Introduction to C

Why use C instead of Java

- Intermediate-level language:
  - Low-level features like raw memory tweaking
  - High-level features like complex data-structures
- Access to all the details of the implementation
  - Explicit memory management
  - Explicit error detection
- More power than Java (so may be made faster)
- All this make C a far better choice for system programming.

Common Syntax with Java

- Basic types are similar (`int`, `short`, `double`…)
- Operators:
  - Arithmetic:

    `+ - * / %`

    `++ -- *= += ...`
  - Relational: `<,>,<=,>=,==,!=`
  - Logical: `&&, ||, !, ? :`
  - Bit: `&,|,^,!,<<,>>`

Common Syntax with Java (cont.)

- Language constructs:

```
if( ) {...} else {...}
while( ) {...}
do {...} while( );
for (i=0; i<100; i++) {...}
switch( ) { case 0: ... break; ... }
break, continue, return
```

- No exception handling statements

➔ most functions return errors as special values (e.g., a negative number). Check for these!

Hello World Example

hello.c

```c
/* Hello World program */
#include <stdio.h>
#include <stdlib.h>

int main(int ac, char **av) {
    printf("Hello World.");
}
```

bash or cmd.exe

```
$ ./hello
Hello World.
```

Primitive Types

- Integer types:
  - **`char`** : used to represent ASCII characters or one byte of data (not 16 bit like in Java)
  - **`int`**, **`short`** and **`long`** : versions of integer (architecture dependent, usually 4, 2, and 4 bytes)
  - **`signed char/short/int/long`**
  - **`unsigned char/short/int/long`**

  ➔ conversion between signed/unsigned often does unexpected things
- Floating point types: **`float`** and **`double`** like in Java.
- No boolean type, int usually used instead.
  - 0 == false
  - everything else == true

Primitive Types Examples

```
char c='A';
char c=65;
int i=-2343234;
unsigned int ui=100000000;

float pi=3.14;
double long_pi=0.31415e+1;
```

Arrays and Strings

- Arrays:

```
int A[10]; // declare and allocate space for array
for (int i=0; i<10; i++) // initialize the elements
     A[i]=0;
```

- Strings: arrays of char terminated by '\0' char

```
char name[] ="CS316"; //{'C','S',‘3','1',‘6','\0'}
name[2] = '3';
name[4]++;
```

  – Strings are mutable
  – Common functions strcpy, strcmp, strcat, strstr, strchr, strdup.
  – Use `#include <string.h>`

Pointers

- An 'address' is an index to a memory location (where some variable is stored).
- A 'pointer' is a variable containing an address to data of a certain type.

Declaring pointer variables:

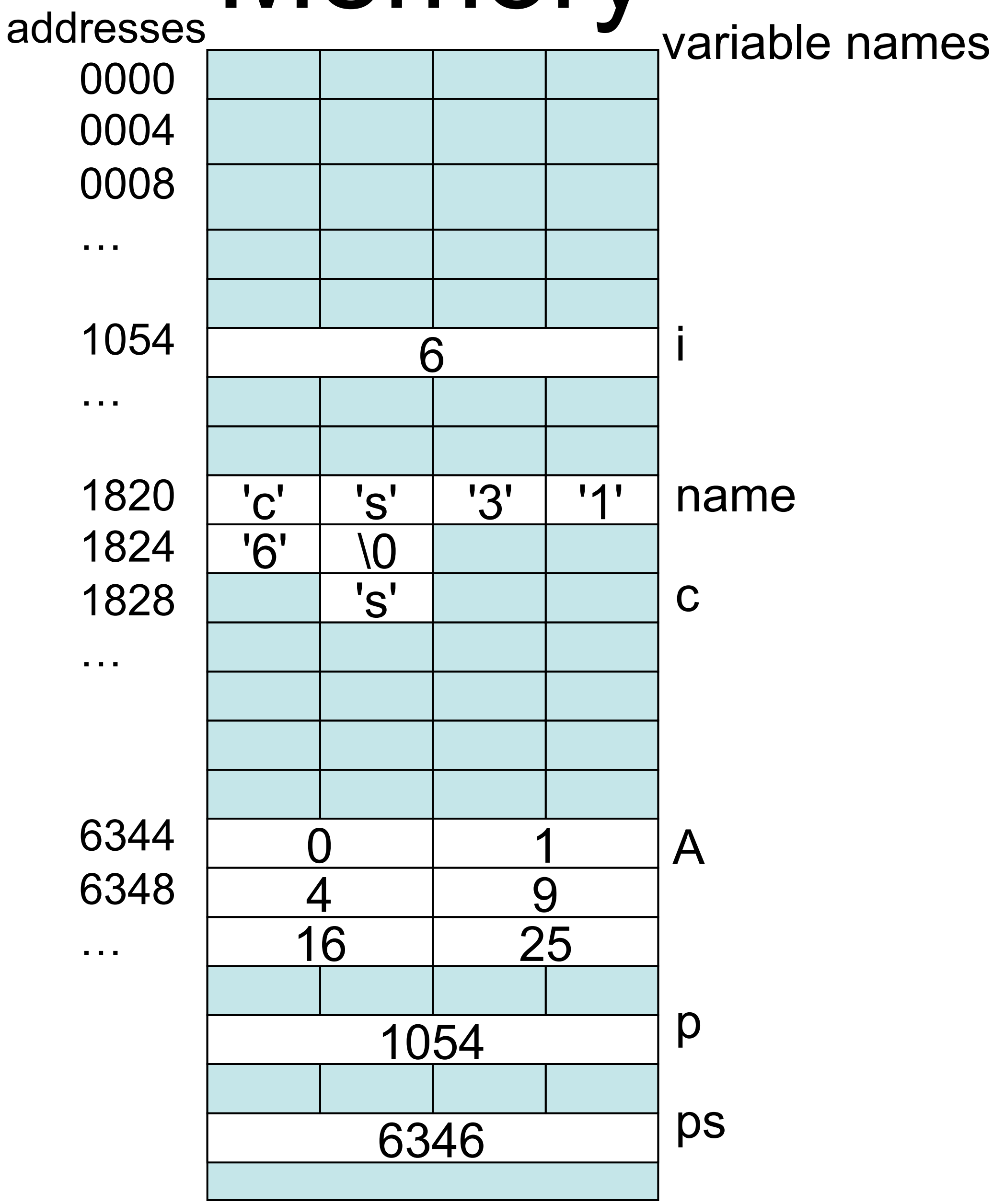
```
int i;
int* p; // p points to some random location - null pointer
```

