Lecture 7

<2016-04-18 Mon>

Contents

1 Structures

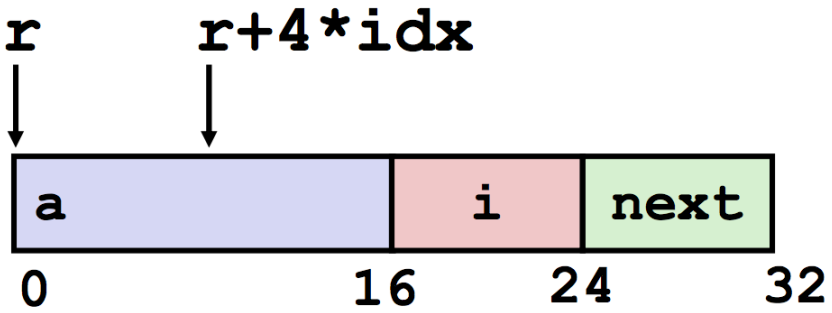
1.1 Structure Representation

- structure represented as block of memory
- fields ordered according to declaration
- compiler determines overall size + position of fields

```
struct rec {
  int a[4];
  size_t i;
  struct rec *next;
}

int *get_ap(struct rec *r, size_t idx) {
  return &r->a[idx];
}

void set_val(struct rec *r, int val) {
  while (r) {
    int i = r->i;
    r->a[i] = val;
    r = r->next;
  }
}
```



register	variable
%rdi	first argument
%rsi	second argument

```
get_ap:
      leaq    (%rdi,%rsi,4), %rax
      ret

set_val:
.L11:
      movsql    16(%rdi), %rax
      movl      %esi, (%rdi,%rax,4)
      movq      24(%rdi), %rdi
      testq     %rdi, %rdi
      jne       .L11
      ret
```

1.2 Structures and Alignment

- Aligned Data
  - primitive data type requires `K` bytes
    - `K` **largest alignment of any element in struct**
  - address must be multiple of `K`
- Motivation
  - memory accessed by (aligned) chunks of 4 or 8 bytes
    - inefficient to load or store datum that spans quad word boundaries
    - virtual memory trickier when datum spans 2 pages

bytes	example	requirement
1 byte	`char`	no restriction
2 bytes	`short`	lowest 1 bit of address must be 0
4 bytes	`int, float`	lowest 2 bit of address must be 00
8 bytes	`double, long, char*`	lowest 3 bit of address must be 000
16 bytes	`long double`	lowest 4 bit of address must be 0000

1.3 Satisfying Alignment with Structures

- within structure
  - satisfy each element's alignment requirement
- overall structure placement

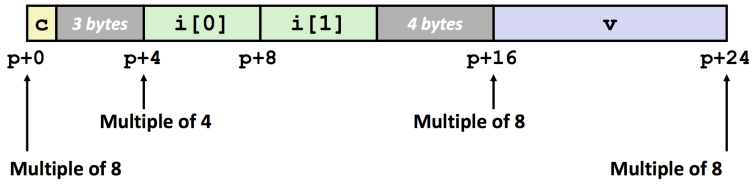
- each structure has alignment requirement `K`
  - `K` = largest alignment of any element in struct
- initial address & structure must be multiples of `K`

1.3.1 example

1. struct

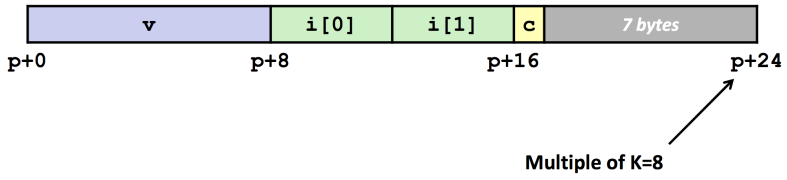
   - `K` = 8, due to `double` element

```
struct S1 {
  char c;
  int i[2];
  double v;
} *p;
```



