Estruturas de Dados

Aula Prática 4

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1. O programa elaborado é de multiplica duas matrizes e imprime as matrizes de entrada e o resultado. No programa, as estruturas de dados críticas são:

   Matrizes A e B: Essas matrizes contêm os dados que serão multiplicados.

   Matriz Resultante: A matriz onde o resultado da multiplicação será armazenado.

   Os segmentos de código críticos são:

   Loop de Multiplicação: O loop aninhado dentro da função `multiplyMatrices` é o segmento de código crítico. É onde a multiplicação das matrizes ocorre. Este loop percorre as linhas de A, as colunas de B e os elementos das colunas de A (para a multiplicação) e acumula os resultados na matriz resultante.

2. As ferramentas que serão usadas para executar o código main.exe são Cachegrind e Callgrind.

3. As métricas importantes de serem coletadas são o número de acessos à memória e o tempo gasto em operações de memória. Os parâmetros são as 2 matrizes de entrada, que são matrizes 3x3, mas que já estão presentes no código.

4. Cachegrind:
   ==90417== Cachegrind, a cache and branch-prediction profiler
   ==90417== Copyright (C) 2002-2017, and GNU GPL'd, by Nicholas Nethercote et al.
   ==90417== Using Valgrind-3.18.1 and LibVEX; rerun with -h for copyright info
   ==90417== Command: ./main.exe
   ==90417==
   --90417-- warning: L3 cache found, using its data for the LL simulation.
   Matrix A:
   1 2
   3 4
   Matrix B:
   5 6

7 8
Matrix resultante:
19 22
43 50
==90417==
==90417== I   refs: 2,331,765
==90417== I1 misses: 2,271
==90417== LLi misses: 2,154
==90417== I1 miss rate: 0.10%
==90417== LLi miss rate: 0.09%
==90417==
==90417== D   refs: 772,145 (564,994 rd + 207,151 wr)
==90417== D1 misses: 14,692 (12,311 rd +   2,381 wr)
==90417== LLd misses: 9,235 (7,638 rd +   1,597 wr)
==90417== D1 miss rate: 1.9% (2.2%   +   1.1%)
==90417== LLd miss rate: 1.2% (1.4%   +   0.8%)
==90417==
==90417== LL refs: 16,963 (14,582 rd +   2,381 wr)
==90417== LL misses: 11,389 (9,792 rd +   1,597 wr)
==90417== LL miss rate: 0.4% (0.3%   +   0.8%)

I1 cache: 32768 B, 64 B, 8-way associative
D1 cache: 49152 B, 64 B, 12-way associative
LL cache: 6291456 B, 64 B, 12-way associative
Command: ./main.exe
Data file: cachegrind.out.90417
Events recorded: Ir I1mr ILmr Dr D1mr DLmr Dw D1mw DLmw
Events shown: Ir I1mr ILmr Dr D1mr DLmr Dw D1mw DLmw
Event sort order: Ir I1mr ILmr Dr D1mr DLmr Dw D1mw DLmw
Thresholds: 0.1 100 100 100 100 100 100 100 100
Include dirs:
User annotated:
Auto-annotation: on

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2,331,765 (100.0%) 2,271 (100.0%) 2,154 (100.0%) 564,994 (100.0%) 12,311 (100.0%) 7,638 (100.0%) 207,151 (100.0%) 2,381 (100.0%) 1,597 (100.0%)  PROGRAM TOTALS