Creating and using pointer values

```
p = &i; // p points to integer i - p stores the address of i
(*p) = 3; // variable pointed by p takes value 3
```

- & is the address-of operator, * is the dereference operator.
- Similar to references in Java.
- Pointers are nearly identical to arrays in C
  - array variables can not be changed (only the contents can change)

Memory




```
int i = 6;
...
char name[] = "cs316";
...
char c = name[1];
...
short A[6];
for (i = 0; i < 6; i++)
  A[i] = i*i;

int *p;
p = &i;

short *ps;
ps = &A[1];
```

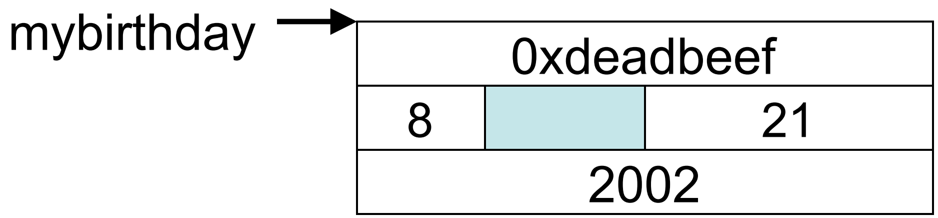
Pointers (cont.)

- ➔ **Attention:** dereferencing an uninitialized pointer can have arbitrary effects (bad!) (including program crash).
- ➔ Dereferencing a NULL pointer will crash the program (better!)
- Advice:
  - initialize with NULL, or some other value
  - if not sure of value, check it before dereferencing

```
if (p == NULL) {
  printf("ack! where's my pointer!\n"); exit(1);
}
```

Structures

- Like Java classes, but only member variables
  - no static variables
  - no functions




```
struct birthday {
     char* name;
     char month;
     short day;
     int year;
};

struct birthday mybirthday = {"elliot",8,21,2002};
mybirthday.name[0] = 'E';
if (mybirthday.month == 6)
   printf("%s is a Cancer\n", mybirthday.name);
```

Structures (cont.)

- Members of a struct can be of any type that is already defined.
- Trick: 'struct X' can contain a pointer to 'struct X'

```
struct intlist {
      int data;
      struct intlist* next;
 };
```

- `->` is syntax sugaring for dereference and take element:

```
struct intlist one = {10, NULL};
struct intlist two = {20, NULL};
struct intlist *head = &one;
one->next = &two;
(*one).next = &two; // Does same thing as previous line
```

printf function

- `printf(formating_string, param1, ...)`
- Formating string: text to be displayed containing special markers where values of parameters will be filled:
  - %d for **`int`**
  - %c for **`char`**
  - %f for **`float`**
  - %g for **`double`**
  - %s for null-terminated strings
- Example:

```
int numstudents = 39;
printf("The number of students in %s is %d.", name,
  numstudents);
```

➔ printf will not complain about wrong types, number of params, etc.

enum: enumerated data-types

```
enum months {
    JANUARY,
    FEBRUARY,
    MARCH,
    ...
};
```

- Each element of enum gets an integer value and can be used as an integer.

```
enum signs {
    CANCER = 6,
    ARIES = 1,
    ...
};
```

Data-type Synonyms

- Syntax: **`typedef X Y;`** **`// Y is a synonym for X`**

```
typedef int CornellID;
CornellID me = 373333;

typedef struct elt* classlist; // bizarre but legal
struct elt {
   CornellID id;
   char *name;
   classlist next; // this is legal
}
```

Memory Allocation and Deallocation

- **Global variables:** declared outside any function.
- Space allocated statically before program execution.
- Initialization statements (if any) done before main() starts.
- Space is deallocated when program finishes.
- Name has to be unique for the whole program.

