Dead Debug Data Elimination Using Fragmented DWARF

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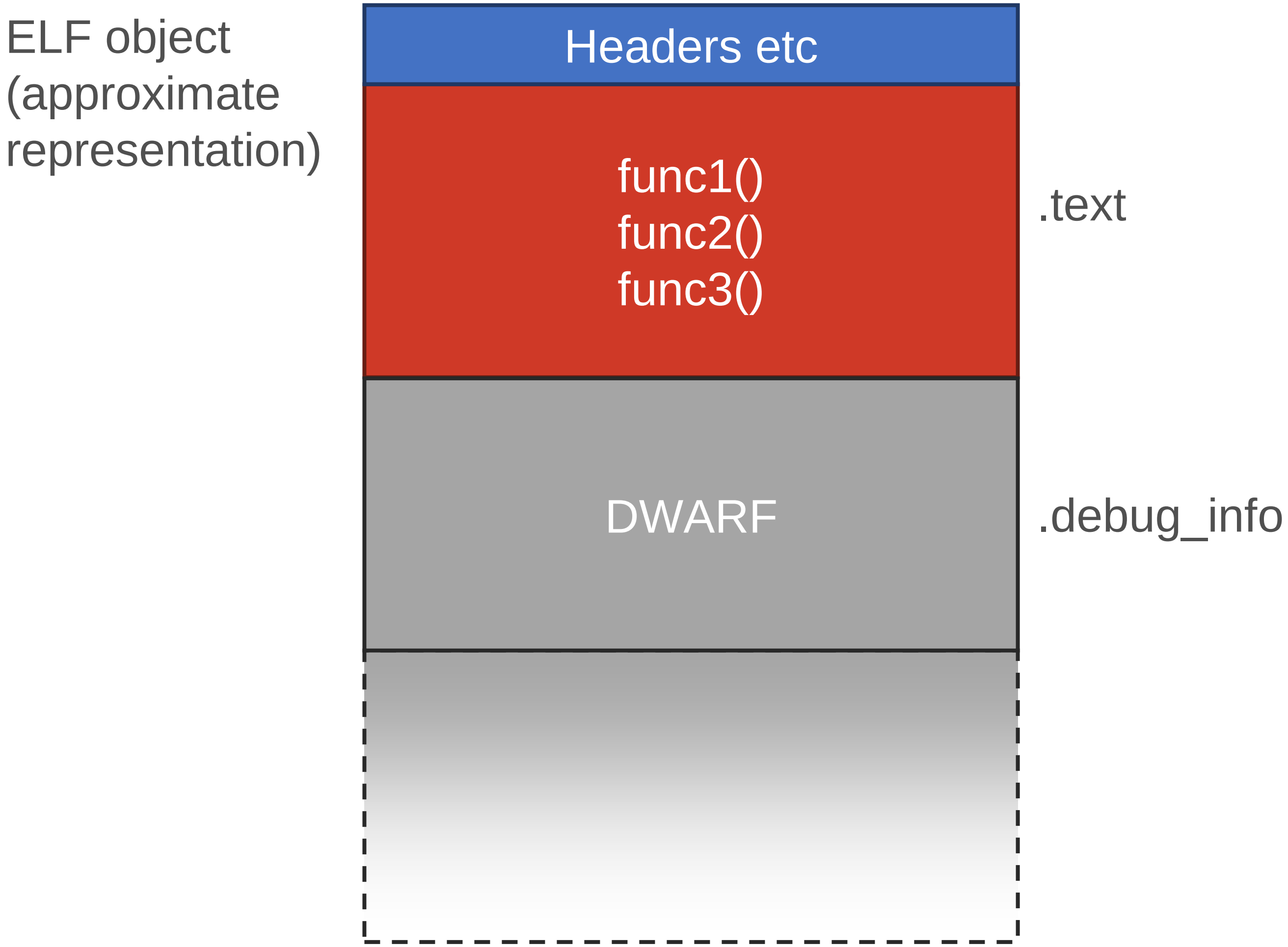
SN Systems (Sony Interactive Entertainment)

