# OBJECT FILES IN LLVM

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Michael Spencer

# What was my goal in doing this object file project…

- I wanted a fast, free, and cross platform linker
- Integrated binary tool-chain
  - Why not replace all of binutils?
- Needed to share object file handling code throughout the tool-chain
  - Library!

# What is an Object File?

- An Object File is a structured collection of binary data
  - PE/COFF, ELF, MachO, …
    - Translation Units, Executables, and Dynamic Libraries
  - Archives
  - Raw ".bin" files
  - LLVM bitcode
- Different formats provide a disjoint set of features

# What is an Object File? (cont)

- There is a common subset of features
  - Symbols
  - Sections
  - Segments
  - Relocations
- Every other feature is based off of these
  - eg C++ Construction and Destruction of static objects must occur before main is run. This requires special handling by the linker and loader.

# Current Technology

- Not much has changed with object files
- Libraries
  - libbfd – Binary File Descriptor
    - 20 years old?
- Linkers
  - gnu-ld – slow and GPL
  - gold – ELF only and GPL
  - link.exe – slow, COFF only, and proprietary
  - Various system linkers

# LLVM's Current Support

- The Machine Code (MC) library handles assembling and writing out object files
- Supports various formats
  - COFF
  - ELF
  - MachO
- Assembler specific, not designed for generic object file handling

# Why Object Files?

- Freedom
  - Not GPL
  - Not Proprietary
- Cross Platform Consistency
  - Toolset
  - API
- Performance
  - IPO Through Shared Libraries
  - JIT Caching
  - Integrated Linker