Memory Allocation and Deallocation

- **Local variables:** declared in the body of a function or inside a '{ }' block.
- Space allocated when entering the function/ block.
- Initialization (if any) before function/block starts.
- Space automatically deallocated when function returns or when block finishes
  - ➔ Attention: referring to a local variable (by means of a pointer for example) after the function returned will cause unexpected behavior.
- Names are visible only within the function/block

Memory Allocation and Deallocation

- **Heap variables**: memory has to be explicitly
  - allocated: **`void* malloc(int)`** (similar to new in Java)

```
char *message = (char *)malloc(100);
intlist *mylist = (intlist *)malloc(sizeof(intlist));
mylist->data = 1;
mylist->next = (intlist *)malloc(sizeof(intlist));
mylist->next->data = 2;
mylist->next->next = NULL;
```

  - deallocated: **`void free(void*)`**

```
free(msg); msg = NULL;
free(mylist->next);
free(mylist);
mylist = NULL;
```

Malloc/Free and pointers

- ➔ You must malloc()
  reading/writing from random addresses is bad.
- ➔ You must malloc() the right amount:
  reading/writing over the end of the space is bad

```
sizeof(struct birthday)
strlen(name)+1; // +1 is for the '\0'
```

- ➔ You must free()
  No garbage collector; if you don't have a free() for every malloc(), you will eventually run out of memory.
- ➔ … but not too much
  Freeing same memory twice is bad ("double free").
- ➔ …and don't use the memory after it is freed
  set pointers to NULL after free.

Memory Allocation and Deallocation

```
struct birthday *clone_student(struct birthday *b) {
    struct birthday *b2 = (struct birthday *)malloc(sizeof(struct birthday));
    b2->name = (char *)malloc(strlen(b->name)+1); // or use strdup()
    memcpy(b2->name, b->name, strlen(b->name)+1);
    b2->day = b->day;
    b2->year = b->year;
    b2->month = b->month;
    return b2;
}

void rename(struct birthday *b, char *new_name) {
    free(b->name); // danger: b->name must be a heap variable
    b->name = strdup(new_name); // same as malloc(...) then memcpy(...)
}
```

Functions

- Can declare using a prototype, then define the body of the function later
  - lets function be used before it is defined.
- Arguments passed by value
  - Use pointers to pass by reference
- Return value passed by value
  - Use malloc()'ed pointer to return by reference

Functions - Basic Example

```
#include <stdio.h>

int sum(int a, int b); // function declaration or
   prototype

int main(int ac, char **av){
    int total = sum(2+2,5); // call function sum with
   parameters 4 and 5
    printf("The total is %d\n", total);
}

/* definition of sum; has to match prototype */
int sum(int a, int b) {// arguments passed by value
    return (a+b); // return by value
}
```

Why pass via pointers?

```
void swap(int, int);
int main(int ac, char **av) {
    int five = 5, ten = 10;
    swap(five, ten);
    printf("five = %d and ten = %d", five, ten);
}
void swap(int n1, int n2) /* pass by value */
    int temp = n1;
    n1 = n2;
    n2 = temp;
}

$ ./swaptest
five = 5 and ten = 10                    NOTHING HAPPENED
```

Why pass by reference?(cont.)

```
void swap(int *, int *);
int main(int ac, char **av) {
    int five = 5, ten = 10;
    swap(&five, &ten);
    printf("five = %d and ten = %d", five, ten);
}
void swap(int *p1, int *p2) /* pass by value */
    int temp = *p1;
    *p1 = *p2;
    *p2 = temp;
}

$ ./swaptest
five = 10 and ten = 5
```

Pointer to Function

```
void kill(int d) { /* do something */ ... }
void eat(int d) { /* do something else */ ... }
typedef void (*simple_function)(int);
      // simple_function is synonym for a pointer to
      // a function returning void and taking an int

void do_stuff(simple_function f, int param) {
     f(param); /* call function f with param */
}

int main(int ac, char **av) {
  kill(3);
  simple_function g = (ac == 1 ? eat : kill);
  do_stuff(g, 8);
}
```

The Preprocessor

- File copy-and-paste

```
/* include standard library declaration */
 #include <stdio.h>
/* include custom declarations */
 #include "myheader.h"
```

- Text substitution

```
#define DEBUG 0
#define MAX_LIST_LENGTH 100
if (DEBUG)
    printf("Max length of list is %d.", MAX_LIST_LENGTH);
```

- Conditional compilation

```
#ifdef DEBUG
    printf("DEBUG: line " _LINE_ " has been reached.");
#endif
```

Programs with Multiple Files

- Header file: my_program.h:
  - function prototypes
  - global variable prototypes: extern int x;
- Program files: one.c, two.c, …
  - each file uses **`#include "my_program.h"`**
  - one of them defines main()
  - each prototype defined in exactly one of the files
- compiler produces one.o, two.o, …
  (or one.obj, two.obj on windows)
- compiler then links together to form program