(Ab)using compiler tools

Reka Kovacs / rekanikolett@gmail.com

CppCon 2019

(Ab)using compiler tools

Two binary analysis tools
Only one of them is strictly connected to compilers
No abuse, no fun

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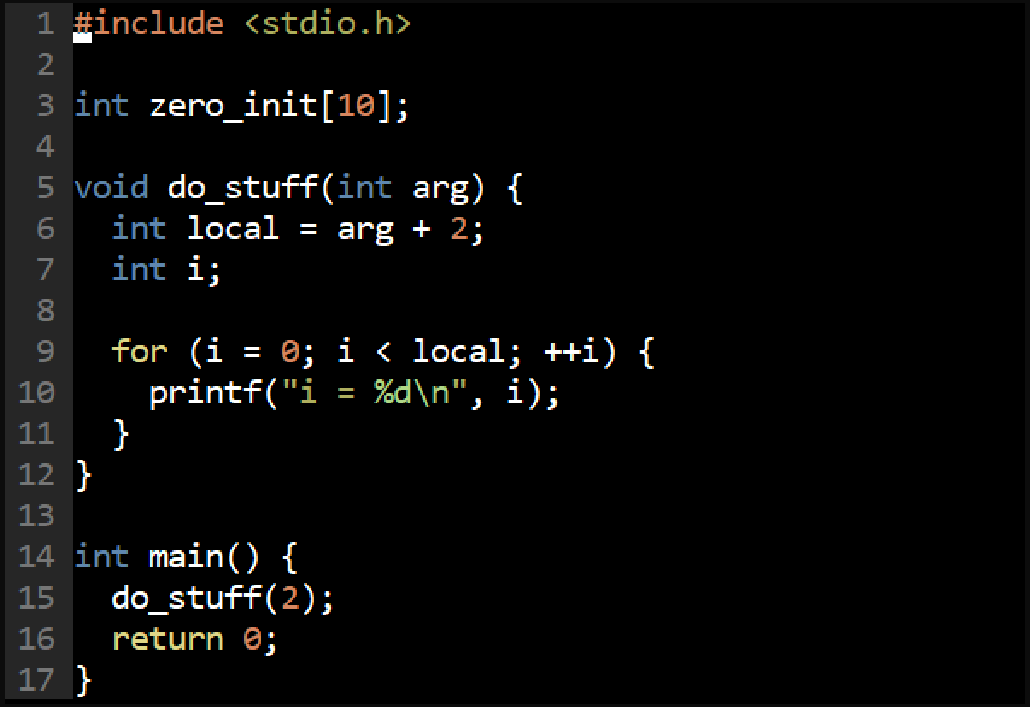
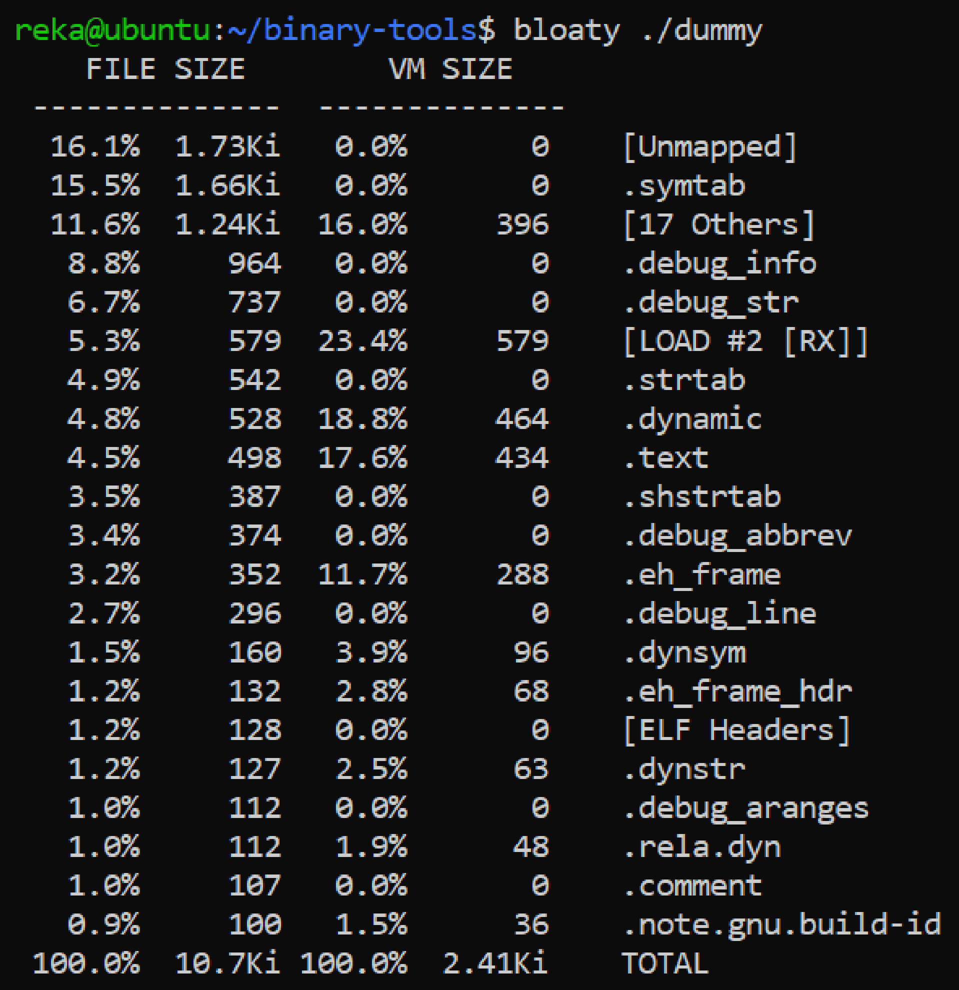
Bloaty McBloatface

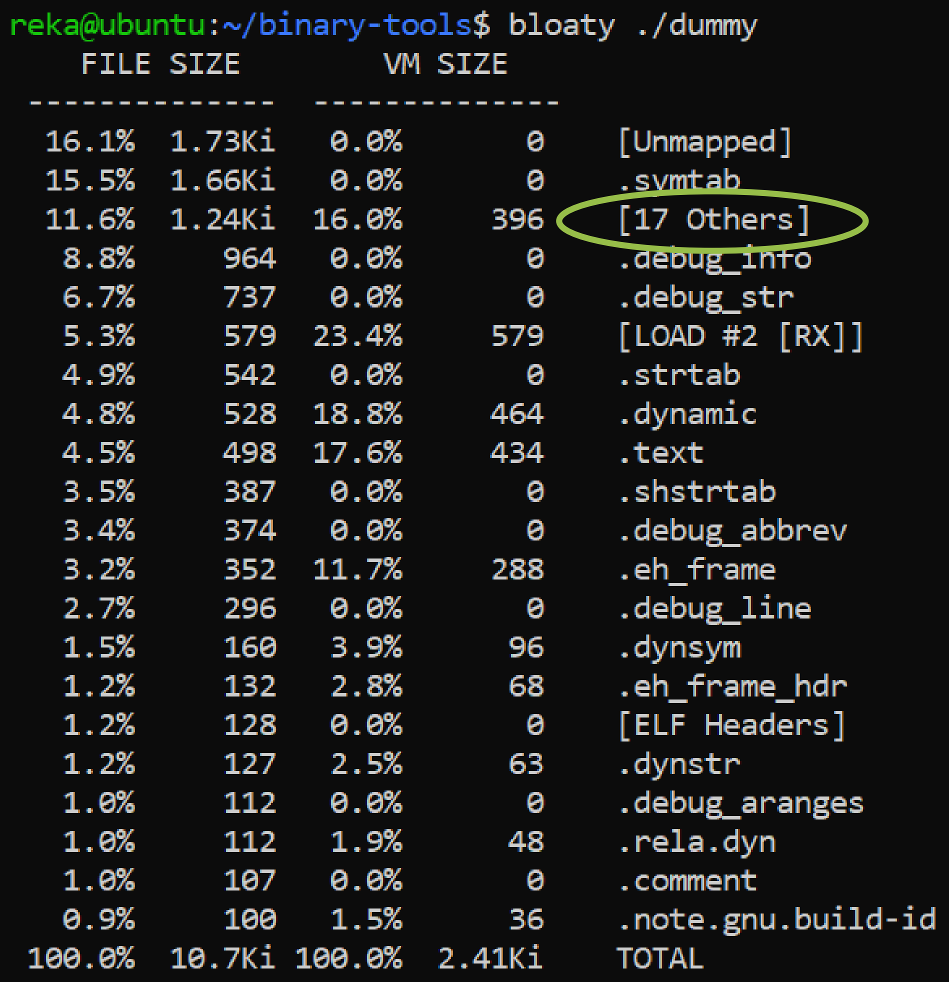
- Josh Haberman, 2016
- https://github.com/google/bloaty
- http://blog.reverberate.org/
- What is taking up space in your binary?
- Supports ELF and Mach-O, PE is desired



```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```



```
reka@ubuntu:~/binary-tools$ bloaty ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  16.1%  1.73Ki   0.0%       0    [Unmapped]
  15.5%  1.66Ki   0.0%       0    .symtab
  11.6%  1.24Ki  16.0%     396    [17 Others]
   8.8%     964   0.0%       0    .debug_info
   6.7%     737   0.0%       0    .debug_str
   5.3%     579  23.4%     579    [LOAD #2 [RX]]
   4.9%     542   0.0%       0    .strtab
   4.8%     528  18.8%     464    .dynamic
   4.5%     498  17.6%     434    .text
   3.5%     387   0.0%       0    .shstrtab
   3.4%     374   0.0%       0    .debug_abbrev
   3.2%     352  11.7%     288    .eh_frame
   2.7%     296   0.0%       0    .debug_line
   1.5%     160   3.9%      96    .dynsym
   1.2%     132   2.8%      68    .eh_frame_hdr
   1.2%     128   0.0%       0    [ELF Headers]
   1.2%     127   2.5%      63    .dynstr
   1.0%     112   0.0%       0    .debug_aranges
   1.0%     112   1.9%      48    .rela.dyn
   1.0%     107   0.0%       0    .comment
   0.9%     100   1.5%      36    .note.gnu.build-id
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```



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reka@ubuntu:~/binary-tools$ bloaty ./dummy
    FILE SIZE        VM SIZE
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   8.8%     964   0.0%       0    .debug_info
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   2.7%     296   0.0%       0    .debug_line
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   1.2%     132   2.8%      68    .eh_frame_hdr
   1.2%     128   0.0%       0    [ELF Headers]
   1.2%     127   2.5%      63    .dynstr
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   1.0%     107   0.0%       0    .comment
   0.9%     100   1.5%      36    .note.gnu.build-id
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
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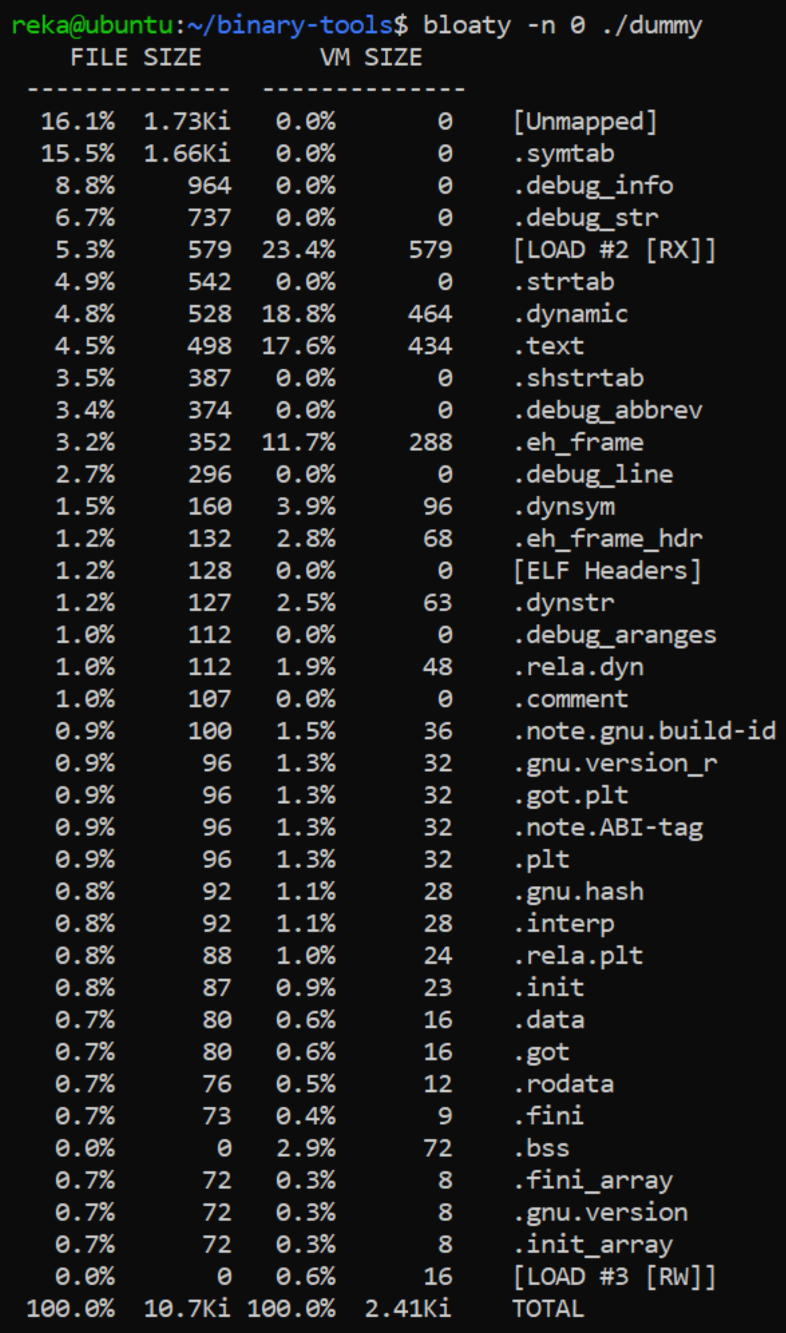

```
reka@ubuntu:~/binary-tools$ bloaty -n 0 ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  16.1%  1.73Ki   0.0%       0    [Unmapped]
  15.5%  1.66Ki   0.0%       0    .symtab
   8.8%     964   0.0%       0    .debug_info
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   1.2%     128   0.0%       0    [ELF Headers]
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   1.0%     112   1.9%      48    .rela.dyn
   1.0%     107   0.0%       0    .comment
   0.9%     100   1.5%      36    .note.gnu.build-id
   0.9%      96   1.3%      32    .gnu.version_r
   0.9%      96   1.3%      32    .got.plt
   0.9%      96   1.3%      32    .note.ABI-tag
   0.9%      96   1.3%      32    .plt
   0.8%      92   1.1%      28    .gnu.hash
   0.8%      92   1.1%      28    .interp
   0.8%      88   1.0%      24    .rela.plt
   0.8%      87   0.9%      23    .init
   0.7%      80   0.6%      16    .data
   0.7%      80   0.6%      16    .got
   0.7%      76   0.5%      12    .rodata
   0.7%      73   0.4%       9    .fini
   0.0%       0   2.9%      72    .bss
   0.7%      72   0.3%       8    .fini_array
   0.7%      72   0.3%       8    .gnu.version
   0.7%      72   0.3%       8    .init_array
   0.0%       0   0.6%      16    [LOAD #3 [RW]]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```
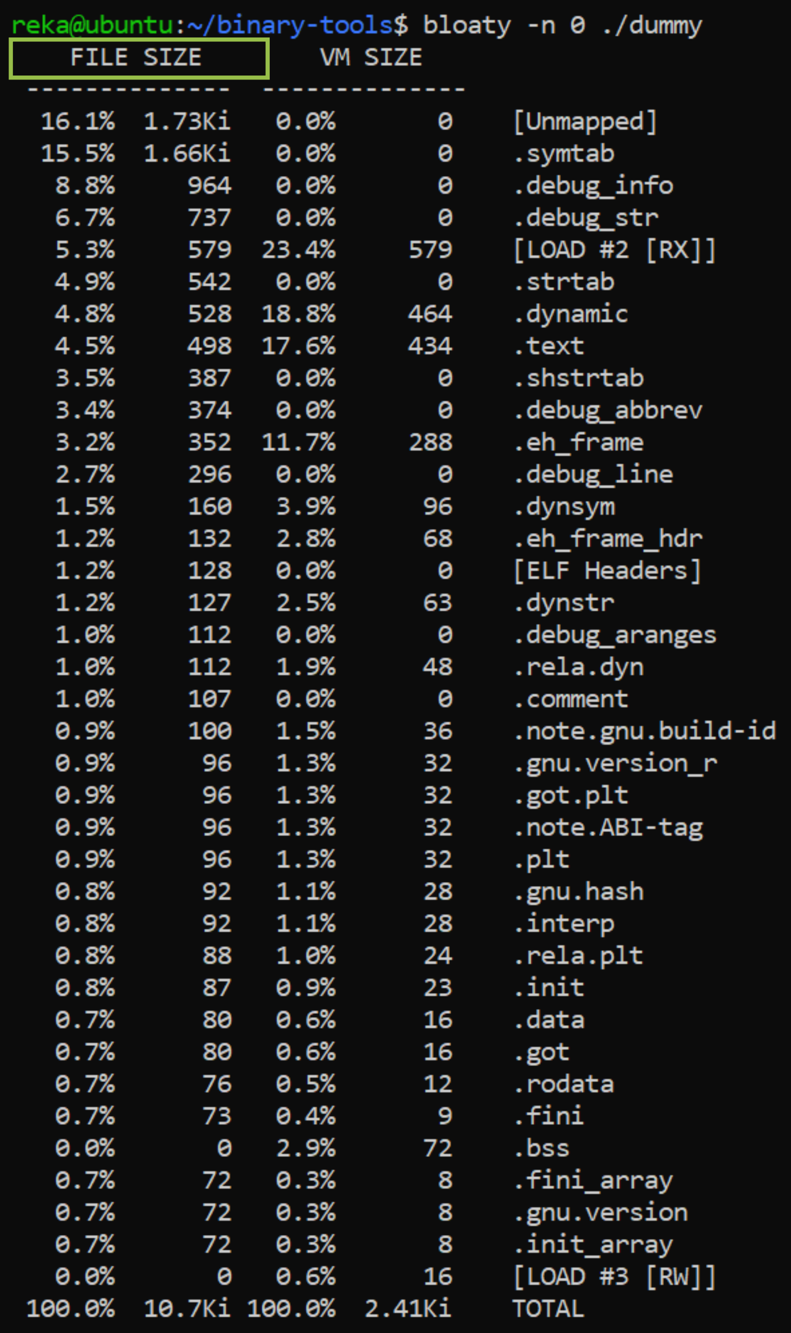

File size

Bytes on disk



