Lecture 3 - Formatted Input/Output

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The `printf` Function

- The `printf` function must be supplied with a ***format string***, followed by any values that are to be inserted into the string during printing:

```
printf(string, expr1, expr2, ...);
```

- The format string may contain both ordinary characters and ***conversion specifications***, which begin with the `%` character.

- A conversion specification is a placeholder representing a value to be filled in during printing.
  - `%d` is used for `int` values
  - `%f` is used for `float` values

The **printf** Function (cont.)

- Ordinary characters in a format string are printed as they appear in the string; conversion specifications are replaced.
- Example:

```
int i, j;
float x, y;

i = 10;
j = 20;
x = 43.2892f;
y = 5527.0f;

printf("i = %d, j = %d, x = %f, y = %f\n", i, j, x, y);
```

- Output:

```
i = 10, j = 20, x = 43.289200, y = 5527.000000
```

The **printf** Function (cont.)

- Compilers aren't required to check that the number of conversion specifications in a format string matches the number of output items.
  - Too many conversion specifications:

```
printf("%d %d\n", i);    /*** WRONG ***/
```

  - Too few conversion specifications:

```
printf("%d\n", i, j);    /*** WRONG ***/
```

- Compilers aren't required to check that a conversion specification is appropriate.
  - If the programmer uses an incorrect specification, the program will produce meaningless output:

```
printf("%f %d\n", i, x);   /*** WRONG ***/
```

Conversion Specifications

- A conversion specification can have the form `%`*m*`.`*pX* or `%-`*m*`.`*pX*, where *m* and *p* are integer constants and *X* is a letter.
- Both *m* and *p* are optional; if *p* is omitted, the period that separates *m* and *p* is also dropped.
  - In the conversion specification `%10.2f`, *m* is 10, *p* is 2, and *X* is `f`.
  - In the specification `%10f`, *m* is 10 and *p* (along with the period) is missing, but in the specification `%.2f`, *p* is 2 and *m* is missing.

Minimum Field Width *m*

- The ***minimum field width***, *m*, specifies the minimum number of characters to print.
- If the value to be printed requires fewer than *m* characters, it is right-justified within the field.
  - `%4d` displays the number 123 as `•123`. (• represents the space character.)
- If the value to be printed requires more than *m* characters, the field width automatically expands to the necessary size.
- Putting a minus sign in front of *m* causes left justification.
  - The specification `%-4d` would display 123 as `123•`.

Precision *p* on %d

- The meaning of the ***precision,*** *p*, depends on the choice of *X*, the ***conversion specifier.***
- The `d` specifier is used to display an integer in decimal form.
  - *p* indicates the minimum number of digits to display (extra zeros are added to the beginning of the number if necessary).

    ```
    %.3d -> 001
    ```

  - If *p* is omitted, it is assumed to be 1.

Precision *p* on floating-point %e, %f and %g

- Conversion specifiers for floating-point numbers:

  `e` — Exponential format. *p* indicates how many (rounded) digits should appear after the decimal point (the default is 6). If *p* is 0, no decimal point is displayed.

  `8.392e+02`

  `f` — "Fixed decimal" format. *p* has the same meaning as for the `e` specifier.

  `839.210`

  `g` — Either exponential format or fixed decimal format, depending on the number's size. *p* indicates the maximum number of significant digits to be displayed. The `g` conversion won't show trailing zeros. If the number has no digits after the decimal point, `g` doesn't display the decimal point.

Program: Using **printf** to Format Numbers

tprintf.c

```
#include <stdio.h>

int main(void)
{
  int i;
  float x;

  i = 40;
  x = 839.21f;

  printf("|%d|%5d|%-5d|%5.3d|\n", i, i, i, i);
  printf("|%10.3f|%10.3e|%-10g|\n", x, x, x);

  return 0;
}
```

```
|40|   40|40   |  040|
|   839.210| 8.392e+02|839.21    |
```

Escape Sequences

- The `\n` code that used in format strings is called an ***escape sequence.***
- Escape sequences enable strings to contain nonprinting (control) characters and characters that have a special meaning (such as ").
- A partial list of escape sequences:

Alert (bell)	`\a`
Backspace	`\b`
New line	`\n`
Horizontal tab	`\t`

Escape Sequences (cont.)

