression.

e_1 `==` e_2	e_1 equal to e_2
e_1 `!=` e_2	e_1 not equal to e_2
e_1 `<` e_2	e_1 less than e_2
e_1 `<=` e_2	e_1 less than or equal to e_2
e_1 `>` e_2	e_1 greater than e_2
e_1 `>=` e_2	e_1 greater than or equal to e_2.

Never write e_1 `<` e_2 `<` e_3
it is legal C, but it doesn't mean anything like what you think it means – if you remember to `-Wall`, the compiler will warn you if you do this!

note: We can compare `float` and `double` expressions in this way - but only `int` comparisons are fully reliable. Why is this?

More complicated Boolean expressions

Assume e_1 and e_2 are boolean expressions ...
Can build more complicated boolean expressions iteratively, using *boolean operators*.

0	false (always)
non-zero	true (always)
`!` e_1	true if e_1 is false
e_1 `&&` e_2	true if (e_1 is true and e_2 is true)
e_1 `||` e_2	true if (e_1 is true or e_2 is true)

For example, **can** write `(`e_1 `<` e_2`) && (`e_2 `<` e_3`)`.
The expressions e_1, e_2 are (formally) integer expressions.
We define *boolean variables* as `int`.
Think of integers as (informally) acting as boolean 'type'.

Boolean expressions in `if-else` statements

We have seem lots of simple and complex boolean expressions: whenever any of these are used as tests in a `if-else` statement, they must be enclosed in parentheses.
For example

- The simple Boolean expression `x < 5+z`, when being used as a test for an `else if`-branch of an `if-else` statement, would appear as

```
else if (x < 5+z) { ... }
```

- The complex Boolean expression `(a != 0) && (b*b > 4*a*c)`, when being used as the test for the `if` branch of an `if-else` statement, would appear as

```
if ( (a != 0) && (b*b > 4*a*c) ) { ...}
```


Nested `if`-statements

- The *statement-sequence* place-holder in the general `if`-statement allows other `if`-statements to be part of the program fragment.
- This is a 'nested' use of the `if`-statement.
- Example – refine the `quadratic.c` program further to include a solution for the $a = 0$ case (given a linear equation).

Improving `quadratic.c`

Issues for improving quadratic:

(i) make our quadratic solver cope with $a = 0$ (`quadratic2.c`)
. . . and with $a = 0, b = 0$.

(ii) complex roots (homework).

quadratic equations – what if $a = 0$

If $ax^2 + bx + c = 0$ is a quadratic, and a is 0, then we have a linear equation:

$$bx + c = 0$$

This has . . .

- Exactly *one* root of value $-c/b$, if $b \neq 0$.
- No root at all, if $b = 0$ and $c \neq 0$.
- Everything is a root, if $b = c = 0$.

Can incorporate this case into our code:

quadratic2.c – header and input code

Start off as before ...

```c
#include <stdio.h>
#include <stdlib.h>
#include <math.h>    // Need to include math.h to use sqrt.

int main(void) {
  int a, b, c, s;
  double x1, x2;

  printf("Input the x^2 co-efficient a: ");
  scanf("%d", &a);
  printf("Input the x co-efficient b: ");
  scanf("%d", &b);
  printf("Input the constant term c: ");
  scanf("%d", &c);
  s = b*b - 4*a*c;
```


quadratic2.c – a != 0 versus a == 0

```c
  if (a != 0) {
    if (s < 0) {              /* THIS (a != 0)  */
     ...                      /* BRANCH IS      */
    }                         /* EXACTLY WHAT   */
    else if (s == 0) {        /* WE PUT FOR THE */
     ...                      /* BODY OF        */
    }                         /* quadratic.c    */
    else {
     ...
    }
  }
  else {                      /* THIS WILL BE THE   */
  ...                         /* SOLUTION FOR a==0  */
  }                           /* (linear equations) */
  return EXIT_SUCCESS;
```

We need to complete the `else` (`a` being `0`) branch.

quadratic2.c – all cases

```c
  if (a != 0) {
    if (s < 0) {
      ... // code from quadratic.c
    }
  }
  else if (b != 0) {              /* a==0 WITH b NON-ZERO */
    x1 = -((double)c)/((double)b);
    printf("1 sol to %dx^2 +%dx +%d = 0.\n", a, b, c);
    printf("It is %lf.\n", x1);
  }
  else if (c != 0) {             /* a AND b BOTH ZERO, c NON-ZERO  */
    printf("No sols to %dx^2 + %dx +%d = 0.\n", a, b, c);
  }
  else {                         /* a, b, c ALL ZERO */
    printf("Degenerate equation - everything is a solution!\n");
  }
  return EXIT_SUCCESS;
}
```


Reading and Working

Relevant sections of "A book on C" are Sections 4.1, 4.2, 4.3, 4.4 (on Boolean expressions, Relational operators, etc) and Section 4.7 (on the `if` and the `if-then-else` statements).

You already have the week 3 Tutorial sheet.
Please attempt all Questions before your tutorial group.
Also please think of one question about the CP material so far, and bring that question to the tutorial.

How about coding up `quadratic2.c`?
Could make `quadratic3.c` by also doing complex roots.