ECE 220

Lecture x000F - 03/07/24

Recap/reminders

- Last time
  - Streams & buffers
  - File I/O
  - Formatted I/O
  - Examples
- Reminders
  - This lecture concludes material for MT2
  - MT2 is on 03/28, plan ahead
  - Drop-deadline is tomorrow

Exercise

- Write a function to transpose a given TSV file and write the output to `transposed.tsv`
- The number of rows and columns will be present as the first line of the input file: `records.tsv`
- TSV stands for Tab-Separated-Values.

```
4   3
Zariski   99 Monday
Newton    43 Sunday
Russel    72 Saturday
Maxwell   32 Wednesday
```



```
3     4
Zariski   Newton   Russel Maxwell
99    43     72     32
Monday    Sunday   Saturday   Wednesday
```

Exercise

- How about comma-separated values? Let us transpose a matrix stored on disk and write it back to disk.

- The input matrix is in file `mat.csv` with the first line specifying the number of rows and columns in the matrix.

- Write output to file `t_mat.csv.`

Introduction to `structs`

- Often useful to the programmer to combine pieces of information into a single abstract unit

- Example(s)
  - A student could have a name (`char[80]`), UIN (`unsigned long int`), year (`unsigned int`) and GPA (`float`)
  - A flight could have an altitude (`unsigned int`), latitude (`float`), longitude (`float`), airspeed (`float`) and airline code (`char[20]`)

Introduction to `structs`

- Achieved by letting the programmer create their own *data type* using the `struct` keyword.

- Examples:

```
struct student{
    char name[80];
    unsigned long UIN;
    unsigned int year;
    float GPA;
};
```

```
struct flightType{
    char flightCode[20];
    unsigned int altitude;
    float longitude;
    float latitude;
    float airSpeed;
};
```

Defining structs

```
struct flightType{
    char flightCode[20];
    unsigned int altitude;
    float longitude;
    float latitude;
    unsigned float airSpeed;
};
```

→

- A `struct` allows the user to define a **new** *data type* that groups together items of types that are *already* defined.
- *Defining* a struct tells the compiler
  - How big the struct is …
  - How to lay items out in memory …

However … no memory allocated yet!

Declaring & using `structs`

- Memory is only allocated when variables are created using the newly defined type.

```
struct flightType plane;
struct student s1;
```

- Elements of a struct are called its *members.* Members can be accused using the “dot” notation.

```
plane.altitude = 1000;
plane.airspeed = 800.0;
```

- `struct` variables can also be initialized at declaration.

```
struct student s1 = {“Garfield”,
123456, 6, 3.5}
```

- Also possible to create arrays of structs

```
struct student bl2[2] = {s1,
{"Scooby", 234578164, 2, 4.0}};
printf(“Name is %s”, bl2[1].name);
```

Memory mapping

- How many bytes of memory should one *instance* of `student` take?

```
struct student{
    char name[80];
    unsigned long UIN;
    unsigned int year;
    float GPA;
};

struct student s1 =
{“Garfield”, 123456, 6, 3.5}
```

	…
G	s1.name[0]
a	s1.name[1]
…	…
…	s1.name[78]
…	s1.name[79]
123456	s1.UIN
6	s1.year
3.5	s1.gpa

80 + 8 + 4 + 4

Memory mapping

- What if we change the definition to this one?

```
struct student{
    char name[74];
    unsigned long UIN;
    unsigned int year;
    float GPA;
};
```

~~80~~ 74 + 8 + 4 + 4 = ?

Let us check using `sizeof` function.

What happened?

Compilers will often perform “padding” to *align* memory.

