SWEN430 - Compiler Engineering

Lecture 18 - Machine Code III

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Data Representation — Overview

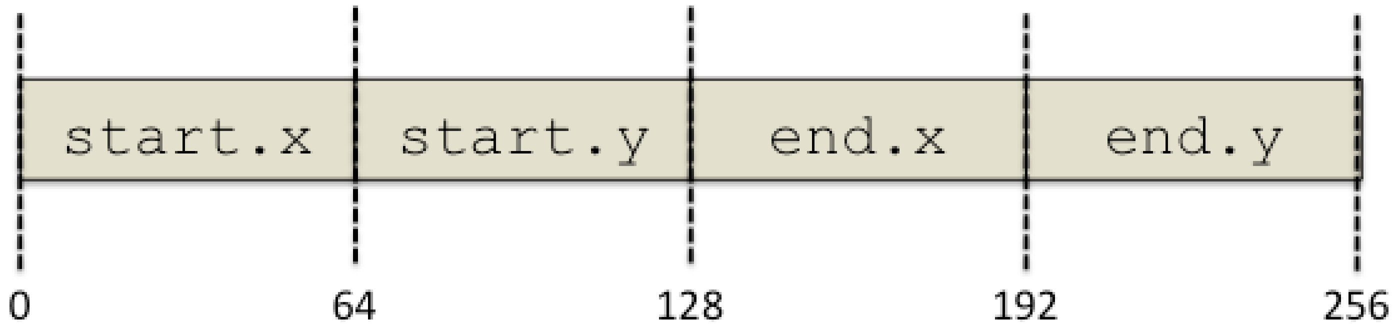
- Need to represent WHILE **data types** in memory!
- Some data types have **fixed widths**
  - » e.g. `int` is 64 bits wide (on x86_64)
  - » e.g. `char` is 8 bits wide (ASCII)
  - » e.g. `{int f, int g}` is 128 bits wide (on x86_64)
- Other data types have **variable widths**
  - » e.g. `int[]` has variable width
  - » e.g. `{int[] array}` has variable width
- In WHILE, lists and strings are **only source** of variable-width types

Data Representation — Records

- Ignoring lists/strings, records have **statically determinable** widths

- Records in WHILE can be **flattened** into a contiguous sequence:

```
type Point is {int x, int y}
type Line is {Point start, Point end}
```



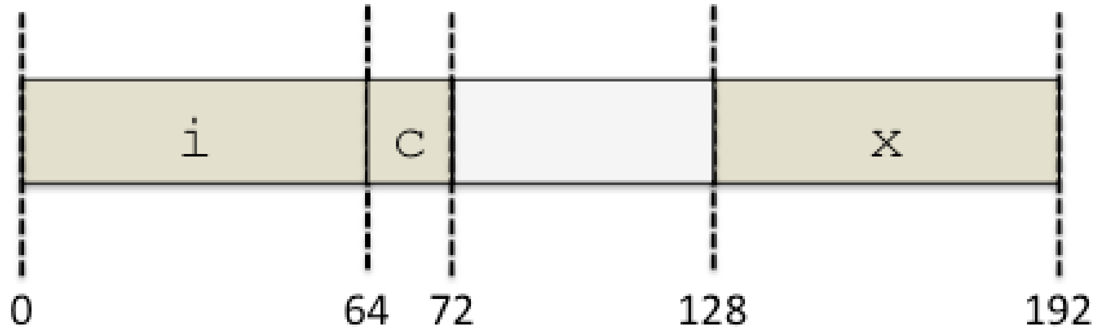
- Every field has **fixed offset** so can exploit addressing modes
  - » e.g. `v = l.end.x` might translate to `mov 8(%edi),%eax`

- Fields sorted **alphabetically** so declaration order independent

Data Representation — Alignment

- Can using padding to ensure fields are **aligned**

```
type Line is {int i, char c, int x}
```



- Alignment is **unnecessary** but can **improve performance**
  - » Because aligned memory accesses are typically faster

