Static and Dynamic Libraries

- **LIBRARIES** are commonly used routines stored as a concatenation of "Object files". A global symbol table is maintained for the entire library with **entry points** for each routine.
- When a routine in a LIBRARY is referenced by an assembly module, the routine's address is resolved by the **LINKER**, and the appropriate code is added to the executable. This sort of linking is called STATIC linking.
- Many programs use common libraries. It is wasteful of both memory and disk space to include the same code in multiple executables. The modern alternative to STATIC linking is to allow the **LOADER** and **THE PROGRAM ITSELF** to resolve the addresses of libraries routines. This form of lining is called DYNAMIC linking (e.x. .dll).

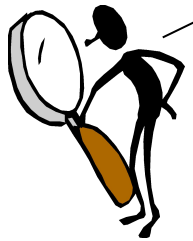
Dynamically Linked Libraries

- C call to library function:

```
printf("sqr[%d] = %d\n", x, y);
```

- Assembly code

```
mov     R0,#1
mov     R1,ctrlstring
ldr     R2,x
ldr     R3,y
mov     IP,__stdio__
mov     LR,PC
ldr     PC,[IP,#16]
```



Why are we loading the PC from a memory location rather than branching?

How does dynamic linking work?

Dynamically Linked Libraries

- Lazy address resolution:

```
sysload: stmfd sp!,[r0-r10,lr]
        .
        .
        ; check if stdio module
        ; is loaded, if not load it
        .
        .
        ; backpatch jump table
        mov  r1,__stdio__
        mov  r0,dfopen
        str  r0,[r1]
        mov  r0,dfclose
        str  r0,[r1,#4]
        mov  r0,dfputc
        str  r0,[r1,#8]
        mov  r0,dfgetc
        str  r0,[r1,#12]
        mov  r0,dfprintf
        str  r0,[r1,#16]
```

Because, the entry points to dynamic library routines are stored in a TABLE. And the contents of this table are loaded on an "as needed" basis!

Before any call is made to a procedure in "stdio.dll"

```
.globl __stdio__:
__stdio__:
fopen:    .word sysload
fclose:   .word sysload
fgetc:    .word sysload
fputc:    .word sysload
fprintf:  .word sysload
```

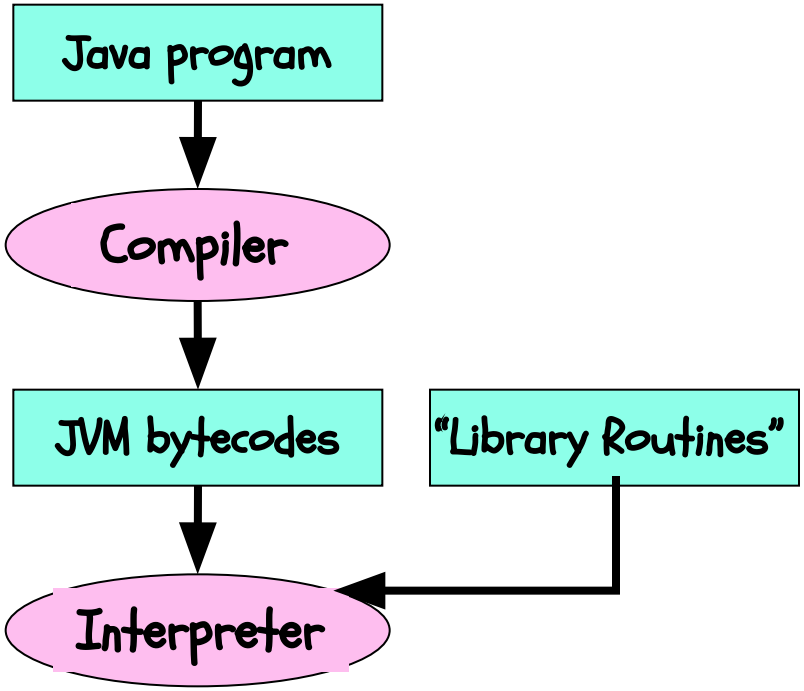
After the first call is made to any procedure in "stdio.dll"

```
.globl __stdio__:
__stdio__:
fopen:    dfopen
fclose:   dclose
fgetc:    dfgetc
fputc:    dfputc
fprintf:  dprintf
```

Modern Languages

Intermediate "object code language"

High-level, portable (architecture independent) program description



PORTABLE mnemonic program description with symbolic memory references

An application that EMULATES a virtual machine. Can be written for any Instruction Set Architecture. In the end, machine language instructions must be executed for each JVM bytecode

