ФЕДЕРАЛЬНОЕ АГЕНТСТВО СВЯЗИ ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ ОБРАЗОВАТЕЛЬНОЕ БЮДЖЕТНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ПРОФЕССИОНАЛЬНОГО ОБРАЗОВАНИЯ «СИБИРСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ ТЕЛЕКОММУНИКАЦИЙ И ИНФОРМАТИКИ» ФАКУЛЬТЕТ ИНФОРМАТИКИ И ВЫЧИСЛИТЕЛЬНОЙ ТЕХНИКИ

Кафедра ВС

Лабораторная работа №2

“Оптимизация доступа к памяти”

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I

Вычисления проводились на процессоре Intel Core i5 - 760 (8M Cache, 2,80 GHz).

dgemm_def	dgemm_transpose	
Time, s	Time, s	Speedup
1.386679	1.036650	1.33

dgemm_block					
BS = 2	BS = 4	BS = 8	BS = 16	BS = 32	BS = 64

T	S	T	S	T	S	T	S	T	S	T	S
1.077739	1.28	0.73112	1.89	0.631488	2.19	0.599509	2.31	0.584593	2.37	0.590072	2.35

Вычисления проводились на процессоре Intel Atom N2600 (1M Cache, 1.6 GHz).

dgemm_def	dgemm_transpose	
Time, s	Time, s	Speedup
22.876353	6.748427	3.39

dgemm_block					
BS = 2	BS = 4	BS = 8	BS = 16	BS = 32	BS = 64

T	S	T	S	T	S	T	S	T	S	T	S
8.598421	2.66	20.11688	1.13	19.42971	1.17	11.87242	1.92	8.98866	2.54	20.63623	1.10

BS — размер подматрицы;
T — время выполнения программы;
S — ускорение.

II

```
statiqbloom@machine:~/Desktop/hpcs_2$ valgrind --tool=cachegrind ./dgemm
==16594== Cachegrind, a cache and branch-prediction profiler
==16594== Copyright (C) 2002-2015, and GNU GPL'd, by Nicholas Nethercote et al.
==16594== Using Valgrind-3.11.0 and LibVEX; rerun with -h for copyright info
==16594== Command: ./dgemm
==16594==
Elapsed time: 286.728893 sec.
==16594==
==16594== I   refs:      21,485,608,363
==16594== I1  misses:              881
==16594== LLi misses:              875
==16594== I1  miss rate:          0.00%
==16594== LLi miss rate:          0.00%
==16594==
==16594== D   refs:      11,818,117,053  (11,011,744,546 rd   + 806,372,507 wr)
==16594== D1  misses:       403,831,143  (   403,732,650 rd   +      98,493 wr)
==16594== LLd misses:       403,791,058  (   403,692,582 rd   +      98,476 wr)
==16594== D1  miss rate:            3.4% (           3.7%     +         0.0%  )
==16594== LLd miss rate:            3.4% (           3.7%     +         0.0%  )
==16594==
==16594== LL refs:          403,832,024  (   403,733,531 rd   +      98,493 wr)
==16594== LL misses:        403,791,933  (   403,693,457 rd   +      98,476 wr)
==16594== LL miss rate:             1.2% (           1.2%     +         0.0%  )
statiqbloom@machine:~/Desktop/hpcs_2$
```

Рис. 1 — Отчёт по количеству произошедших событий [функция *dgemm_def()*]

```
statiqbloom@machine:~/Desktop/hpcs_2$ valgrind --tool=cachegrind ./dgemm
==17174== Cachegrind, a cache and branch-prediction profiler
==17174== Copyright (C) 2002-2015, and GNU GPL'd, by Nicholas Nethercote et al.
==17174== Using Valgrind-3.11.0 and LibVEX; rerun with -h for copyright info
==17174== Command: ./dgemm
==17174==
Elapsed time: 254.706401 sec.
==17174==
==17174== I   refs:      21,485,608,283
==17174== I1  misses:              881
==17174== LLi misses:              875
==17174== I1  miss rate:          0.00%
==17174== LLi miss rate:          0.00%
==17174==
==17174== D   refs:      11,818,117,009  (11,011,744,520 rd   + 806,372,489 wr)
==17174== D1  misses:        50,627,943  (    50,529,450 rd   +      98,493 wr)
==17174== LLd misses:        50,627,794  (    50,529,318 rd   +      98,476 wr)
==17174== D1  miss rate:            0.4% (           0.5%     +         0.0%  )
==17174== LLd miss rate:            0.4% (           0.5%     +         0.0%  )
==17174==
==17174== LL refs:           50,628,824  (    50,530,331 rd   +      98,493 wr)
==17174== LL misses:         50,628,669  (    50,530,193 rd   +      98,476 wr)
==17174== LL miss rate:             0.2% (           0.2%     +         0.0%  )
statiqbloom@machine:~/Desktop/hpcs_2$
```