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Ir              I1mr           ILmr          Dr               D1mr            DLmr           Dw               D1mw           DLmw           file:function
--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
979,562 (42.01%)  11 ( 0.48%)   11 ( 0.51%) 164,031 (29.03%) 1,913 (15.54%) 1,646 (21.55%) 52,609 (25.40%)   11 ( 0.46%)   1 ( 0.06%) ./elf/./elf/dl-lookup.c:_dl_lookup_symbol_x
565,995 (24.27%)  37 ( 1.63%)   35 ( 1.62%) 189,253 (33.50%) 3,109 (25.25%)  834 (10.92%) 79,527 (38.39%)   55 ( 2.31%)  38 ( 2.38%) ./elf/./elf/dl-lookup.c:do_lookup_x
259,915 (11.15%)  27 ( 1.19%)   27 ( 1.25%)  64,926 (11.49%) 2,852 (23.17%) 2,430 (31.81%) 21,661 (10.46%) 1,592 (66.86%) 907 (56.79%) ./elf/../sysdeps/x86_64/dl-machine.h:_dl_reloca
te_object
118,221 ( 5.07%)   6 ( 0.26%)    6 ( 0.28%)  39,399 ( 6.97%)   378 ( 3.07%)  230 ( 3.01%) 13,166 ( 6.36%)    4 ( 0.17%)   1 ( 0.06%) ./elf/./elf/dl-lookup.c:check_match
108,434 ( 4.65%)  17 ( 0.75%)   17 ( 0.79%)  34,156 ( 6.05%) 2,530 (20.55%) 1,795 (23.50%) 10,284 ( 4.96%)    3 ( 0.13%)   0          ./elf/./elf/do-rel.h:_dl_relocate_object
 73,249 ( 3.14%)  55 ( 2.42%)   43 ( 2.00%)  18,375 ( 3.25%)   182 ( 1.48%)   88 ( 1.15%)      0              0            0          ./string/../sysdeps/x86_64/strcmp.S:strcmp
 19,698 ( 0.84%)   0             0               0               0              0          4,384 ( 2.12%)     0            0          ./elf/../sysdeps/generic/dl-protected.h:do_look
up_x
 18,771 ( 0.81%)   6 ( 0.26%)    6 ( 0.28%)   3,429 ( 0.61%)    55 ( 0.45%)   55 ( 0.72%)     86 ( 0.04%)     2 ( 0.08%)   2 ( 0.13%) ./elf/./elf/dl-tunables.c:__GI___tunables_init
 12,128 ( 0.52%)   6 ( 0.26%)    6 ( 0.28%)   3,552 ( 0.63%)     0              0            256 ( 0.12%)     0            0          ???:std::locale::_Impl::_M_install_facet(std::l
ocale::id const*, std::locale::facet const*)
 11,753 ( 0.50%)  20 ( 0.88%)   20 ( 0.93%)   4,067 ( 0.72%)    86 ( 0.70%)   83 ( 1.09%)    861 ( 0.42%)    65 ( 2.73%)  64 ( 4.01%) ./elf/../sysdeps/generic/ldsodefs.h:_dl_check_map_versions
 10,885 ( 0.47%)   1 ( 0.04%)    1 ( 0.05%)   2,177 ( 0.39%)     0              0              0              0            0          ./elf/../sysdeps/generic/ldsodefs.h:do_lookup_x
 10,240 ( 0.44%)   4 ( 0.18%)    4 ( 0.19%)   3,072 ( 0.54%)     4 ( 0.03%)    0          1,536 ( 0.74%)     0            0          ./wcsmbs/./wcsmbs/btowc.c:btowc
 10,170 ( 0.44%)   0             0            3,390 ( 0.60%)     0              0              0              0            0          ./elf/../sysdeps/generic/ldsodefs.h:_dl_relocat
e_object
  8,088 ( 0.35%)   7 ( 0.31%)    7 ( 0.32%)   2,924 ( 0.52%)   259 ( 2.10%)   53 ( 0.69%)    776 ( 0.37%)     1 ( 0.04%)   0          ./elf/./elf/dl-runtime.c:_dl_fixup
  4,635 ( 0.20%) 291 (12.81%)  266 (12.35%)   1,918 ( 0.34%)   146 ( 1.19%)   10 ( 0.13%)    525 ( 0.25%)    22 ( 0.92%)  13 ( 0.81%) ???:???
  4,174 ( 0.18%)  16 ( 0.70%)   16 ( 0.74%)     331 ( 0.06%)    44 ( 0.36%)    0            143 ( 0.07%)     0            0          ./elf/./elf/dl-reloc.c:_dl_relocate_object
  3,782 ( 0.16%)  41 ( 1.81%)   41 ( 1.90%)     825 ( 0.15%)    54 ( 0.44%)   54 ( 0.71%)    394 ( 0.19%)    22 ( 0.92%)  22 ( 1.38%) ./elf/./elf/dl-load.c:_dl_map_object_from_fd
  3,526 ( 0.15%)   4 ( 0.18%)    4 ( 0.19%)   4,128 ( 0.73%)     0              0          4,300 ( 2.08%)    11 ( 0.46%)   4 ( 0.25%) ./elf/../sysdeps/x86_64/dl-trampoline.h:_dl_run
time_resolve_xsave
  3,456 ( 0.15%)   3 ( 0.13%)    3 ( 0.14%)     896 ( 0.16%)     0              0            512 ( 0.25%)     0            0          ./wcsmbs/./wcsmbs/wctob.c:wctob
  3,269 ( 0.14%)  10 ( 0.44%)   10 ( 0.46%)     499 ( 0.09%)     8 ( 0.06%)    8 ( 0.10%)     78 ( 0.04%)     0            0          ./elf/../sysdeps/x86/dl-cacheinfo.h:intel_check
_word.constprop.0