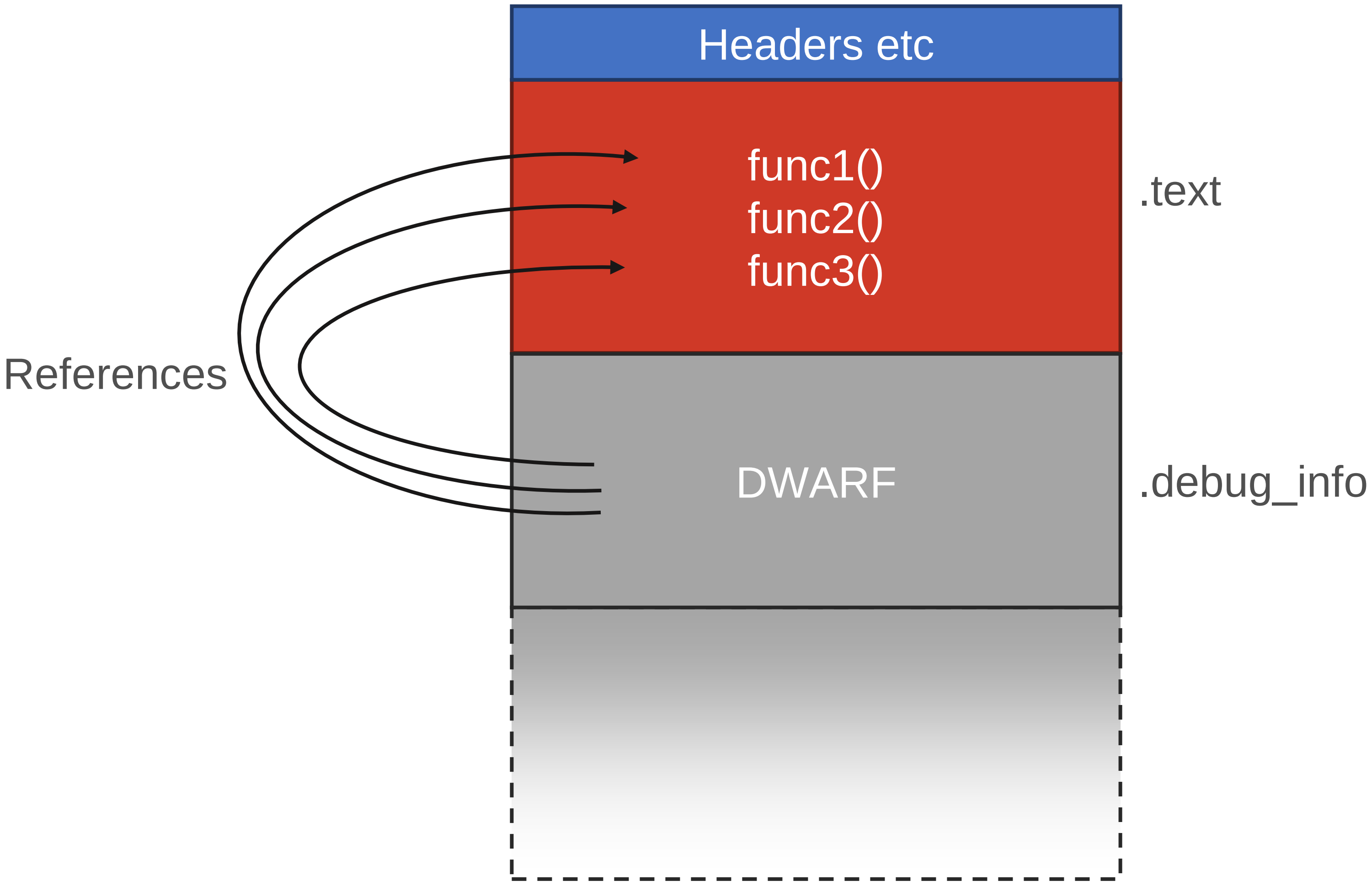
LLVM Developers' Meeting 2020

The Problem



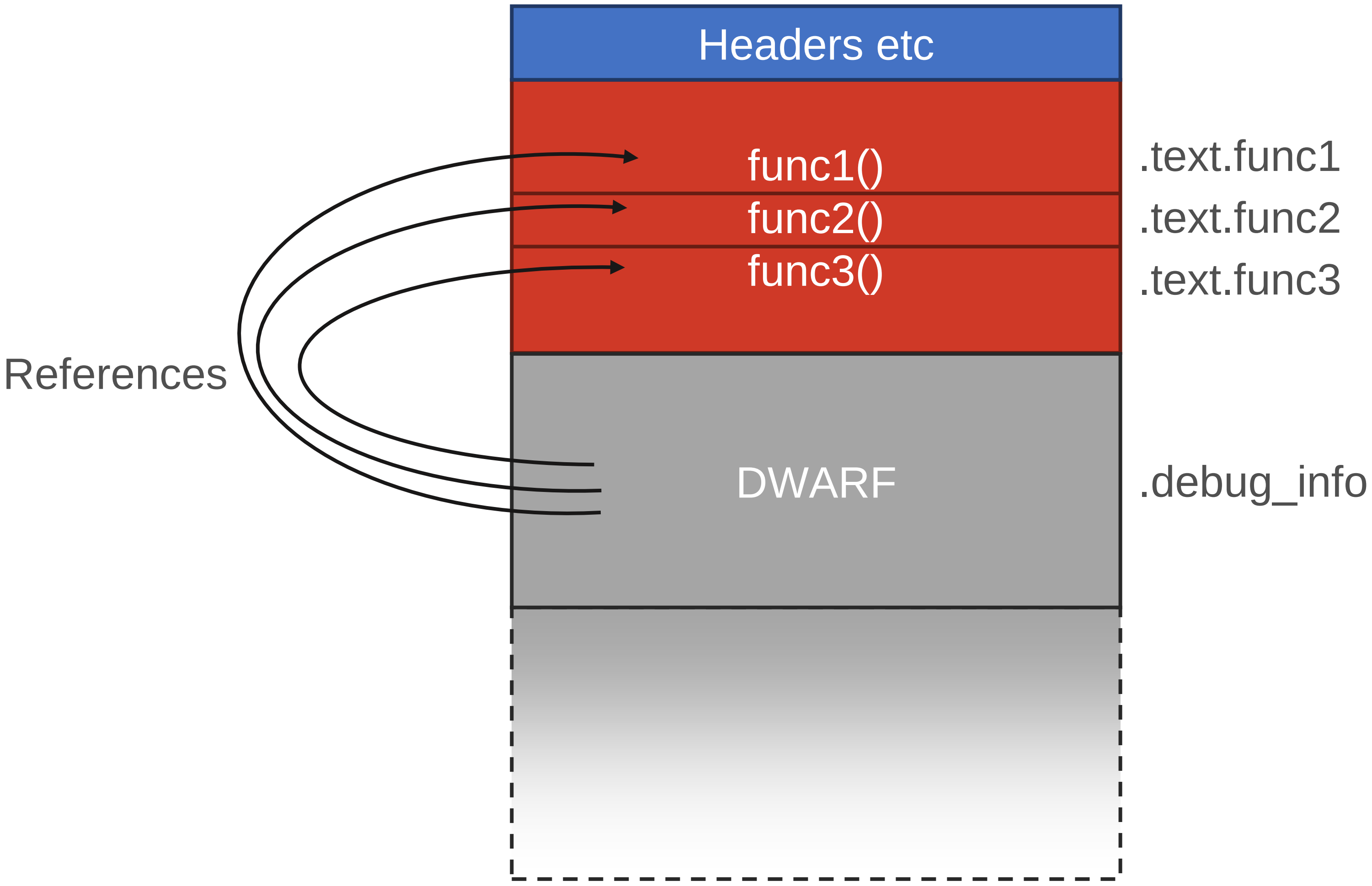
ELF object
(approximate
representation)
Headers etc
func1()
func2()
func3()
.text
DWARF
.debug_info

