

Announcements

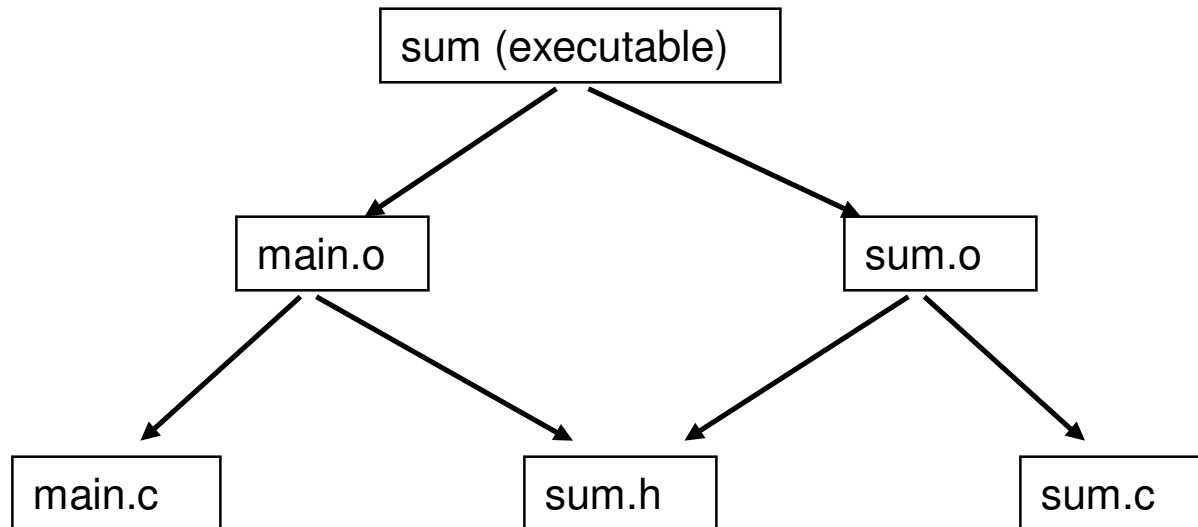
- Program #1A
 - due one week from today (next Thursday)
- Submit
 - be careful of spelling of things like “Invalid” and “Instruction”
 - for this project they are all public tests
- Environment
 - must use Linux
- Reading
 - Should have already read Chapter 1-4
 - Chapter 7 [skip 7.6] (by next class)
- Email
 - send mail from a umd account only
 - spam filters discarding aol, hotmail, etc. e-mails

Make: A Tool to Compile Programs

- Problem: Compiling programs is often tedious, accident prone and wasteful of time
- Solution: Automate it!
- Done in Unix by the make command
 - Uses a file called Makefile
 - A makefile is a file (script) containing :
 - Project structure (files, dependencies)
 - Instructions for file creation
- Make is not limited to C programs

Describing Files to Make

- Makefile contains project dependencies
 - represented as a DAG (= Directed Acyclic Graph)
- Example:
 - Program contains 3 files
 - main.c, sum.c, sum.h
 - sum.h included in both .c files
 - Executable should be the file named sum



Makefile for Previous Example

```
sum: main.o sum.o
```

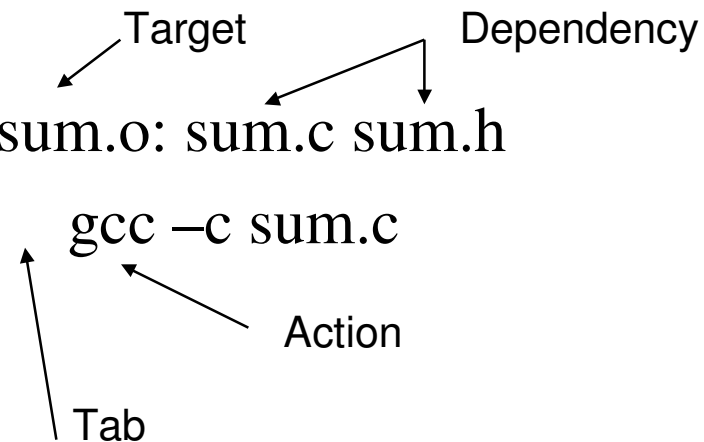
```
    gcc -o sum main.o sum.o
```

```
main.o: main.c sum.h
```

```
    gcc -c main.c
```

```
sum.o: sum.c sum.h
```

```
    gcc -c sum.c
```