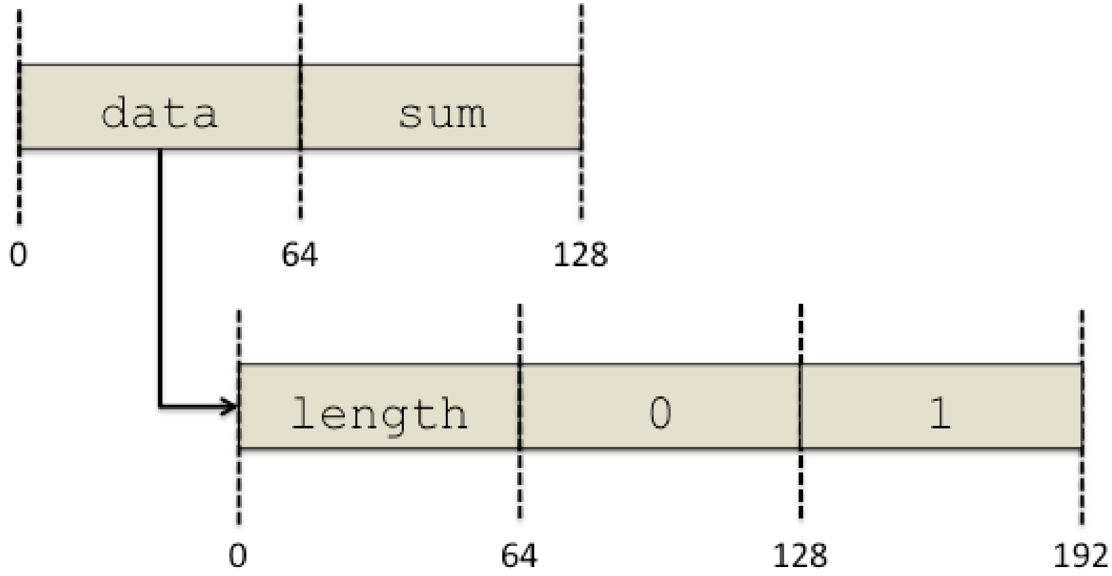
- But, alignment can also **reduce performance**!
  - » e.g. if record no longer fits in a single **cache line**

Data Representation — Variable Width

- For lists and strings, we **cannot predetermine** their width:

```
type SumList is {int[] data, int sum}
```

- Instead, lists and strings are **dynamically allocated**:



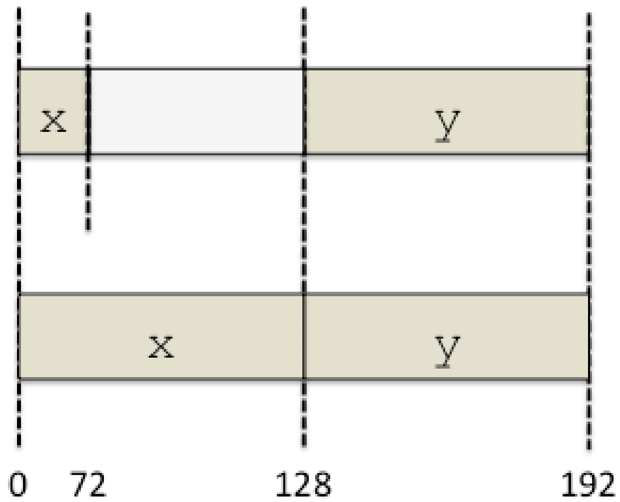
- Enclosing record has fixed width with list represented as **pointer**

- This makes dealing with **value semantics** quite tricky!

Data Representation — Untagged Unions

- For union can compute **maximum** size of elements

```
type SumList is {int x,int y} | {char x, int y}
```



- This is how **unions** of **structs** are implemented in C
- Common elements accessible via **common initial sequence**
- For WHILE, it is a little more complicated ...

