Programming in C

4. Misc. Library Features, Gotchas, Hints and Tips

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(based on notes from and with thanks to Anil Madhavapeddy, Alan Mycroft, Alastair Beresford and Andrew Moore)

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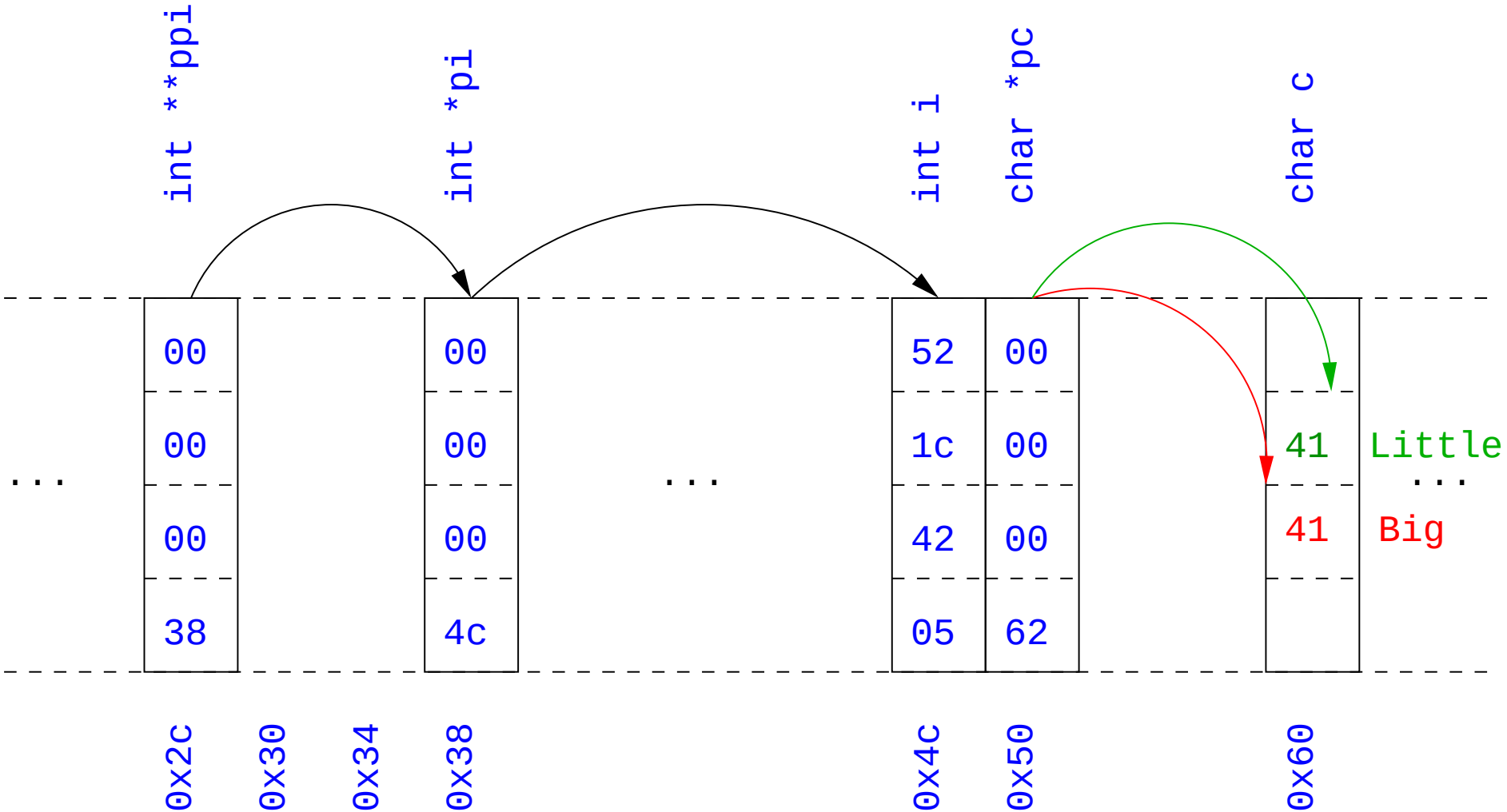
Example


int **ppi
int *pi
int i
char *pc
char c
00
00
00
38
00
00
00
4c
52
1c
42
05
00
00
00
62
41
41
Little
Big
...
...
...
0x2c
0x30
0x34
0x38
0x4c
0x50
0x60