```
reka@ubuntu:~/binary-tools$ bloaty -n 0 ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  16.1%  1.73Ki   0.0%       0    [Unmapped]
  15.5%  1.66Ki   0.0%       0    .symtab
   8.8%     964   0.0%       0    .debug_info
   6.7%     737   0.0%       0    .debug_str
   5.3%     579  23.4%     579    [LOAD #2 [RX]]
   4.9%     542   0.0%       0    .strtab
   4.8%     528  18.8%     464    .dynamic
   4.5%     498  17.6%     434    .text
   3.5%     387   0.0%       0    .shstrtab
   3.4%     374   0.0%       0    .debug_abbrev
   3.2%     352  11.7%     288    .eh_frame
   2.7%     296   0.0%       0    .debug_line
   1.5%     160   3.9%      96    .dynsym
   1.2%     132   2.8%      68    .eh_frame_hdr
   1.2%     128   0.0%       0    [ELF Headers]
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   0.8%      92   1.1%      28    .gnu.hash
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   0.8%      88   1.0%      24    .rela.plt
   0.8%      87   0.9%      23    .init
   0.7%      80   0.6%      16    .data
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   0.7%      76   0.5%      12    .rodata
   0.7%      73   0.4%       9    .fini
   0.0%       0   2.9%      72    .bss
   0.7%      72   0.3%       8    .fini_array
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   0.7%      72   0.3%       8    .init_array
   0.0%       0   0.6%      16    [LOAD #3 [RW]]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```
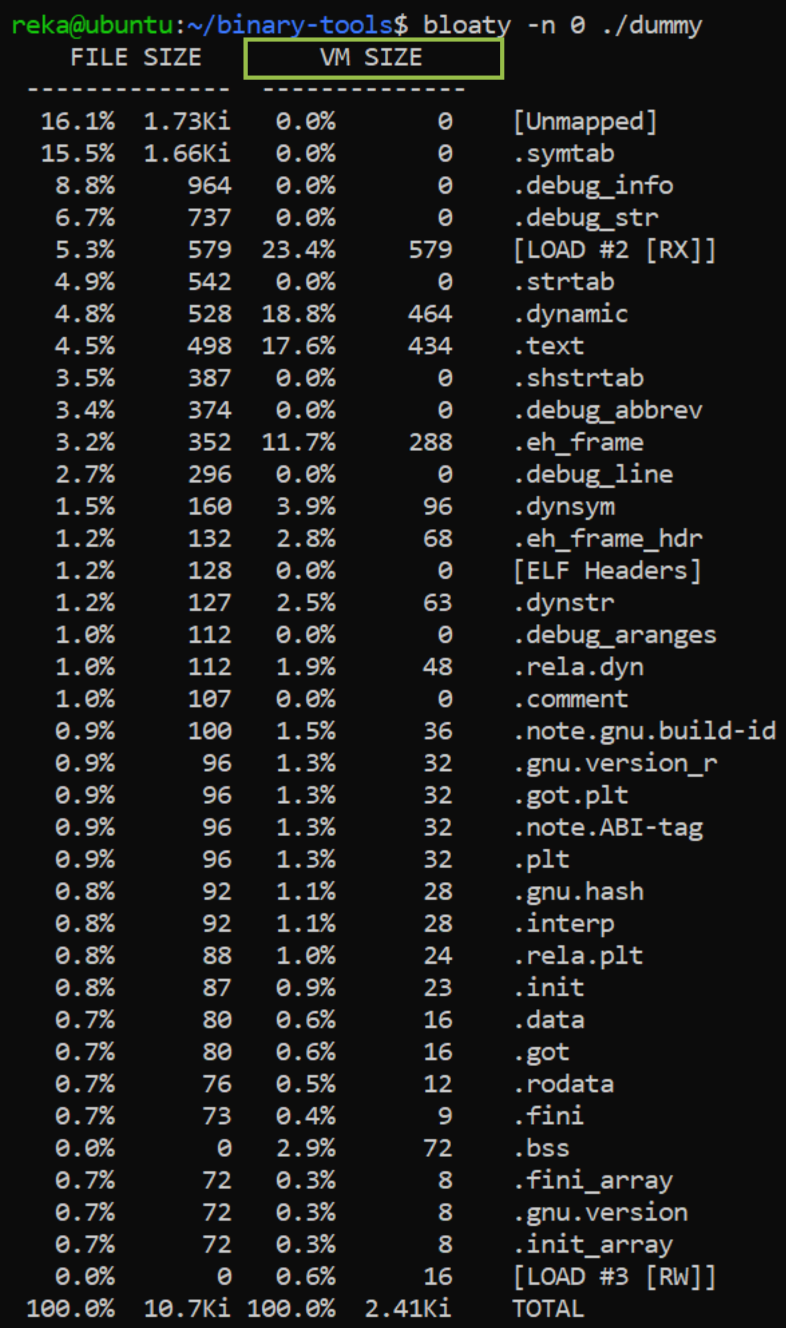

File size

Bytes on disk



```
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  16.1%  1.73Ki   0.0%       0    [Unmapped]
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   8.8%     964   0.0%       0    .debug_info
   6.7%     737   0.0%       0    .debug_str
   5.3%     579  23.4%     579    [LOAD #2 [RX]]
   4.9%     542   0.0%       0    .strtab
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   3.5%     387   0.0%       0    .shstrtab
   3.4%     374   0.0%       0    .debug_abbrev
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   0.7%      72   0.3%       8    .init_array
   0.0%       0   0.6%      16    [LOAD #3 [RW]]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```
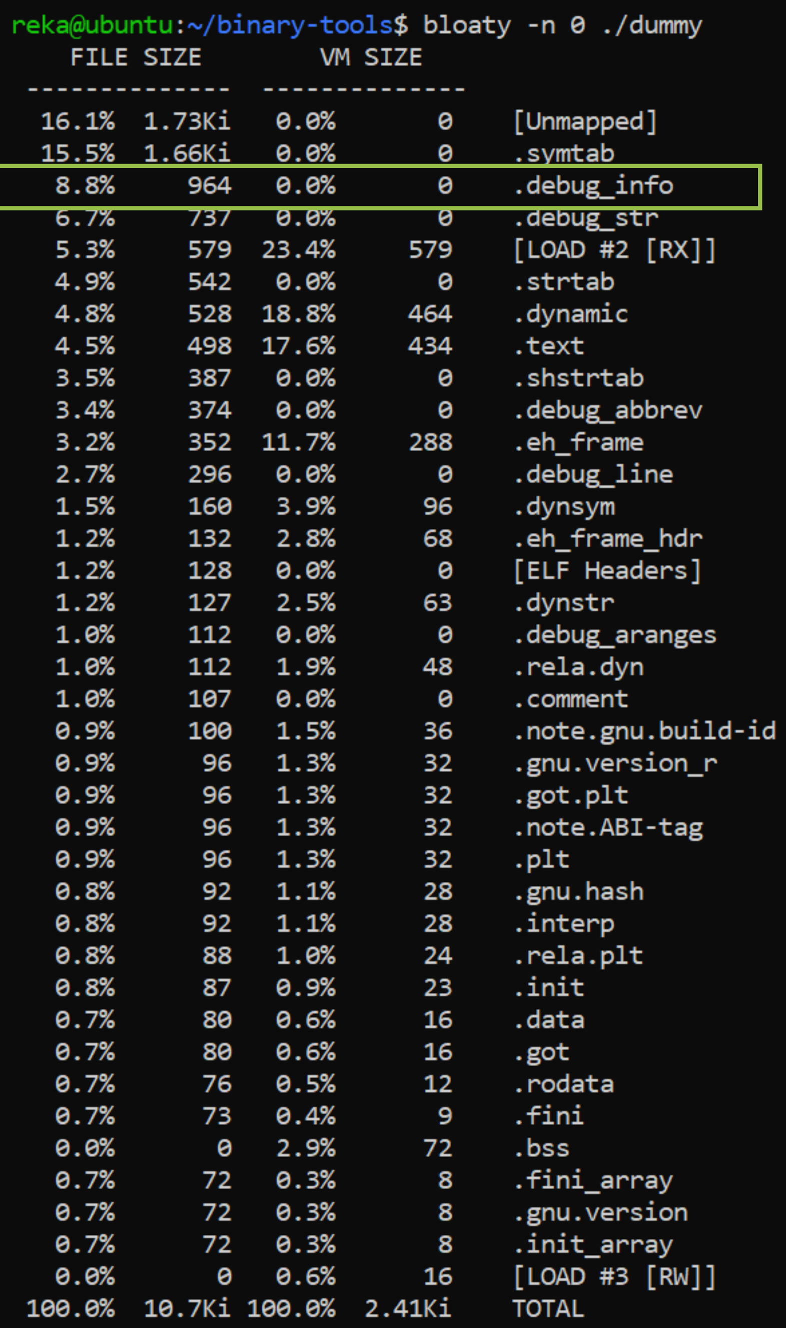

VM size

Bytes in virtual memory after the executable is loaded



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   0.9%      96   1.3%      32    .plt
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   0.8%      88   1.0%      24    .rela.plt
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   0.7%      80   0.6%      16    .data
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   0.0%       0   2.9%      72    .bss
   0.7%      72   0.3%       8    .fini_array
   0.7%      72   0.3%       8    .gnu.version
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   0.0%       0   0.6%      16    [LOAD #3 [RW]]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
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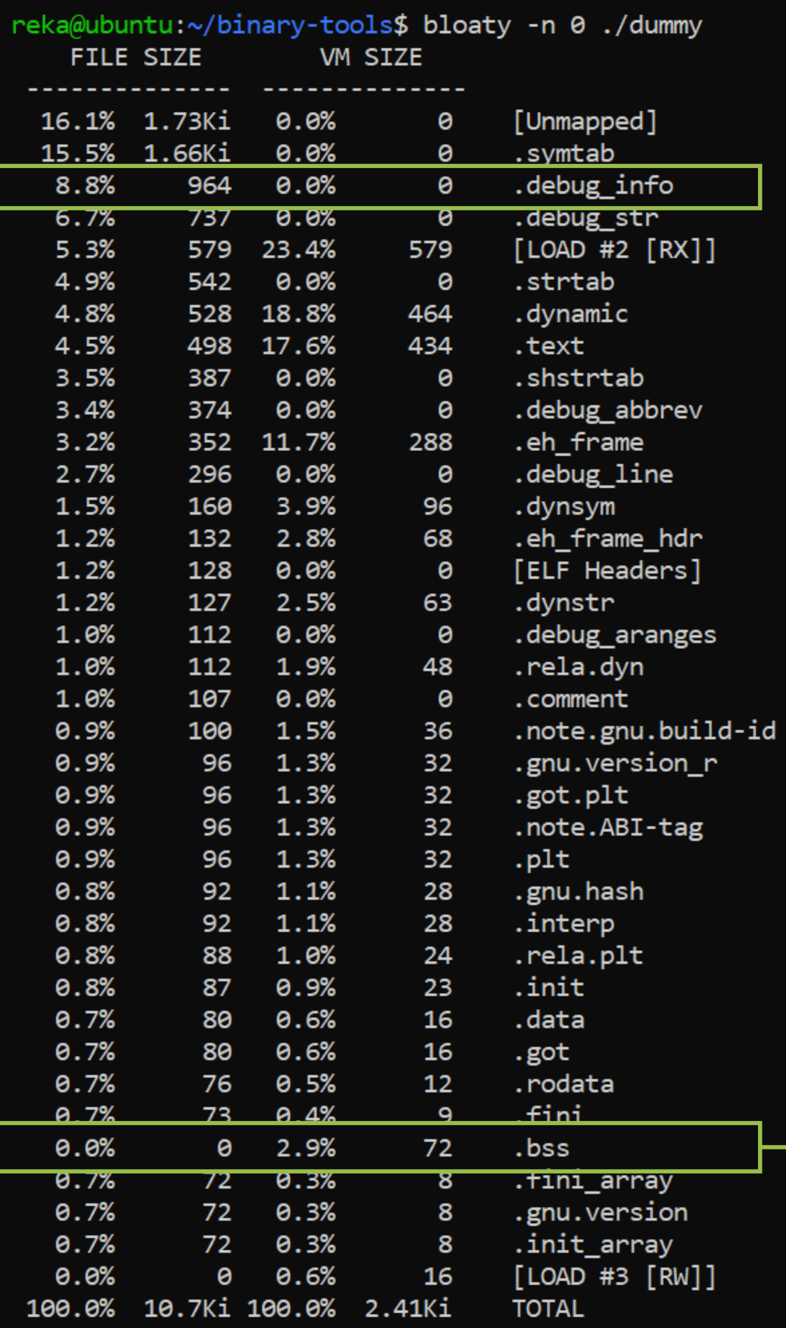
File size

Bytes on disk

VM size

Bytes in virtual memory after the executable is loaded



```
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   3.4%     374   0.0%       0    .debug_abbrev
   3.2%     352  11.7%     288    .eh_frame
   2.7%     296   0.0%       0    .debug_line
   1.5%     160   3.9%      96    .dynsym
   1.2%     132   2.8%      68    .eh_frame_hdr
   1.2%     128   0.0%       0    [ELF Headers]
   1.2%     127   2.5%      63    .dynstr
   1.0%     112   0.0%       0    .debug_aranges
   1.0%     112   1.9%      48    .rela.dyn
   1.0%     107   0.0%       0    .comment
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   0.9%      96   1.3%      32    .gnu.version_r
   0.9%      96   1.3%      32    .got.plt
   0.9%      96   1.3%      32    .note.ABI-tag
   0.9%      96   1.3%      32    .plt
   0.8%      92   1.1%      28    .gnu.hash
   0.8%      92   1.1%      28    .interp
   0.8%      88   1.0%      24    .rela.plt
   0.8%      87   0.9%      23    .init
   0.7%      80   0.6%      16    .data
   0.7%      80   0.6%      16    .got
   0.7%      76   0.5%      12    .rodata
   0.7%      73   0.4%       9    .fini
   0.0%       0   2.9%      72    .bss
   0.7%      72   0.3%       8    .fini_array
   0.7%      72   0.3%       8    .gnu.version
   0.7%      72   0.3%       8    .init_array
   0.0%       0   0.6%      16    [LOAD #3 [RW]]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

File size

Bytes on disk

VM size

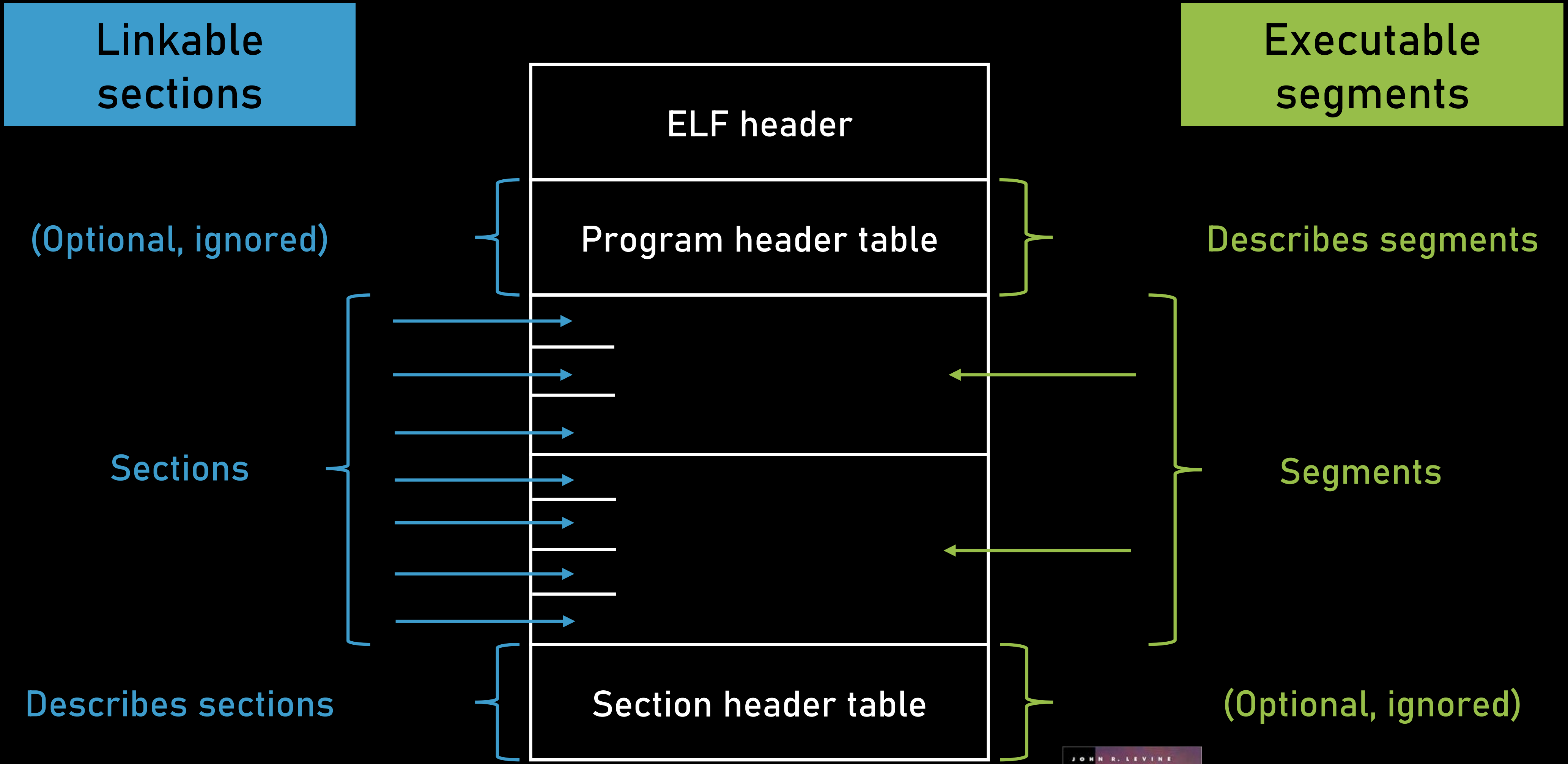
Bytes in virtual memory after the executable is loaded

ELF (Executable and Linkage Format)

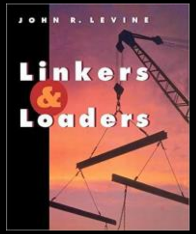
File type for binaries on Linux

3 flavors:

- Relocatable – needs to be processed by the linker
- Executable – all symbols resolved (except for shared lib symbols), runnable
- Shared object – has both symbol info for the linker and runnable code



John Levine: Linkers and Loaders



Segments and sections

```
reka@ubuntu:~/binary-tools$ bloaty -d segments ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
   5.0%     544  25.6%     632    LOAD #3 [RW]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Segments and sections

```
reka@ubuntu:~/binary-tools$ bloaty -d segments ./dummy
    FILE SIZE        VM SIZE
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  58.4%  6.26Ki   0.0%       0    [Unmapped]
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
   5.0%     544  25.6%     632    LOAD #3 [RW]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```
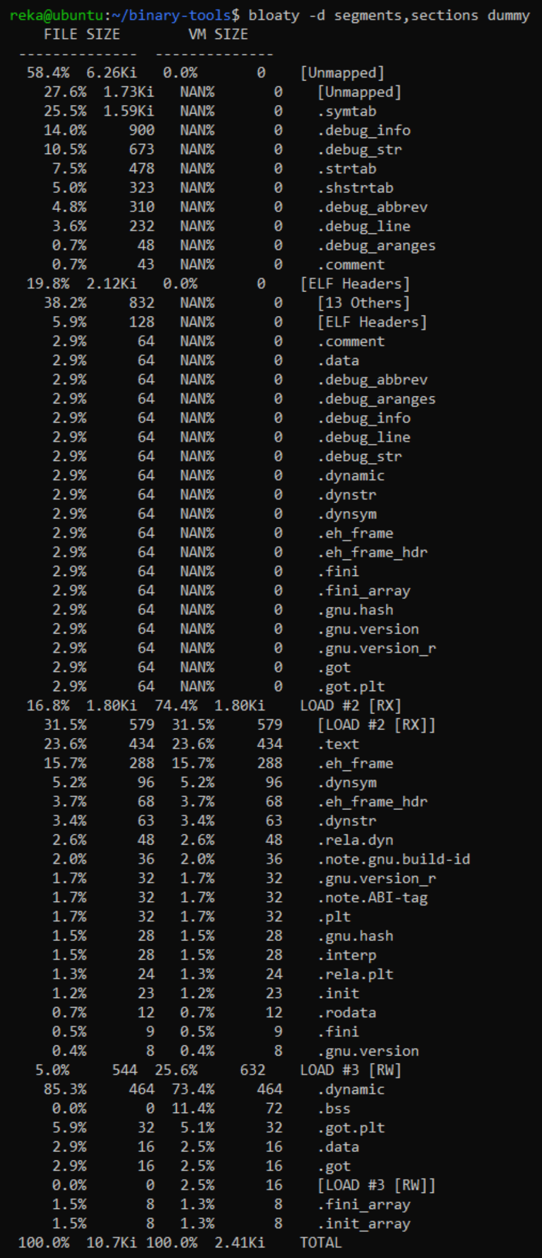

```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
```

