DRuntime and You

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Agenda

- *Warmup:* TypeInfo and ModuleInfo
- Exception handling
- Garbage collection
- Thread-local storage
- Fibers
- *Interlude:* C program startup
- Shared libraries
- Linker-level dead code elimination (`--gc-sections`)

Packages

- `object`: Top-level module, imported automatically
- `core.*`: User interface, C standard library/operating system bindings
- etc.*: Also user-facing, currently just `etc.linux.memoryerror`
- `gc.*`: Garbage collector implementation
- rt.*: Compiler support code, runtime initialization

- gcc.*
- ldc.*

```
class TypeInfo {
  string toString();
  size_t toHash();
  int opCmp(Object o);
  bool opEquals(Object o);
  size_t getHash(in void* p);

  TypeInfo next();
  uint flags();

  void[] init();
  size_t tsize();
  size_t talign();

  bool equals(in void* p1,
              in void* p2);
  int compare(in void* p1,
              in void* p2);
  void swap(void* p1, void* p2);
  void destroy(void* p);
  void postblit(void* p);

  OffsetTypeInfo[] offTi();

  void* rtInfo();
}
```

```d
struct ModuleInfo {
  string name();
  uint flags();
  void function() tlsctor();
  void function() tlsdtor();
  void function() ctor();
  void function() dtor();
  void function() unitTest();
  ModuleInfo*[] importedModules();
  TypeInfo_Class[] localClasses();
  void function() ictor();
  void* xgetMembers();
  uint index();

  static int opApply(scope int
    delegate(ModuleInfo*) dg);
}
```

```
module foo.bar;

class C {
    this() { x = 10; }
    int x;
}

void main() {
    auto c = cast(C)Object.factory("foo.bar.C");
    assert(c !is null && c.x == 10);
}
```

Exception Handling

- Two main tasks: Stack unwinding, finding landing pads (`catch`/`finally`/scopes with destructors)
- Compiler- and platform-specific
- DMD/Win32: Structured Exception Handling (SEH), `rt.deh_win32`
- DMD/Win64 and Posix: Custom implementation, `rt.deh_win64_posix`
- GDC and LDC (except Win64): libunwind does heavy lifting, we provide *personality function*, see `gcc.deh` and `ldc.eh`
- LDC/Win64: SEH, `ldc.eh2`
- Backtrace generation

Garbage collection

- Mark-and-Sweep collector:
  - Mark phase: Transitively mark all reachable objects as live
  - Sweep phase: Free those allocations that have not been marked (potentially also reclaim entire page, etc.)
- Potential GC roots:
  - Stack
  - (Shared) globals
  - TLS globals
  - (Explicitly added roots/ranges using core.memory.GC interface)

Thread-Local Storage (TLS)

```
module test;
int myGlobal;
int foo() {
  return myGlobal;
}
```

- Linux x86_64 static TLS model:

```
_D4test3fooFZi:
        mov eax, dword ptr fs:[_D4test8myGlobali@TPOFF]
        ret
```

Thread-Local Storage (TLS)

```
module test;
int myGlobal;
int foo() {
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}
```

- Linux x86_64 global dynamic TLS model:

```
_D4test3fooFZi:
        lea rdi, qword ptr [rip + _D4test8myGlobali@TLSGD]
        call    __tls_get_addr@PLT
        mov     eax, dword ptr [rax]
        pop     rdx
        ret
```

TLS on OS X

OS X had native TLS only since 10.7 (which LDC requires), DMD has a custom implementation:

- Emit TLS variables to named `__tls_data` and `__tlscoal_nt` sections
- `rt.sections_osx`:
    - `getTLSBlock()`: Lazily create pthreads TLS variable
    - `getTLSBlockAlloc()`: Read that variable, if TLS not yet initialized for this thread copy initializers from above sections
    - `__tls_get_addr()`: Takes an address in either of the two sections, translates it to thread-local copy. Calls emitted by compiler.

TLS on OS X

LDC on OS X:

- Use default LLVM implementation
- Need to use functions from dyld_priv.h to get GC ranges
    - Might be a problem for App Store deployment?
    - API uses Apple-specific Blocks extension

Fibers

```
import core.thread : Fiber;

void f() {
    writeln(”In f(), yielding execution”);
    Fiber.yield();
    writeln(”Back in f() again”);
}

auto fiber = new Fiber(&f);
fiber.call();
writeln(”In caller”);
fiber.call();
```

Fibers

- Cooperative, user-space multitasking
- Just save the registers to the stack, switch out stack and instruction pointers, load registers from new stack
- Need to keep TLS and EH intact (easy in theory; in practice however…)

```
int tlsGlobal = 42;
void bar() {
  writeln(tlsGlobal);
  Fiber.yield();
  writeln(tlsGlobal);
}
```

Pop quiz: You are writing a C program on GNU/Linux using GCC. What's the name of the first function that is executed when your program starts?