- Notes About Makefiles:

- Target is first item in a dependency
- Items after ":" required to build target
- Actions must have a tab at start
- First target in file is the default root

Make's Operation

- Project dependencies tree is constructed
- A target is out of date when any one of its dependencies (directly or indirectly) is newer than itself.
- If out of date, recreate the target
 - Perform action specified
 - Done on the way up the tree
- touch
 - UNIX command that allows you to change the modification time
 - don't use this unless you are sure (can prevent necessary compilations)
- Notes:
 - make ensures minimum compilation, with proper project structure
 - Avoid writing something like:
 prog: main.c sum1.c sum2.c sum.h
 gcc -o prog main.c sum1.c sum2.c
 - this requires full compilation when something changes

Additional Make Features

- Macros

- `<variable> = <value>`
- Example:
 `CC = gcc`
 `CFLAGS = -g -Wall`
 `Foo.o: foo.c foo.h`
 `$(CC) $(CFLAGS) -c foo.c`

```
Foo.o: foo.c foo.h
      gcc -g -Wall -c foo.c
```

- Default or Implied Action

- `$(CC) -c $(CFLAGS)`

- Default or Implied Dependencies

- `xxx.o` must be created from a source file named `xxx.?`
- in our case `xxx.o` comes from `xxx.c`

- Actions can sometimes delete files not create them

- Example:
 `clean:`
 `rm *.o`

More Complex Makefile

Created for Class Example

all: intCount table

Two top-level programs

clean:

rm -f *.o *.bb *.bbg *.da *.png

Not part of main tree
built by typing "make clean"

intCount: intCount.o

\$(CC) -o intCount intCount.o

table: table.o main.o hashTable.o

\$(CC) -o table table.o main.o hashTable.o

Links together several files

table.o: table.c table.h

hashTable.o: hashTable.c table.h

main.o: main.c table.h

intCount.o: table.h

Uses Default Rule

CC = gcc

CFLAGS = -g -Wall

Macro Definitions

Data Types in C

- Integer Family

<u>name</u>	<u>minimum by ANSI standard</u>	<u>ours</u>
– char	8 bits	8 bits
– short	16 bits	16 bits
– int	16 bits	32 bits
– long	32 bits	32 bits
– long long	64 bits	64 bits

- Floating Point

– float	32 bits	32 bits
– double	64 bits	64 bits
– long double	80 bits	96 bits

- Signed by default, but all can be made unsigned

- integer types are defined in the ANSI standard: unsigned int or unsigned long
- unsigned floating types are not in the ANSI standard but are on some compilers

- Literals (examples)

- Decimal 255
- negative signed decimal int -255
- Hex 0xff
- floating point types: 3.14159, 1E10, 25., 6.023e23
- Characters: 'a', '\n'
- C-Strings: "a long dull string", "\n", ""

Data Types in C (cont.)

● Pointers

- holds an address
- points to a specific storage space
- usually declared to point to a space of a certain type
- space pointed at can be dynamically allocated (later) but this is not necessary

```
#include <stdio.h>
```

```
int main(){
```

```
    double a;
```

```
    double *b;
```

```
    printf("size of a is %d and size of b = %d\n", sizeof(a), sizeof(b));
```

```
    a = 5;
```

```
    b = &a;
```

```
    printf("a = %.2f and b indicates %.2f\n", a, *b);
```

```
    a = 21;
```

```
    printf("a = %.2f and b indicates %.2f\n", a, *b);
```

```
    return 0;
```

```
}
```

Data Types in C (cont.)