  2,848 ( 0.12%)   2 ( 0.09%)    2 ( 0.09%)     761 ( 0.13%)     0              0            443 ( 0.21%)     1 ( 0.04%)   1 ( 0.06%) ./elf/./elf/dl-misc.c:_dl_name_match_p
  2,733 ( 0.12%)   4 ( 0.18%)    4 ( 0.19%)       5 ( 0.00%)     0              0            810 ( 0.39%)    20 ( 0.84%)  20 ( 1.25%) ???:std::ctype<wchar_t>::_M_initialize_ctype()
  2,698 ( 0.12%)   4 ( 0.18%)    4 ( 0.19%)     397 ( 0.07%)    23 ( 0.19%)   23 ( 0.30%)      0              0            0          ./elf/./elf/dl-cache.c:_dl_cache_libcmp
  2,351 ( 0.10%)   1 ( 0.04%)    1 ( 0.05%)     460 ( 0.08%)     1 ( 0.01%)    1 ( 0.01%)      0              0            0          ./elf/./elf/dl-tunables.h:__GI___tunables_init
```

5. Callgrind:

==91594== Callgrind, a call-graph generating cache profiler

==91594== Copyright (C) 2002-2017, and GNU GPL'd, by Josef Weidendorfer et al.

==91594== Using Valgrind-3.18.1 and LibVEX; rerun with -h for copyright info

==91594== Command: ./main.exe

==91594==

==91594== For interactive control, run 'callgrind_control -h'.

Matrix A:

1 2

3 4

Matrix B:

5 6

7 8

Matrix resultante:

19 22

43 50

==91594==

==91594== Events   : Ir

==91594== Collected : 2330612

==91594==

==91594== I   refs: 2,330,612

Profile data file 'callgrind.out.91594' (creator: callgrind-3.18.1)

I1 cache:

D1 cache:

LL cache:

Timerange: Basic block 0 - 371274
Trigger: Program termination
Profiled target: ./main.exe (PID 91594, part 1)
Events recorded: Ir
Events shown: Ir
Event sort order: Ir
Thresholds: 99
Include dirs:
User annotated:
Auto-annotation: on

Ir

2,330,612 (100.0%) PROGRAM TOTALS

Ir   file:function

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    204 ( 0.01%)  ???:int* std::__copy_move_a<false, __gnu_cxx::__normal_iterator<int const*, std::vector<int, std::allocator<int> > >, int*>(__gnu_cxx::__normal_iterator<int const*,
std::vector<int, std::allocator<int> > >, __gnu_cxx::__normal_iterator<int const*, std::vector<int, std::allocator<int> > >, int*) [/home/lets/ED_Atividades/AP4/src/main.exe]
    204 ( 0.01%)  ???:void std::vector<int, std::allocator<int> >::_M_range_initialize<int const*>(int const*, int const*, std::forward_iterator_tag) [/home/lets/ED_Atividades/AP4/sr
c/main.exe]
    203 ( 0.01%)  ./elf/./elf/dl-setup_hash.c:_dl_setup_hash [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    201 ( 0.01%)  ???:0x00000000048e76b0 [???]
    198 ( 0.01%)  ./elf/./elf/dl-deps.c:openaux [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    198 ( 0.01%)  ./elf/./elf/dl-load.c:_dl_dst_count [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    198 ( 0.01%)  ???:std::_Vector_base<int, std::allocator<int> >::_M_deallocate(int*, unsigned long) [/home/lets/ED_Atividades/AP4/src/main.exe]
    196 ( 0.01%)  ???:0x00000000000c2320 [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
    194 ( 0.01%)  ./elf/../sysdeps/x86/dl-cacheinfo.h:init_cpu_features.constprop.0
    192 ( 0.01%)  ???:std::vector<int, std::allocator<int> >::operator[](unsigned long) const [/home/lets/ED_Atividades/AP4/src/main.exe]
    189 ( 0.01%)  ???:__gnu_cxx::new_allocator<int>::~new_allocator() [/home/lets/ED_Atividades/AP4/src/main.exe]
    189 ( 0.01%)  ???:std::_Vector_base<int, std::allocator<int> >::_M_create_storage(unsigned long) [/home/lets/ED_Atividades/AP4/src/main.exe]
    187 ( 0.01%)  ???:std::_Vector_base<int, std::allocator<int> >::_Vector_impl::_Vector_impl(std::allocator<int> const&) [/home/lets/ED_Atividades/AP4/src/main.exe]
    186 ( 0.01%)  ???:std::basic_ostream<char, std::char_traits<char> >& std::endl<char, std::char_traits<char> >(std::basic_ostream<char, std::char_traits<char> >&) [/usr/lib/x86_64
-linux-gnu/libstdc++.so.6.0.30]
    182 ( 0.01%)  ???:std::_Vector_base<int, std::allocator<int> >::_M_get_Tp_allocator() [/home/lets/ED_Atividades/AP4/src/main.exe]
