

# Programming in C and C++

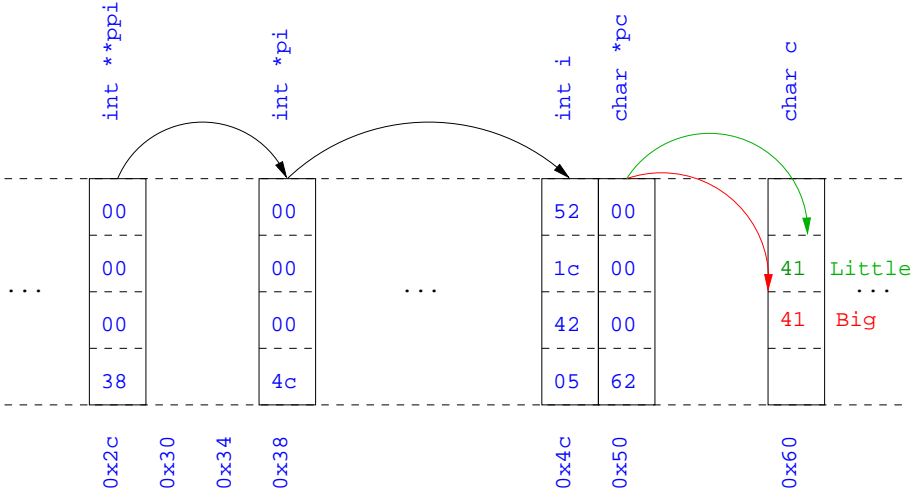
## 4. Misc. — Library Features — Gotchas — Hints 'n' Tips

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(based on previous years –  
thanks to Alan Mycroft, Alastair Beresford and Andrew Moore)

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# Example



## Uses of const and volatile

- ▶ Any declaration can be prefixed with `const` or `volatile`
- ▶ A `const` variable can only be assigned a value when it is defined
- ▶ The `const` declaration can also be used for parameters in a function definition
- ▶ The `volatile` keyword can be used to state that a variable may be changed by hardware or the kernel.
  - ▶ For example, the `volatile` keyword may prevent unsafe compiler optimisations for memory-mapped input/output
- ▶ The use of pointers and the `const` keyword is quite subtle:
  - ▶ `const int *p` is a pointer to a `const` int
  - ▶ `int const *p` is also a pointer to a `const` int
  - ▶ `int *const p` is a `const` pointer to an int
  - ▶ `const int *const p` is a `const` pointer to a `const` int

## Example

```
1 int main(void) {
2     int i = 42;
3     int j = 28;
4
5     const int *pc = &i;           //Also: "int const *pc"
6     *pc = 41;                    //Wrong
7     pc = &j;
8
9     int *const cp = &i;
10    *cp = 41;
11    cp = &j;                       //Wrong
12
13    const int *const cpc = &i;
14    *cpc = 41;                     //Wrong
15    cpc = &j;                       //Wrong
16    return 0;
17 }
```

# Typedefs

- ▶ The `typedef` operator, creates a synonym for a data type; for example, `typedef unsigned int Radius;`
- ▶ Once a new data type has been created, it can be used in place of the usual type name in declarations and casts; for example, `Radius r = 5; ...; r = (Radius) rshort;`
- ▶ A `typedef` declaration does not create a new type
  - ▶ It just creates a synonym for an existing type
- ▶ A `typedef` is particularly useful with structures and unions:

```
1 typedef struct llist *llptr;
2 typedef struct llist {
3     int val;
4     llptr next;
5 } linklist;
```

## Inline functions

- ▶ A function in C can be declared `inline`; for example:

```
1 inline int fact(unsigned int n) {  
2     return n ? n*fact(n-1) : 1;  
3 }
```

- ▶ The compiler will then try to “inline” the function
  - ▶ A clever compiler might generate `120` for `fact(5)`
- ▶ A compiler might not always be able to “inline” a function
- ▶ An `inline` function must be defined in the same execution unit as it is used
- ▶ The `inline` operator does not change function semantics
  - ▶ the inline function itself still has a unique address
  - ▶ static variables of an inline function still have a unique address
- ▶ Both `inline` and `register` are largely unnecessary with modern compilers and hardware

# That's it!

- ▶ We have now explored most of the C language
- ▶ The language is quite subtle in places; in particular watch out for:
  - ▶ operator precedence
  - ▶ pointer assignment (particularly function pointers)
  - ▶ implicit casts between `ints` of different sizes and `chars`
- ▶ There is also extensive standard library support, including:
  - ▶ shell and file I/O (`stdio.h`)
  - ▶ dynamic memory allocation (`stdlib.h`)
  - ▶ string manipulation (`string.h`)
  - ▶ character class tests (`ctype.h`)
  - ▶ ...
  - ▶ (Read, for example, K&R Appendix B for a quick introduction)
  - ▶ (Or type “`man function`” at a Unix shell for details)