Рис. 2 — Отчёт по количеству произошедших событий [функция *dgemm_transpose()*]

```
--------------------------------------------------------------------------------
           Ir I1mr ILmr            Dr        D1mr        DLmr          Dw   D1mw   DLmw
--------------------------------------------------------------------------------
21,485,608,363  881  875 11,011,744,546 403,732,650 403,692,582 806,372,507 98,493 98,476  PROGRAM TOTALS

--------------------------------------------------------------------------------
           Ir I1mr ILmr            Dr        D1mr        DLmr          Dw   D1mw   DLmw  file:function
--------------------------------------------------------------------------------
16,918,525,470    3    3 8,862,309,900 403,731,456 403,691,520 403,441,158      0      0  /home/statiqbloom/Desktop/hpcs_2/dgemm.c:dgemm_def
 4,565,766,666    4    4 2,148,796,932           1           1 402,915,842 98,304 98,304  /home/statiqbloom/Desktop/hpcs_2/dgemm.c:init_matrix

--------------------------------------------------------------------------------
-- User-annotated source: /home/statiqbloom/Desktop/hpcs_2/dgemm.c
--------------------------------------------------------------------------------
           Ir I1mr ILmr            Dr        D1mr        DLmr          Dw   D1mw   DLmw

-- line 13 ----------------------------------------
            .    .    .             .           .           .           .      .      .  enum {
            .    .    .             .           .           .           .      .      .        N = 512,
            .    .    .             .           .           .           .      .      .        NREPS = 3
            .    .    .             .           .           .           .      .      .  };
            .    .    .             .           .           .           .      .      .
            .    .    .             .           .           .           .      .      .  double A[N * N], B[N * N], C[N * N];
            .    .    .             .           .           .           .      .      .
            .    .    .             .           .           .           .      .      .  void dgemm_def(double *a, double *b, double *c, int n)
            9    0    0             0           0           0           3      0      0  {
            .    .    .             .           .           .           .      .      .        int i, j, k;
            .    .    .             .           .           .           .      .      .
        6,159    1    1         4,614           0           0           3      0      0        for (i = 0; i < n; i++) {
    3,153,408    1    1     2,362,368           0           0       1,536      0      0                for (j = 0; j < n; j++) {
 1,614,544,896    0    0 1,209,532,416           0           0     786,432      0      0                        for (k = 0; k < n; k++) {
15,300,820,992    1    1 7,650,410,496 403,731,456 403,691,520 402,653,184      0      0                                *(c + i * n + j) += *(a
+ i * n + k) * *(b + k * n + j);
            .    .    .             .           .           .           .      .      .                        }
            .    .    .             .           .           .           .      .      .                }
            .    .    .             .           .           .           .      .      .        }
            6    0    0             6           0           0           0      0      0  }
            .    .    .             .           .           .           .      .      .
```