- A string may contain any number of escape sequences:

```
printf("Item\tUnit\tPurchase\n\tPrice\tDate\n");
```

- Executing this statement prints a two-line heading:

```
Item    Unit    Purchase
        Price   Date
```

- Another common escape sequence is `\"`, which represents the `"` character:

```
printf("\"Hello!\"");/* prints "Hello!" */
```

- To print a single `\` character, put two `\` characters in the string:

```
printf("\\");  /* prints one \ character */
```

The `scanf` Function

- A `scanf` format string may contain both ordinary characters and conversion specifications.
- The conversions allowed with `scanf` are essentially the same as those used with `printf`.
- When using `scanf`, the programmer must check that the number of conversion specifications matches the number of input variables and that each conversion is appropriate for the corresponding variable.
- The `&` symbol, which normally precedes each variable, is usually (but not always) required, and it's the programmer's responsibility to remember to use it.

The `scanf` Function (cont.)

- In many cases, a `scanf` format string will contain only conversion specifications:

```
int i, j;
float x, y;

scanf("%d%d%f%f", &i, &j, &x, &y);
```

- Sample input:

```
1 -20 .3 -4.0e3
```

`scanf` will assign 1, –20, 0.3, and –4000.0 to `i`, `j`, `x`, and `y`, respectively.

How **`scanf`** Works

- `scanf` tries to match groups of input characters with conversion specifications in the format string.
- For each conversion specification, `scanf` tries to locate an item of the appropriate type in the input data, skipping blank space if necessary.
- `scanf` then reads the item, stopping when it reaches a character that can't belong to the item.
  - If the item was read successfully, `scanf` continues processing the rest of the format string.
  - If not, `scanf` returns immediately.

How **scanf** Works (cont.)

- As it searches for a number, `scanf` ignores ***white-space characters*** (space, horizontal and vertical tab, form-feed, and new-line).
- A call of `scanf` that reads four numbers:

```
scanf("%d%d%f%f", &i, &j, &x, &y);
```

- The numbers can be on one line or spread over several lines:

```
   1
-20   .3
   -4.0e3
```

- `scanf` sees a stream of characters (¤ represents new-line):

```
••1¤-20•••.3¤•••-4.0e3¤
ssrsrrrsssrrssssrrrrrr
```

(`s` = skipped; `r` = read)

- `scanf` "peeks" at the final new-line without reading it.

How **`scanf`** Works (cont.)

- When asked to read an integer, `scanf` first searches for a digit, a plus sign, or a minus sign; it then reads digits until it reaches a nondigit.
- When asked to read a floating-point number, `scanf` looks for
  - a plus or minus sign (optional), followed by
  - digits (possibly containing a decimal point), followed by
  - an *exponent* (optional). An exponent consists of the letter `e` (or `E`), an optional sign, and one or more digits.
- `%e`, `%f`, and `%g` are interchangeable when used with `scanf`.

How **scanf** Works (cont.)

- When `scanf` encounters a character that can't be part of the current item, the character is "put back" to input buffer (to be read again later).
- Sample input:

  `1-20.3-4.0e3¤`
- The call of `scanf` is the same as before:

  ```
  scanf("%d%d%f%f", &i, &j, &x, &y);
  ```
- Here's how `scanf` would process the new input:
  - `%d`. Stores 1 into `i` and puts the `-` character back.
  - `%d`. Stores –20 into `j` and puts the `.` character back.
  - `%f`. Stores 0.3 into `x` and puts the `-` character back.
  - `%f`. Stores -4.0×10^3 into `y` and puts the new-line character back.