The Problem



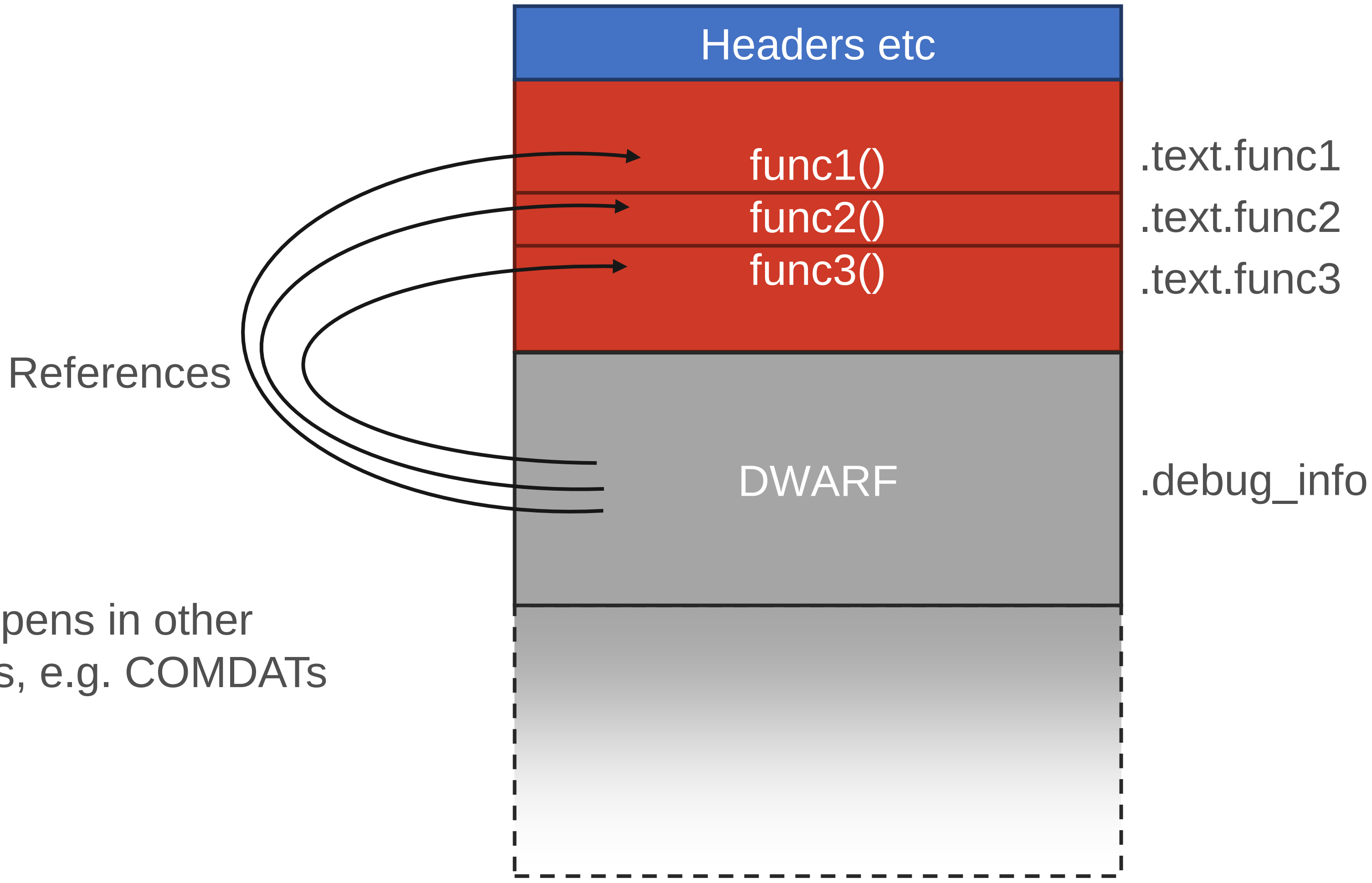
Headers etc
func1()
func2()
func3()
.text
References
DWARF
.debug_info

The Problem



clang -ffunction-sections ("section per function")