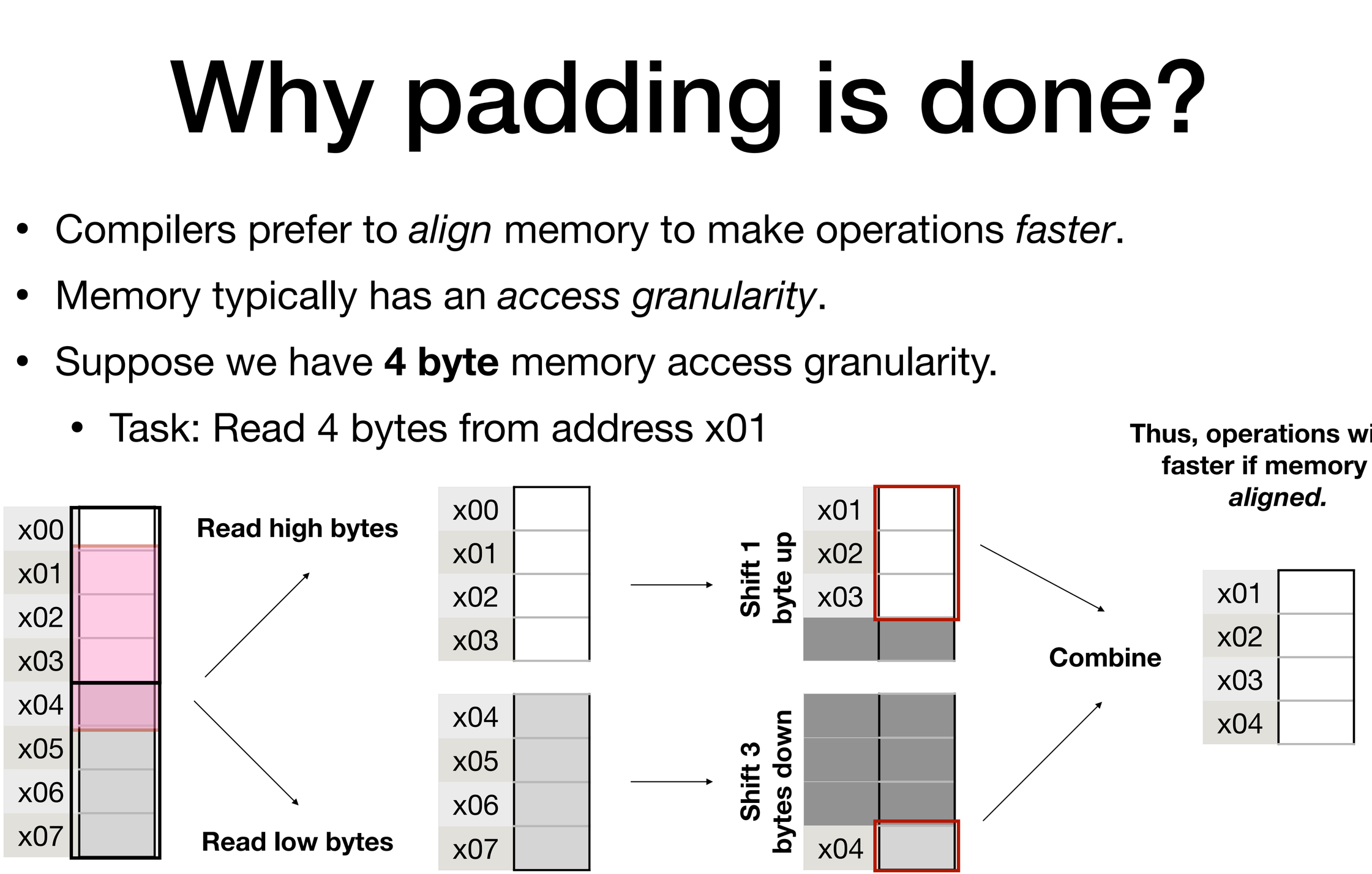
Use the `sizeof` operator to get accurate results!

https://en.cppreference.com/w/c/language/object#Alignment

Why padding is done?