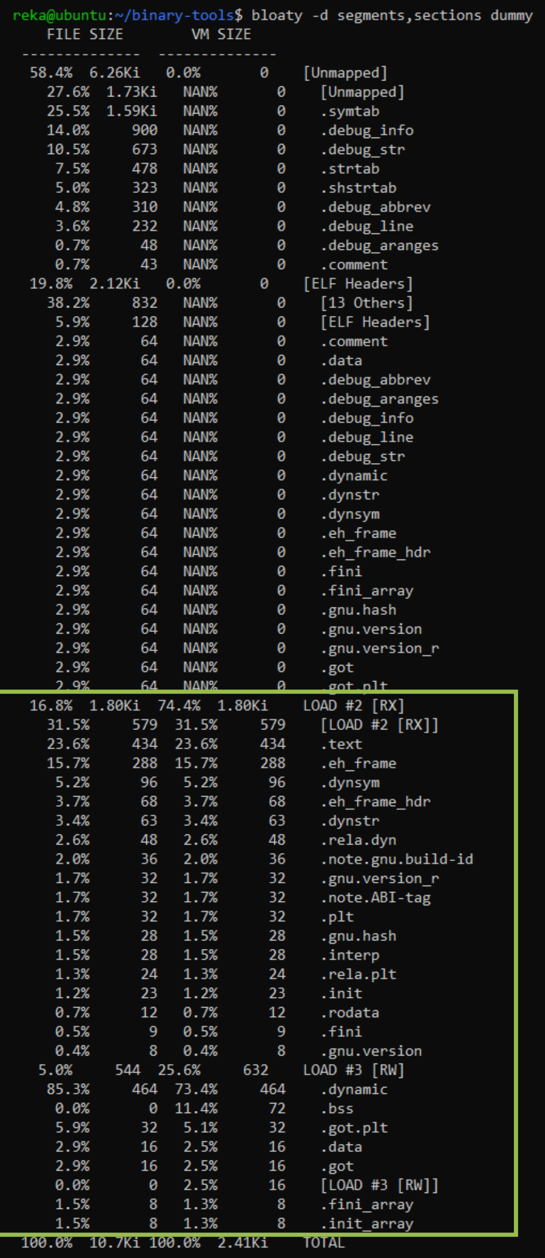


```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
    27.6%  1.73Ki   NAN%       0    [Unmapped]
    25.5%  1.59Ki   NAN%       0    .symtab
    14.0%     900   NAN%       0    .debug_info
    10.5%     673   NAN%       0    .debug_str
     7.5%     478   NAN%       0    .strtab
     5.0%     323   NAN%       0    .shstrtab
     4.8%     310   NAN%       0    .debug_abbrev
     3.6%     232   NAN%       0    .debug_line
     0.7%      48   NAN%       0    .debug_aranges
     0.7%      43   NAN%       0    .comment
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
    38.2%     832   NAN%       0    [13 Others]
     5.9%     128   NAN%       0    [ELF Headers]
     2.9%      64   NAN%       0    .comment
     2.9%      64   NAN%       0    .data
     2.9%      64   NAN%       0    .debug_abbrev
     2.9%      64   NAN%       0    .debug_aranges
     2.9%      64   NAN%       0    .debug_info
     2.9%      64   NAN%       0    .debug_line
     2.9%      64   NAN%       0    .debug_str
     2.9%      64   NAN%       0    .dynamic
     2.9%      64   NAN%       0    .dynstr
     2.9%      64   NAN%       0    .dynsym
     2.9%      64   NAN%       0    .eh_frame
     2.9%      64   NAN%       0    .eh_frame_hdr
     2.9%      64   NAN%       0    .fini
     2.9%      64   NAN%       0    .fini_array
     2.9%      64   NAN%       0    .gnu.hash
     2.9%      64   NAN%       0    .gnu.version
     2.9%      64   NAN%       0    .gnu.version_r
     2.9%      64   NAN%       0    .got
     2.9%      64   NAN%       0    .got.plt
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
    31.5%     579  31.5%     579    [LOAD #2 [RX]]
    23.6%     434  23.6%     434    .text
    15.7%     288  15.7%     288    .eh_frame
     5.2%      96   5.2%      96    .dynsym
     3.7%      68   3.7%      68    .eh_frame_hdr
     3.4%      63   3.4%      63    .dynstr
     2.6%      48   2.6%      48    .rela.dyn
     2.0%      36   2.0%      36    .note.gnu.build-id
     1.7%      32   1.7%      32    .gnu.version_r
     1.7%      32   1.7%      32    .note.ABI-tag
     1.7%      32   1.7%      32    .plt
     1.5%      28   1.5%      28    .gnu.hash
     1.5%      28   1.5%      28    .interp
     1.3%      24   1.3%      24    .rela.plt
     1.2%      23   1.2%      23    .init
     0.7%      12   0.7%      12    .rodata
     0.5%       9   0.5%       9    .fini
     0.4%       8   0.4%       8    .gnu.version
   5.0%     544  25.6%     632    LOAD #3 [RW]
    85.3%     464  73.4%     464    .dynamic
     0.0%       0  11.4%      72    .bss
     5.9%      32   5.1%      32    .got.plt
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Segments and sections

```
reka@ubuntu:~/binary-tools$ bloaty -d segments ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
   5.0%     544  25.6%     632    LOAD #3 [RW]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
```

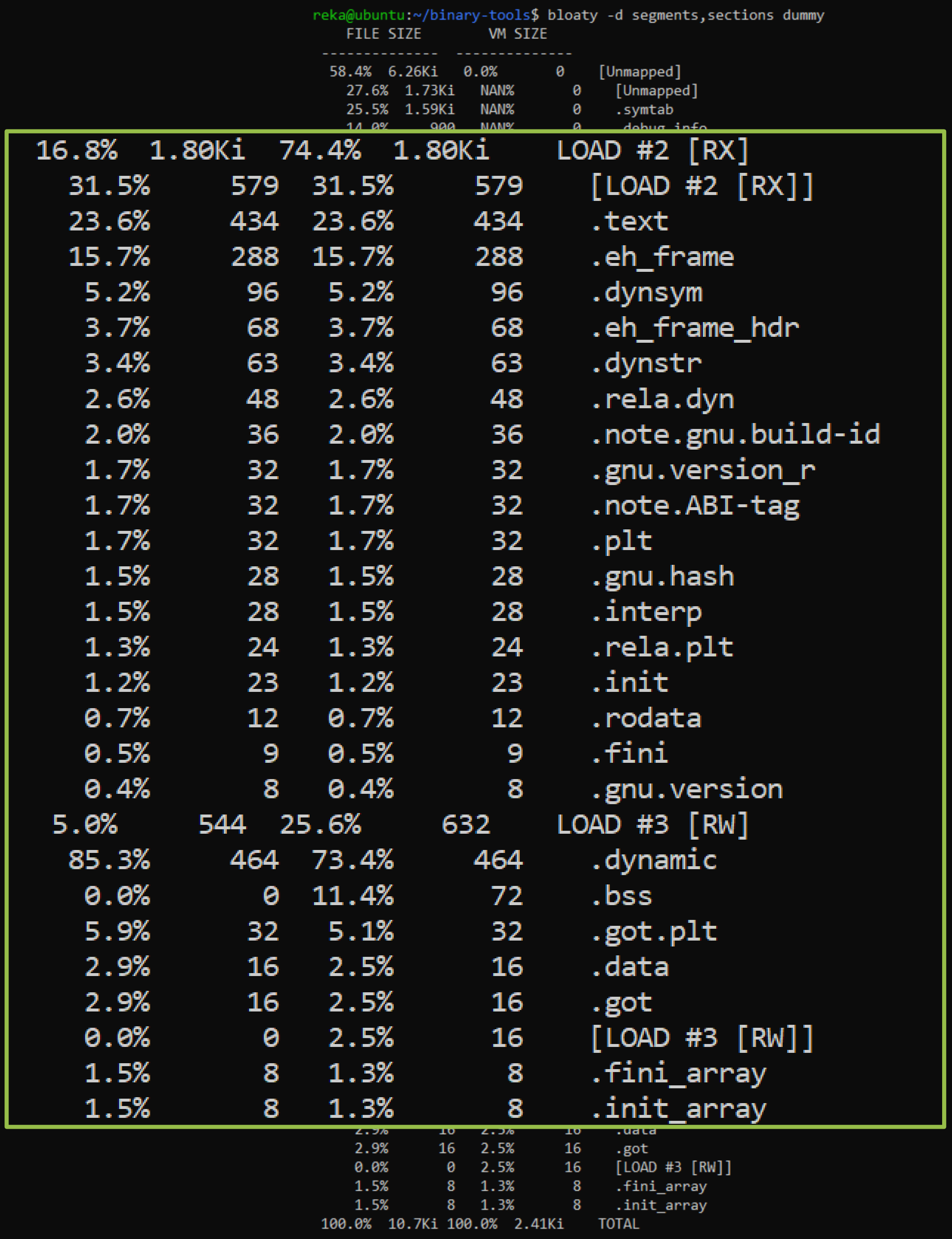


```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
    27.6%  1.73Ki   NAN%       0    [Unmapped]
    25.5%  1.59Ki   NAN%       0    .symtab
    14.0%     900   NAN%       0    .debug_info
    10.5%     673   NAN%       0    .debug_str
     7.5%     478   NAN%       0    .strtab
     5.0%     323   NAN%       0    .shstrtab
     4.8%     310   NAN%       0    .debug_abbrev
     3.6%     232   NAN%       0    .debug_line
     0.7%      48   NAN%       0    .debug_aranges
     0.7%      43   NAN%       0    .comment
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
    38.2%     832   NAN%       0    [13 Others]
     5.9%     128   NAN%       0    [ELF Headers]
     2.9%      64   NAN%       0    .comment
     2.9%      64   NAN%       0    .data
     2.9%      64   NAN%       0    .debug_abbrev
     2.9%      64   NAN%       0    .debug_aranges
     2.9%      64   NAN%       0    .debug_info
     2.9%      64   NAN%       0    .debug_line
     2.9%      64   NAN%       0    .debug_str
     2.9%      64   NAN%       0    .dynamic
     2.9%      64   NAN%       0    .dynstr
     2.9%      64   NAN%       0    .dynsym
     2.9%      64   NAN%       0    .eh_frame
     2.9%      64   NAN%       0    .eh_frame_hdr
     2.9%      64   NAN%       0    .fini
     2.9%      64   NAN%       0    .fini_array
     2.9%      64   NAN%       0    .gnu.hash
     2.9%      64   NAN%       0    .gnu.version
     2.9%      64   NAN%       0    .gnu.version_r
     2.9%      64   NAN%       0    .got
     2.9%      64   NAN%       0    .got.plt
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
    31.5%     579  31.5%     579    [LOAD #2 [RX]]
    23.6%     434  23.6%     434    .text
    15.7%     288  15.7%     288    .eh_frame
     5.2%      96   5.2%      96    .dynsym
     3.7%      68   3.7%      68    .eh_frame_hdr
     3.4%      63   3.4%      63    .dynstr
     2.6%      48   2.6%      48    .rela.dyn
     2.0%      36   2.0%      36    .note.gnu.build-id
     1.7%      32   1.7%      32    .gnu.version_r
     1.7%      32   1.7%      32    .note.ABI-tag
     1.7%      32   1.7%      32    .plt
     1.5%      28   1.5%      28    .gnu.hash
     1.5%      28   1.5%      28    .interp
     1.3%      24   1.3%      24    .rela.plt
     1.2%      23   1.2%      23    .init
     0.7%      12   0.7%      12    .rodata
     0.5%       9   0.5%       9    .fini
     0.4%       8   0.4%       8    .gnu.version
   5.0%     544  25.6%     632    LOAD #3 [RW]
    85.3%     464  73.4%     464    .dynamic
     0.0%       0  11.4%      72    .bss
     5.9%      32   5.1%      32    .got.plt
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Segments and sections

```
reka@ubuntu:~/binary-tools$ bloaty -d segments ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
   5.0%     544  25.6%     632    LOAD #3 [RW]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
```

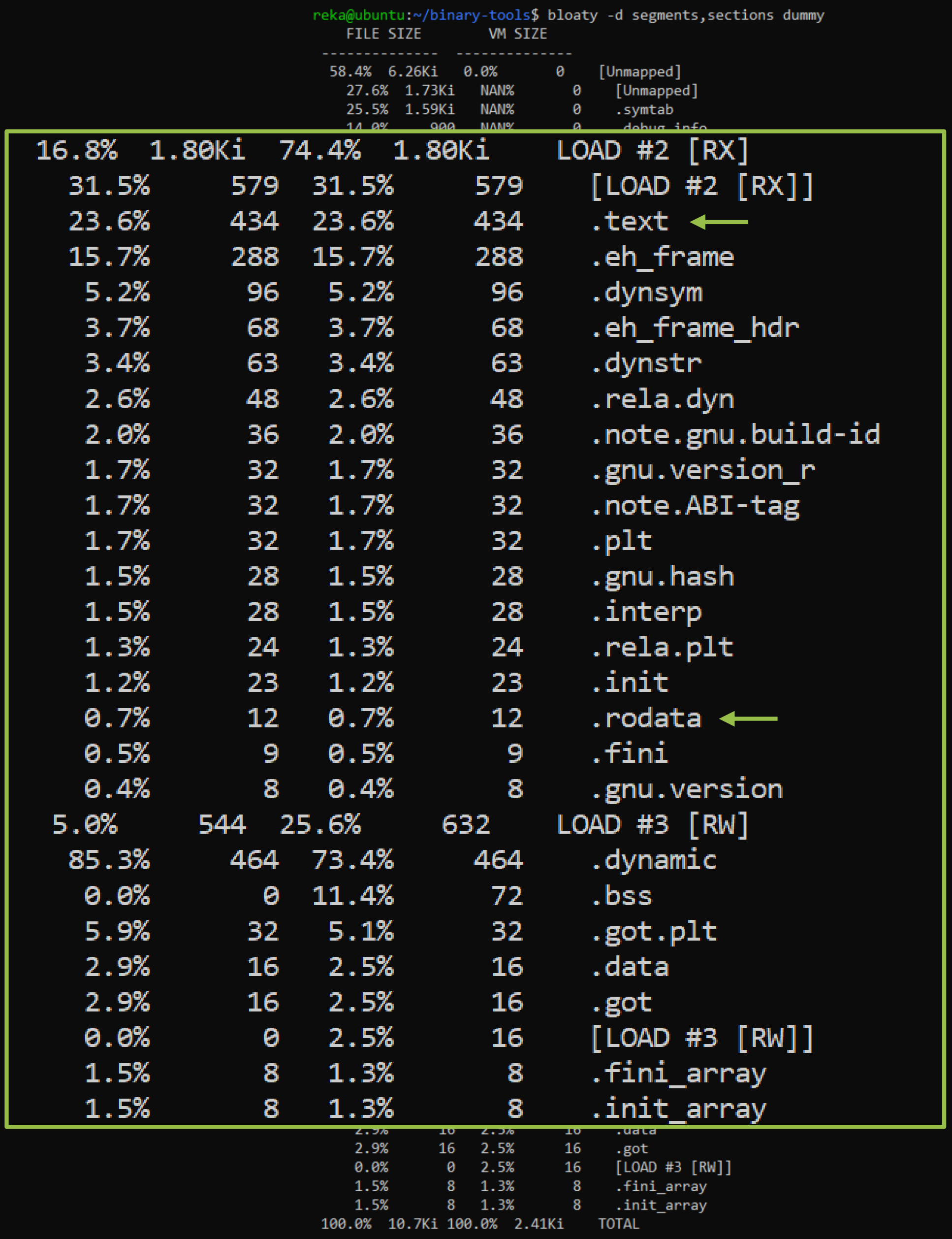


```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
    27.6%  1.73Ki   NAN%       0    [Unmapped]
    25.5%  1.59Ki   NAN%       0    .symtab
    14.0%     900   NAN%       0    .debug_info
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
    31.5%     579  31.5%     579    [LOAD #2 [RX]]
    23.6%     434  23.6%     434    .text
    15.7%     288  15.7%     288    .eh_frame
     5.2%      96   5.2%      96    .dynsym
     3.7%      68   3.7%      68    .eh_frame_hdr
     3.4%      63   3.4%      63    .dynstr
     2.6%      48   2.6%      48    .rela.dyn
     2.0%      36   2.0%      36    .note.gnu.build-id
     1.7%      32   1.7%      32    .gnu.version_r
     1.7%      32   1.7%      32    .note.ABI-tag
     1.7%      32   1.7%      32    .plt
     1.5%      28   1.5%      28    .gnu.hash
     1.5%      28   1.5%      28    .interp
     1.3%      24   1.3%      24    .rela.plt
     1.2%      23   1.2%      23    .init
     0.7%      12   0.7%      12    .rodata
     0.5%       9   0.5%       9    .fini
     0.4%       8   0.4%       8    .gnu.version
   5.0%     544  25.6%     632    LOAD #3 [RW]
    85.3%     464  73.4%     464    .dynamic
     0.0%       0  11.4%      72    .bss
     5.9%      32   5.1%      32    .got.plt
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Segments and sections

```
reka@ubuntu:~/binary-tools$ bloaty -d segments ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]  ←
   5.0%     544  25.6%     632    LOAD #3 [RW]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
```



```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
    27.6%  1.73Ki   NAN%       0    [Unmapped]
    25.5%  1.59Ki   NAN%       0    .symtab
    14.0%     900   NAN%       0    .debug_info
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
    31.5%     579  31.5%     579    [LOAD #2 [RX]]
    23.6%     434  23.6%     434    .text  ←
    15.7%     288  15.7%     288    .eh_frame
     5.2%      96   5.2%      96    .dynsym
     3.7%      68   3.7%      68    .eh_frame_hdr
     3.4%      63   3.4%      63    .dynstr
     2.6%      48   2.6%      48    .rela.dyn
     2.0%      36   2.0%      36    .note.gnu.build-id
     1.7%      32   1.7%      32    .gnu.version_r
     1.7%      32   1.7%      32    .note.ABI-tag
     1.7%      32   1.7%      32    .plt
     1.5%      28   1.5%      28    .gnu.hash
     1.5%      28   1.5%      28    .interp
     1.3%      24   1.3%      24    .rela.plt
     1.2%      23   1.2%      23    .init
     0.7%      12   0.7%      12    .rodata  ←
     0.5%       9   0.5%       9    .fini
     0.4%       8   0.4%       8    .gnu.version
   5.0%     544  25.6%     632    LOAD #3 [RW]
    85.3%     464  73.4%     464    .dynamic
     0.0%       0  11.4%      72    .bss
     5.9%      32   5.1%      32    .got.plt
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
```

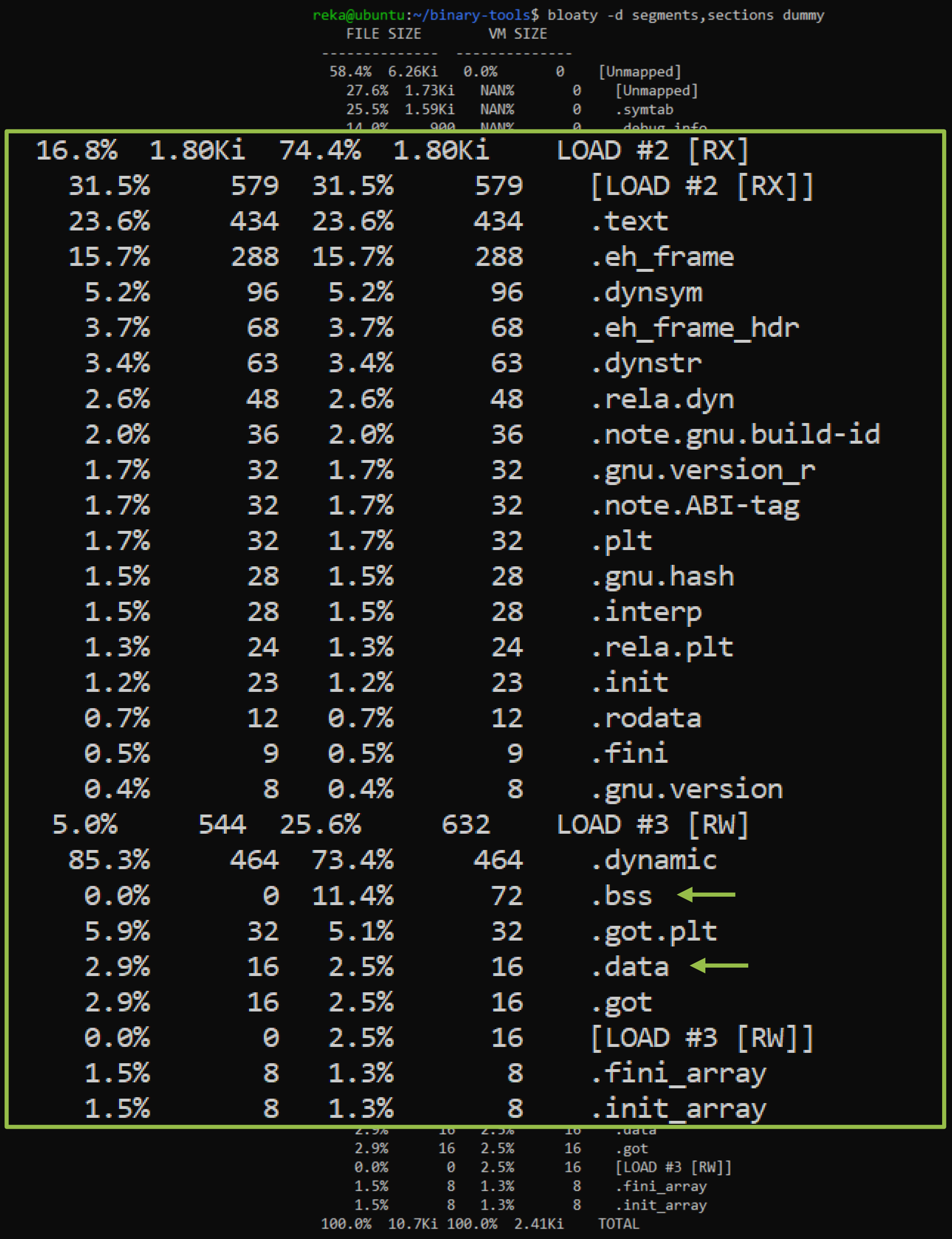
```
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
```