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 `int`s of different sizes and `char`s
- 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);`

```c
#include<stdio.h>
#define BUFSIZE 1024

int main(void) {
  FILE *fp;
  char buffer[BUFSIZE];

  if ((fp=fopen("somefile.txt","rb")) == 0) {
    perror("fopen error:");
    return 1;
  }

  while(!feof(fp)) {
      int r = fread(buffer,sizeof(char),BUFSIZE,fp);
      fwrite(buffer,sizeof(char),r,stdout);
  }

  fclose(fp);
  return 0;
}
```

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

```c
#include<stdio.h>

struct test {int i;};
typedef struct test test_t;

int main(void) {

  test_t a,b;
  test_t *p[] = {&a,&b};
  p[0]->i=0;
  p[1]->i=0;
  test_t *q = p[0];

  printf("%d\n",++q->i); //What does this do?

  return 0;
}
```

Gotchas: `i++`

```c
#include <stdio.h>

int main(void) {

   int i=2;
   int j=i++ + ++i;
   printf("%d %d\n",i,j); //What does this print?

   return 0;
}
```

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 }
```

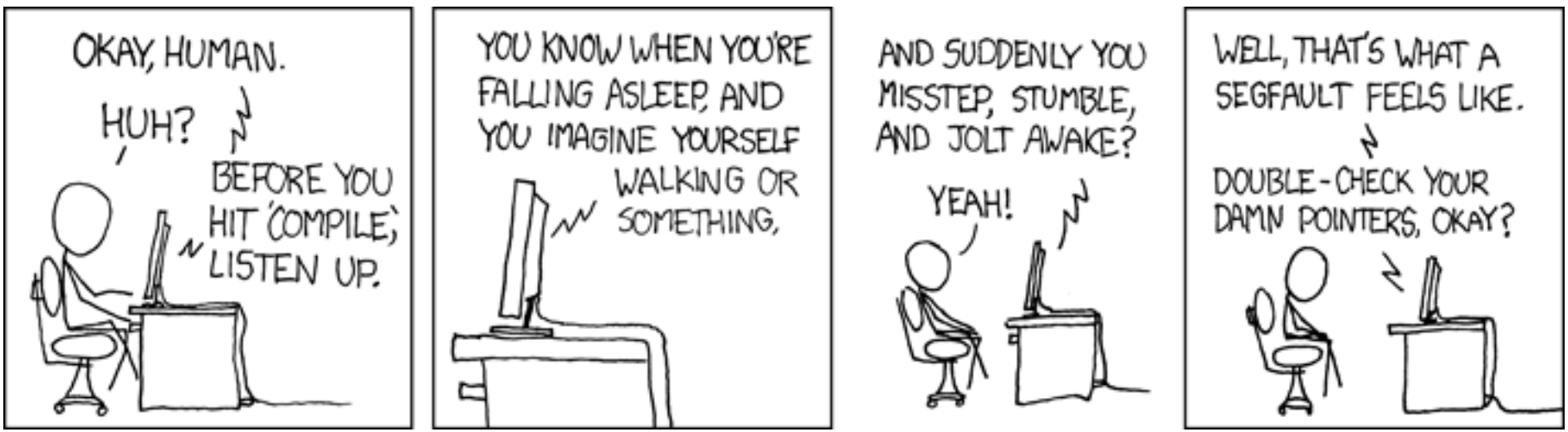
Gotchas: local stack (contd.)

```
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

```c
#include <stdio.h>

struct values { int a; int b; };

int main(void) {
 struct values  test2 = {2,3};
 struct values  test1 = {0,1};

 int *pi = &(test1.a);
 pi += 1; //Is this sensible?
 printf("%d\n",*pi);
 pi += 2; //What could this point at?
 printf("%d\n",*pi);

 return 0;
}
```

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   }
```