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(Hint: It's not ”main”.)

GNU/Linux program startup

- loader calls `_start`, defined in glibc
- `_start` calls `__libc_start_main` (glibc/csu/libc-start.c)
    - Store stack end
    - Set `__environ`
    - Call global constructors (.ctors, `__attribute__((constructor))`
    - `main(…)`
    - Call global destructors (.dtors, `__attribute__((destructor))`

Recap

Need to determine:

- All `ModuleInfos`
- Stack region
- Global data segments (.data, .bss)
- TLS segments for each thread
- DMD: Exception handling tables

”Old” module registration

- `_Dmodule_ref`: Global linked list of `ModuleInfo` references
- Each object file adds its module using a (C) global constructor
- Simple, portable, does not need any special compiler support
- Still used by LDC on platforms without shared library support, on Solaris/Android/other Posixen by DMD
- For GC ranges, just use `_bss_start`, `_end`, et al.
- DMD: Bracketing symbols for EH tables
- However: Shared libraries

Shared libraries

- Only applies to Posix/ELF for now

- Different use cases:
  - D program linking to D shared libraries
  - D program loading D shared libraries at runtime
  - C program linking to D shared libraries
  - C program loading D shared libraries at runtime

- All require use of shared druntime/Phobos

Module conflict detection

- Want to prohibit defining same D module in two different images, chaos would ensue
- Idea: When loading a shared library:
  - Iterate through all `ModuleInfo` references
  - For each of them check if the address is in the current image
  - If not, dynamic linker has merged it with same module in other library, fail
- Problem: Copy relocations

Detour: Copy relocations

- What if you have a non-PIC executable (position-dependent code)…
- …that references a data symbol defined in a shared library it links to?

- Fix:
  - Allocate space in the executable's .bss section
  - When loading library, copy symbol from library into that memory
  - Fix up references in library, which is built with PIC

- Breaks our simple module conflict detection!