```
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Segments and sections

```
reka@ubuntu:~/binary-tools$ bloaty -d segments ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
  19.8%  2.12Ki   0.0%       0    [ELF Headers]
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
   5.0%     544  25.6%     632    LOAD #3 [RW]
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
```

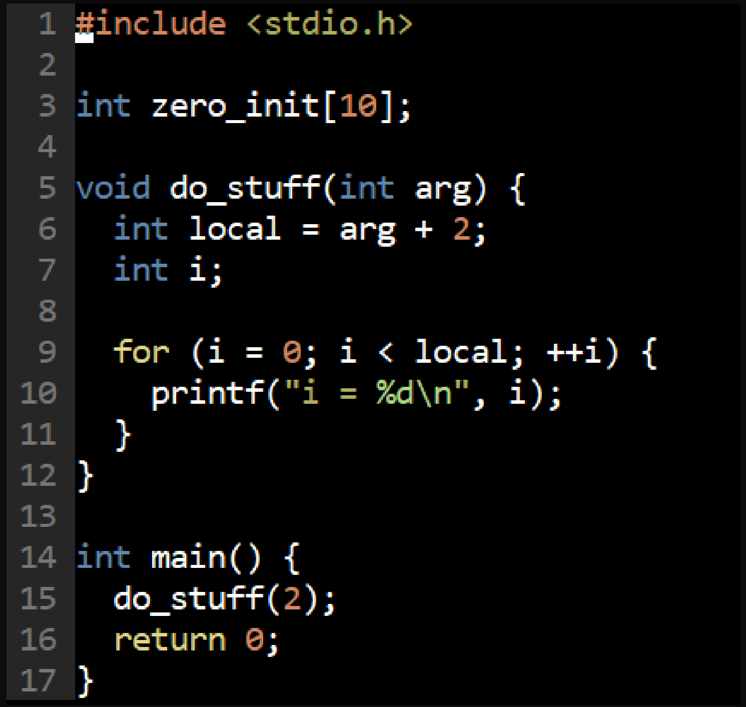


```
reka@ubuntu:~/binary-tools$ bloaty -d segments,sections dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  58.4%  6.26Ki   0.0%       0    [Unmapped]
    27.6%  1.73Ki   NAN%       0    [Unmapped]
    25.5%  1.59Ki   NAN%       0    .symtab
    14.0%     900   NAN%       0    .debug_info
  16.8%  1.80Ki  74.4%  1.80Ki    LOAD #2 [RX]
    31.5%     579  31.5%     579    [LOAD #2 [RX]]
    23.6%     434  23.6%     434    .text
    15.7%     288  15.7%     288    .eh_frame
     5.2%      96   5.2%      96    .dynsym
     3.7%      68   3.7%      68    .eh_frame_hdr
     3.4%      63   3.4%      63    .dynstr
     2.6%      48   2.6%      48    .rela.dyn
     2.0%      36   2.0%      36    .note.gnu.build-id
     1.7%      32   1.7%      32    .gnu.version_r
     1.7%      32   1.7%      32    .note.ABI-tag
     1.7%      32   1.7%      32    .plt
     1.5%      28   1.5%      28    .gnu.hash
     1.5%      28   1.5%      28    .interp
     1.3%      24   1.3%      24    .rela.plt
     1.2%      23   1.2%      23    .init
     0.7%      12   0.7%      12    .rodata
     0.5%       9   0.5%       9    .fini
     0.4%       8   0.4%       8    .gnu.version
   5.0%     544  25.6%     632    LOAD #3 [RW]
    85.3%     464  73.4%     464    .dynamic
     0.0%       0  11.4%      72    .bss
     5.9%      32   5.1%      32    .got.plt
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
```

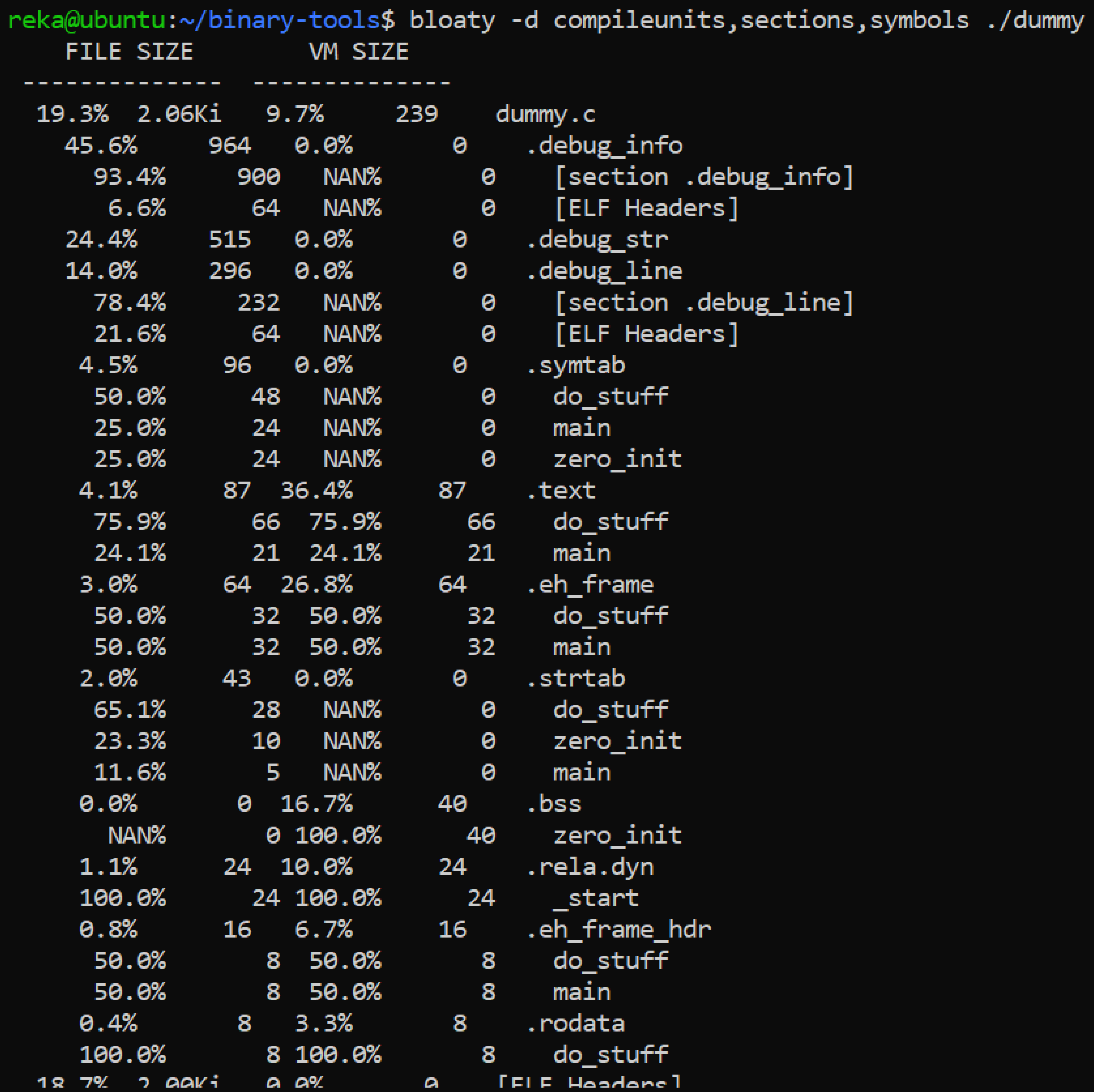
```
     2.9%      16   2.5%      16    .data
     2.9%      16   2.5%      16    .got
     0.0%       0   2.5%      16    [LOAD #3 [RW]]
     1.5%       8   1.3%       8    .fini_array
     1.5%       8   1.3%       8    .init_array
```

```
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Track changes

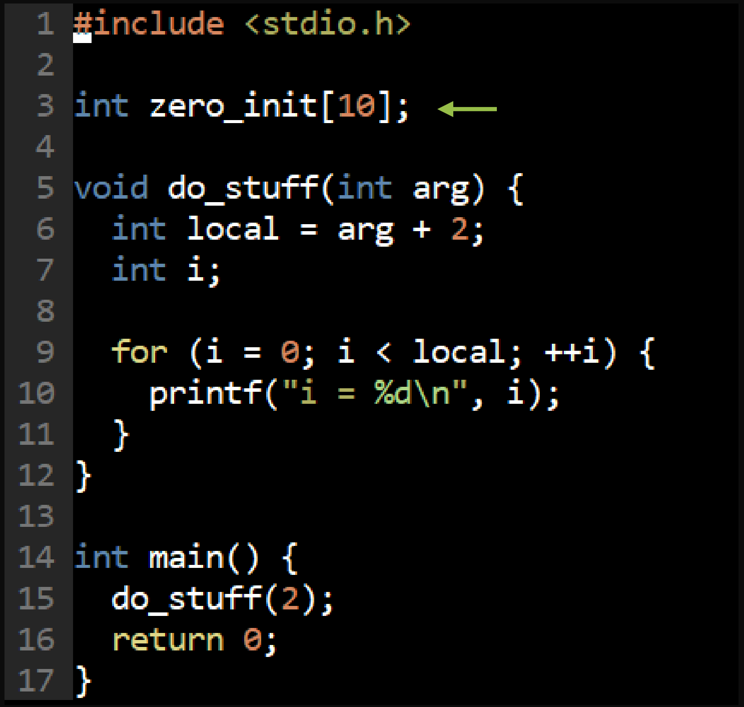


```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```

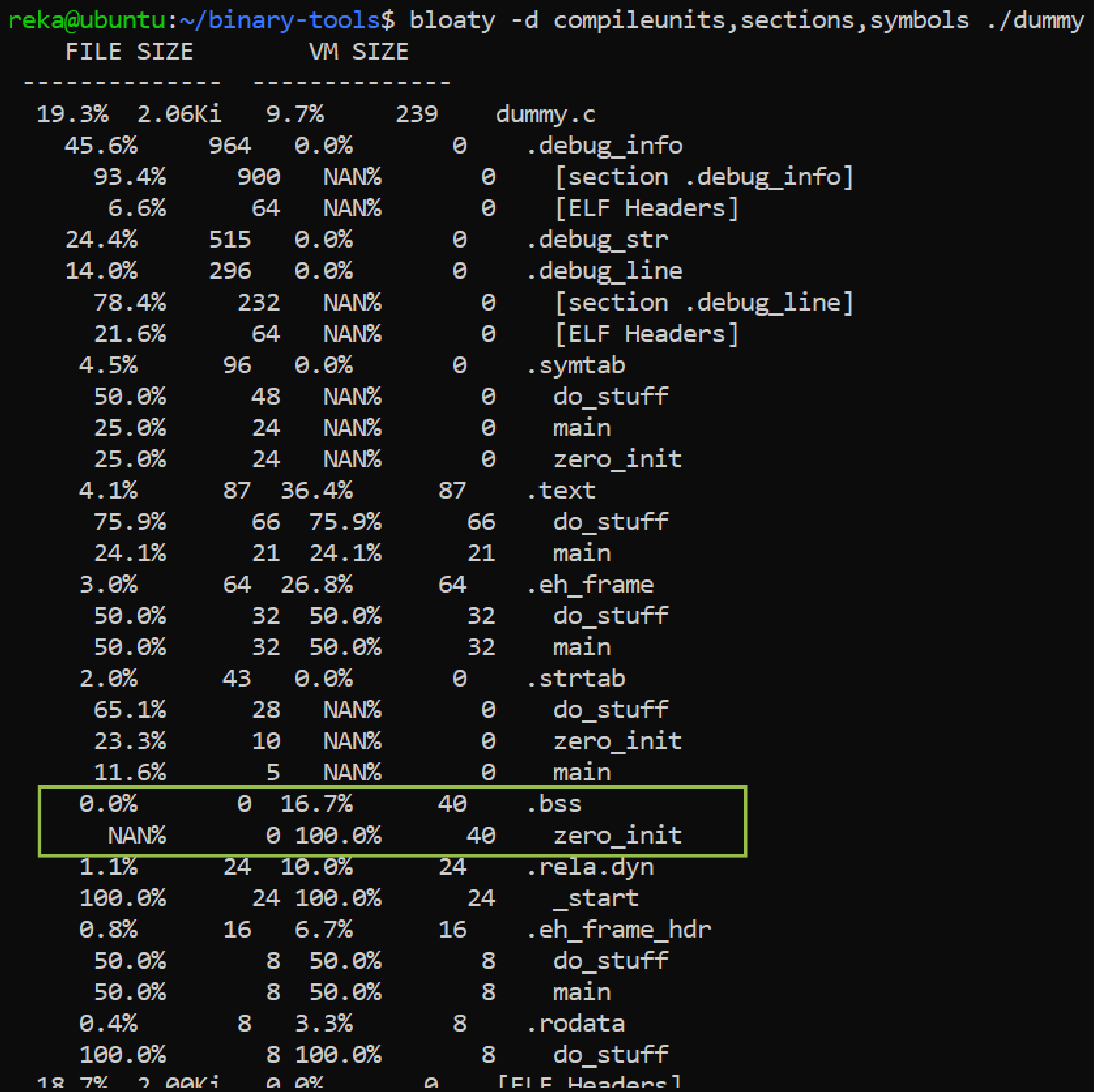


```
reka@ubuntu:~/binary-tools$ bloaty -d compileunits,sections,symbols ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  19.3%  2.06Ki   9.7%     239    dummy.c
    45.6%     964   0.0%       0    .debug_info
      93.4%     900   NAN%       0      [section .debug_info]
       6.6%      64   NAN%       0      [ELF Headers]
    24.4%     515   0.0%       0    .debug_str
    14.0%     296   0.0%       0    .debug_line
      78.4%     232   NAN%       0      [section .debug_line]
      21.6%      64   NAN%       0      [ELF Headers]
     4.5%      96   0.0%       0    .symtab
      50.0%      48   NAN%       0      do_stuff
      25.0%      24   NAN%       0      main
      25.0%      24   NAN%       0      zero_init
     4.1%      87  36.4%      87    .text
      75.9%      66  75.9%      66      do_stuff
      24.1%      21  24.1%      21      main
     3.0%      64  26.8%      64    .eh_frame
      50.0%      32  50.0%      32      do_stuff
      50.0%      32  50.0%      32      main
     2.0%      43   0.0%       0    .strtab
      65.1%      28   NAN%       0      do_stuff
      23.3%      10   NAN%       0      zero_init
      11.6%       5   NAN%       0      main
     0.0%       0  16.7%      40    .bss
       NAN%       0 100.0%      40      zero_init
     1.1%      24  10.0%      24    .rela.dyn
     100.0%      24 100.0%      24      _start
     0.8%      16   6.7%      16    .eh_frame_hdr
      50.0%       8  50.0%       8      do_stuff
      50.0%       8  50.0%       8      main
     0.4%       8   3.3%       8    .rodata
     100.0%       8 100.0%       8      do_stuff
  18.7%  2.00Ki   0.0%       0    [ELF Headers]
```

Track changes

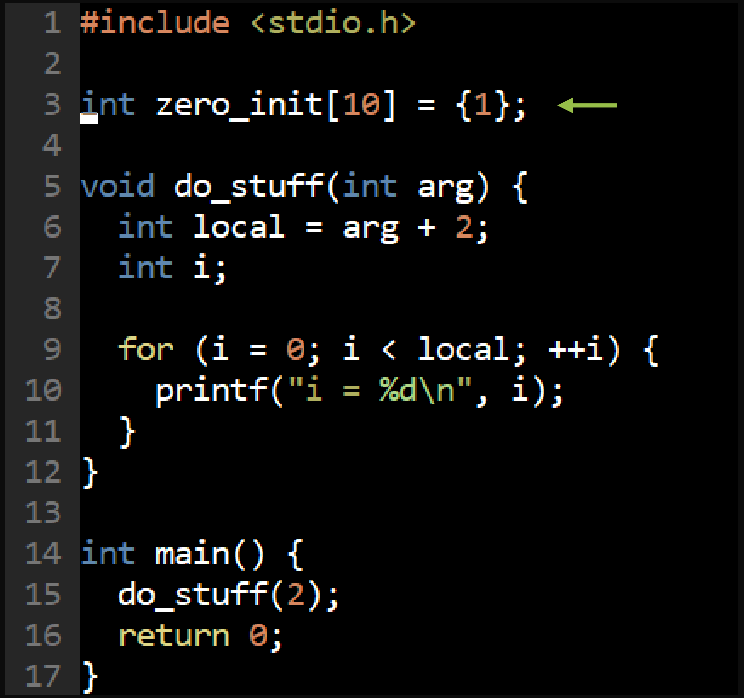


```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```

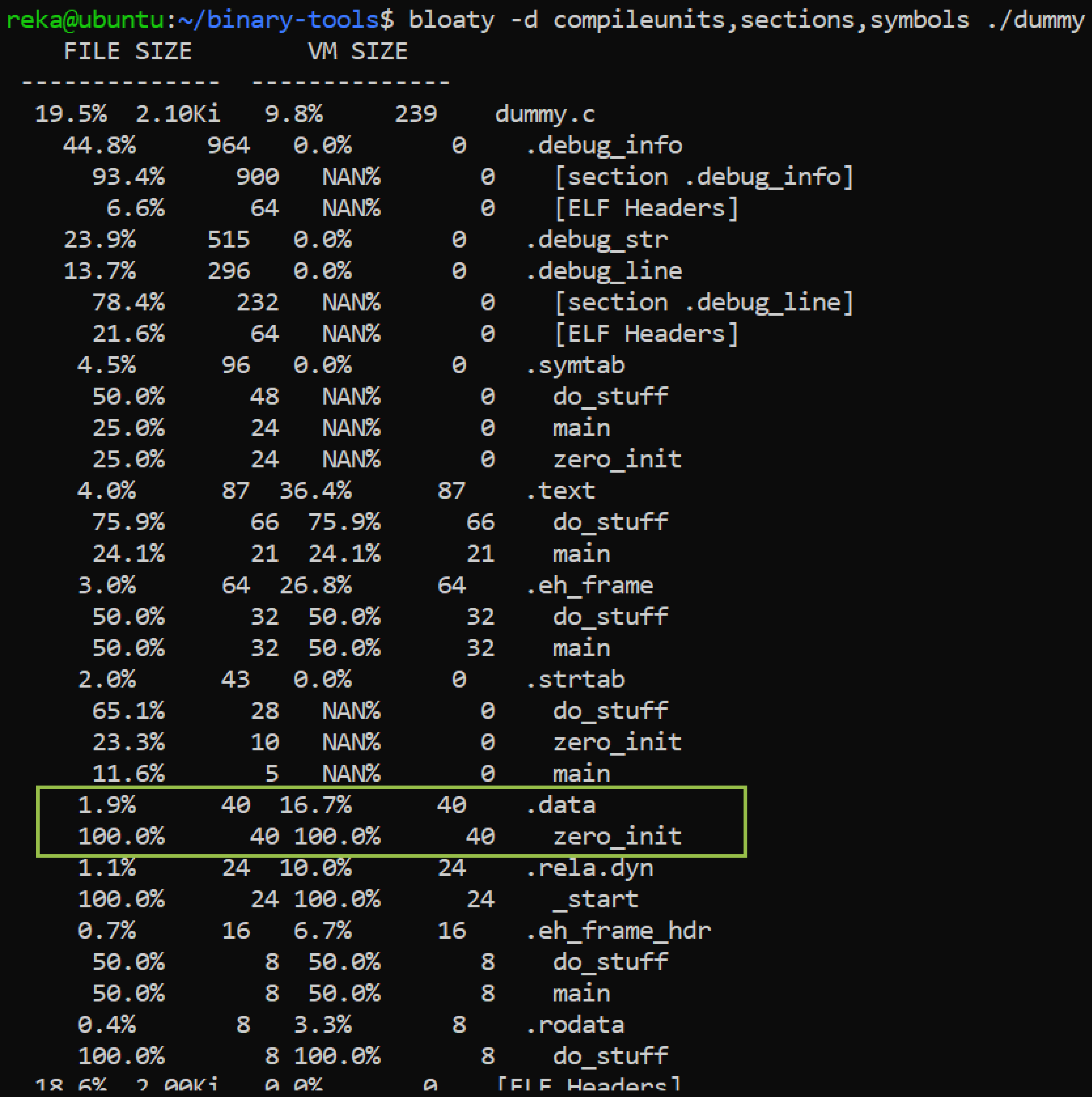


