System-Wide Elimination of Dynamic Symbols

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Background

Lots of “dead weight” in shared libraries:

- Obsolete interfaces (`gets()`)
- Very rarely used APIs (<complex.h>)
- Backwards compatibility

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No need for most of that on special-purpose hardware

- Special-purpose distros (Android, Tizen)
- Small-devices (IoT) Tizen profile

Problem Statement

Slim down by eliminating unused code/data from shared libraries

Possible? Not in general:

- Future applications may use any public API
- Binaries may use any backward-compat API

Assume “closed world” full-distro rebuilds

- Can see what APIs get used
- No “potential future uses”

Aside: Elimination in Static Linking

For static linking, already available in practice:

1. Compile with `gcc -ffunction-sections -fdata-sections`:

Per-function sections

```
        .section        .text.foo,"ax",@progbits
        .globl  foo
        .type   foo, @function
foo:
        movl    $42, %eax
        ret
```

2. Link with `-gc-sections`
   Linker omits sections not reachable by relocations from the entry point

-gc-sections for Dynamic Modules

Can we use `-gc-sections` for shared libraries?
For dynamic linking, entrypoint is not the only GC root

- The `.dynamic` section is another root
  Points to dynamic symbols and global library constructors/destructors
- Most code is reachable from dynamic symbols (the library's interface)
- Reducing the API surface (changing symbol's *visibility* to "hidden") allows GC

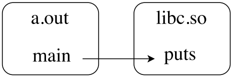
Dynamic Dependencies

Want to compute reachability on dynamic symbol set

- Explicit dependencies

Direct Call

```
int main()
{
  puts("Hello World");
}
```



Dynamic Dependencies

Want to compute reachability on dynamic symbol set

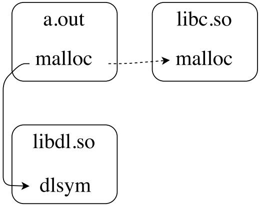
- Explicit dependencies
- Implicit, via dlsym()

Dynamic Lookup via dlsym

```
#include <dlfcn.h>

void *dlsym(void *handle,
            const char *name);

void malloc(size_t n)
{
  void *real_malloc =
      dlsym(RTLD_NEXT, "malloc");
  ...
}
```



Dynamic Dependencies

Want to compute reachability on dynamic symbol set

- Explicit dependencies
- Implicit, via `dlsym()`
- Non-standard runtime lookups

Dynamic Lookup via direct inspection

```
#include <elf.h>
extern Elf64_Dyn _DYNAMIC[];

...
  Elf64_Dyn *dyn = ...;
  for (int i = 0; dyn[i] != DT_NULL; i++)
    if (dyn[i].d_tag == DT_SYMTAB) {
      ...
    }
...
```

Dynamic Dependencies

Want to compute reachability on dynamic symbol set

- Explicit dependencies
- Implicit, via `dlsym()`
- Non-standard runtime lookups

Must be conservative

- Missed explicit deps — build-time link error
- Missed runtime deps — run-time fallback or error

Handling Runtime Dependencies

Targets of runtime lookups impossible to compute exactly:

- Custom, non-dlsym lookups impossible to analyze
- Issues with dlsym lookups:
  - dlsym wrappers
  - Non-constant *name* argument
  - Interpreters may expose dlsym to scripts (Lua, Python)

However, calls to dlsym are statically visible

- Discover wrappers for dlsym
- Best-effort analysis of dlsym-like functions
- Allow manual annotation where static analysis fails
- Completely punt on low-level lookups

High-level Approach

1. Discover dlsym wrappers
2. Try to compute dlsym lookup targets
3. Record static dependencies
4. Analyze distro-wide symbol dependency graph
5. Eliminate unused symbols

Three distro-wide rebuilds required in total

Implementation goals:

- GCC plugins for dlsym analysis
- Linker plugins for explicit deps and elimination

Annotating dlsym Wrappers

Constraints/assumptions:

- Wrappers may be used across translation units
- Link-time analysis not sufficient
- Symbol *name* argument passed unchanged

Solution: two-stage algorithm:

1. Dump all *jump functions* distro-wide

Definition (Jump functions)

GCC IPA term for function call argument transfer

If we have

```
void *next(const char *name) {return dlsym(RTLD_NEXT, name)
```

then we have a graph edge `dlsym/1` → `next/0`

Annotating dlsym Wrappers

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- Wrappers may be used across translation units
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- Symbol *name* argument passed unchanged

Solution: two-stage algorithm:

1. Dump all *jump functions* distro-wide
2. Compute *transitive closure* on jump function graph from root `dlsym/1`

Computing dlsym Targets

Multiple targets per one dlsym call site

```
const char *ICU_API[] = {"ucol_open", "ucol_close", ...};
...
  for (i = 0; i < ICU_FUNC_CNT; i++) {
    handle = dlsym(g_dl_icu_handle, ICU_API[i]);
    ...
    icu_handle[i] = handle;
  }
```

In the compiler plugin:

- Iteration over callsites of dlsym-like functions
- Simple GIMPLE analysis for array/struct references

Recording Static Dependencies

Use LTO plugin interface for introspection

- Avoid patching the linker
- Avoid duplicated work (search in static archives)

The `claim_file_handler` API hook allows to inspect object files

- Find symbol tables
- Find relocation tables
- Resolved relocations give intra-DSO dependencies
- Cross-DSO deps are given by dynamic relocations

Eliminating Unused Symbols

Two opportunities: compile time (in GCC) and link time

1. At compile time: optional, for optimization
   - Compiler doesn't process asm inputs
   - More constrained
2. At link time: required
   - Can eliminate more than the compiler

Implementation:

1. Force-enable `-gc-sections`
2. Set *hidden visibility* on eliminated symbols
   Linker plugin makes copies of `.o` files with adjusted visibility info

Identifying Matching Object Files

Need to robustly identify translation units

- Names can be too common: `conftest.c`
- ...or unstable: `/tmp/cc123abc.o`

Generate a stable, unique *srcid* for each object file

- Strong hash of *blinded* IR dump before optimizations
- “Blinding” removes string contents: stabilize against `__DATE__` substitutions
- Emit an empty `.comment.privplugid.`*`srcid`* section

Pitfalls

Global transformation proved to be problematic

- Must ensure all dependencies seen in analysis
- Must be able to rebuild all packages with elimination

Issues with driving elimination from linker plugin

- Some projects only build with `ld.bfd` (Glibc)
- Linker plugin API underspecified
- Not interoperable with LTO
- Versioned symbols poorly supported
- BFD linker incorrectly orders shared libraries with plugin

Results: Aggregate Section Sizes before/after Optimization

section name	original size, KB	optimized size, KB	delta, KB	delta, %
.text	30211	24176	6035	19
.data	310	293	17	5
.data.rel.ro	262	233	29	11
.rodata	5831	4701	1130	19
.dynstr	1885	859	1025	54
.dynsym	1347	860	486	36
.got	248	192	56	22
.plt	610	452	158	25
.rel.dyn	415	356	59	14
.rel.plt	397	292	105	26
.hash	594	383	211	35

Thank you!