Module conflict detection, v2

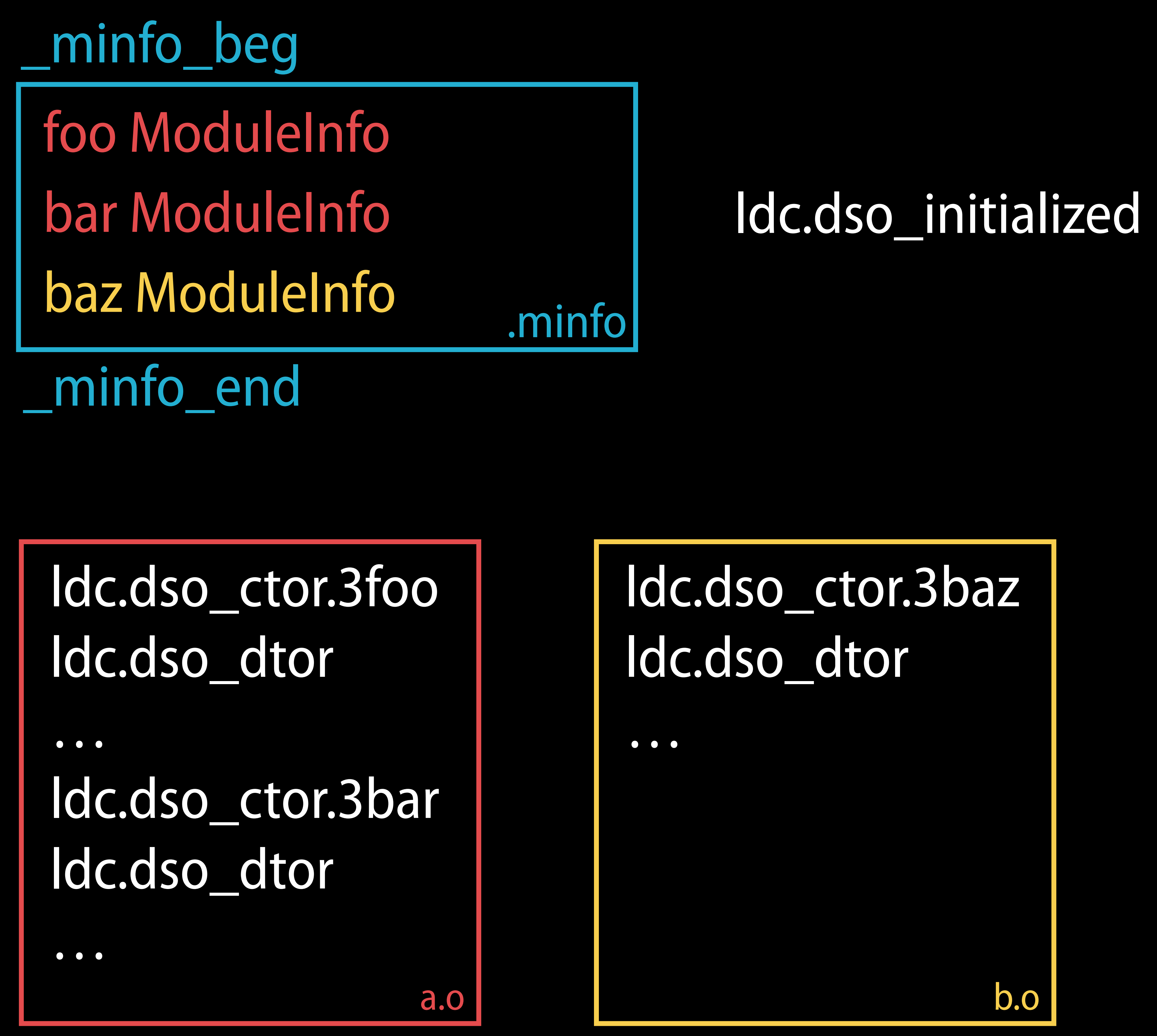
- Want to prohibit defining same D module in two different shared libraries, chaos would ensue
- Idea: When loading a shared library:
  - Iterate through all `ModuleInfo` references
  - For each of them check if the address is in the *current image* or in the *main executable's BSS section*
  - If not, dynamic linker has merged it with same module in other library, fail
- Seems innocent enough, but we'll have fun due to linker bugs

Design constraints

- Want to stay on LLVM IR level for tooling and ease of use
  - Cannot emit arbitrary relocations
- Custom linker scripts are out
- LLVM IR does not support COMDAT symbols in custom sections (arguably a bug, certainly an arbitrary limitation)

`_d_dso_registry:`

- Checks whether DSO has already been registered
- Uses `dl_iterate_phdr` to locate data/TLS segments
- Checks module collisions
- Registers module with global list, runs constructors, etc.



_minfo_beg

foo ModuleInfo
bar ModuleInfo
baz ModuleInfo
.minfo

_minfo_end

ldc.dso_initialized

ldc.dso_ctor.3foo
ldc.dso_dtor
…
ldc.dso_ctor.3bar
ldc.dso_dtor
…
a.o

ldc.dso_ctor.3baz
ldc.dso_dtor
…
b.o

druntime | executable

--gc-sections

- Linker-level removal of object file sections that are not referenced by any other code (certain sections are *roots*, see KEEP in `ld --verbose`)
- Idea: Put each function/variable into its own section
- Do not want linker to remove ModuleInfo references in .minfo, for DMD also custom EH tables
- Custom linker script breaks just using gcc to link, other tooling
- ld.gold merges COMDATs before checking their dependencies

--gc-sections

- Unsolved in DMD, `WONTFIX` for GDC
- Having one .ctor per module (LDC) naturally solves this, pin the `ModuleInfo` there
- Because of a bug in ld.bfd, cannot use `__bss_start`, `_end` are made local to the main executable; have weak `_d_execBss{Beg, End}Addr`
- LDC binaries (static runtime, release mode) are typically ≈¼ as big as DMD built ones, ≈1⁄16 the size of default GDC binaries
- Possible alternative: Whole program/link time optimization

Resources

- OS X open source tools:
  - System linker: *http://opensource.apple.com/source/ld64*
  - Runtimer linker/loader: *http://opensource.apple.com/source/dyld*
- (Linux) linker internals: *http://www.airs.com/blog/archives/38*
- Linux TLS: *http://www.akkadia.org/drepper/tls.pdf*
- Windows TLS: *http://www.nynaeve.net/?tag=tls*
- Issues with migrating fibers across threads: *LDC GitHub #666*
- Relevant dlang Bugzilla issues: *879, 11378, 13025*

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