```
reka@ubuntu:~/binary-tools$ bloaty -d compileunits,sections,symbols ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  19.3%  2.06Ki   9.7%     239    dummy.c
    45.6%     964   0.0%       0    .debug_info
      93.4%     900   NAN%       0    [section .debug_info]
       6.6%      64   NAN%       0    [ELF Headers]
    24.4%     515   0.0%       0    .debug_str
    14.0%     296   0.0%       0    .debug_line
      78.4%     232   NAN%       0    [section .debug_line]
      21.6%      64   NAN%       0    [ELF Headers]
     4.5%      96   0.0%       0    .symtab
      50.0%      48   NAN%       0    do_stuff
      25.0%      24   NAN%       0    main
      25.0%      24   NAN%       0    zero_init
     4.1%      87  36.4%      87    .text
      75.9%      66  75.9%      66    do_stuff
      24.1%      21  24.1%      21    main
     3.0%      64  26.8%      64    .eh_frame
      50.0%      32  50.0%      32    do_stuff
      50.0%      32  50.0%      32    main
     2.0%      43   0.0%       0    .strtab
      65.1%      28   NAN%       0    do_stuff
      23.3%      10   NAN%       0    zero_init
      11.6%       5   NAN%       0    main
     0.0%       0  16.7%      40    .bss
       NAN%       0 100.0%      40    zero_init
     1.1%      24  10.0%      24    .rela.dyn
     100.0%      24 100.0%      24    _start
     0.8%      16   6.7%      16    .eh_frame_hdr
      50.0%       8  50.0%       8    do_stuff
      50.0%       8  50.0%       8    main
     0.4%       8   3.3%       8    .rodata
     100.0%       8 100.0%       8    do_stuff
  18.7%  2.00Ki   0.0%       0    [ELF Headers]
```

Track changes



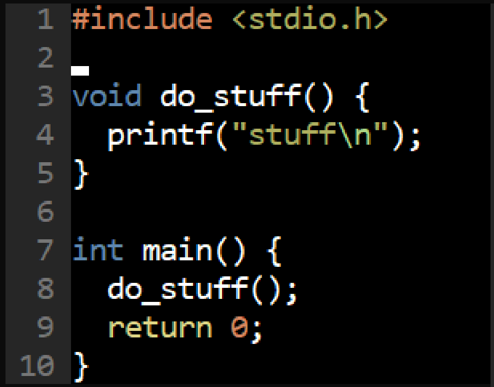
```c
#include <stdio.h>

int zero_init[10] = {1};

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```



```
reka@ubuntu:~/binary-tools$ bloaty -d compileunits,sections,symbols ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  19.5%  2.10Ki   9.8%     239    dummy.c
    44.8%     964   0.0%       0    .debug_info
      93.4%     900   NAN%       0    [section .debug_info]
       6.6%      64   NAN%       0    [ELF Headers]
    23.9%     515   0.0%       0    .debug_str
    13.7%     296   0.0%       0    .debug_line
      78.4%     232   NAN%       0    [section .debug_line]
      21.6%      64   NAN%       0    [ELF Headers]
     4.5%      96   0.0%       0    .symtab
      50.0%      48   NAN%       0    do_stuff
      25.0%      24   NAN%       0    main
      25.0%      24   NAN%       0    zero_init
     4.0%      87  36.4%      87    .text
      75.9%      66  75.9%      66    do_stuff
      24.1%      21  24.1%      21    main
     3.0%      64  26.8%      64    .eh_frame
      50.0%      32  50.0%      32    do_stuff
      50.0%      32  50.0%      32    main
     2.0%      43   0.0%       0    .strtab
      65.1%      28   NAN%       0    do_stuff
      23.3%      10   NAN%       0    zero_init
      11.6%       5   NAN%       0    main
     1.9%      40  16.7%      40    .data
     100.0%      40 100.0%      40    zero_init
     1.1%      24  10.0%      24    .rela.dyn
     100.0%      24 100.0%      24    _start
     0.7%      16   6.7%      16    .eh_frame_hdr
      50.0%       8  50.0%       8    do_stuff
      50.0%       8  50.0%       8    main
     0.4%       8   3.3%       8    .rodata
     100.0%       8 100.0%       8    do_stuff
  18.6%  2.00Ki   0.0%       0    [ELF Headers]
```

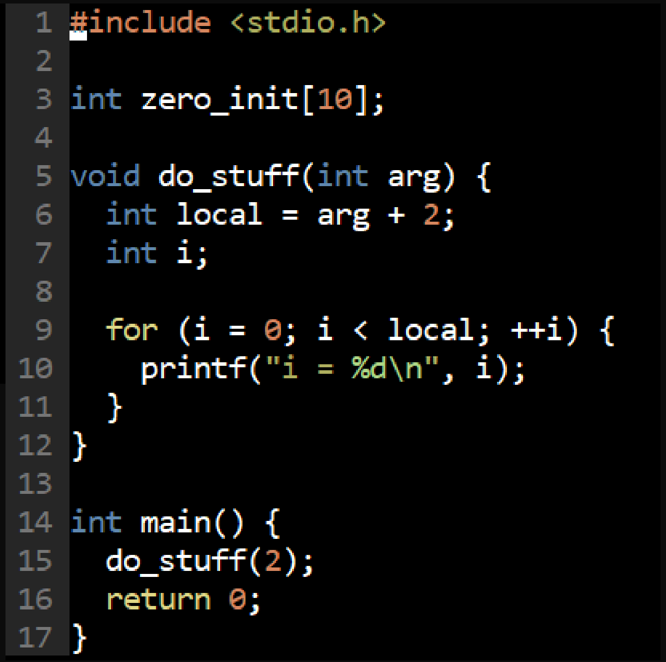
Diff mode

```
$ vim olddummy.c
```



```c
#include <stdio.h>

void do_stuff() {
  printf("stuff\n");
}

int main() {
  do_stuff();
  return 0;
}
```

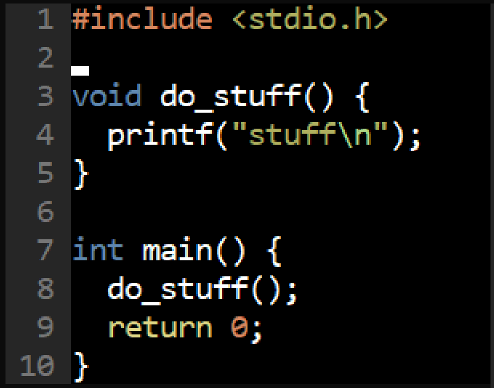
```
$ vim dummy.c
```



```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```

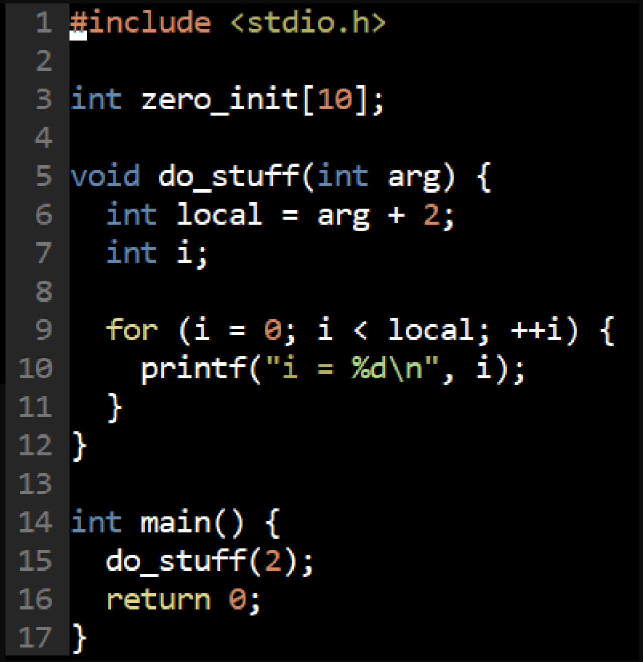
Diff mode

```
$ vim olddummy.c
```

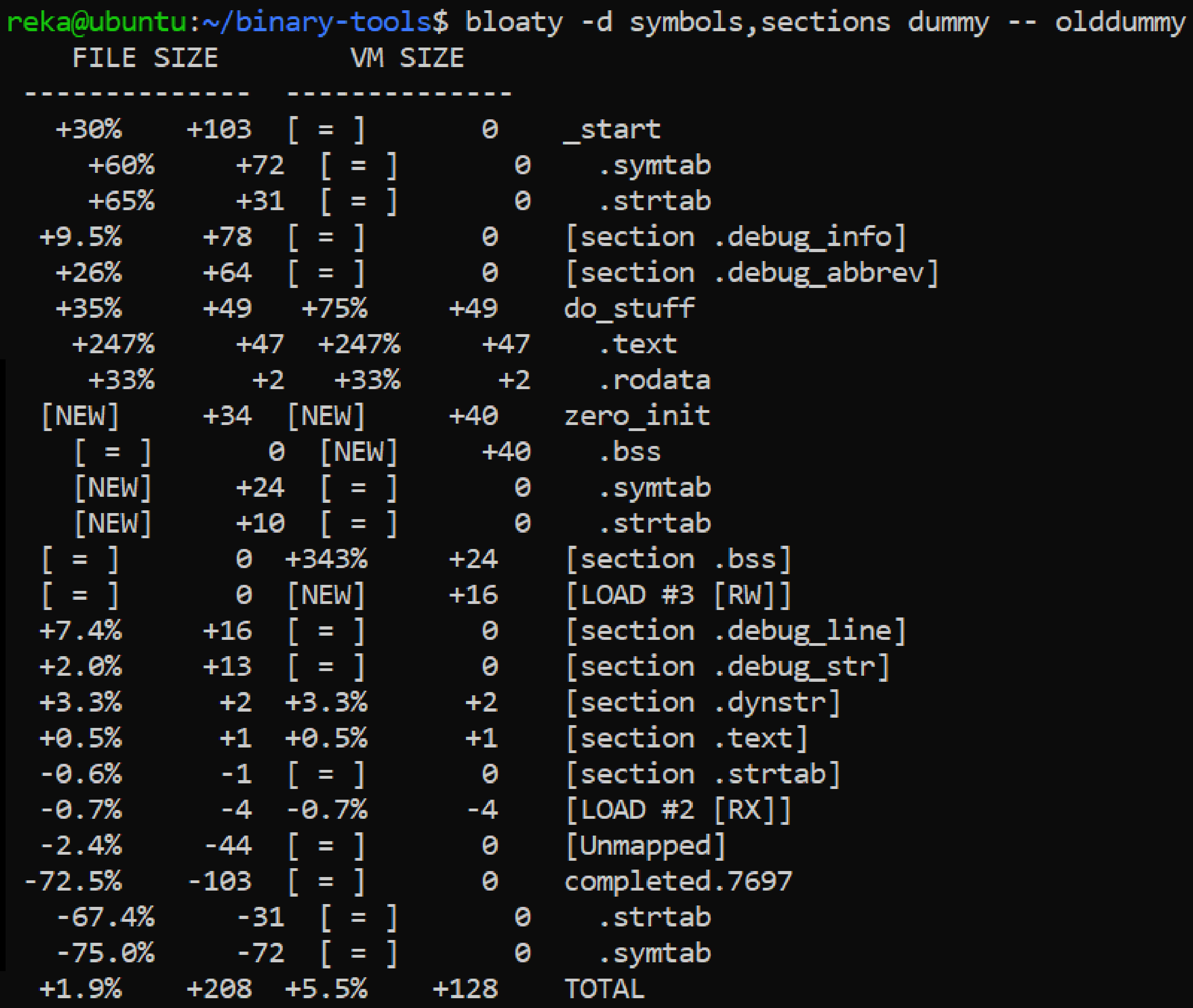


```c
#include <stdio.h>

void do_stuff() {
  printf("stuff\n");
}

int main() {
  do_stuff();
  return 0;
}
```

```
$ vim dummy.c
```



```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```



```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections dummy -- olddummy
    FILE SIZE        VM SIZE
 -------------- --------------
   +30%    +103  [ = ]       0    _start
     +60%     +72  [ = ]       0      .symtab
     +65%     +31  [ = ]       0      .strtab
  +9.5%     +78  [ = ]       0    [section .debug_info]
   +26%     +64  [ = ]       0    [section .debug_abbrev]
   +35%     +49   +75%     +49    do_stuff
    +247%     +47  +247%     +47      .text
     +33%      +2   +33%      +2      .rodata
  [NEW]     +34  [NEW]     +40    zero_init
    [ = ]       0  [NEW]     +40      .bss
    [NEW]     +24  [ = ]       0      .symtab
    [NEW]     +10  [ = ]       0      .strtab
  [ = ]       0  +343%     +24    [section .bss]
  [ = ]       0  [NEW]     +16    [LOAD #3 [RW]]
  +7.4%     +16  [ = ]       0    [section .debug_line]
  +2.0%     +13  [ = ]       0    [section .debug_str]
  +3.3%      +2  +3.3%      +2    [section .dynstr]
  +0.5%      +1  +0.5%      +1    [section .text]
  -0.6%      -1  [ = ]       0    [section .strtab]
  -0.7%      -4  -0.7%      -4    [LOAD #2 [RX]]
  -2.4%     -44  [ = ]       0    [Unmapped]
 -72.5%    -103  [ = ]       0    completed.7697
   -67.4%     -31  [ = ]       0      .strtab
   -75.0%     -72  [ = ]       0      .symtab
  +1.9%    +208  +5.5%    +128    TOTAL
```

Diff mode

```
$ vim olddummy.c
```

```c
#include <stdio.h>

void do_stuff() {
  printf("stuff\n");
}

int main() {
  do_stuff();
  return 0;
}
```

```
$ vim dummy.c
```

```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```

```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections dummy -- olddummy
    FILE SIZE        VM SIZE
 --------------  --------------
  +30%    +103  [ = ]       0    _start
    +60%     +72  [ = ]       0    .symtab
    +65%     +31  [ = ]       0    .strtab
 +9.5%     +78  [ = ]       0    [section .debug_info]
  +26%     +64  [ = ]       0    [section .debug_abbrev]
  +35%     +49  +75%     +49    do_stuff
   +247%     +47  +247%     +47    .text
    +33%      +2  +33%      +2    .rodata
 [NEW]     +34  [NEW]     +40    zero_init
   [ = ]       0  [NEW]     +40    .bss
   [NEW]     +24  [ = ]       0    .symtab
   [NEW]     +10  [ = ]       0    .strtab
 [ = ]       0  +343%     +24    [section .bss]
 [ = ]       0  [NEW]     +16    [LOAD #3 [RW]]
 +7.4%     +16  [ = ]       0    [section .debug_line]
 +2.0%     +13  [ = ]       0    [section .debug_str]
 +3.3%      +2  +3.3%      +2    [section .dynstr]
 +0.5%      +1  +0.5%      +1    [section .text]
 -0.6%      -1  [ = ]       0    [section .strtab]
 -0.7%      -4  -0.7%      -4    [LOAD #2 [RX]]
 -2.4%     -44  [ = ]       0    [Unmapped]
-72.5%    -103  [ = ]       0    completed.7697
  -67.4%     -31  [ = ]       0    .strtab
  -75.0%     -72  [ = ]       0    .symtab
 +1.9%    +208  +5.5%    +128    TOTAL
```

Diff mode

```
$ vim olddummy.c
```

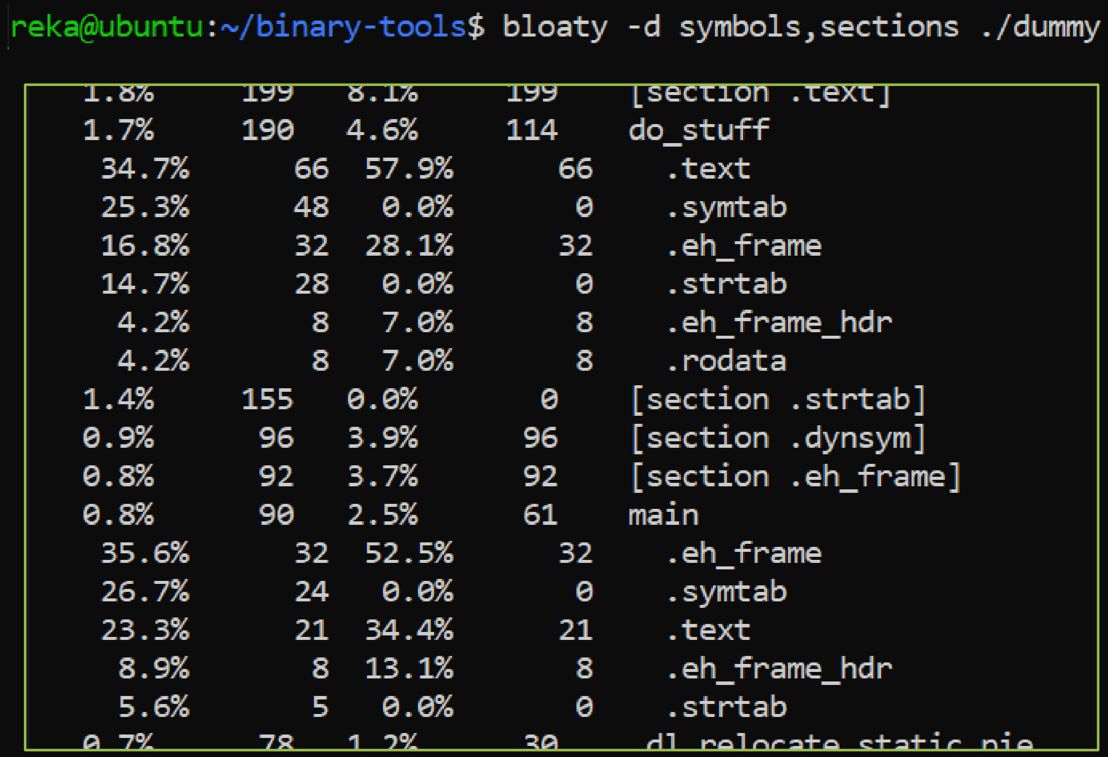
```c
#include <stdio.h>