Рис. 3 — Аннотированный текст программы [функция *dgemm_def()*]

```
--------------------------------------------------------------------------------
           Ir I1mr ILmr            Dr       D1mr       DLmr          Dw   D1mw   DLmw
--------------------------------------------------------------------------------
21,485,608,283  881  875 11,011,744,520 50,529,450 50,529,318 806,372,489 98,493 98,476  PROGRAM TOTALS

--------------------------------------------------------------------------------
           Ir I1mr ILmr            Dr       D1mr       DLmr          Dw   D1mw   DLmw  file:function
--------------------------------------------------------------------------------
16,918,525,470    3    3 8,862,309,900 50,528,256 50,528,256 403,441,158      0      0  /home/statiqbloom/Desktop/hpcs_2/dgemm.c:dgemm_transpose
 4,565,766,666    4    4 2,148,796,932          1          1 402,915,842 98,304 98,304  /home/statiqbloom/Desktop/hpcs_2/dgemm.c:init_matrix

--------------------------------------------------------------------------------
-- User-annotated source: /home/statiqbloom/Desktop/hpcs_2/dgemm.c
--------------------------------------------------------------------------------
           Ir I1mr ILmr            Dr       D1mr       DLmr          Dw   D1mw   DLmw

-- line 13 ----------------------------------------
            .    .    .             .          .          .           .      .      .  enum {
            .    .    .             .          .          .           .      .      .        N = 512,
            .    .    .             .          .          .           .      .      .        NREPS = 3
            .    .    .             .          .          .           .      .      .  };
            .    .    .             .          .          .           .      .      .
            .    .    .             .          .          .           .      .      .  double A[N * N], B[N * N], C[N * N];
            .    .    .             .          .          .           .      .      .
            .    .    .             .          .          .           .      .      .  void dgemm_transpose(double *a, double *b, double *c, in
t n)
            9    0    0             0          0          0           3      0      0  {
            .    .    .             .          .          .           .      .      .        int i, j, k;
            .    .    .             .          .          .           .      .      .
        6,159    1    1         4,614          0          0           3      0      0        for (i = 0; i < n; i++) {
    3,153,408    1    1     2,362,368          0          0       1,536      0      0                for (k = 0; k < n; k++) {
 1,614,544,896    0    0 1,209,532,416          0          0     786,432      0      0                        for (j = 0; j < n; j++) {
15,300,820,992    1    1 7,650,410,496 50,528,256 50,528,256 402,653,184      0      0                                *(c + i * n + j) += *(a
+ i * n + k) * *(b + k * n + j);
            .    .    .             .          .          .           .      .      .                        }
            .    .    .             .          .          .           .      .      .                }
            .    .    .             .          .          .           .      .      .        }
            6    0    0             6          0          0           0      0      0  }
```

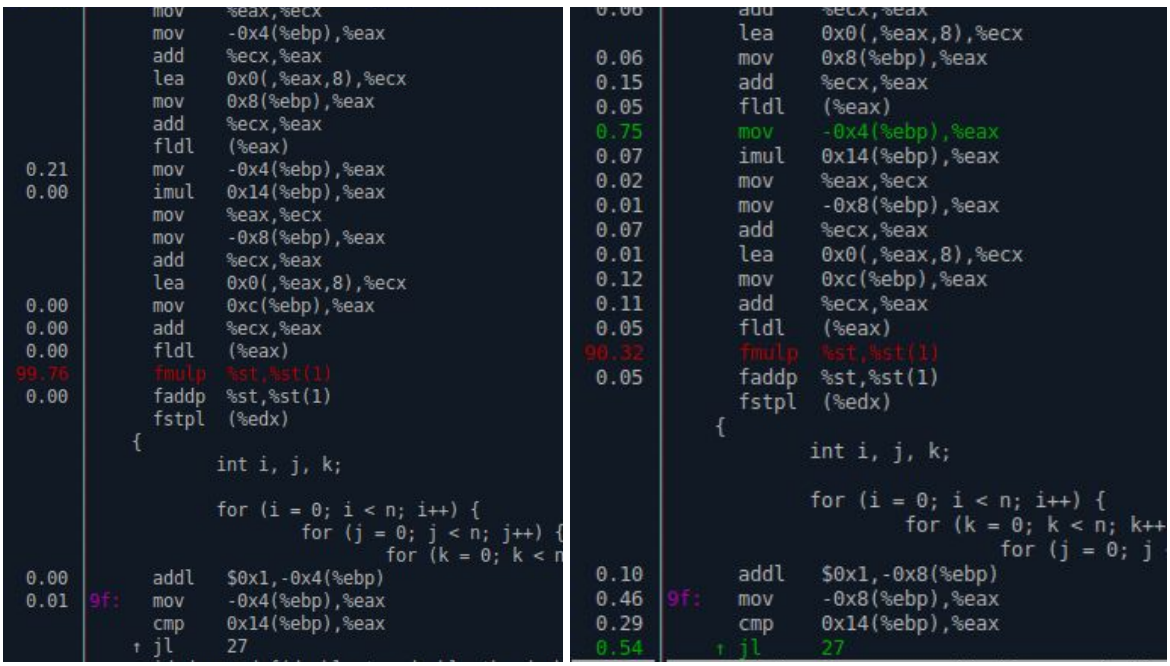
Рис. 4 — Аннотированный текст программы [функция *dgemm_transpose()*]

```
statiqbloom@machine:~/Desktop/hpcs_2$ perf record -e cache-misses ./dgemm
WARNING: Kernel address maps (/proc/{kallsyms,modules}) are restricted,
check /proc/sys/kernel/kptr_restrict.

Samples in kernel functions may not be resolved if a suitable vmlinux
file is not found in the buildid cache or in the vmlinux path.

Samples in kernel modules won't be resolved at all.

If some relocation was applied (e.g. kexec) symbols may be misresolved
even with a suitable vmlinux or kallsyms file.

Elapsed time: 24.462934 sec.
[ perf record: Woken up 44 times to write data ]
[ perf record: Captured and wrote 11.155 MB perf.data (~487371 samples) ]
[kernel.kallsyms] with build id 2cdc80b0b85e3ae4a5f492135cd6ed02ceffc3ce not found, continuing without symbols
statiqbloom@machine:~/Desktop/hpcs_2$
```