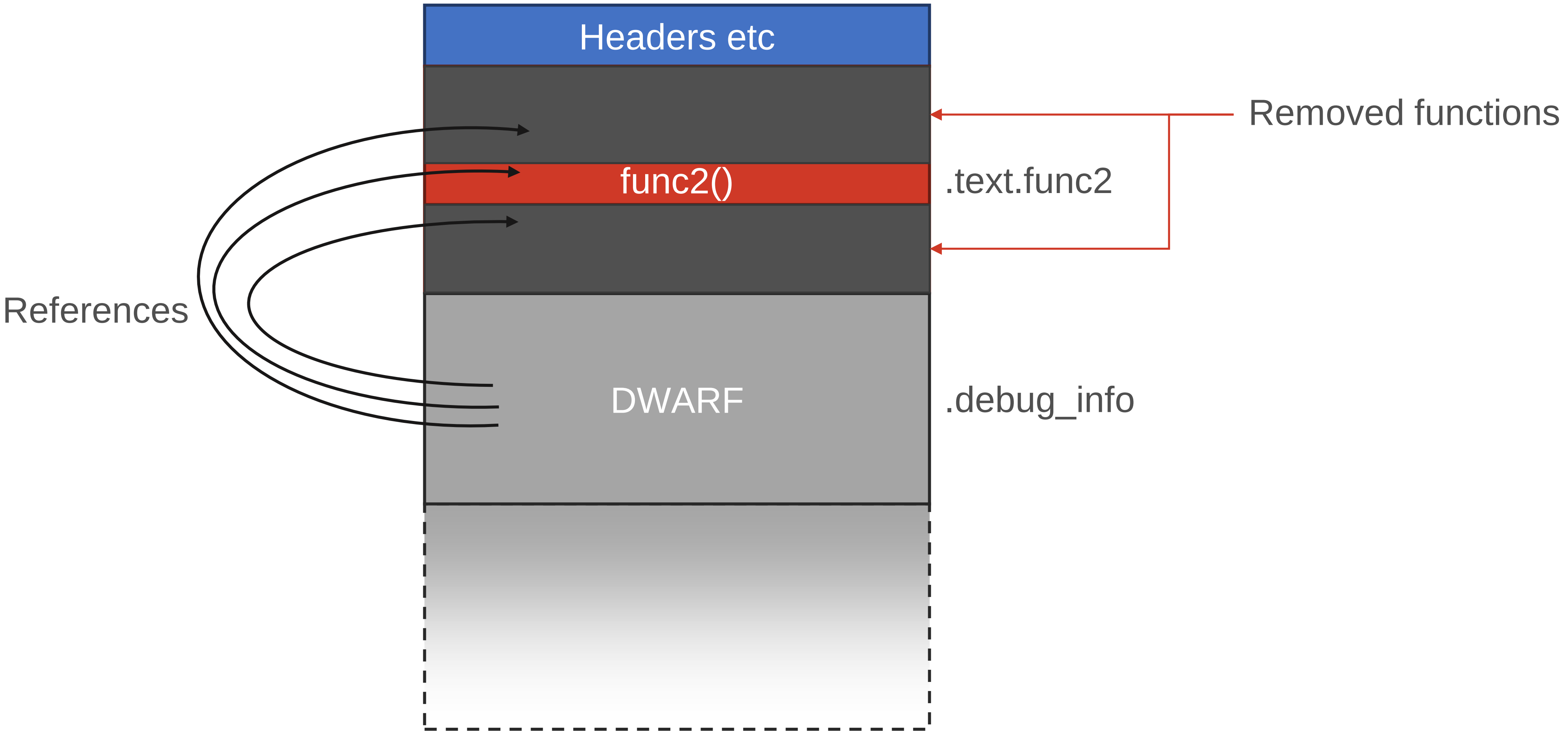
The Problem



Also happens in other situations, e.g. COMDATs

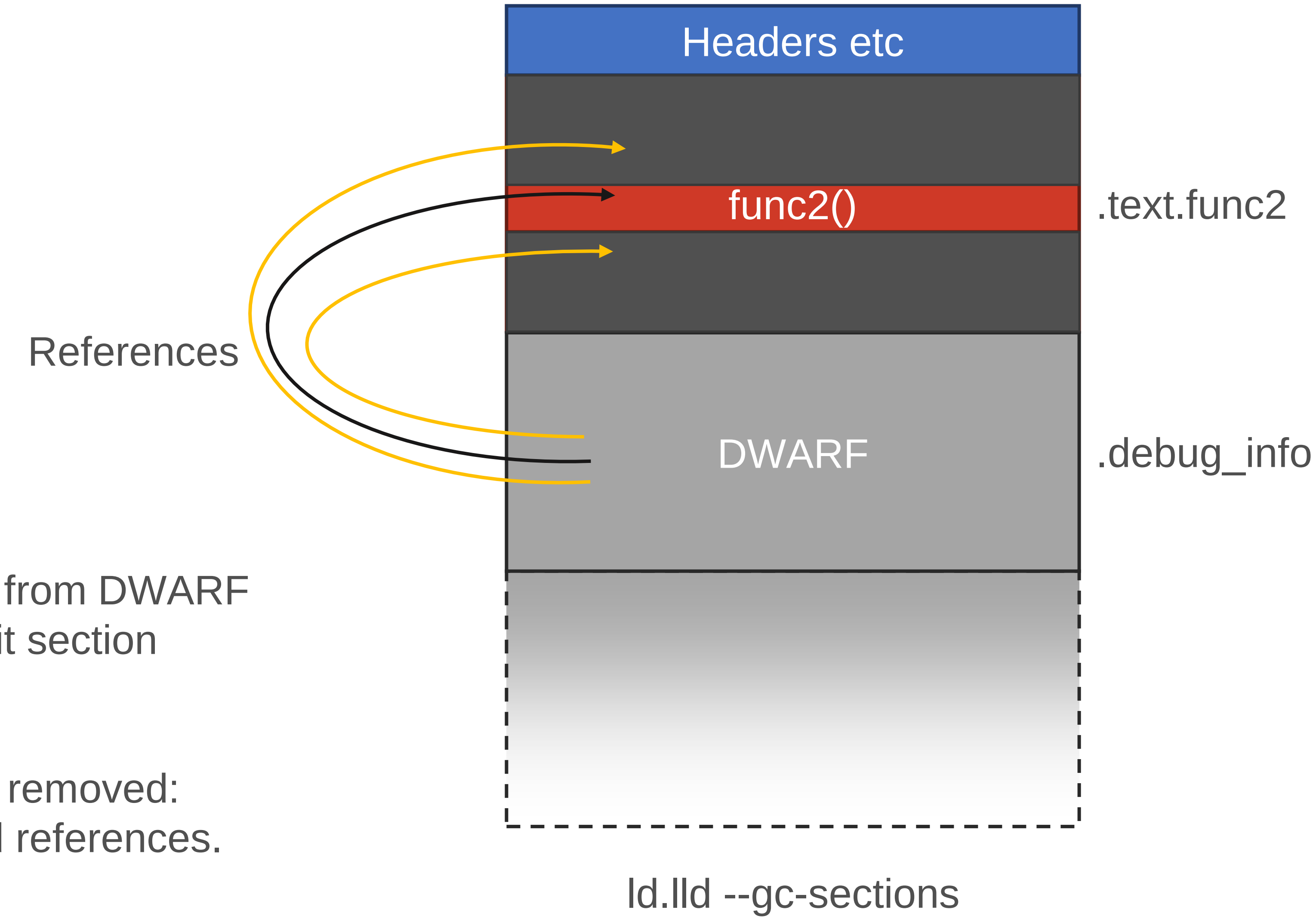
clang -ffunction-sections

The Problem



ld.lld --gc-sections

The Problem



References from DWARF do not inhibit section removal.

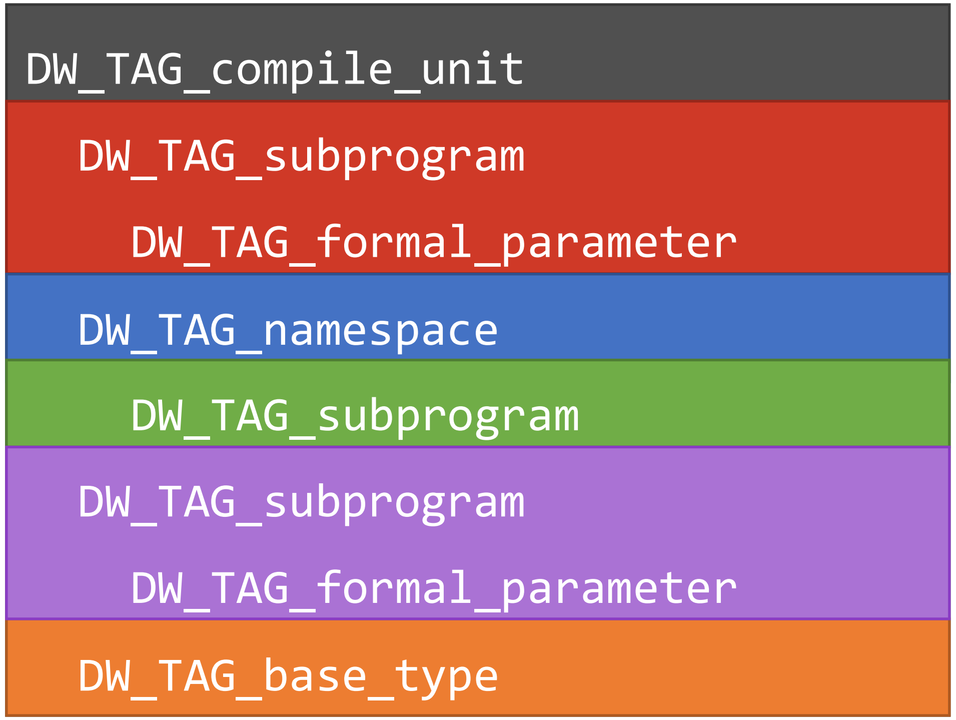
No DWARF removed: leaves dead references.

Fragmenting DWARF (example)

```
DW_TAG_compile_unit
  DW_TAG_subprogram
    DW_TAG_formal_parameter
  DW_TAG_namespace
    DW_TAG_subprogram
  DW_TAG_subprogram
    DW_TAG_formal_parameter
  DW_TAG_base_type
```

- Example (simplified) .debug_info tree.
- Contains 3 functions (“subprograms”).

Fragmenting DWARF (example)



- Fragment by splitting into “generic” bits and parts for specific functions (and variables).
- Result is 6 separate .debug_info sections.
- .debug_info sections for functions linked to corresponding .text sections.