- Compilers prefer to *align* memory to make operations *faster*.
- Memory typically has an *access granularity*.
- Suppose we have **4 byte** memory access granularity.
  - Task: Read 4 bytes from address x01

Thus, operations will be faster if memory is *aligned.*



The `typedef` keyword

- Note how we declared a struct variable:

```
struct flightType plane;
struct student s1;
```

- *Annoying* to keep having to say `struct xyz, struct abc` - more so in the context of function calls

- C provides a mechanism to avoid this verbosity.

```
typedef struct flightType{
    char flightCode[20];
    unsigned int altitude;
    float longitude;
    float latitude;
    unsigned float airSpeed;
} Flight;

Flight f1 = {“AA 4324”,
                33000,
                87.6,
                41.8,
                700};
```

Pointers to structs

- One can define pointers to structs the usual way.

```
Flight planes[100];
Flight *ptr1;
ptr1 = &planes[10];
Flight *ptr2;
ptr2 = planes;
```

- To access struct elements via pointers you can
  - Dereference and dot

```
printf("I am %f feet high",
        (*ptr1).altitude);
```

  - Arrow

Special syntax! ⟵

```
printf("I am %f feet high",
        ptr1->altitude);
```

Passing `structs` as arguments

- One can write function definitions involving using structs in either way:

```
void print_student(struct student s){
   printf("Student %s is associated with UIN: %lu\n", s.name, s.UIN);
   printf("%s is in Year %d with GPA %f\n", s.name, s.year, s.GPA);
}


void print_flight(Flight f){
  printf("Flight #%s is at altitude %u\n", f.flightCode, f.altitude);
  printf("%s has speed %f\n", f.flightCode, f.airSpeed);
}
```

Passing `structs` as arguments

- We could also pass the struct via reference:

```
void print_flight_loc(Flight *f){
  printf("Flight #%s is at altitude %u\n", f->flightCode, f->altitude);
  printf("%s has lattitude: %f\n", f->flightCode, f->latitude);
  printf("%s has longitude: %f\n", f->flightCode, f->longitude);
}
```

- Which is cheaper in terms of memory/run-time stack?
  - What if we had an array of structs?

Structs within structs

- Nothing stops us from creating a struct composed of structs.

Suppose we have:

```
struct geoloc{
  float lattitude;
  float longitude;
};
```

- Then we can do:

```
typedef struct flight{
  char code[8];
  unsigned int arrival_time;
  unsigned int depart_time;
  struct geoloc origin;
  struct geoloc destination;
} Flight;
```

Other user defined types: `enums`

- Enum is short for *enumeration.* Idea is to assign meaningful names to integers for code readability.

- *Syntax:* `enum [tag] {enumerator list};`

```
enum weekday {SUN, MON, TUE, WED, THR, FRI, SAT};

int is_workday(enum weekday day){
  if (day>SUN && day<SAT)
    return 1;
  else
    return 0;
}
```

Can you override default values assigned to enums?
See gitlab: https://gitlab.engr.illinois.edu/itabrah2/ece220-fa23/

Other user defined types: enums

```c
int main(void){

  enum weekday today=THR;
  enum weekday day_after_next = today+2;

  printf("Today is day #%d of the week.\n", today);
  printf("Today is %s\n", is_workday(today) ? "a workday" : "not a workday");

  printf("\n");
  printf("Day after tomorrow is day #%d of the week.\n", day_after_next);
  printf("That day is %s\n",
         is_workday(day_after_next) ? "a workday" : "not a workday");
}
```

Other user defined types: unions

- Unions are similar to structs … both have members.

```
typedef union union1{
char c;
int x;
double y;
}Union1;
```

```
typedef struct struct1{
char c;
int x;
double y;
}Struct1;
```

- However, all members of a union share the same memory location; i.e., it allows an identifier to change between some predefined types.

Example: Airport management

- Writing a struct to a file:

```
fwrite(void *ptr, size, n_memb, FILE *stream)
```

- `ptr` is pointer to instance of the struct to **write**
- `size` is the size in bytes of each element to be **written** (use sizeof)
- `n_memb` is the number of items to **write**, each with size of size bytes
- `stream` is the pointer to FILE object in ***binary write mode.***

Example: Airport management

- Writing a struct to a file:

```
fread(void *ptr, size, n_memb, FILE *stream)
```

- `ptr` is pointer to instance of the struct to **hold data**
- `size` is the size in bytes of each element to be **read** (use sizeof)
- `n_memb` is the number of items to **read**, each with size of size bytes
- `stream` is the pointer to FILE object in ***binary read mode.***

Have a Happy