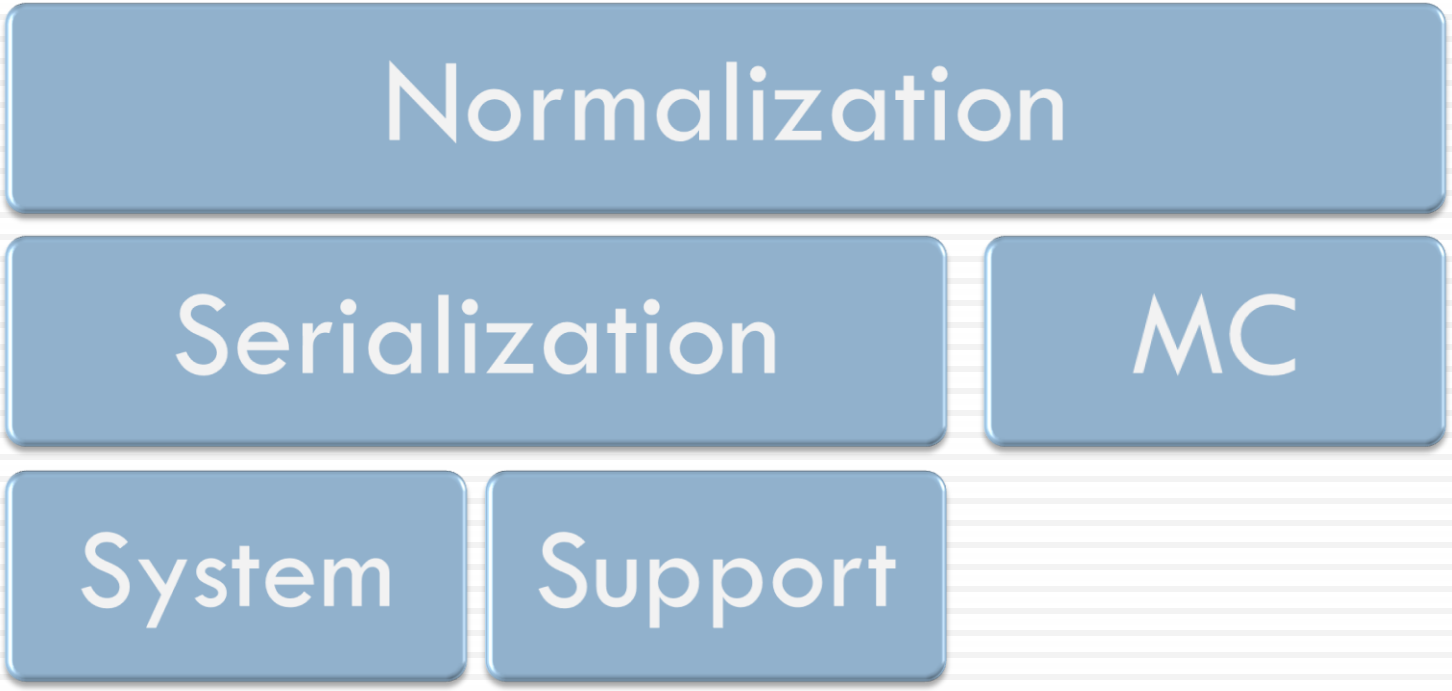
# More Than Just a Linker

- Make it easy to add link time features that would normally require a “prelinker”
  - Constructors and Destructors
    - Already handled because of C++, but required changes to linkers and loaders.
  - C++ Open Methods
  - LTO

# The LLVM Object File Library

- Goals
  - Library based
  - Unified API for various formats
  - Access to details when needed
  - Provide replacements for all of binutils
  - Speed

# Architecture



# Architecture

- Layered
  - Low Level: Serialization
    - Base library that reads and writes
      - Depends only on the LLVM System and Support libraries
    - No interpretation is performed at this point
      - Provides symbols, sections, segments, and relocations
      - eg. In ELF the relocation section shows up here, even though other object files store relocations differently
      - Useful for tools like objdump and nm

# Architecture

- High Level: Normalization
  - Interprets data into a common representation
  - Provides a common API for tools to use to access the data provided by the serialization layer
  - Understands and can perform relocations, layout, etc…
  - Common form -> {ELF, COFF, MachO} -> Common Form will end up with what you started with (if the format supports the feature).

# How is libobj faster?

- Zero-Copy
  - *libbfd* copies non-section data from the memory mapped object file into a struct
  - *libobj* returns an object that contains a reference into the memory mapped object file and knows how to extract data from it
  - This lowers the physical memory usage and therefore increases cache reuse and reduces swap file usage

# How is libobj faster? (cont)

- Read data a field at a time
  - Object File formats are generally specified in terms of C structs with a specified endianness and alignment
  - *libbfd* deals with these issues by reading a byte at a time
  - *libobj* speeds this up by reading an entire field at a time and byte swapping if necessary. It reverts to reading a byte at a time only when the format does not guarantee alignment and the host does not support misaligned loads

# Implementation

- Endianness and Alignment
  - Transparently and quickly dealt with using packed_endian_specific_integral

```
// Read in some data from disk.
uint8_t *data = read_binary_data();

// Read a little endian int32
int32_t value = *reinterpret_cast<little32_t*>(data);

// Read a big endian int32
int32_t be_value = *reinterpret_cast<big32_t*>(data + 4);

// Print the result
printf("%d-%d", value, be_value);
```

```
calll _read_binary_data
movl (%eax), %eax
movl %eax, 4(%esp)
movl 4(%eax), %eax
bswapl %eax
movl %eax, 8(%esp)
movl $L_.str, (%esp)
calll _printf
```

# Implementation

- Endianness and Alignment (cont…)
  - These can be combined into a POD struct.

```
typedef struct {
  aligned_ulittle32_t r_offset;
  aligned_ulittle32_t r_info;
} Elf32_Rel;

Elf32_Rel *reloc =
        (Elf32_Rel*)read_binary_data(location_of_relocation_entry);

printf("Reloc{ addr: %p, info: %u }",
        (void*)(reloc->r_offset),
        unsigned(reloc->r_info));
```

# Performance

- I added object file support to llvm-nm and tested it vs binutils-nm.
- 2x faster on Linux
- ~30x faster on Windows (vs. nm via MinGW)

# Current Status

- I have currently implemented symbols and sections in the Serialization layer for COFF and ELF
- I have also worked on some tools
  - llvm-nm
    - Modified to support object files
  - llvm-objdump
    - Added with support for disassembly via MC
- Working on getting patches into trunk, please review!

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Questions?