Fragmenting DWARF (example)

```
DW_TAG_compile_unit

  DW_TAG_namespace

  DW_TAG_subprogram
    DW_TAG_formal_parameter
  DW_TAG_base_type
```

- If linker discards .text section, it also discards associated .debug_info section.

Fragmenting DWARF (example)

```
DW_TAG_compile_unit
  DW_TAG_namespace
  DW_TAG_subprogram
    DW_TAG_formal_parameter
  DW_TAG_base_type
```

- Linker concatenates like-named sections together.
- Result is smaller DWARF with no dead references.
- Same approach works for other debug sections.

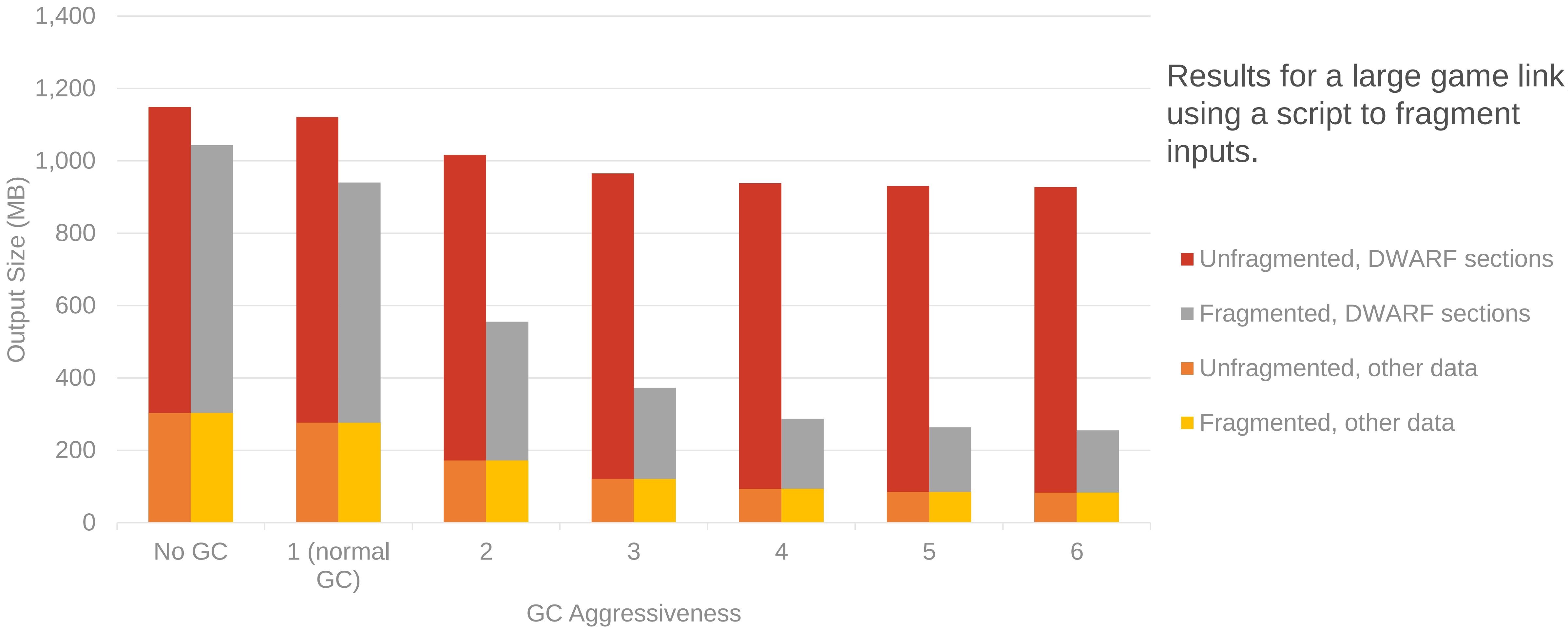
Fragmenting DWARF Limitations

- Works for .debug_info, .debug_line, .debug_aranges, .debug_ranges and .debug_loc.
  - Other sections don’t have direct references to variables/functions.
  - Doesn’t work for DWARF v5 .debug_rnglists/.debug_loclists, due to usage of entry indexes.

- Doesn’t get rid of all “useless” information.
  - E.g. empty namespace tags, unused .debug_abbrev entries.