    180 ( 0.01%)  ./libio/./libio/putc.c:putc [/usr/lib/x86_64-linux-gnu/libc.so.6]

--------------------------------------------------------------------------
The following files chosen for auto-annotation could not be found:
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979,562 (42.03%)  ./elf/./elf/dl-lookup.c:_dl_lookup_symbol_x [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
565,995 (24.29%)  ./elf/./elf/dl-lookup.c:do_lookup_x [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
259,909 (11.15%)  ./elf/../sysdeps/x86_64/dl-machine.h:_dl_relocate_object
118,217 ( 5.07%)  ./elf/./elf/dl-lookup.c:check_match [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
108,430 ( 4.65%)  ./elf/./elf/do-rel.h:_dl_relocate_object
 73,249 ( 3.14%)  ./string/../sysdeps/x86_64/strcmp.S:strcmp [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
 19,698 ( 0.85%)  ./elf/../sysdeps/generic/dl-protected.h:do_lookup_x
 18,771 ( 0.81%)  ./elf/./elf/dl-tunables.c:__GI___tunables_init [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
 12,128 ( 0.52%)  ???:std::locale::_Impl::_M_install_facet(std::locale::id const*, std::locale::facet const*) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
 11,753 ( 0.50%)  ./elf/./elf/dl-version.c:_dl_check_map_versions [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
 10,885 ( 0.47%)  ./elf/../sysdeps/generic/ldsodefs.h:do_lookup_x
 10,240 ( 0.44%)  ./wcsmbs/./wcsmbs/btowc.c:btowc [/usr/lib/x86_64-linux-gnu/libc.so.6]
 10,170 ( 0.44%)  ./elf/../sysdeps/generic/ldsodefs.h:_dl_relocate_object
  8,088 ( 0.35%)  ./elf/./elf/dl-runtime.c:_dl_fixup [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  4,166 ( 0.18%)  ./elf/./elf/dl-reloc.c:_dl_relocate_object [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  3,782 ( 0.16%)  ./elf/./elf/dl-load.c:_dl_map_object_from_fd [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  3,526 ( 0.15%)  ./elf/../sysdeps/x86_64/dl-trampoline.h:_dl_runtime_resolve_xsave [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  3,456 ( 0.15%)  ./wcsmbs/./wcsmbs/wctob.c:wctob [/usr/lib/x86_64-linux-gnu/libc.so.6]
  3,085 ( 0.13%)  ./elf/../sysdeps/x86/dl-cacheinfo.h:intel_check_word.constprop.0 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  2,848 ( 0.12%)  ./elf/./elf/dl-misc.c:_dl_name_match_p [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  2,733 ( 0.12%)  ???:std::ctype<wchar_t>::_M_initialize_ctype() [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
  2,698 ( 0.12%)  ./elf/./elf/dl-cache.c:_dl_cache_libcmp [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  2,243 ( 0.10%)  ./elf/./elf/dl-load.c:_dl_map_object [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  2,226 ( 0.10%)  ./elf/./elf/dl-deps.c:_dl_map_object_deps [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  2,222 ( 0.10%)  ./elf/../bits/stdlib-bsearch.h:intel_check_word.constprop.0
  1,819 ( 0.08%)  ./malloc/./malloc/malloc.c:_int_malloc [/usr/lib/x86_64-linux-gnu/libc.so.6]
  1,631 ( 0.07%)  ./elf/./elf/dl-tunables.h:__GI___tunables_init
  1,582 ( 0.07%)  ./libio/./libio/fileops.c:_IO_file_xsputn@@GLIBC_2.2.5 [/usr/lib/x86_64-linux-gnu/libc.so.6]
  1,513 ( 0.06%)  ./elf/./elf/dl-load.c:open_verify.constprop.0 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  1,492 ( 0.06%)  ./elf/get-dynamic-info.h:_dl_map_object_from_fd
  1,457 ( 0.06%)  ./libio/./libio/iofwrite.c:fwrite [/usr/lib/x86_64-linux-gnu/libc.so.6]
  1,308 ( 0.06%)  ./elf/./elf/rtld.c:dl_main [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  1,266 ( 0.05%)  ./elf/./elf/dl-load.c:open_path [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  1,162 ( 0.05%)  ./string/../sysdeps/x86_64/multiarch/strlen-avx2.S:__strlen_avx2 [/usr/lib/x86_64-linux-gnu/libc.so.6]
  1,129 ( 0.05%)  ./elf/./elf/dl-object.c:_dl_new_object [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