void do_stuff() {
  printf("stuff\n");
}

int main() {
  do_stuff();
  return 0;
}
```

```
$ vim dummy.c
```

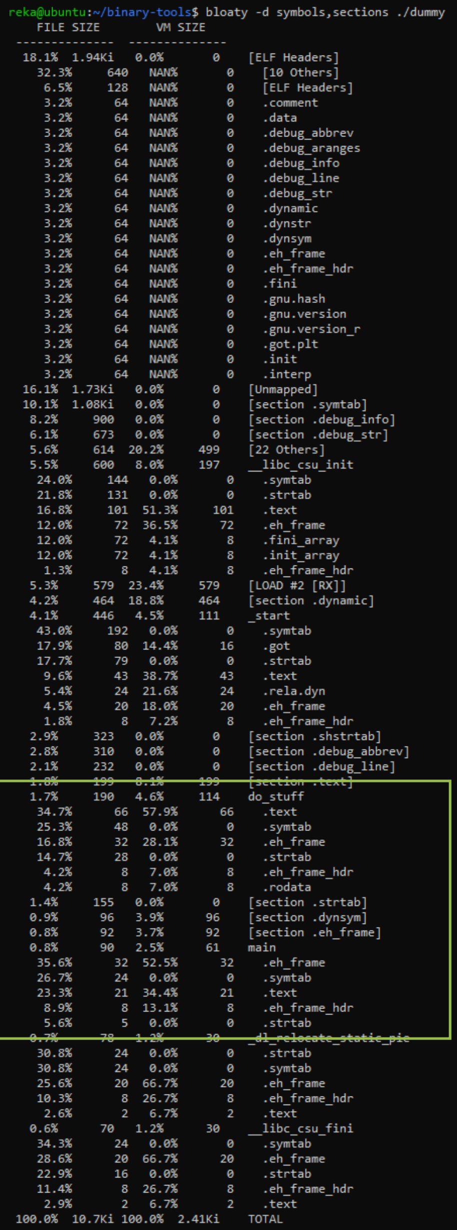
```c
#include <stdio.h>

int zero_init[10];

void do_stuff(int arg) {
  int local = arg + 2;
  int i;

  for (i = 0; i < local; ++i) {
    printf("i = %d\n", i);
  }
}

int main() {
  do_stuff(2);
  return 0;
}
```

```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections dummy -- olddummy
    FILE SIZE        VM SIZE
 --------------  --------------
   +30%    +103  [ = ]       0    _start
     +60%     +72  [ = ]       0      .symtab
     +65%     +31  [ = ]       0      .strtab
  +9.5%     +78  [ = ]       0    [section .debug_info]
   +26%     +64  [ = ]       0    [section .debug_abbrev]
   +35%     +49  +75%     +49    do_stuff
    +247%     +47  +247%     +47      .text
     +33%      +2   +33%      +2      .rodata
  [NEW]     +34  [NEW]     +40    zero_init
    [ = ]       0  [NEW]     +40      .bss
    [NEW]     +24  [ = ]       0      .symtab
    [NEW]     +10  [ = ]       0      .strtab
  [ = ]       0  +343%     +24    [section .bss]
  [ = ]       0  [NEW]     +16    [LOAD #3 [RW]]
  +7.4%     +16  [ = ]       0    [section .debug_line]
  +2.0%     +13  [ = ]       0    [section .debug_str]
  +3.3%      +2  +3.3%      +2    [section .dynstr]
  +0.5%      +1  +0.5%      +1    [section .text]
  -0.6%      -1  [ = ]       0    [section .strtab]
  -0.7%      -4  -0.7%      -4    [LOAD #2 [RX]]
  -2.4%     -44  [ = ]       0    [Unmapped]
 -72.5%    -103  [ = ]       0    completed.7697
   -67.4%     -31  [ = ]       0      .strtab
   -75.0%     -72  [ = ]       0      .symtab
  +1.9%    +208  +5.5%    +128    TOTAL
```

Data Sources

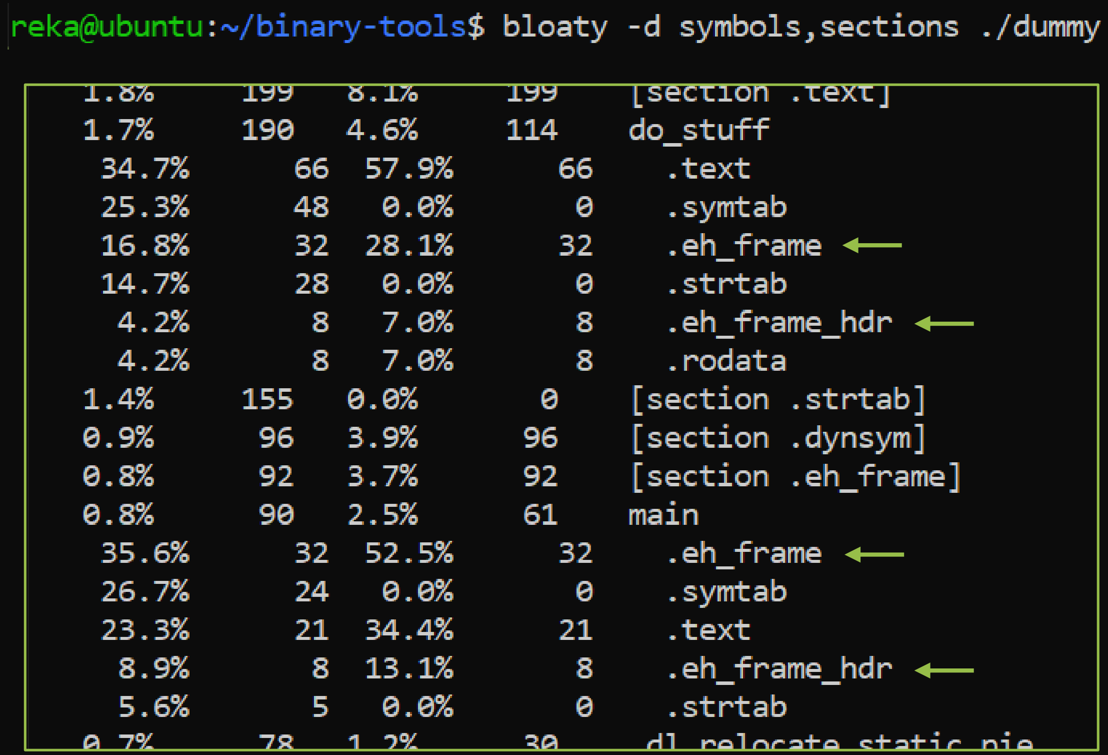


```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections ./dummy
   1.8%     199   8.1%     199    [section .text]
   1.7%     190   4.6%     114    do_stuff
    34.7%      66  57.9%      66      .text
    25.3%      48   0.0%       0      .symtab
    16.8%      32  28.1%      32      .eh_frame
    14.7%      28   0.0%       0      .strtab
     4.2%       8   7.0%       8      .eh_frame_hdr
     4.2%       8   7.0%       8      .rodata
   1.4%     155   0.0%       0    [section .strtab]
   0.9%      96   3.9%      96    [section .dynsym]
   0.8%      92   3.7%      92    [section .eh_frame]
   0.8%      90   2.5%      61    main
    35.6%      32  52.5%      32      .eh_frame
    26.7%      24   0.0%       0      .symtab
    23.3%      21  34.4%      21      .text
     8.9%       8  13.1%       8      .eh_frame_hdr
     5.6%       5   0.0%       0      .strtab
   0.7%      78   1.2%      30     _dl_relocate_static_pie
```



```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections ./dummy
    FILE SIZE        VM SIZE
 --------------  --------------
  18.1%  1.94Ki   0.0%       0    [ELF Headers]
    32.3%     640   NAN%       0      [10 Others]
     6.5%     128   NAN%       0      [ELF Headers]
     3.2%      64   NAN%       0      .comment
     3.2%      64   NAN%       0      .data
     3.2%      64   NAN%       0      .debug_abbrev
     3.2%      64   NAN%       0      .debug_aranges
     3.2%      64   NAN%       0      .debug_info
     3.2%      64   NAN%       0      .debug_line
     3.2%      64   NAN%       0      .debug_str
     3.2%      64   NAN%       0      .dynamic
     3.2%      64   NAN%       0      .dynstr
     3.2%      64   NAN%       0      .dynsym
     3.2%      64   NAN%       0      .eh_frame
     3.2%      64   NAN%       0      .eh_frame_hdr
     3.2%      64   NAN%       0      .fini
     3.2%      64   NAN%       0      .gnu.hash
     3.2%      64   NAN%       0      .gnu.version
     3.2%      64   NAN%       0      .gnu.version_r
     3.2%      64   NAN%       0      .got.plt
     3.2%      64   NAN%       0      .init
     3.2%      64   NAN%       0      .interp
  16.1%  1.73Ki   0.0%       0    [Unmapped]
  10.1%  1.08Ki   0.0%       0    [section .symtab]
   8.2%     900   0.0%       0    [section .debug_info]
   6.1%     673   0.0%       0    [section .debug_str]
   5.6%     614  20.2%     499    [22 Others]
   5.5%     600   8.0%     197    __libc_csu_init
    24.0%     144   0.0%       0      .symtab
    21.8%     131   0.0%       0      .strtab
    16.8%     101  51.3%     101      .text
    12.0%      72  36.5%      72      .eh_frame
    12.0%      72   4.1%       8      .fini_array
    12.0%      72   4.1%       8      .init_array
     1.3%       8   4.1%       8      .eh_frame_hdr
   5.3%     579  23.4%     579    [LOAD #2 [RX]]
   4.2%     464  18.8%     464    [section .dynamic]
   4.1%     446   4.5%     111    _start
    43.0%     192   0.0%       0      .symtab
    17.9%      80  14.4%      16      .got
    17.7%      79   0.0%       0      .strtab
     9.6%      43  38.7%      43      .text
     5.4%      24  21.6%      24      .rela.dyn
     4.5%      20  18.0%      20      .eh_frame
     1.8%       8   7.2%       8      .eh_frame_hdr
   2.9%     323   0.0%       0    [section .shstrtab]
   2.8%     310   0.0%       0    [section .debug_abbrev]
   2.1%     232   0.0%       0    [section .debug_line]
   1.8%     199   8.1%     199    [section .text]
   1.7%     190   4.6%     114    do_stuff
    34.7%      66  57.9%      66      .text
    25.3%      48   0.0%       0      .symtab
    16.8%      32  28.1%      32      .eh_frame
    14.7%      28   0.0%       0      .strtab
     4.2%       8   7.0%       8      .eh_frame_hdr
     4.2%       8   7.0%       8      .rodata
   1.4%     155   0.0%       0    [section .strtab]
   0.9%      96   3.9%      96    [section .dynsym]
   0.8%      92   3.7%      92    [section .eh_frame]
   0.8%      90   2.5%      61    main
    35.6%      32  52.5%      32      .eh_frame
    26.7%      24   0.0%       0      .symtab
    23.3%      21  34.4%      21      .text
     8.9%       8  13.1%       8      .eh_frame_hdr
     5.6%       5   0.0%       0      .strtab
   0.7%      78   1.2%      30    _dl_relocate_static_pie
    30.8%      24   0.0%       0      .strtab
    30.8%      24   0.0%       0      .symtab
    25.6%      20  66.7%      20      .eh_frame
    10.3%       8  26.7%       8      .eh_frame_hdr
     2.6%       2   6.7%       2      .text
   0.6%      70   1.2%      30    __libc_csu_fini
    34.3%      24   0.0%       0      .symtab
    28.6%      20  66.7%      20      .eh_frame
    22.9%      16   0.0%       0      .strtab
    11.4%       8  26.7%       8      .eh_frame_hdr
     2.9%       2   6.7%       2      .text
 100.0%  10.7Ki 100.0%  2.41Ki    TOTAL
```

Data Sources



```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections ./dummy
```

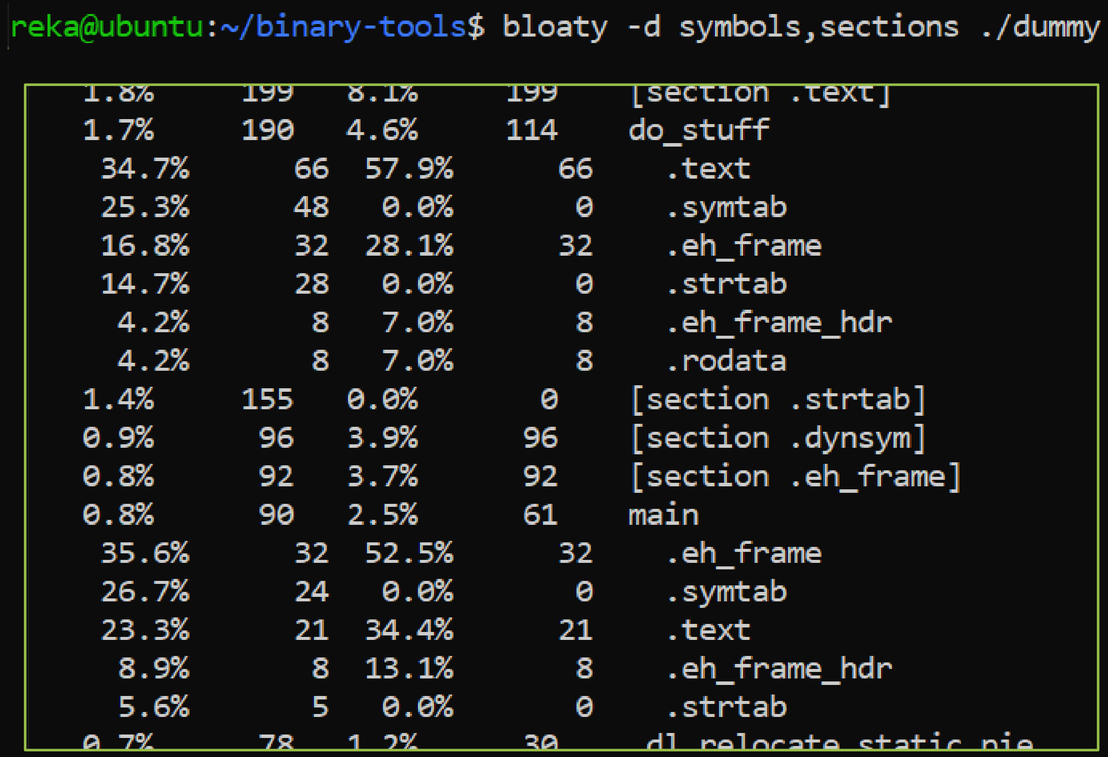
```
     1.8%     199   8.1%     199   [section .text]
     1.7%     190   4.6%     114   do_stuff
      34.7%      66  57.9%      66     .text
      25.3%      48   0.0%       0     .symtab
      16.8%      32  28.1%      32     .eh_frame ←
      14.7%      28   0.0%       0     .strtab
       4.2%       8   7.0%       8     .eh_frame_hdr ←
       4.2%       8   7.0%       8     .rodata
     1.4%     155   0.0%       0   [section .strtab]
     0.9%      96   3.9%      96   [section .dynsym]
     0.8%      92   3.7%      92   [section .eh_frame]
     0.8%      90   2.5%      61   main
      35.6%      32  52.5%      32     .eh_frame ←
      26.7%      24   0.0%       0     .symtab
      23.3%      21  34.4%      21     .text
       8.9%       8  13.1%       8     .eh_frame_hdr ←
       5.6%       5   0.0%       0     .strtab
     0.7%      78   1.2%      30    _dl_relocate_static_pie
```

The symbol table only refers to the machine code of the function

Other artifacts a function emits into the binary:

- Unwind info

Data Sources



```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections ./dummy
```

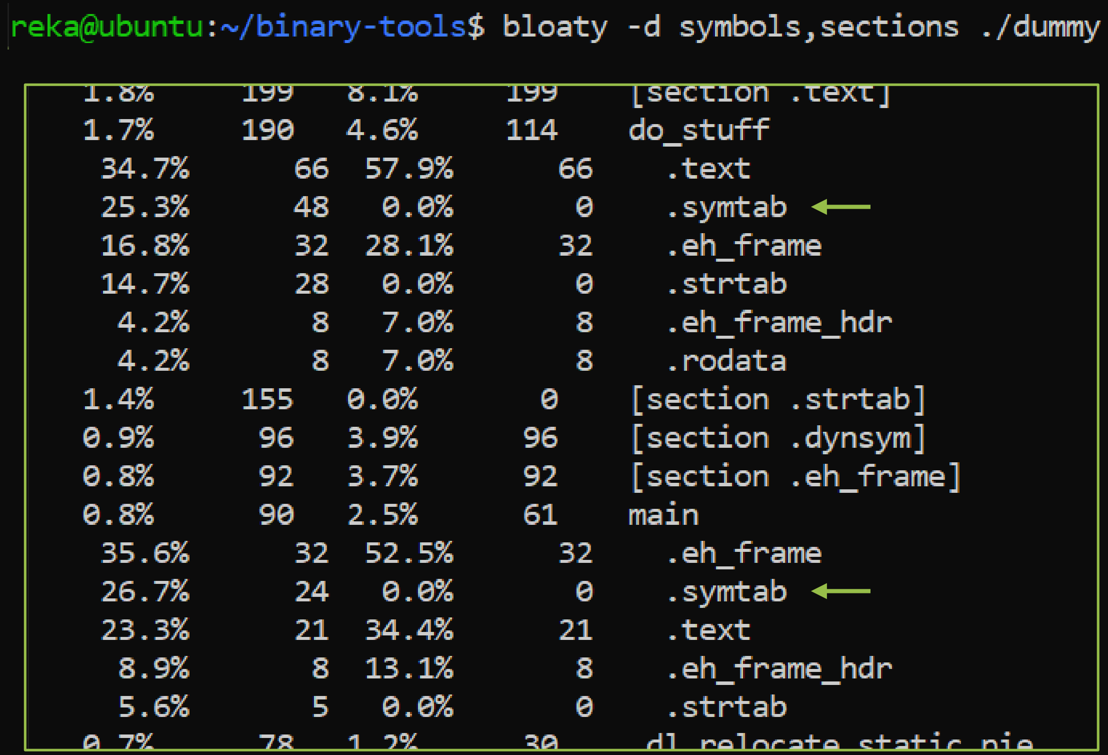
```
   1.8%     199   8.1%     199   [section .text]
   1.7%     190   4.6%     114   do_stuff
    34.7%      66  57.9%      66     .text
    25.3%      48   0.0%       0     .symtab
    16.8%      32  28.1%      32     .eh_frame
    14.7%      28   0.0%       0     .strtab
     4.2%       8   7.0%       8     .eh_frame_hdr
     4.2%       8   7.0%       8     .rodata
   1.4%     155   0.0%       0   [section .strtab]
   0.9%      96   3.9%      96   [section .dynsym]
   0.8%      92   3.7%      92   [section .eh_frame]
   0.8%      90   2.5%      61   main
    35.6%      32  52.5%      32     .eh_frame
    26.7%      24   0.0%       0     .symtab
    23.3%      21  34.4%      21     .text
     8.9%       8  13.1%       8     .eh_frame_hdr
     5.6%       5   0.0%       0     .strtab
   0.7%      78   1.2%      30    _dl_relocate_static_pie
```

The symbol table only refers to the machine code of the function

Other artifacts a function emits into the binary:

- Unwind info
- Relocation info
- Debug info

Data Sources