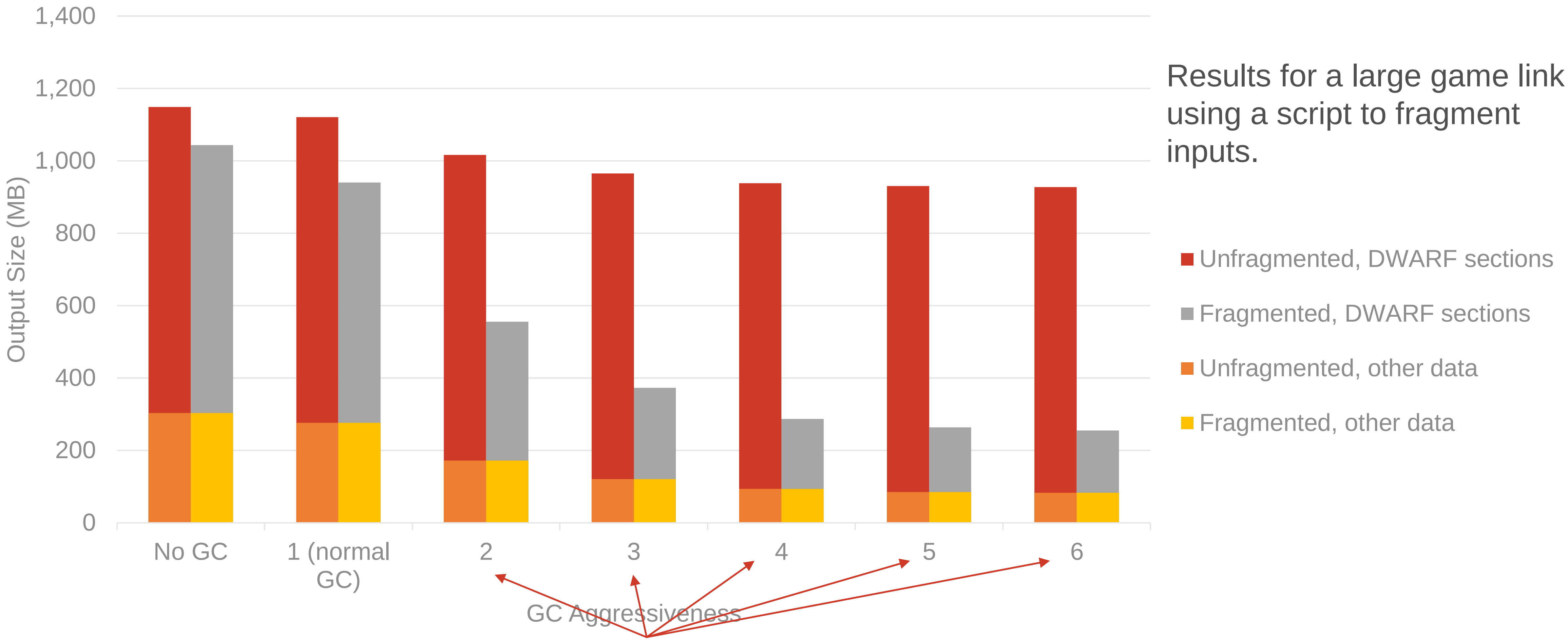
- Intermediate objects not valid DWARF…
  - … but consumers could be taught how to read them.

Performance (Output Size)



Results for a large game link, using a script to fragment inputs.

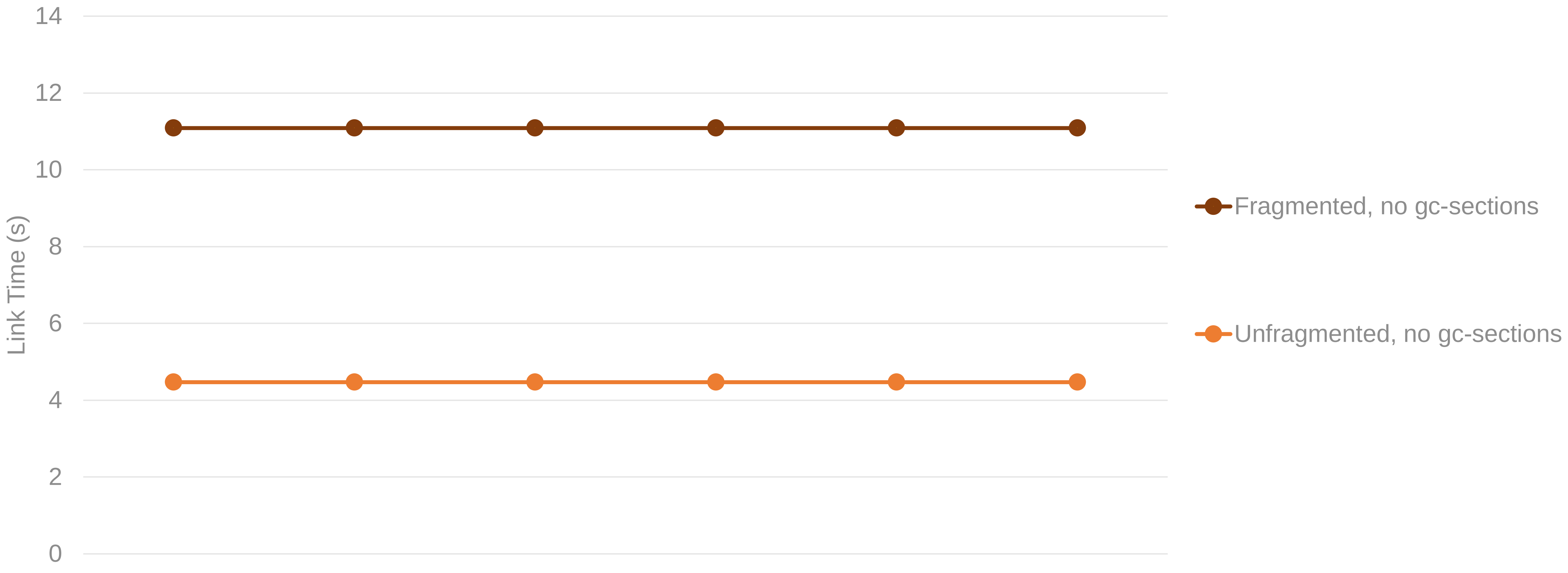
Performance (Output Size)