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  1,116 ( 0.05%)  ???:std::ostreambuf_iterator<char, std::char_traits<char> > std::num_put<char, std::ostreambuf_iterator<char, std::char_traits<char> > >::_M_insert_int<long>(std::o
streambuf_iterator<char, std::char_traits<char> >, std::ios_base&, char, long) const [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
  1,115 ( 0.05%)  ./elf/./elf/dl-minimal-malloc.c:__minimal_malloc [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  1,111 ( 0.05%)  ???:std::ostream::sentry::sentry(std::ostream&) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
  1,095 ( 0.05%)  ./string/../sysdeps/x86_64/multiarch/memcmp-avx2-movbe.S:__memcmp_avx2_movbe [/usr/lib/x86_64-linux-gnu/libc.so.6]
  1,063 ( 0.05%)  ./elf/./elf/dl-cache.c:_dl_load_cache_lookup [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
  1,036 ( 0.04%)  ./wctype/./wctype/wctype_l.c:wctype_l [/usr/lib/x86_64-linux-gnu/libc.so.6]
  1,020 ( 0.04%)  ???:std::locale::id::_M_id() const [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
    896 ( 0.04%)  ./malloc/./malloc/malloc.c:_int_free [/usr/lib/x86_64-linux-gnu/libc.so.6]
    896 ( 0.04%)  ./wcsmbs/wcsmbsload.h:btowc
    883 ( 0.04%)  ./elf/../sysdeps/x86_64/dl-machine.h:_dl_start
    840 ( 0.04%)  ???:std::basic_ostream<char, std::char_traits<char> >& std::__ostream_insert<char, std::char_traits<char> >(std::basic_ostream<char, std::char_traits<char> >&, char
const*, long) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
    816 ( 0.04%)  ./string/../sysdeps/x86_64/multiarch/memset-vec-unaligned-erms.S:memset [/usr/lib/x86_64-linux-gnu/libc.so.6]
    815 ( 0.03%)  ./elf/./elf/do-rel.h:_dl_start
    809 ( 0.03%)  ???:main [/home/lets/ED_Atividades/AP4/src/main.exe]
    797 ( 0.03%)  ./string/../sysdeps/x86_64/multiarch/strlen-vec.S:strlen [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    776 ( 0.03%)  ./malloc/./malloc/malloc.c:ptmalloc_init.part.0
    774 ( 0.03%)  ./elf/../sysdeps/nptl/dl-tls_init_tp.c:rtld_mutex_dummy [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    768 ( 0.03%)  ./elf/./elf/dl-hwcaps.c:_dl_important_hwcaps [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    768 ( 0.03%)  ./elf/./elf/dl-profstub.c:_dl_mcount_wrapper_check [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    768 ( 0.03%)  ./iconv/./iconv/gconv_simple.c:__gconv_btowc_ascii [/usr/lib/x86_64-linux-gnu/libc.so.6]
    744 ( 0.03%)  ./string/../sysdeps/x86_64/multiarch/../strchr.S:index [/usr/lib/x86_64-linux-gnu/libc.so.6]
    740 ( 0.03%)  ./elf/./elf/dl-tunables.c:__tunable_get_val [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    732 ( 0.03%)  ???:std::ctype<char>::_M_widen_init() const [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
    730 ( 0.03%)  ./elf/../dl-map-segments.h:_dl_map_object_from_fd
    727 ( 0.03%)  ./libio/./libio/fileops.c:_IO_file_overflow@@GLIBC_2.2.5 [/usr/lib/x86_64-linux-gnu/libc.so.6]
    705 ( 0.03%)  ./stdlib/./stdlib/cxa_finalize.c:__cxa_finalize [/usr/lib/x86_64-linux-gnu/libc.so.6]
    696 ( 0.03%)  ???:std::ostream& std::ostream::_M_insert<long>(long) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
    666 ( 0.03%)  ???:std::locale::_Impl::_Impl(unsigned long) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
    657 ( 0.03%)  ./malloc/./malloc/malloc.c:malloc [/usr/lib/x86_64-linux-gnu/libc.so.6]
    629 ( 0.03%)  ./string/../sysdeps/x86_64/multiarch/memmove-vec-unaligned-erms.S:mempcpy [/usr/lib/x86_64-linux-gnu/libc.so.6]
    596 ( 0.03%)  ./elf/../sysdeps/x86/dl-cacheinfo.h:handle_intel.constprop.0 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    570 ( 0.02%)  ./libio/./libio/ioflush.c:fflush [/usr/lib/x86_64-linux-gnu/libc.so.6]
    530 ( 0.02%)  ./elf/./elf/dl-sort-maps.c:dfs_traversal.part.0 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
    517 ( 0.02%)  ???:0x00000000048e9a60 [???]
```

