Week 6: Miscellaneous C and Makefiles

- Assignment 2 is posted
- There is a lab for this week. It will be posted later today.
  - short PCRS question on Makefiles
  - complete some code to submit on MarkUs (related to A2)

External and static variables

- External variable: declared outside the body of a function
- File scope: visible from the point of the declaration to the end of the file.
- Static storage duration: through the duration of the program.
- External/global variables have file scope and static storage duration.

static variables

```
static int i;
```

restricted scope in current file

```
void f(void) {
   static int j;
}
```

?

- static used outside a block means that the variable is only visible in the file in which it is declared
- static used in a block means that the variable lives beyond the duration of the block, and is initialized only once.

Example

```
#include <stdio.h>

int nextvalue()
{
    static int i = 0;
    i++;
    return i;
}

int main()
{
    int i;
    for(i = 10; i > 0; i--) {
        printf("%d\n", nextvalue());
    }
    return 0;
}
```

```
output:
1
2
3
4
5
6
7
8
9
10
```

extern

filea.c

```
extern int i;

void f(void) {
     i++;
}
```

fileb.c

```
int i = 0;
extern void f(void);

void g(void) {
     f();
     printf("%d\n", i);
}
```

- informs the compiler that `i` is an `int` variable, but doesn't cause it to allocate space.

typedef

- You can define new types using `typedef`.
- You have already seen the effects of typedef

```
typedef unsigned int size_t;
```

- Example

```
struct personrec {
   char name[20];
   int age;
};
typedef struct personrec Person;
Person *p = malloc(sizeof(Person));
```

typedef

- Example

```
typedef struct {
   char name[20];
   int age;
} Person;

Person *p = malloc(sizeof(Person));
```

Header files

- When you begin to split up your C program into multiple files, you need header files to store function and type declarations.

header file
1. should not allocate space
2. should not put body of function

main.c

```
void add(int);
int isEmpty();
extern List *head;
int main()
{
    add(10);
    isEmpty();
    head = NULL;
}
```

list.c

```
List *head = NULL;
int isEmpty()
{...}
void add(int v)
{...}
void remove(int v)
{...}
```

have to add function signature everytime want to use external function

a list of common definition in header file

list.h

```
struct node {
     int value;
     struct node * next;
} ;
typedef struct node List;
extern List *head;
int isEmpty(int);
void add(int);
void remove(int)
```

main.c

```
#include "list.h"

int main()
{
    add(10);
    isEmpty();
    head = NULL;
}
```

head in main uses memory allocated in list

list.c

```
#include "list.h"
List *head = NULL;
int isEmpty()
{...}
void add(int v)
{...}
void remove(int v)
{...}
```


head defined in individual c file because they are different things

list.h

```
struct node {
     int value;
     struct node * next;
} ;
typedef struct node List;
List *head = NULL;
int isEmpty();
void add(int);
void remove(int)
```

Wrong!

main.c

```
#include "list.h"

int main()
{
   add(10);
   isEmpty();
}
```

list.c

```
#include "list.h"

int isEmpty()
{...}
void add(int v)
{...}
void remove(int v)
{...}
```

Wrong!

main.c

```
#include "list.c"

int main()
{
    add(10);
    isEmpty();
}
```

list.c

```
List *head = NULL;
int isEmpty()
{...}
void add(int v)
{...}
void remove(int v)
{...}
```

list.h

```
struct node {
     int value;
     struct node * next;
} ;
typedef struct node List;

int isEmpty(List *);
void add(List *, int);
void remove(List *, int)
```

Allows more than one List to be used

main.c

```
#include "list.h"

int main()
{
   List *list1 = NULL;
   add(list1, 10);
   isEmpty(list1);
}
```