## Library support: I/O

I/O is not managed directly by the compiler; support in `stdio.h`:

- ▶ `FILE *stdin, *stdout, *stderr;`
- ▶ `int printf(const char *format, ...);`
- ▶ `int sprintf(char *str, const char *format, ...);`
- ▶ `int fprintf(FILE *stream, const char *format, ...);`
- ▶ `int scanf(const char *format, ...); // sscanf, fscanf`
  
- ▶ `FILE *fopen(const char *path, const char *mode);`
- ▶ `int fclose(FILE *fp);`
- ▶ `size_t fread(void *ptr, size_t size, size_t nmemb, FILE *stream);`
- ▶ `size_t fwrite(const void *ptr, size_t size, size_t nmemb, FILE *stream);`



```
1 #include<stdio.h>
2 #define BUFSIZE 1024
3
4 int main(void) {
5     FILE *fp;
6     char buffer[BUFSIZE];
7
8     if ((fp=fopen("somefile.txt","rb")) == 0) {
9         perror("fopen error:");
10        return 1;
11    }
12
13    while(!feof(fp)) {
14        int r = fread(buffer,sizeof(char),BUFSIZE,fp);
15        fwrite(buffer,sizeof(char),r,stdout);
16    }
17
18    fclose(fp);
19    return 0;
20 }
```

## Library support: dynamic memory allocation

- ▶ Dynamic memory allocation is not managed directly by the C compiler
- ▶ Support is available in `stdlib.h`:
  - ▶ `void *malloc(size_t size)`
  - ▶ `void *calloc(size_t nobj, size_t size)`
  - ▶ `void *realloc(void *p, size_t size)`
  - ▶ `void free(void *p)`
- ▶ The C `sizeof` unary operator is handy when using `malloc`:  
`p = (char *) malloc(sizeof(char)*1000)`
- ▶ Any successfully allocated memory must be deallocated manually
  - ▶ Note: `free()` needs the pointer to the allocated memory
- ▶ Failure to deallocate will result in a memory leak

## Gotchas: operator precedence

```
1 #include<stdio.h>
2
3 struct test {int i;};
4 typedef struct test test_t;
5
6 int main(void) {
7
8     test_t a,b;
9     test_t *p[] = {&a,&b};
10    p[0]->i=0;
11    p[1]->i=0;
12    test_t *q = p[0];
13
14    printf("%d\n",++q->i); //What does this do?
15
16    return 0;
17 }
```

## Gotchas: `i++`

```
1 #include <stdio.h>
2
3 int main(void) {
4
5     int i=2;
6     int j=i++ + ++i;
7     printf("%d %d\n",i,j); //What does this print?
8
9     return 0;
10 }
```

Expressions like `i++ + ++i` are known as grey (or gray) expressions in that their meaning is compiler dependent in C (even if they are defined in Java)

## Gotchas: local stack

```
1 #include <stdio.h>
2
3 char *unary(unsigned short s) {
4     char local[s+1];
5     int i;
6     for (i=0;i<s;i++) local[i]='1';
7     local[s]='\0';
8     return local;
9 }
10
11 int main(void) {
12     printf("%s\n",unary(6)); //What does this print?
13     return 0;
14 }
```

## Gotchas: local stack (contd.)

```
1 #include <stdio.h>
2
3 char global[10];
4
5 char *unary(unsigned short s) {
6     char local[s+1];
7     char *p = s%2 ? global : local;
8     int i;
9     for (i=0;i<s;i++) p[i]='1';
10    p[s]='\0';
11    return p;
12 }
13
14 int main(void) {
15     printf("%s\n",unary(6)); //What does this print?
16     return 0;
17 }
```

## Gotchas: careful with pointers

```
1 #include <stdio.h>
2
3 struct values { int a; int b; };
4
5 int main(void) {
6     struct values test2 = {2,3};
7     struct values test1 = {0,1};
8
9     int *pi = &(test1.a);
10    pi += 1; //Is this sensible?
11    printf("%d\n",*pi);
12    pi += 2; //What could this point at?
13    printf("%d\n",*pi);
14
15    return 0;
16 }
```

## Gotchas: XKCD pointers





## Tricks: Duff's device

```
1 boring_send(int *to, int *from, int count) {
2     do {
3         *to = *from++;
4     } while(--count > 0);
5 }
6
7 send(int *to, int *from, int count) {
8     int n = (count+7)/8;
9     switch (count%8) {
10    case 0: do{ *to = *from++;
11    case 7:     *to = *from++;
12    case 6:     *to = *from++;
13    case 5:     *to = *from++;
14    case 4:     *to = *from++;
15    case 3:     *to = *from++;
16    case 2:     *to = *from++;
17    case 1:     *to = *from++;
18                } while(--n>0);
19 }
```