```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections ./dummy
```

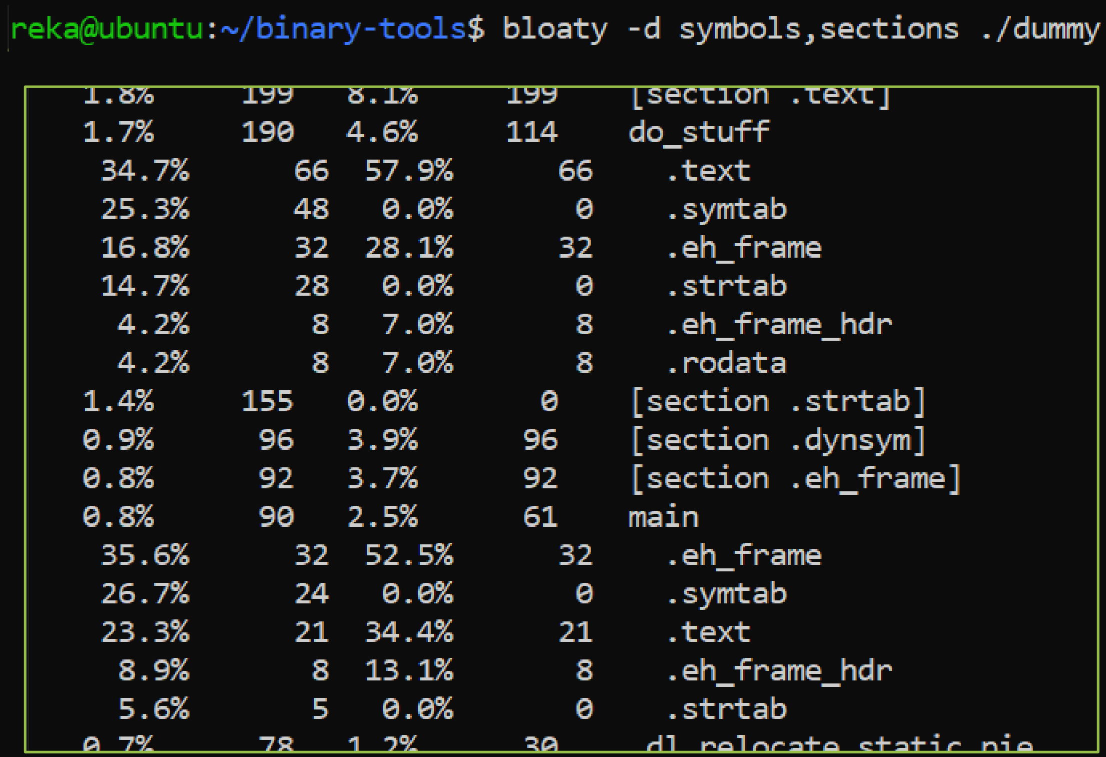
```
   1.8%     199   8.1%     199    [section .text]
   1.7%     190   4.6%     114    do_stuff
    34.7%      66  57.9%      66      .text
    25.3%      48   0.0%       0      .symtab  ←
    16.8%      32  28.1%      32      .eh_frame
    14.7%      28   0.0%       0      .strtab
     4.2%       8   7.0%       8      .eh_frame_hdr
     4.2%       8   7.0%       8      .rodata
   1.4%     155   0.0%       0    [section .strtab]
   0.9%      96   3.9%      96    [section .dynsym]
   0.8%      92   3.7%      92    [section .eh_frame]
   0.8%      90   2.5%      61    main
    35.6%      32  52.5%      32      .eh_frame
    26.7%      24   0.0%       0      .symtab  ←
    23.3%      21  34.4%      21      .text
     8.9%       8  13.1%       8      .eh_frame_hdr
     5.6%       5   0.0%       0      .strtab
   0.7%      78   1.2%      30     _dl_relocate_static_pie
```

The symbol table only refers to the machine code of the function

Other artifacts a function emits into the binary:

- Unwind info
- Relocation info
- Debug info
- Its entry in the symbol table itself

Data Sources