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511 ( 0.02%)  ./string/../sysdeps/x86_64/multiarch/memmove-vec-unaligned-erms.S:memcpy [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
502 ( 0.02%)  ./elf/../sysdeps/x86/dl-prop.h:_dl_map_object_from_fd
494 ( 0.02%)  ???:multiplyMatrices(std::vector<std::vector<int, std::allocator<int> >, std::allocator<std::vector<int, std::allocator<int> > > > const&, std::vector<std::vector<i
nt, std::allocator<int> >, std::allocator<std::vector<int, std::allocator<int> > > > const&) [/home/lets/ED_Atividades/AP4/src/main.exe]
491 ( 0.02%)  ./libio/../libio/fileops.c:_IO_do_write@@GLIBC_2.2.5 [/usr/lib/x86_64-linux-gnu/libc.so.6]
468 ( 0.02%)  ./string/../sysdeps/x86_64/multiarch/memmove-vec-unaligned-erms.S:__memcpy_avx_unaligned_erms [/usr/lib/x86_64-linux-gnu/libc.so.6]
466 ( 0.02%)  ???:std::ostream::flush() [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
464 ( 0.02%)  ???:std::ios_base::ios_base() [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
459 ( 0.02%)  ./libio/../libio/libioP.h:fwrite
447 ( 0.02%)  ./elf/../elf/dl-sysdep.c:_dl_sysdep_start [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
437 ( 0.02%)  ./elf/../elf/dl-hwcaps_split.c:_dl_hwcaps_split_masked [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
436 ( 0.02%)  ./elf/../elf/dl-find_object.h:_dl_find_object_from_map [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
429 ( 0.02%)  ./stdlib/../stdlib/cxa_atexit.c:__cxa_atexit [/usr/lib/x86_64-linux-gnu/libc.so.6]
421 ( 0.02%)  ./elf/../elf/dl-init.c:call_init.part.0 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
420 ( 0.02%)  ./elf/../elf/dl-error-skeleton.c:_dl_catch_exception [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
414 ( 0.02%)  ./elf/../elf/dl-fini.c:_dl_fini [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
414 ( 0.02%)  ???:std::__cxx11::numpunct<char>::_M_initialize_numpunct(__locale_struct*) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
414 ( 0.02%)  ???:std::numpunct<char>::_M_initialize_numpunct(__locale_struct*) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
400 ( 0.02%)  ./io/../sysdeps/unix/sysv/linux/open64_nocancel.c:__open_nocancel [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
392 ( 0.02%)  ./stdlib/../stdlib/cxa_atexit.c:__new_exitfn [/usr/lib/x86_64-linux-gnu/libc.so.6]
378 ( 0.02%)  ???:std::ostream::put(char) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
378 ( 0.02%)  ???:std::vector<int, std::allocator<int> >::vector(std::vector<int, std::allocator<int> > const&) [/home/lets/ED_Atividades/AP4/src/main.exe]
374 ( 0.02%)  ???:std::locale::locale() [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
364 ( 0.02%)  ???:__cpu_indicator_init [/usr/lib/x86_64-linux-gnu/libgcc_s.so.1]
360 ( 0.02%)  ./libio/../libio/fileops.c:_IO_file_sync@@GLIBC_2.2.5 [/usr/lib/x86_64-linux-gnu/libc.so.6]
360 ( 0.02%)  ???:bool __gnu_cxx::operator!=<int const*, std::vector<int, std::allocator<int> > >(__gnu_cxx::__normal_iterator<int const*, std::vector<int, std::allocator<int> >
> const&, __gnu_cxx::__normal_iterator<int const*, std::vector<int, std::allocator<int> > > const&) [/home/lets/ED_Atividades/AP4/src/main.exe]
350 ( 0.02%)  ./elf/../elf/dl-tls.c:_dl_allocate_tls_storage [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
350 ( 0.02%)  ???:std::__cxx11::numpunct<wchar_t>::_M_initialize_numpunct(__locale_struct*) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
350 ( 0.02%)  ???:std::numpunct<wchar_t>::_M_initialize_numpunct(__locale_struct*) [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
344 ( 0.01%)  ./elf/../elf/dl-sort-maps.c:_dl_sort_maps [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
344 ( 0.01%)  ???:0x000000000012e8f0 [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
342 ( 0.01%)  ./elf/../get-dynamic-info.h:dl_main
342 ( 0.01%)  ./libio/../libio/libioP.h:fflush
336 ( 0.01%)  ???:__gnu_cxx::__normal_iterator<int const*, std::vector<int, std::allocator<int> > >::base() const [/home/lets/ED_Atividades/AP4/src/main.exe]