list.c

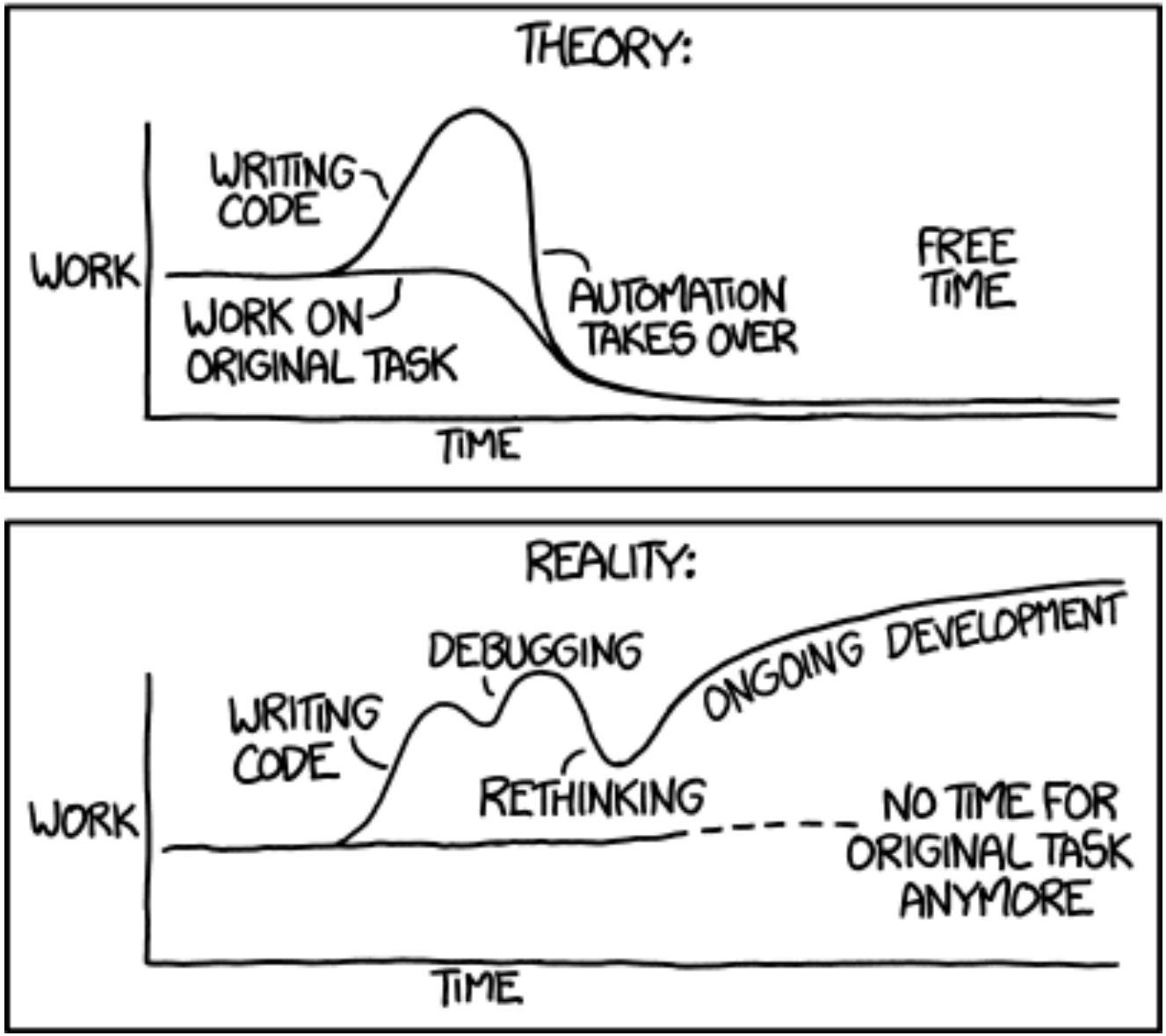
```
#include "list.h"

int isEmpty(List *h)
{...}
void add(List *h, int v)
{...}
void remove(List *h, int v)
{...}
```

Protecting header files

- Compilation errors may result if a header file is included more than once.
- This causes a problem if the header file defines types.
- Use preprocessor directives to selectively compile.

```
#ifndef LIST_H
#define LIST_H
...(contents of the header file)
#endif
```

"I SPEND A LOT OF TIME ON THIS TASK.
I SHOULD WRITE A PROGRAM AUTOMATING IT!"



xkcd.com

Makefiles

- Makefiles were originally designed to support separate compilation of C files.

```
testlist : testlist.o list.o test1.o
        gcc -Wall -g -o testlist testlist.o list.o test1.o

testlist.o : testlist.c
        gcc -Wall -g -c testlist.c

list.o : list.c list.h
        gcc -Wall -g -c list.c

test1.o : test1.c  list.h
        gcc -Wall -g -c test1.c
```

Terminology

Target

Prerequiste(s)

```
reverse : reverse.c
    gcc -Wall -o reverse reverse.c
```

Rule

do not have to rebuild file that is up to date

Actions(s)

- May be many prerequisites (dependency)
- Rule may have many actions (one per line)

Running make

- `make`
  - with no options looks for a file called Makefile, and evaluates the first rule
- `make query`
  - Looks for a file called Makefile and looks for a rule with the target `query` and evaluates it.

How it works

- Make looks at the when the target and its prerequisites were last modified
  - It assumes targets are files and checks the dates of the files
- Make does nothing…
  - If the target exists, and
  - Is more recent than all its prerequisites
- Make executes the actions…
  - If the target doesn't exist, or
  - If any prerequisite is more recent than the target

Variables

```
CFLAGS= -g -Wall
reverse : reverse.c
  gcc ${CFLAGS} -o reverse
  reverse.c
```

Make defines variables to represent parts of rules

$@	Target
$<	First prerequisite
$?	All out of date prerequisites
$^	All prerequisites

Example

```
all : packetize read_stream
```

all -> packetize -> recursively compile update this list of files

```
packetize : packetize.o crc16.o list.o data.h
     gcc -Wall -g -o packetize packetize.o list.o
crc16.o

read_stream : read_stream.o crc16.o list.o data.h
     gcc -Wall -g -o read_stream read_stream.o
list.o crc16.o

crc16.o : crc16.c data.h
     gcc -Wall -g -c crc16.c
list.o : list.c data.h
        gcc -Wall -g -c list.c
packetize.o : packetize.c data.h
        gcc -Wall -g -c packetize.c
read_stream.o : read_stream.c data.h
        gcc -Wall -g -c read_stream.c
```

Example

```
all : packetize read_stream

packetize : packetize.o crc16.o list.o data.h
     gcc -Wall -g -o $@ $^

read_stream : read_stream.o crc16.o list.o data.h
     gcc -Wall -g -o $@ $^

%.o : %.c data.h
     gcc -Wall -g -c $<
```

note do not put header file in compile line

why first prereq here: BECAUSE do not need header file, they are included with #include “data.h” by compiler
But data.h is here in dependencies because want to recompile if header file changes

Pattern rules

Most files are compiled the same way

- So write a pattern rule for the general case

```
%.o : %.c
   gcc ${CFLAGS} –c $<
```

- Use % to mark the stem of the file's name
- Like using * in commands in Unix

-c flag in gcc does compilation of file without linking.

Multiple Targets and Phony Targets

- Often you want one command to build a number of other targets

all is phony because it cannot be a file

```
all : packetize readstream

packetize : …

   …

readstream : …
```

Or targets aren't building anything

```
clean:
        rm *.o packetize readstream
```

no prereq always run if do make clean