● Enumerated Types

- Declaring an enumerated type:
 - `enum opType { plusOperator, minusOperator };`
- Declaring a variable of an enumerated type:
 - `enum opType opName;`
- Using an enumerated type in an expression:
 - `opName = plusOperator;`
- Can control values of enumerated type:
 - `enum opType { plusOperator=3, minusOperator =8};`

```
#include <stdio.h>
int main(void){
    enum opType {plusOperator, minusOperator};
    enum opType opName1, opName2;
    opName1 = minusOperator;  opName2 = plusOperator;
    if (opName1 < opName2)
        printf("first is less\n");
    else
        printf("second is less\n");
    printf("first is %d and second is %d\n",opName1, opName2);
    return 0;
}
```

Variable Declarations

- `<type> <variable1>, <variable2>, ... ;`
 - `int a, b, c;`
 - `short d;   or   short int d;`
- Variables names
 - May not be reserved words
 - May contain alphanumeric characters and underscore
 - (A-Z, a-z, 0-9, and “_”)
 - examples:
 - `aValid_Variable_Name`
 - `aValid_Variable_Name_2`
 - `a2`
 - Must start with non-numeric: A-Z, a-z or _
- May initialize variables as part of declaration
 - `int a = 4;`
- Implicit Declarations (Book section 3.2.4)
 - Skip section book and don't ever use

Simple Arrays

- Array dimensions must be known at compile time
- Array Declaration
 - `int a[10];` `/* array of 10 integers */`
 - really one big chunk of space – big enough for 10 integers
- Accessing array elements
 - Arrays start from 0 and go to n-1 elements
 - Compiler will let programmer access invalid elements
 - Can lead to many problems that are hard to find
 - mathematically calculates the “offset”
 - Examples of array references (assume: `int i = 2`);
 - `a[0]`
 - `a[i]`
 - `a[i+3]`
 - what if `int i = 7;` ??

Typedef

- Sometimes you want to name your own type
 - Makes program easier to read
 - Makes it easier to change types later
- `typedef double dollars;`

Variable Scope

- File Scope
 - Entire file
 - Not declared inside any function
- Block Scope
 - Before any executable statement in a block of code { .. }
- Repeating same variables in nested scope is allowed but should be avoided!!

```
main() {  
    int a;  
    { int a; a = 3; }  
}
```

Storage and Linkage

- Linkage

- Determines how multi-file visibility issues are resolved
- extern - There is only one instance of this variable
- static - This variable is private to this file

foo.c:

static int a;

bar.c:

static int a;

- Storage Classes

- Default is automatic:
 - one variable instance per function instance
 - lifetime limited to while function is active
 - running or in called subroutine
- Static changes default
 - one variable instance
 - lifetime is the current run of the entire program

Storage Class and Linkage Example

```
#include <stdio.h>
#include "funct.h"
```

```
extern int a;
static int b = 3;
```

```
int main(void){
    printf("%d and %d\n", a,b);
    funct1();
    printf("%d and %d\n", a,b);
    funct1();
    printf("%d and %d\n", a,b);
    return 0;
}
```

```
#include <stdio.h>
#include "funct.h"
```

```
int a = 33;
static int b = 99;
```

```
void funct1(void){
    int m = 3;
    static int n = 5;
    printf("at beginning of function a = %d and b = %d\n",a,b);
    printf("and m = %d and n = %d\n",m,n);
    a = 27, b = 20;
    m += 100; n += 200;
    printf("at beginning of function a = %d and b = %d\n",a,b);
    printf("and m = %d and n = %d\n",m,n);
    return;
}
```

33 and 3

at beginning of function a = 33 and b = 99
and m = 3 and n = 5

at beginning of function a = 27 and b = 20
and m = 103 and n = 205

27 and 3

at beginning of function a = 27 and b = 20
and m = 3 and n = 205

at beginning of function a = 27 and b = 20
and m = 103 and n = 405