333 ( 0.01%)  ./libio/../libio/fileops.c:_IO_file_write@@GLIBC_2.2.5 [/usr/lib/x86_64-linux-gnu/libc.so.6]
```

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312 ( 0.01%)  ./elf/../elf/dl-load.c:_dl_init_paths [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
310 ( 0.01%)  ./setjmp/../sysdeps/x86_64/setjmp.S:__sigsetjmp [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
308 ( 0.01%)  ./malloc/../malloc/malloc.c:free [/usr/lib/x86_64-linux-gnu/libc.so.6]
308 ( 0.01%)  ???:std::allocator<int>::allocator(std::allocator<int> const&) [/home/lets/ED_Atividades/AP4/src/main.exe]
297 ( 0.01%)  ???:std::allocator<int>::~allocator() [/home/lets/ED_Atividades/AP4/src/main.exe]
294 ( 0.01%)  ???:0x000000000000dc6c0 [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
288 ( 0.01%)  ???:__gnu_cxx::__normal_iterator<int const*, std::vector<int, std::allocator<int> > >::__normal_iterator(int const* const&) [/home/lets/ED_Atividades/AP4/src/main.e
xe]
285 ( 0.01%)  ???:std::basic_ostream<char, std::char_traits<char> >& std::operator<< <std::char_traits<char> >(std::basic_ostream<char, std::char_traits<char> >&, char const*) [/
usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
278 ( 0.01%)  ./elf/../elf/dl-find_object.c:_dlfo_process_initial [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
275 ( 0.01%)  ./elf/../elf/dl-environ.c:_dl_next_ld_env_entry [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
275 ( 0.01%)  ???:std::_Vector_base<int, std::allocator<int> >::~_Vector_base() [/home/lets/ED_Atividades/AP4/src/main.exe]
273 ( 0.01%)  ???:std::ios_base::Init::Init() [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
270 ( 0.01%)  ???:std::vector<std::vector<int, std::allocator<int> >, std::allocator<std::vector<int, std::allocator<int> > > >::operator[](unsigned long) const [/home/lets/ED_At
ividades/AP4/src/main.exe]
268 ( 0.01%)  ./elf/../elf/dl-lookup-direct.c:_dl_lookup_direct [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
265 ( 0.01%)  ./elf/../elf/dl-object.c:_dl_add_to_namespace_list [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
264 ( 0.01%)  ???:__gnu_cxx::new_allocator<int>::allocate(unsigned long, void const*) [/home/lets/ED_Atividades/AP4/src/main.exe]
261 ( 0.01%)  ???:0x000000000048e7f30 [???]
260 ( 0.01%)  ???:int* std::__copy_move<false, true, std::random_access_iterator_tag>::__copy_m<int>(int const*, int const*, int*) [/home/lets/ED_Atividades/AP4/src/main.exe]
252 ( 0.01%)  ???:0x000000000012b240 [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
251 ( 0.01%)  ./elf/../elf/dl-load.c:open_verify.constprop.1 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
248 ( 0.01%)  ./elf/../elf/dl-find_object.c:_dlfo_sort_mappings [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
248 ( 0.01%)  ./elf/../elf/dl-minimal.c:strsep [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
245 ( 0.01%)  ./elf/../elf/dl-tunables.c:__GI___tunable_set_val [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
244 ( 0.01%)  ./elf/../sysdeps/x86/dl-prop.h:dl_main
243 ( 0.01%)  ./elf/../get-dynamic-info.h:_dl_start
242 ( 0.01%)  ???:std::vector<int, std::allocator<int> >::~vector() [/home/lets/ED_Atividades/AP4/src/main.exe]
240 ( 0.01%)  ???:std::vector<int, std::allocator<int> >::end() const [/home/lets/ED_Atividades/AP4/src/main.exe]
234 ( 0.01%)  ./misc/../sysdeps/unix/sysv/linux/mmap64.c:mmap [/usr/lib/x86_64-linux-gnu/libc.so.6]
233 ( 0.01%)  ./string/../sysdeps/x86_64/strcspn.S:strcspn [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
228 ( 0.01%)  ???:std::vector<int, std::allocator<int> >::begin() const [/home/lets/ED_Atividades/AP4/src/main.exe]
225 ( 0.01%)  ./stdlib/../stdlib/exit.c:__run_exit_handlers [/usr/lib/x86_64-linux-gnu/libc.so.6]
215 ( 0.01%)  ./elf/../sysdeps/x86/dl-cacheinfo.h:get_common_cache_info.constprop.0 [/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2]
208 ( 0.01%)  ???:std::ios_base::_M_init() [/usr/lib/x86_64-linux-gnu/libstdc++.so.6.0.30]
```