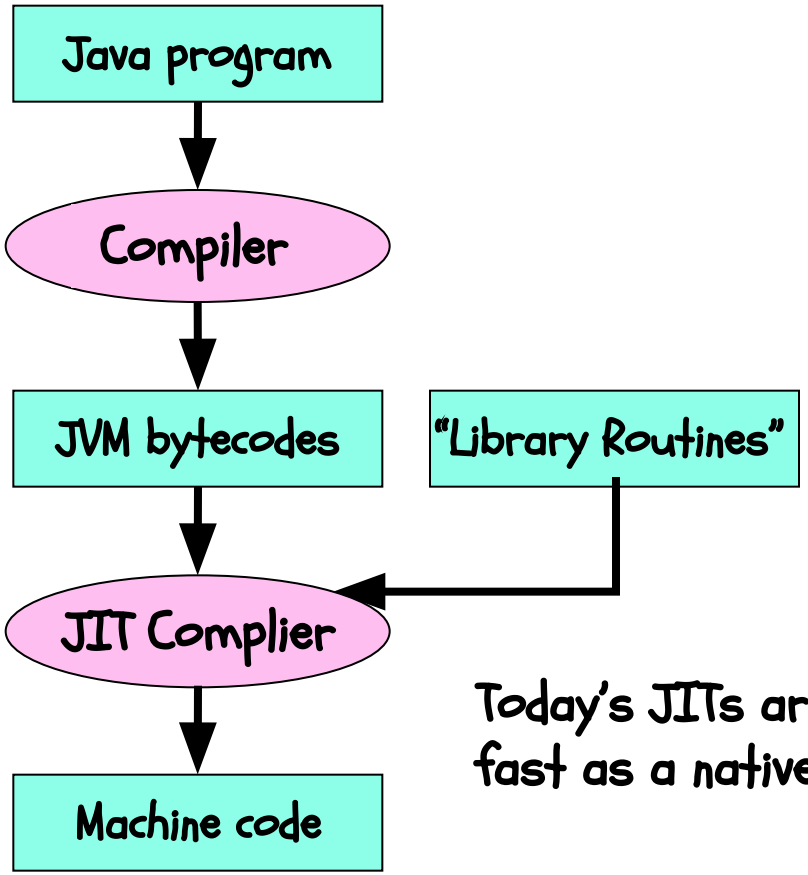
Modern Languages

Intermediate "object code language"

High-level, portable (architecture independent) program description

PORTABLE mnemonic program description with symbolic memory references

While interpreting on the first pass the JIT keeps a copy of the machine language instructions used.
Future references access machine language code, avoiding further interpretation



Today's JITs are nearly as fast as a native compiled code.

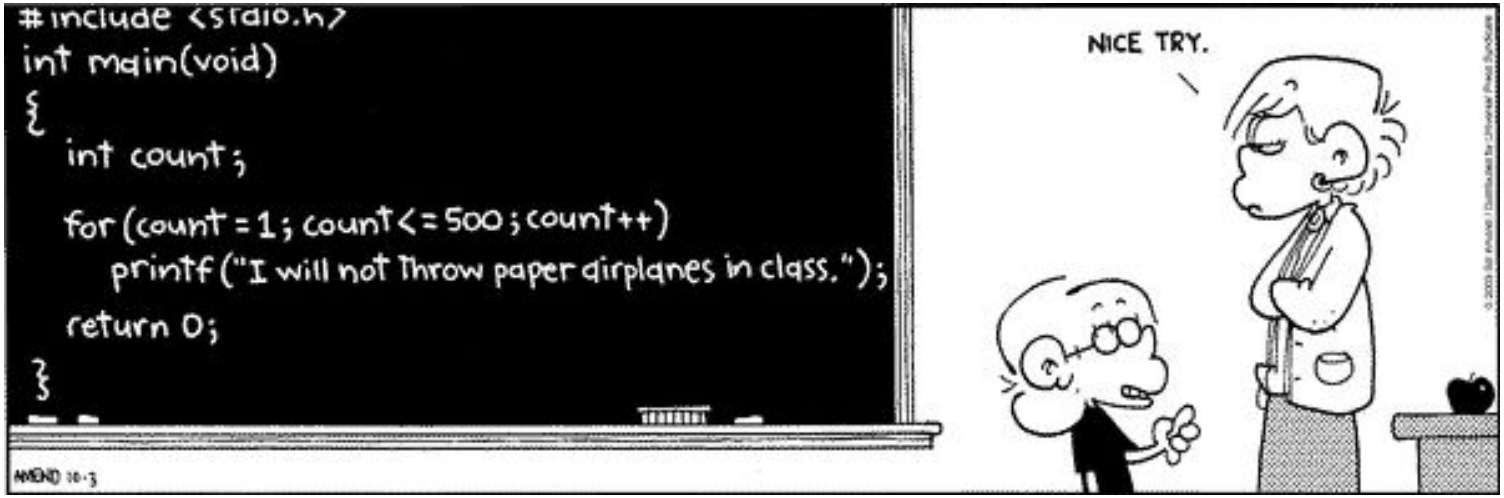
Assembly? Really?