## Assessed exercise

See “Head of Department’s Announcement”

- ▶ To be completed by noon on Monday 8th February 2016
- ▶ Viva examinations 1300-1600 on 12th February 2016
- ▶ Viva examinations 1300-1600 on 13th February 2016
- ▶ Download the starter pack from:  
<http://www.cl.cam.ac.uk/Teaching/current/CandC++/>
- ▶ This should contain eight files:  
server.c    rfc0791.txt    message1    message3  
client.c    rfc0793.txt    message2    message4

## Exercise aims

Demonstrate an ability to:

- ▶ Understand (simple) networking code
- ▶ Use control flow, functions, structures and pointers
- ▶ Use libraries, including reading and writing files
- ▶ Understand a specification
- ▶ Compile and test code
- ▶ Comprehending man pages

Task is split into three parts:

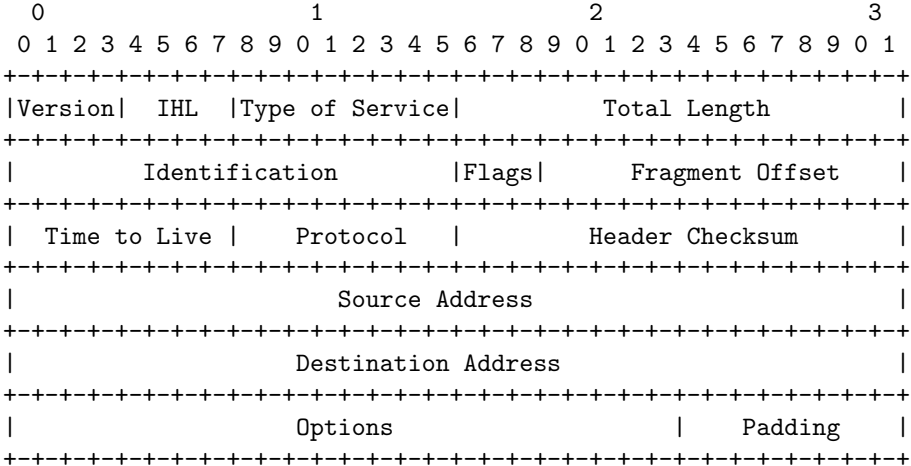
- ▶ Comprehension and debugging
- ▶ Preliminary analysis
- ▶ Completed code and testing

## Exercise submission

- ▶ Assessment is in the form of a 'tick'
- ▶ There will be a short viva; remember to sign up!
- ▶ Submission is via email to `c-tick@cl.cam.ac.uk`
- ▶ Your submission should include seven files, packed in to a ZIP file called crsid.zip and attached to your submission email:

```
answers.txt      client1.c      summary.c      message1.txt  
                 server1.c      extract.c      message2.jpg
```

# Hints: IP header



## Hints: IP header (in C)

```
1 #include <stdint.h>
2
3 struct ip {
4     uint8_t hlenver;
5     uint8_t tos;
6     uint16_t len;
7     uint16_t id;
8     uint16_t off;
9     uint8_t ttl;
10    uint8_t p;
11    uint16_t sum;
12    uint32_t src;
13    uint32_t dst;
14 };
15
16 #define IP_HLEN(lenver) (lenver & 0x0f)
17 #define IP_VER(lenver) (lenver >> 4)
```

## Hints: network byte order

- ▶ The IP network is big-endian; x86 is little-endian; ARM can be either
- ▶ Reading multi-byte values requires possible conversion
- ▶ The BSD API specifies:
  - ▶ `uint16_t ntohs(uint16_t netshort)`
  - ▶ `uint32_t ntohl(uint32_t netlong)`
  - ▶ `uint16_t htons(uint16_t hostshort)`
  - ▶ `uint32_t htonl(uint32_t hostlong)`

which encapsulate the notions of host and network and their interconversion (which may be a no-op)

## Exercises

1. What is the value of `i` after executing each of the following:
  - 1.1 `i = sizeof(char);`
  - 1.2 `i = sizeof(int);`
  - 1.3 `int a; i = sizeof a;`
  - 1.4 `char b[5]; i = sizeof(b);`
  - 1.5 `char *c=b; i = sizeof(c);`
  - 1.6 `struct {int d;char e;} s; i = sizeof s;`
  - 1.7 `void f(int j[5]) { i = sizeof j;}`
  - 1.8 `void f(int j[][10]) { i = sizeof j;}`
2. Use `struct` to define a data structure suitable for representing a binary tree of integers. Write a function `heapify()`, which takes a pointer to an integer array of values and a pointer to the head of an (empty) tree and builds a binary heap of the integer array values. (Hint: you should `malloc()` and a binary tree data structure)
3. What other C data structure can be used to represent a heap? Would using this structure lead to a more efficient implementation of `heapify()`?