6.

1. Quão bem o programa se comporta em termos de memória?

Ao avaliar o desempenho do programa em relação à memória e observando as métricas de misses nas diferentes caches, ou seja, I1 (Instruções nível 1), D1 (Dados nível 1) e LL (Last Level, geralmente se refere ao nível mais próximo da memória principal), conforme indicado nos resultados do CacheGrind:

Taxa de miss na cache I1: 0,10%

Taxa de miss na cache D1: 1,9%

Taxa de miss na cache LL: 0,4%

No geral, essas taxas de misses são bastante baixas, o que é um indicativo positivo do desempenho do programa em relação à memória. Isso sugere que o programa está se comportando de forma eficiente na gestão de memória. O fato de que a maioria das operações de busca na cache está sendo bem-sucedida indica que o programa está aproveitando eficazmente as caches, minimizando assim a necessidade

de buscar dados na memória principal. Esse é um aspecto crítico em termos de otimização de memória.

2. Quais estruturas de dados devem ser caracterizadas para melhor entendimento?

A partir das saídas do CacheGrind e do CallGrind, não podemos identificar diretamente as estruturas de dados específicas usadas no programa, pois essas ferramentas não fornecem detalhes da estrutura interna do código.

3. Quais segmentos de código devem ser instrumentados para suportar a caracterização?

A saída do CallGrind fornece informações sobre as funções do programa que consomem a maior parte dos recursos. Pode-se identificar os segmentos de código que devem ser instrumentados ou otimizados olhando as funções com as maiores contagens de instruções (I refs) ou as funções com a maior porcentagem de tempo gasto. Por exemplo: "./elf/./elf/dl-lookup.c:_dl_lookup_symbol_x" tem uma contagem significativa de instruções e é uma parte crítica do código.