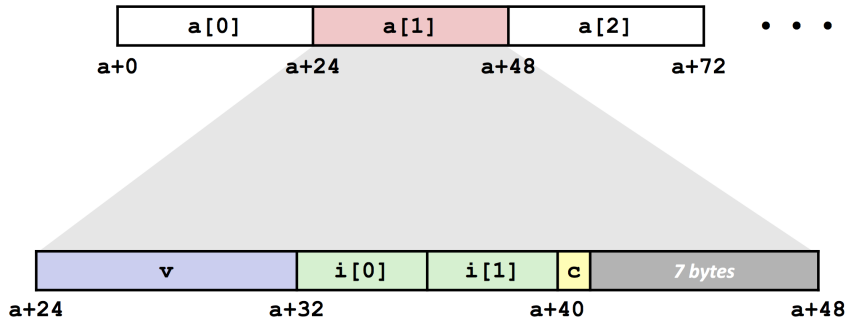
2. reordered within struct

```
struct S2 {
  double v;
  int i[2];
  char c;
} *p;
```



1.4 Arrays of Structures

```
struct S2 {
  double v;
  int i[2];
  char c;
} a[10];
```



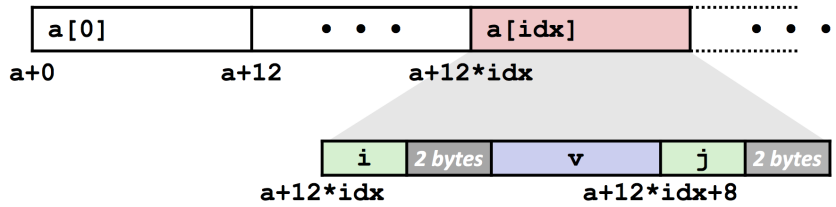
- overall structure length of multiple of K
- satify alignment requirement for every element

1.4.1 Access Array Elements

```
struct S3 {
  short i;
  float v;
  short j;
} a[10];

short get_j(int idx) {
  return a[idx].j;
}
```

```
leaq    (%rdi,%rdi,2), %rax     ;%rax *= 3
movzwl  a+8(,%rax,4), %eax
```



- compute array offset `12 * idx`
  - `sizeof(S3)`, including alignment spacers
- element j is at offset 8 within structure
- assembler gives offset a+8 (resolved during linking)

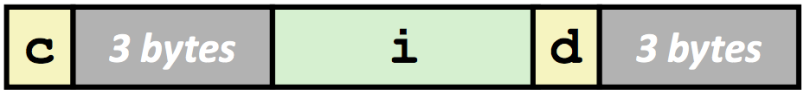
1.4.2 Save Space

- put large data types first

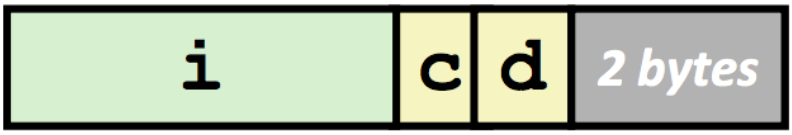
```
struct s4 {
  char c;
  int i;
  char d;
};

struct s5 {
  int i;
  char c;
  char d;
};
```