Рис. 5 — Аннотированние текста программы с помощью Perf [функция *dgemm_def()*]

```
statiqbloom@machine:~/Desktop/hpcs_2$ perf record -e cache-misses ./dgemm
WARNING: Kernel address maps (/proc/{kallsyms,modules}) are restricted,
check /proc/sys/kernel/kptr_restrict.

Samples in kernel functions may not be resolved if a suitable vmlinux
file is not found in the buildid cache or in the vmlinux path.

Samples in kernel modules won't be resolved at all.

If some relocation was applied (e.g. kexec) symbols may be misresolved
even with a suitable vmlinux or kallsyms file.

Elapsed time: 6.964762 sec.
[ perf record: Woken up 3 times to write data ]
[ perf record: Captured and wrote 0.646 MB perf.data (~28209 samples) ]
[kernel.kallsyms] with build id 2cdc80b0b85e3ae4a5f492135cd6ed02ceffc3ce not found, continuing without symbols
statiqbloom@machine:~/Desktop/hpcs_2$ perf report
```

Рис. 6 — Аннотированние текста программы с помощью Perf [функция *dgemm_transpose()*]



III

Вычисления проводились на процессоре Intel Core i5 - 760 (8M Cache, 2,80 GHz).

dgemm_transpose											
—		D = 2		D = 4		D = 8		D = 16		D = 32	
T	S	T	S	T	S	T	S	T	S	T	S
1.03665	1.33	0.986398	1.41	0.966342	1.43	0.950848	1.46	0.932794	1.48	0.951328	1.45

dgemm_block (BS = 32)											
—		D = 2		D = 4		D = 8		D = 16		D = 32	
T	S	T	S	T	S	T	S	T	S	T	S
0.584593	2.37	0.61761	2.24	0.571185	2.42	0.566095	2.45	0.562648	2.46	0.448973	3.08

D — глубина раскрутки цикла;
T — время выполнения программы;
S — ускорение.

Метод раскрутки цикла при вычислениях на процессоре Intel Atom не принес должного ускорения (напротив, наблюдалась деградация производительности). Вследствие этого, данными результатами можно пренебречь. Оформим вывод в виде таблицы:

	transpose (S)	Depth	block (S)	BS	D
Core i5 - 760	1.48	16	3.08	32	32
Atom N2600	3.39	—	2.66	2	—