Ordinary Characters in Format Strings

`"%d %d"`

- When it encounters one or more white-space characters in a format string, `scanf` reads white-space characters from the input until it reaches a non-white-space character (which is “put back”).

`"%d/%d"`

- When it encounters a non-white-space character in a format string, `scanf` compares it with the next input character.
  - If they match, `scanf` discards the input character and continues processing the format string.
  - If they don’t match, `scanf` puts the offending character back into the input, then aborts.

Ordinary Characters in Format Strings (cont.)

- Examples:
  - If the format string is `"%d/%d"` and the input is `•5/•96`, `scanf` succeeds.
  - If the input is `•5•/•96` , `scanf` fails, because the `/` in the format string doesn't match the space in the input.
- To allow spaces after the first number, use the format string `"%d /%d"` instead.

Confusing **`printf`** with **`scanf`**

- Although calls of `scanf` and `printf` may appear similar, there are significant differences between the two.
- One common mistake is to put `&` in front of variables in a call of `printf`:

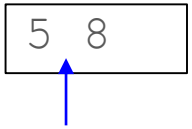
```
printf("%d %d\n", &i, &j);  /*** WRONG ***/
```

Confusing **`printf`** with **`scanf`** (cont.)

- Consider the following call of `scanf`:

```
scanf("%d, %d", &i, &j);
```

  - `scanf` will first look for an integer in the input, which it stores in the variable `i`.
  - `scanf` will then try to match a comma with the next input character.
  - If the next input character is a space, not a comma, `scanf` will terminate without reading a value for `j`.



Confusing `printf` with `scanf` (cont.)

- Putting a new-line character at the end of a `scanf` format string is usually a bad idea.
- To `scanf`, a new-line character in a format string is equivalent to a space; both cause `scanf` to advance to the next non-white-space character.
- If the format string is `"%d\n"`, `scanf` will skip white space, read an integer, then skip to the next non-white-space character.
- A format string like this can cause an interactive program to "hang."

Program: Adding Fractions

```
/* Adds two fractions */   addfrac.c
#include <stdio.h>
int main(void)
{
  int num1, denom1, num2, denom2, result_num, result_denom;

  printf("Enter first fraction: ");
  scanf("%d/%d", &num1, &denom1);

  printf("Enter second fraction: ");
  scanf("%d/%d", &num2, &denom2);

  result_num = num1 * denom2 + num2 *denom1;
  result_denom = denom1 * denom2;
  printf("The sum is %d/%d\n",result_num, result_denom);

  return 0;
}
```

```
Enter first fraction: 5/6
Enter second fraction: 3/4
The sum is 38/24
```

A Quick Review to This Lecture

- The `printf()` function

```
printf(string, expr1, expr2, …);
```

  - Format string
    - ordinary character (abcd)
    - conversion specifications (%d, %f, %e, %g)
- Conversion specification for X: %m.pX or %-m.pX (right or left justification)
  - m: minimum field width
  - p: precision
- Escape Sequences (\n \t \" \\ \a \b)

A Quick Review to This Lecture (cont.)

- The `scanf()` function

```
scanf("%d%d%f%f", &i, &j, &x, &y);
```

- Format string similar to that for `printf()`
  - `%e`, `%f`, and `%g` are interchangeable with `scanf`.
- In most cases, put `&` symbol in front of each variable
- Ordinary characters in format string
  - White-space: read white spaces until reaching non-white-space
  - Non-white-space:
    - Match: discard char. and continue reading
    - Not match: put back char. and abort reading

`"%d %d"`

`"%d/%d"`

A Quick Review to This Lecture (cont.)

- Confusing `scanf()` and `printf()`
  - Put `&` in front of variables in `printf`:

```
printf("%d %d\n", &i, &j);
```

will print out unexpected value

  - Put unnecessary char. in format string in `scanf`:

```
scanf("%d, %d", &i, &j);
```

may terminate without reading the unnecessary char.

  - Put a new-line char. at the end of a `scanf` format string :

```
scanf("%d\n", &i);
```

may cause an interactive program to "hang."