- s4 : 12 bytes



- s5 : 8 bytes



2 Union

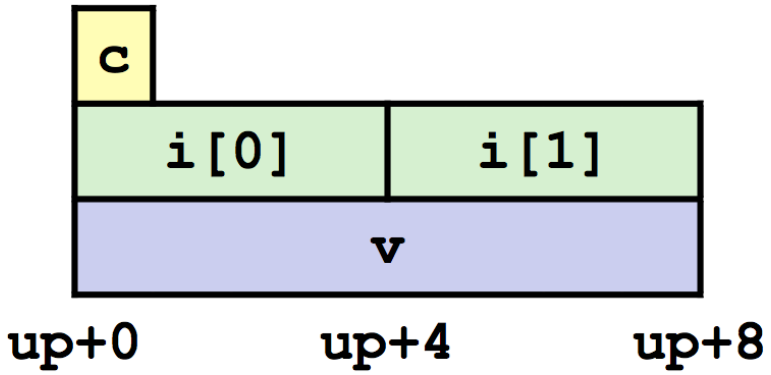
2.1 Union Allocation

- allocate according to largest element
- can only use 1 field at a time

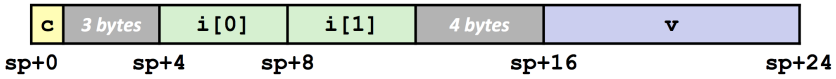
```
union u1 {
  char c;
  int i[2];
  double v;
} *up;

struct s1 {
  char c;
  int i[2];
  double v;
} *sp;
```

- union



- struct



```
typedef union {
  float f;
  unsigned u;
} bit_float_t;

bit_float_t arg;
arg.u;                          /* interpret arg as unsigned */
arg.f;                          /* interpret arg as float */
```

- interpret bytes pattern as `unsigned` / `float`
- not same as casting

3 Byte Ordering Revisited

- `short` / `long` / `quad` stored in memory as 2/4/8 consecutive bytes
- which byte is most significant
- can cause problem across machine

3.1 Big Endian

- most significant byte has lowest address
- e.g. Sparc

3.2 Little Endian

- least significant byte has lowest address
- e.g. Intel x86, ARM Android, iOS

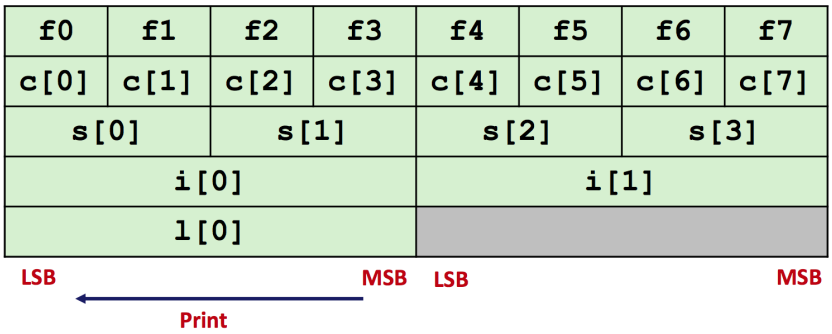
3.3 Bi Endian

- can be configured either way
- e.g. ARM

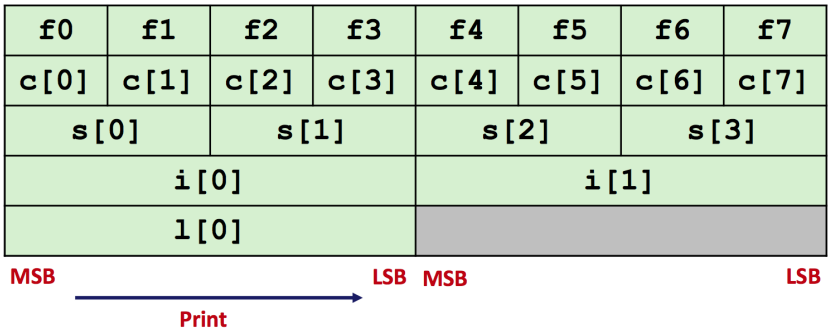
3.4 example

```
union {
  unsigned char c[8];
  unsigned short s[4];
  unsigned int i[2];
  unsigned long l[1];
} dw;
```

3.4.1 32 bit, Little Endian



3.4.2 32 bit, Big Endian



4 Summary of Compound Types in C

4.1 Arrays

- contiguous allocation of memory

- aligned to satisfy every element's alignment requirement
- pointer to first element
- no bounds checking

4.2 Structure

- allocate bytes in order declared
- pad in middle and at end to satify alignment

4.3 Unions

- overlay declarations
- way to circumvent type system