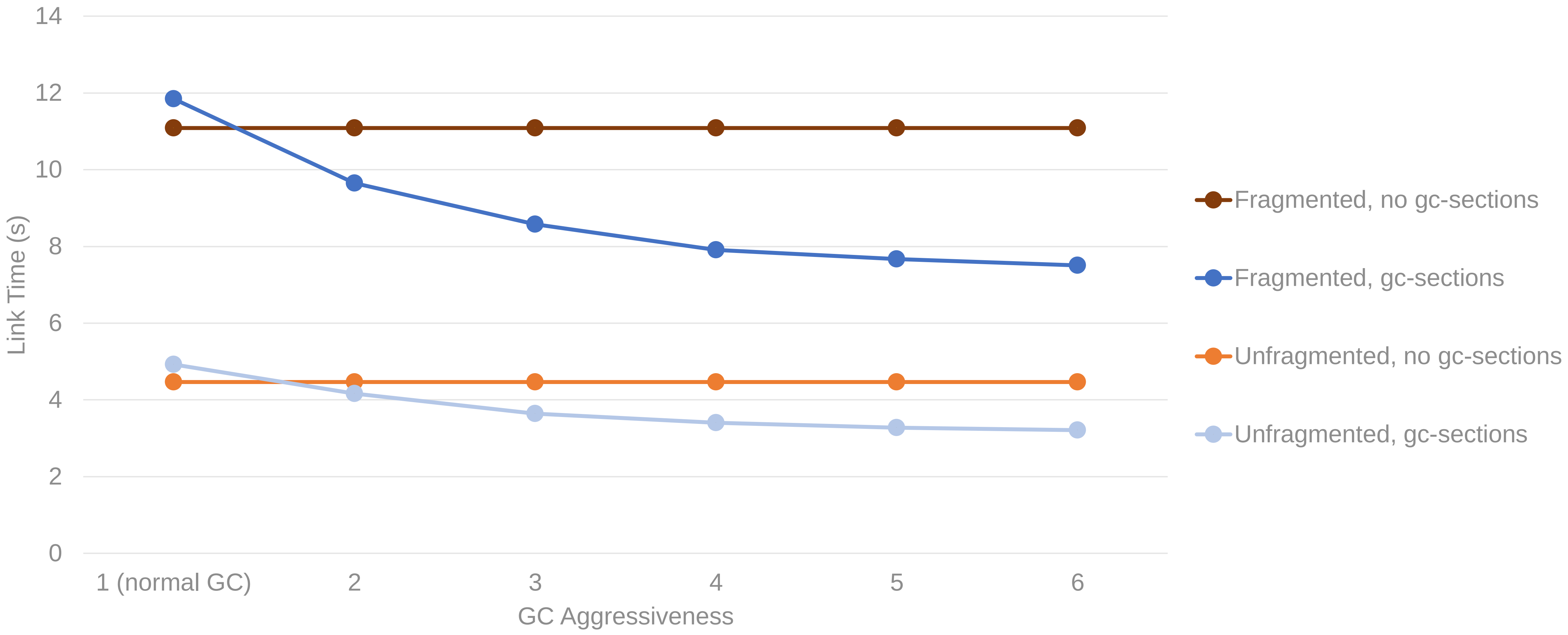
Artificially treat more sections as “dead” by ignoring relocations in liveness analysis

Results for a large game link, using a script to fragment inputs.

Performance (Link Time)



Performance (Link Time)



Caveats

- Results use a modified LLD to support:
  - Using SHF_LINK_ORDER without ordering anything.
    - Reordering would corrupt the debug data.
  - References sections in groups, from outside the group.
    - Illegal according to the ABI.
  - Could use Group Sections instead.

- Figures include LLD patch improving performance.
  - Avoids doing some unnecessary string comparisons for debug sections.
  - May not be 100% correct for all objects - needs further investigation.

Alternative Solutions

- Rewrite DWARF at link time.
    - What the Sony proprietary linker does for PlayStation® 4 .debug_line.
    - Theoretically what LTO could effectively do.
    - Investigated within LLD by Alexey Lapshin (https://reviews.llvm.org/D74169).
    - Slow, and not particularly within traditional linker's feature set.
        - 8 times slower in Alexey's initial prototype when linking clang.

- Post-link optimization
    - Wasted I/O.
    - Relies on being able to identify dead debug data without relocations.
    - See llvm-dwarfutil proposal (http://lists.llvm.org/pipermail/llvm-dev/2020-August/144579.html).

- Change DWARF structure in new standard
    - Doesn't solve issue for existing standards.

Conclusion

- Fragmenting the sections adds a lot of overhead.
  - Profiling LLD suggests it is largely due to the cost of creating more input sections internally.
  - String matching makes things slow.
  - Time savings from writing less outweighed by this overhead.

- Big size savings available, if willing to pay link time cost.
  - The more dead code, the better the trade-off.
  - Should improve debugger load times.

- Future work:
  - Investigate debugger load time improvements.
  - Use ELF Group sections instead of SHF_LINK_ORDER.
  - Investigate LLD performance improvements for many input sections.
  - Implement script in MC.

Appendix: Duration/Size Changes vs Unfragmented

- Figures for fragmented approach as a percentage of the unfragmented approach:

Relocations used for GC liveness analysis	Link Time	Size (total)	Size (debug data)
No GC	248%	91%	88%
100% (normal GC)	240%	84%	79%
80%	232%	55%	45%
60%	236%	39%	30%
40%	232%	31%	23%
20%	234%	28%	21%
0%	234%	28%	20%