```
reka@ubuntu:~/binary-tools$ bloaty -d symbols,sections ./dummy
   1.8%     199   8.1%     199   [section .text]
   1.7%     190   4.6%     114   do_stuff
    34.7%      66  57.9%      66     .text
    25.3%      48   0.0%       0     .symtab
    16.8%      32  28.1%      32     .eh_frame
    14.7%      28   0.0%       0     .strtab
     4.2%       8   7.0%       8     .eh_frame_hdr
     4.2%       8   7.0%       8     .rodata
   1.4%     155   0.0%       0   [section .strtab]
   0.9%      96   3.9%      96   [section .dynsym]
   0.8%      92   3.7%      92   [section .eh_frame]
   0.8%      90   2.5%      61   main
    35.6%      32  52.5%      32     .eh_frame
    26.7%      24   0.0%       0     .symtab
    23.3%      21  34.4%      21     .text
     8.9%       8  13.1%       8     .eh_frame_hdr
     5.6%       5   0.0%       0     .strtab
   0.7%      78   1.2%      30    dl relocate static pie
```

The symbol table only refers to the machine code of the function

Other artifacts a function emits into the binary:

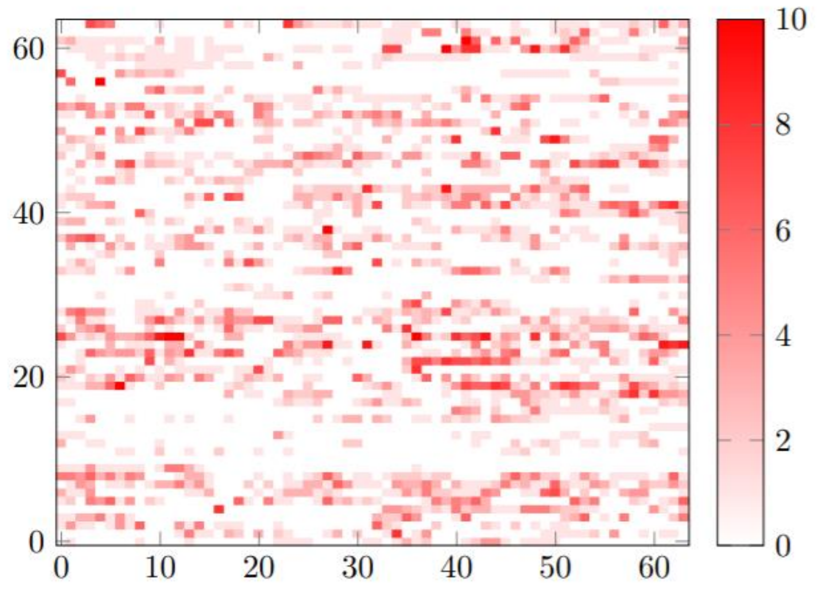
- Unwind info
- Relocation info
- Debug info
- Its entry in the symbol table itself

Bloaty attributes these to the function to get a faithful total size

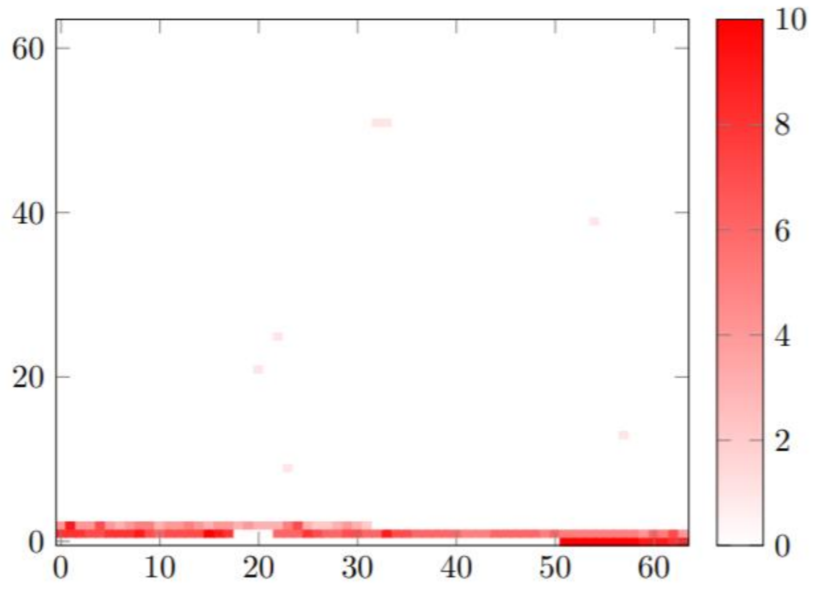
In practice, there is no 100% coverage – (Unmapped)

BOLT

- Maksim Panchenko et al., 2018
- https://github.com/facebookincubator/BOLT
- https://arxiv.org/abs/1807.06735
- Binary layout optimization
- Supports ELF x86-64, AArch64, uses LLVM libs & perf



(a) without BOLT



(b) with BOLT

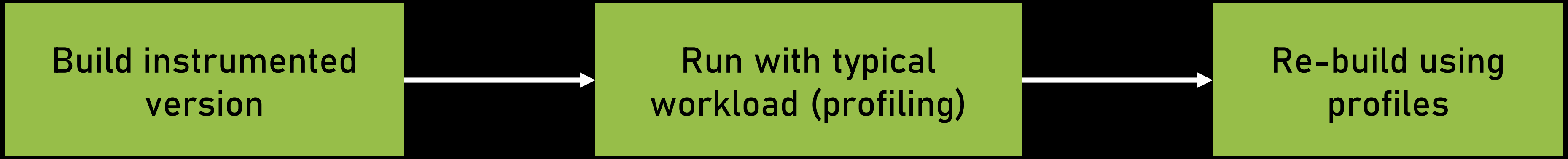
Heat maps for instruction memory accesses of the HHVM binary, without and with BOLT. Heat is in a log scale.

HHVM became 8% faster on top of compiler opts + link-time function layout tool

Clang & GCC binaries up to 20% faster with PGO+LTO+BOLT than with PGO+LTO

PGO (Profile-Guided Optimization)

Also POGO or FDO (Feedback-Directed Optimization)


Build instrumented version
Run with typical workload (profiling)
Re-build using profiles

- Inserting profile data early means that many optimizations can benefit from them
- CPU and memory overhead

LTO (Link-Time Optimization)

Also LTCG (Link-Time Code Generation)

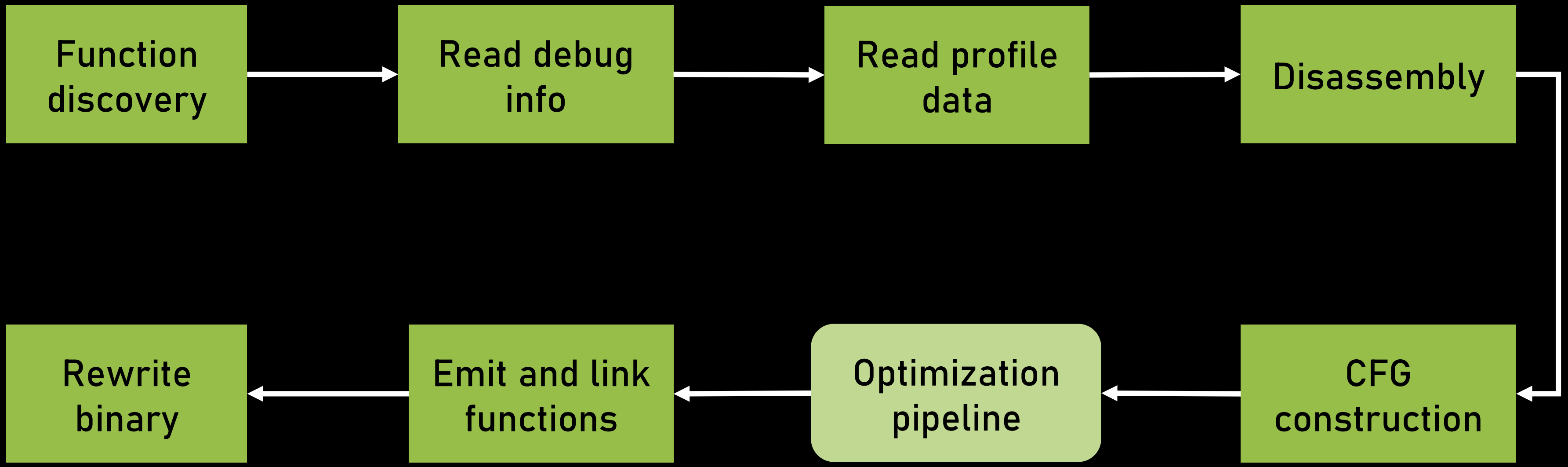
- Whole program analysis, cross-module optimization

BOLT

- Can optimize 3rd party libraries and assembly code
- Designed to work with the output of different compilers
- Uses sample-based profiling
  - Hardware profile counters e.g. Last Branch Records (Intel)
  - Negligible overhead
  - No special build required
- Binary-level profile data is applied on a binary level
  - No retrofitting needed, accurate

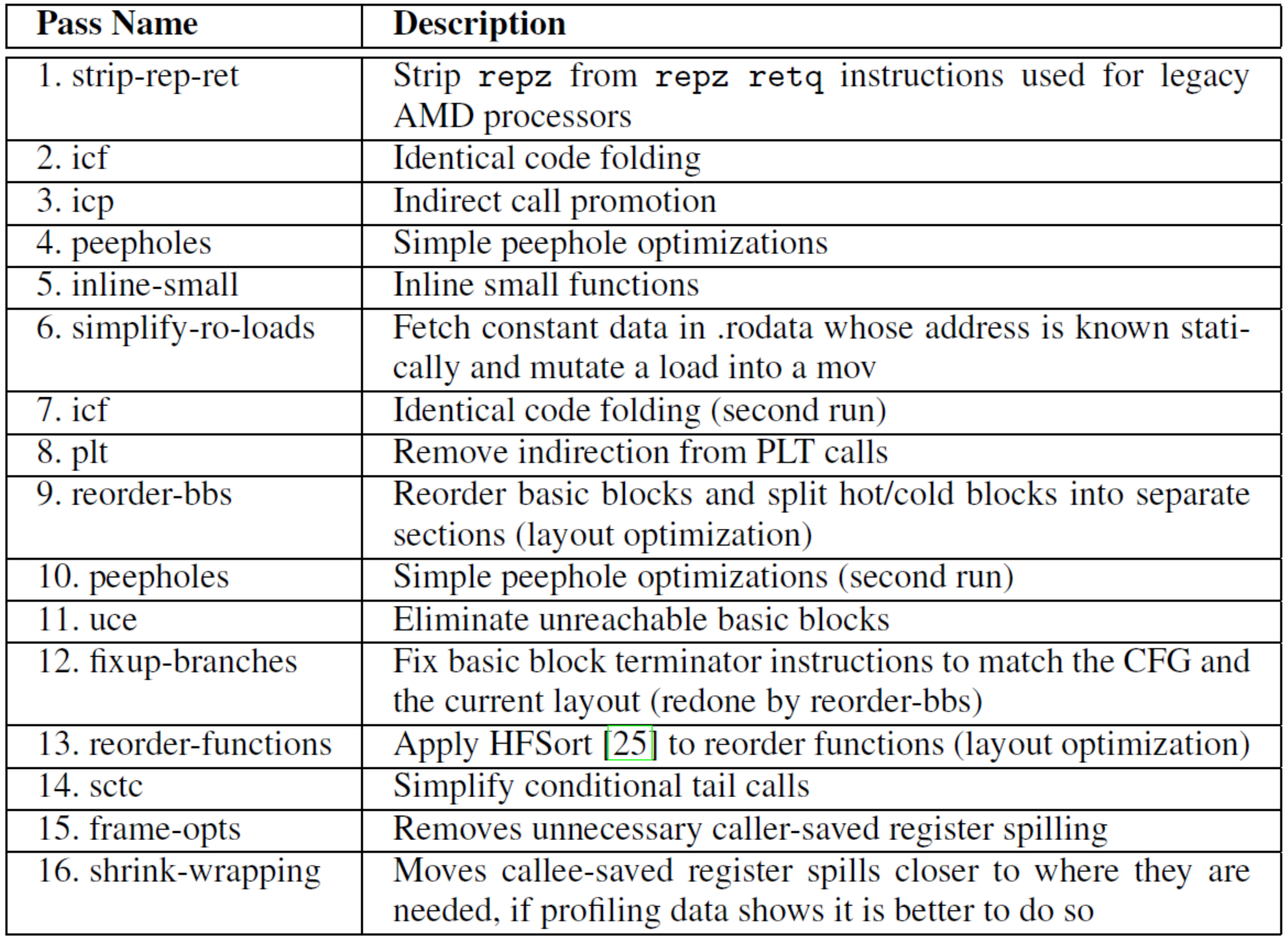
BOLT

Binary rewriting pipeline



BOLT

Optimization pipeline



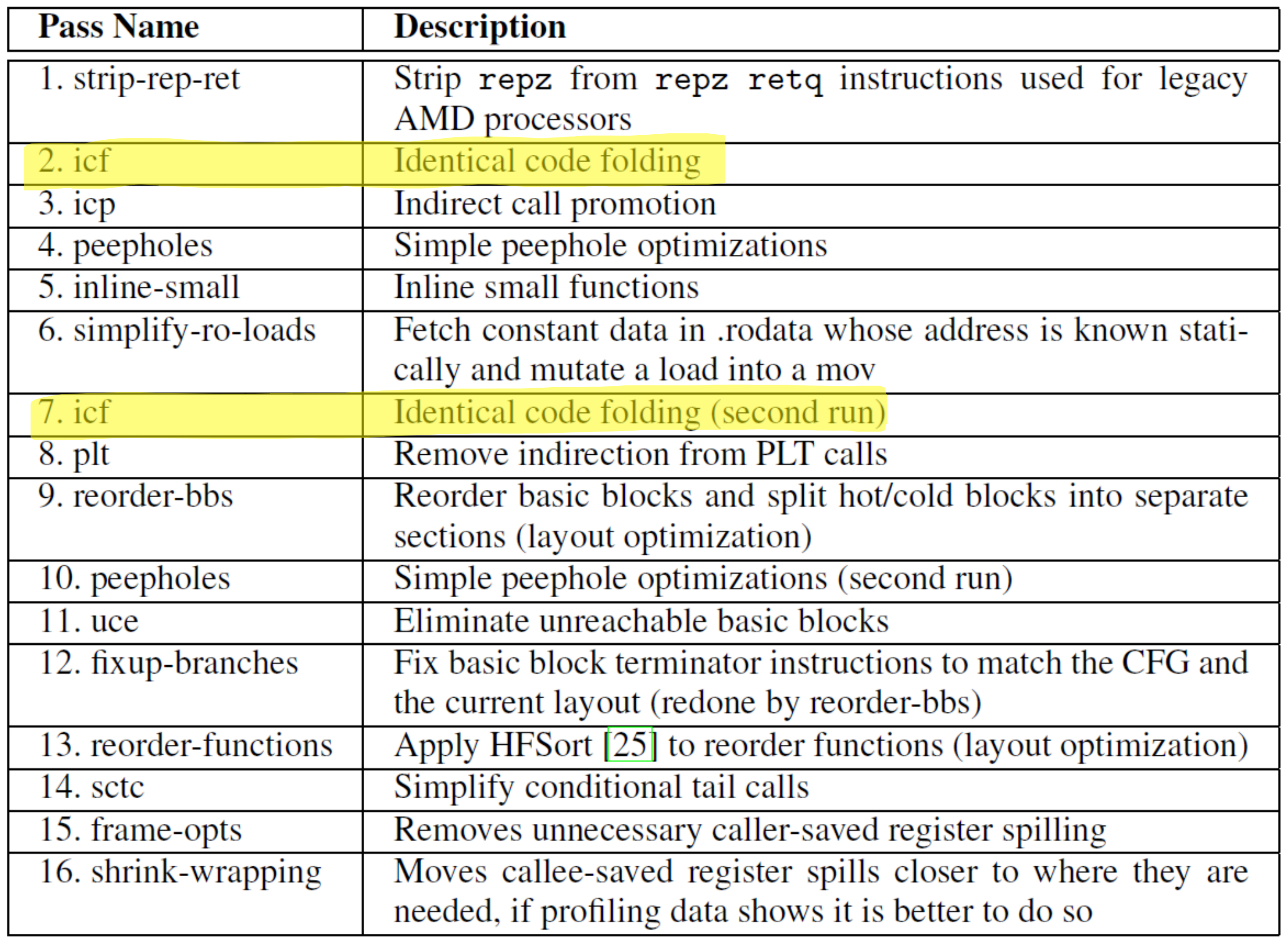
Pass Name	**Description**
1. strip-rep-ret	Strip `repz` from `repz retq` instructions used for legacy AMD processors
2. icf	Identical code folding
3. icp	Indirect call promotion
4. peepholes	Simple peephole optimizations
5. inline-small	Inline small functions
6. simplify-ro-loads	Fetch constant data in .rodata whose address is known statically and mutate a load into a mov
7. icf	Identical code folding (second run)
8. plt	Remove indirection from PLT calls
9. reorder-bbs	Reorder basic blocks and split hot/cold blocks into separate sections (layout optimization)
10. peepholes	Simple peephole optimizations (second run)
11. uce	Eliminate unreachable basic blocks
12. fixup-branches	Fix basic block terminator instructions to match the CFG and the current layout (redone by reorder-bbs)
13. reorder-functions	Apply HFSort [25] to reorder functions (layout optimization)
14. sctc	Simplify conditional tail calls
15. frame-opts	Removes unnecessary caller-saved register spilling
16. shrink-wrapping	Moves callee-saved register spills closer to where they are needed, if profiling data shows it is better to do so

BOLT

Optimization pipeline

Optimize functions compiled without `-ffunction-sections`

3% code size reduction for HHVM



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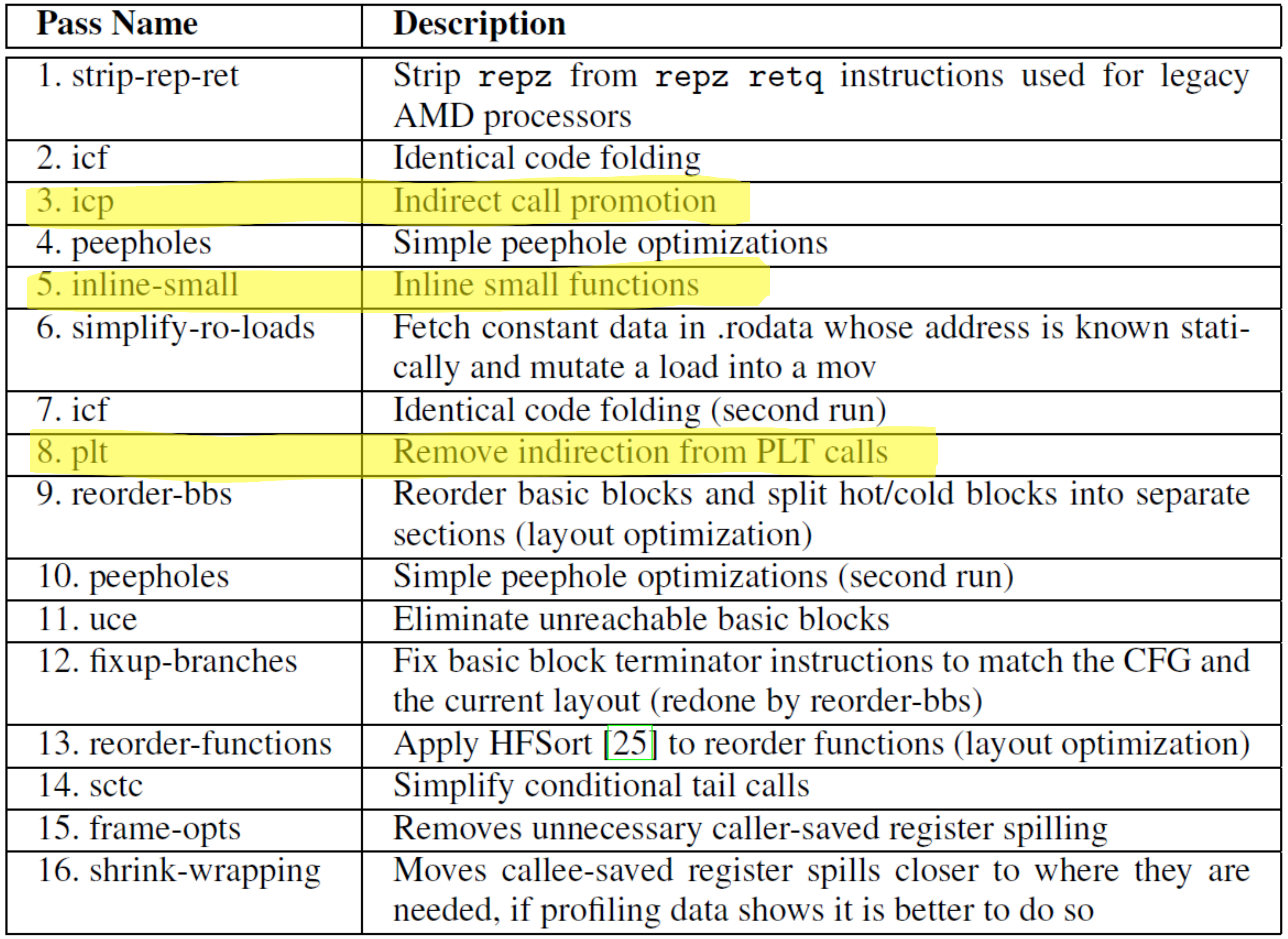
BOLT

Optimization pipeline

Use call frequency information to eliminate or change calls



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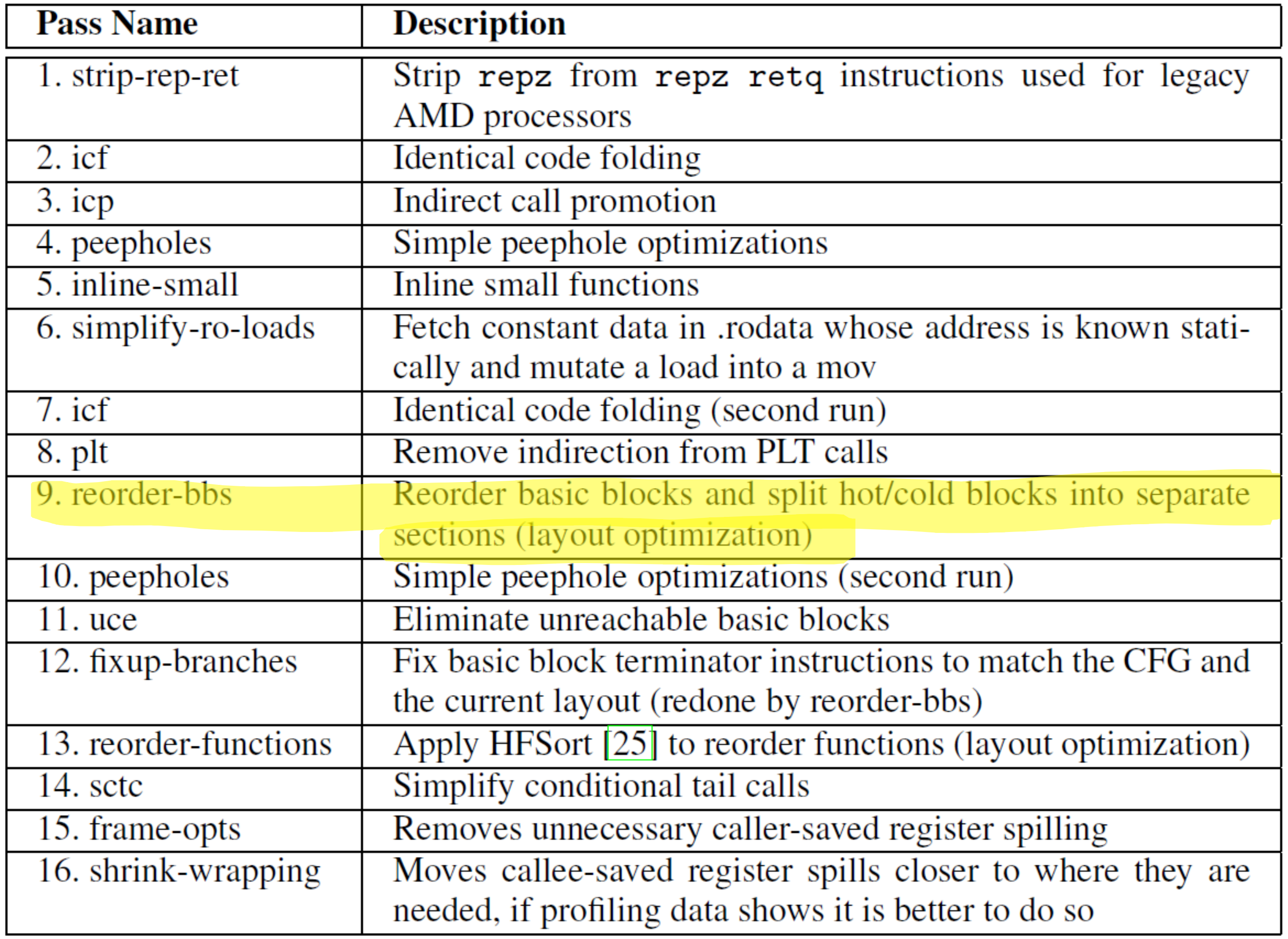
BOLT

Optimization pipeline

Reduce the number of taken branches by making the hottest successor most likely a fall-though



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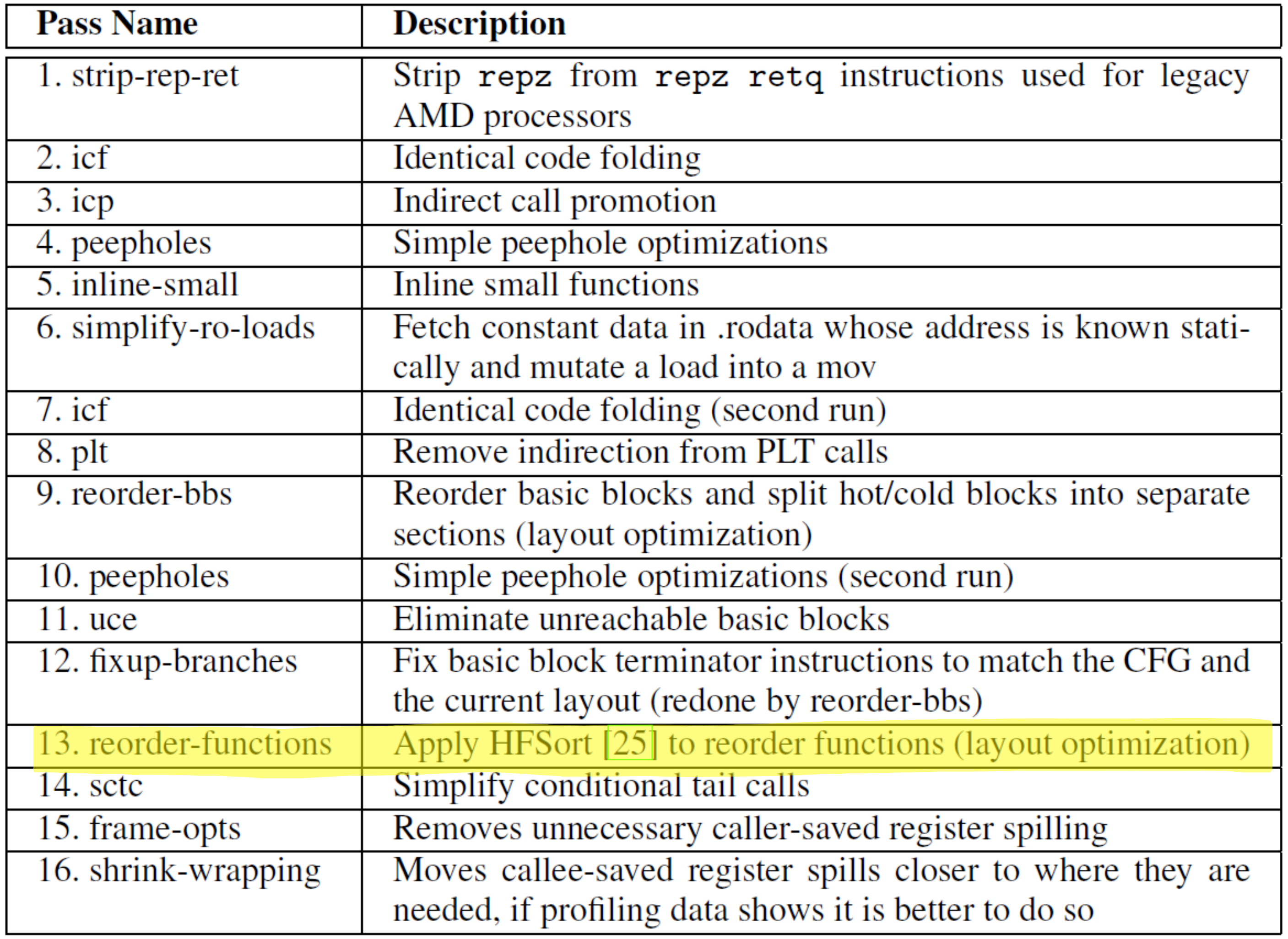
BOLT

Optimization pipeline

Uses a weighted call graph to do the reordering



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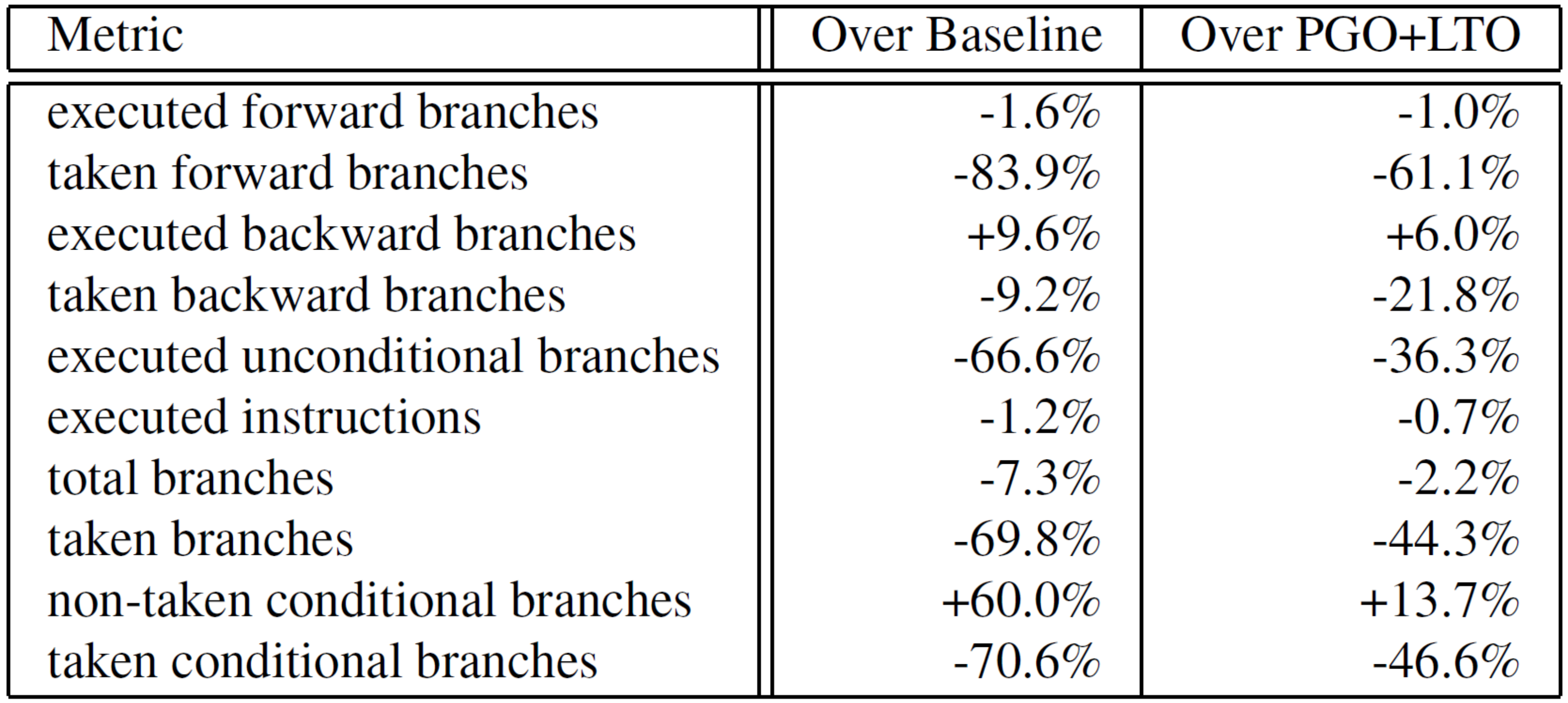
Workflow

0) Have a binary that does not fit into the instruction cache
1) Build a copy of it with `-Wl,-q` (or pass `--emit-relocs` to the linker)
2) Collect execution profiles with `perf`
3) Run `llvm-bolt` with the output of `perf`
4) Diff running times
5) See reduced number of instruction cache misses with `perf`

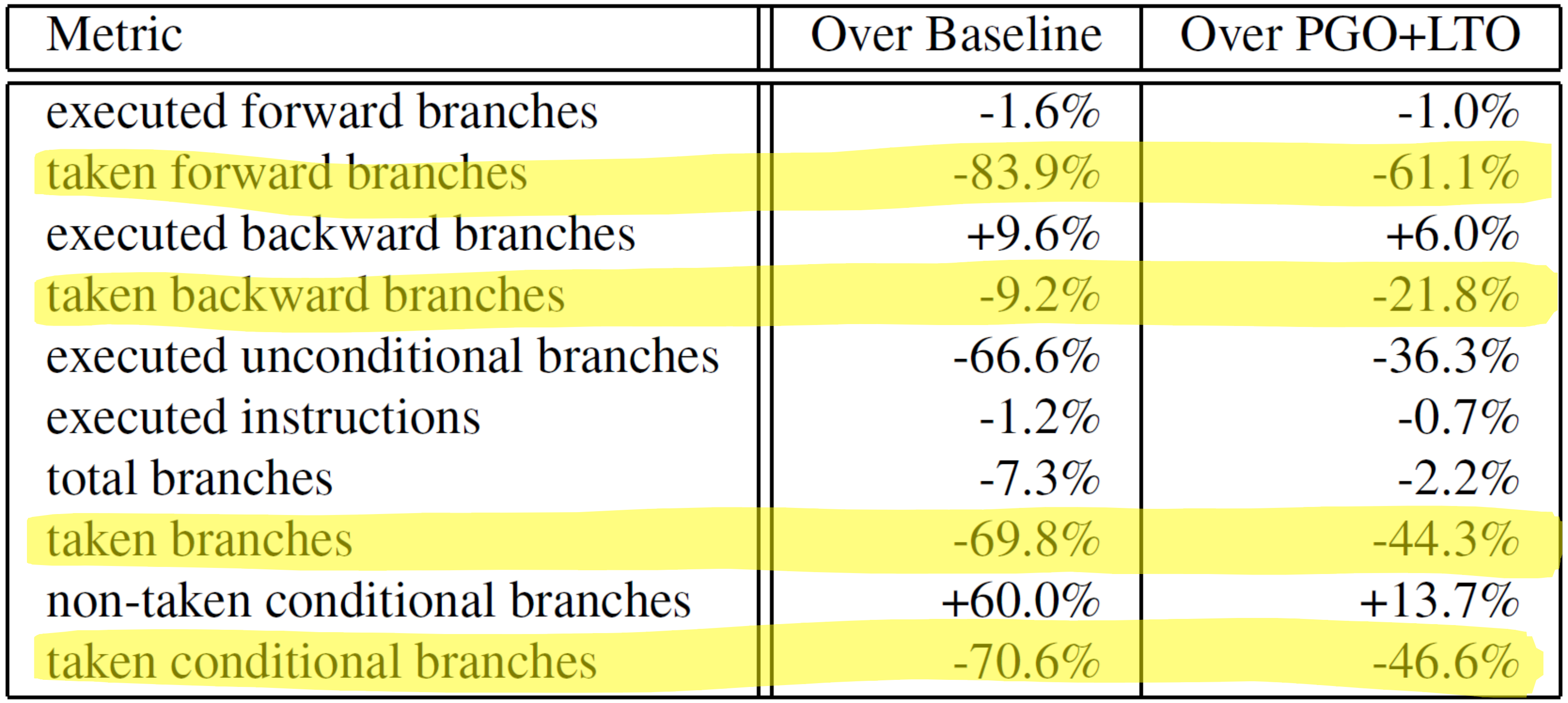
Clang binaries up to 20% faster with PGO+LTO+BOLT than with PGO+LTO



Metric	Over Baseline	Over PGO+LTO
executed forward branches	-1.6%	-1.0%
taken forward branches	-83.9%	-61.1%
executed backward branches	+9.6%	+6.0%
taken backward branches	-9.2%	-21.8%
executed unconditional branches	-66.6%	-36.3%
executed instructions	-1.2%	-0.7%
total branches	-7.3%	-2.2%
taken branches	-69.8%	-44.3%
non-taken conditional branches	+60.0%	+13.7%
taken conditional branches	-70.6%	-46.6%

Stats reported by BOLT when applied to Clang’s baseline and PGO+LTO binaries

Clang binaries up to 20% faster with PGO+LTO+BOLT than with PGO+LTO



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Thanks!