Data Representation — Tagged Unions

- Need a way to **determine at runtime** what a union is:

```
int f(int|null item) {
    if(item is int) { return (int) item; }
    else { return 0; }
}
```

- If `sizeof(item) == sizeof(int)` then **cannot** to do this!

- Instead, need to add special **tag** field to representation of `item`:

- Here, only **1 bit tag** required; in general, depends on number of **distinct types**

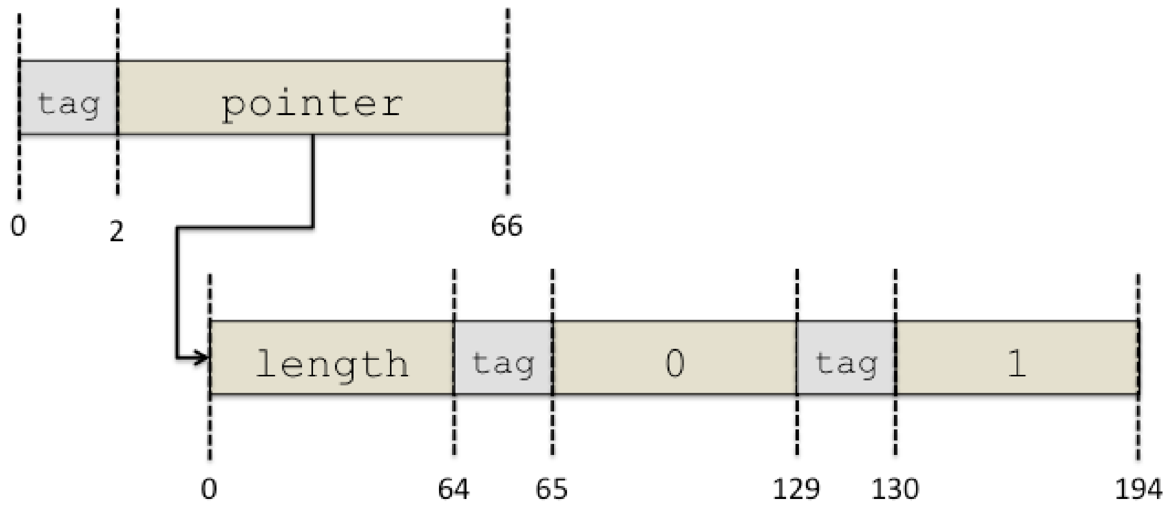
Data Representation — Tagged Unions

```
type NullPoint as {int|null x, int|null y}
```

- How many tags bits **required** to represent a `NullPoint`?

- Representing lists is slightly **more complicated**:

```
type NullList as (int|null)[]
```



- Why might we choose to add **two tag bits** for the pointer as well?

Data Representation — Retagging

- Consider this example:

```
int|null f(int x) {
  return x;
}
```

- In the above, need to **initialise** tag for return value

- Now, consider this example:

```
int|null|char f(int|null x) {
  return x;
}
```

- In this case, we need to **retag** variable `x` on return

Switch Statements

For performance, `switch` implemented with **jump tables**:

```
int main(int argc, char** argv) {
  switch(argc - 1) {
     case 1:
        return 0;
     case 2:
        return 1;
     default:
        return -1;
} }
```

Switch Statements

For performance, `switch` implemented with **jump tables**:

```
  .text
  .globl main
main:
  movq %rdi, %rbx  // read argc into rbx
  dec %rbx         // argc - 1
  cmpq 0, %rbx
  jle CD           // if <=0
  cmpq 2, %rbx
  jg CD            // if > 2
  movq JUMPTABLE(,%rbx,8), %rbx
  jmp *%rbx        // jump to place
JUMPTABLE:
  .quad CD         // pad 0 value
  .quad L1         // offset 1
  .quad L2         // offset 2
CD:
  movq -1, %rax   // -1 into return register
  jmp END
L1:
  movq 0, %rax    // 0 into return register
  jmp END
L2:
  movq 1, %rax    // 1 into return register
  jmp END
END:
  ret              // return / end
```