- In the early days compilers were dumb
  - literal line-by-line generation of assembly code of "C" source
  - This was efficient in terms of S/W development time
    - C is portable, ISA independent, write once- run anywhere
    - C is easier to read and understand
    - Details of stack allocation and memory management are hidden
  - However, a savvy programmer could nearly always generate code that would execute faster
- Enter the modern era of Compilers
  - Focused on optimized code-generation
  - Captured the common tricks that low-level programmers used
  - Meticulous bookkeeping (i.e. will I ever use this variable again?)
  - It is hard for even the best hacker to improve on code generated by good optimizing compilers

Next Time

- Compiler code optimization
- We look deeper into the Rabbit hole

What would a compiler do?



Today we'll look at the assembly code that compiler's generate…

Code generation

Example C code:

```
int array[10];
int total;

int main( ) {
    int i;

    total = 0;
    for (i = 0; i < 10; i++) {
        array[i] = i;
        total = total + i;
    }
}
```

Code we might write

```
        .word 0x03fffffc, main

array:  .space  10
total:  .space  1

main:                                   ; int main() {
        sub     sp,sp,#4                ;     int i;
        mov     r0,#0
        str     r0,total                ;     total = 0;
        str     r0,[sp]                 ;     for (i = 0; i < 10; i++) {
        b       _L02
_L01:
        mov     r1,#array
        str     r0,[r1,r0,lsl #2]       ;         array[i] = i;
        ldr     r1,total
        add     r1,r1,r0
        str     r1,total                ;         total = total + i;
        add     r0,r0,#1
        str     r0,[sp]
_L02:
        cmp     r0,#10
        blt     _L01                    ;     }
        add     sp,sp,#4
*       bx      lr
```

An online ARM7 Compiler

Available at: http://csbio.unc.edu/mcmillan/index.py?run=arm

UNC miniARM C-compiler V 0.1

```
int array[10];
int total;

int main( ) {
    int i;

    total = 0;
    for (i = 0; i < 10; i++) {
        array[i] = i;
        total = total + i;
    }
}
```

Compile Optimize

Unoptimized Compiler Output

Why is this code so bad?

Because it generated for debugging.
Essentially, each line is translated directly.


```
.word 0x03fffffc, main
array:  .space 10
total:  .space 1
        .global main
main:
        str     fp, [sp, #-4]!
        add     fp, sp, #0
        sub     sp, sp, #12
        ldr     r3, _L4
        mov     r2, #0
        str     r2, [r3, #0]
        mov     r3, #0
        str     r3, [fp, #-8]
        b       _L2
_L3:
        ldr     r3, _L4+4
        ldr     r2, [fp, #-8]
        ldr     r1, [fp, #-8]
        str     r1, [r3, r2, asl #2]
        ldr     r3, _L4
        ldr     r2, [r3, #0]
        ldr     r3, [fp, #-8]
        add     r2, r2, r3
        ldr     r3, _L4
        str     r2, [r3, #0]
        ldr     r3, [fp, #-8]
        add     r3, r3, #1
        str     r3, [fp, #-8]
_L2:
        ldr     r3, [fp, #-8]
        cmp     r3, #9
        ble     _L3
        mov     r0, r3
        add     sp, fp, #0
        ldmfd   sp!, {fp}
        bx      lr
_L5:
_L4:
        .word   total
        .word   array
```

Optimized Code

```
                .word 0x03fffffc, main
                .global main
main:
                ldr     r2, _L4
                mov     r3, #0
_L2:
                str     r3, [r2, #4]!
                add     r3, r3, #1
                cmp     r3, #10
                bne     _L2
                mov     r2, #45
                ldr     r3, _L4+4
                str     r2, [r3, #0]
*               bx      lr
_L5:
_L4:
                .word   array-4
                .word   total
total:          .space 1
array:          .space 10
```

It even relaid out the variables so that all writes are sequential,

Next Time

We look into the hardware