PB173 - Tématický vývoj aplikací v C/C++

Skupina: Aplikovaná kryptografie a bezpečné programování

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Optimization

Optimization steps

1. Do not optimize prematurely - write clean and correct code first!

2. When code works, find performance bottleneck and remove it

3. Document optimization and test it thoroughly

Performance measurement - manual

- Manual speed measure
  1. Measure time before target operation
  2. Execute operation
  3. Measure time after target operation
  4. Compute and print difference

```
clock_t elapsed = -clock();
aes256_encrypt_ecb(&ctx, buf);
elapsed += clock();
```

Manual measurement – possible problems

- It is time consuming
  - additional code, manually inserted
  - less readable, error prone (use DEBUG macro)
- Precision
  - some function returns time in seconds (e.g., time())
    - short operations will take 0
  - prefer functions returning result in ms or CPU ticks
    - e.g., clock()
    - check documentation for real precision
  - run operation multiple times (e.g., 1000x)
    - and divide the resulting time by that factor

Manual measurement – possible problems

- Additional unintended overhead may screw the results
  - one-time initialization of objects
  - cache usage, disk swap
  - garbage collection (not in C/C++)
- Need to know the probable bottleneck in advance
  - timing code is inserted manually
  - you are selecting what you like to measure
  - time consuming to localize bottleneck

Automatic measurement - profiling

- Automatic tool to measure time and memory used
- “Time” spend in specific function
- How often a function is called
- Call tree
  - what function called actual one
  - based on real code execution (condition jumps)
- Many other statistics, depend on the tools

Profiling methods

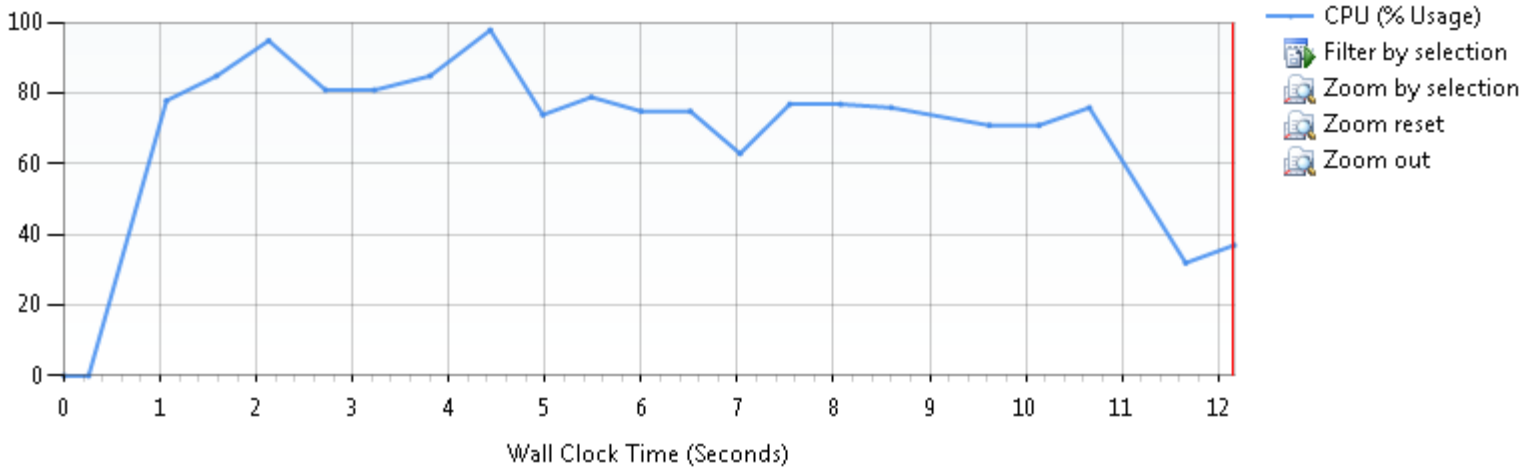
- Profiling method: CPU Sampling
  - check periodically what is executed on CPU
  - accurate, low overhead
- Profiling method: Instrumentation
  - automatically inserts special accounting code
  - will return exact function call counter
  - (may affect performance timings a bit)
    - additional code present

MS Visual Studio Profiler

- Visual Studio 2013 or earlier
  - Analyze->Launch Performance Wizard
- Visual Studio 2015
  - Debug → Profiler → Start diagnostic tools
- May require admin privileges (will ask)

MS VS Profiler – results (Summary)

- Where to start the optimization work?



Hot Path

The most expensive call path based on sample counts

Name	Inclusive %	Exclusive %
aes_subBytes(unsigned char *)	79.20	0.23
rj_sbox(unsigned char)	78.97	1.26
gf_mulinv(unsigned char)	77.59	0.75
gf_log(unsigned char)	**39.43**	**39.43**
gf_alog(unsigned char)	**37.30**	**37.30**

MS VS Profiler – results (Functions)

- Result given in number of sampling hits
  - meaningful result is % of total time spend in function
- Inclusive sampling
  - samples hit in function or its children
  - aggregate over call stack for given function
- Exclusive sampling
  - samples hit in exclusively in given function
  - usually what you want
    - fraction of time spend in function code (not in subfunctions)

MS VS Profiler – results (Functions)

pb173_aes101115.vsp | time.h | aes32.h | pb173_aes.cpp

Current View: Functions

Function Name	Inclusive Samples	Exclusive Samples	Inclusive Samples %	Exclusive Samples %
[pb173_aes.exe]	5	5	0.29	0.29
__RTC_CheckEsp	1	1	0.06	0.06
__tmainCRTStartup	1,740	0	100.00	0.00
_main	1,740	0	100.00	0.00
_mainCRTStartup	1,740	0	100.00	0.00
aes_addRoundKey(unsignec	10	10	0.57	0.57
aes_expandEncKey(unsigne	322	1	18.51	0.06
aes_mixColumns(unsigned	26	10	1.49	0.57
aes_shiftRows(unsigned cha	3	3	0.17	0.17
aes_subBytes(unsigned char	1,378	4	79.20	0.23
aes256_encrypt_ecb(struct a	1,740	1	100.00	0.06
gf_alog(unsigned char)	806	806	46.32	46.32
gf_log(unsigned char)	846	846	48.62	48.62
gf_mulinv(unsigned char)		14	95.86	0.80
rj_sbox(unsigned char)		24	97.36	1.38
rj_xtime(unsigned char)		15	0.86	0.86
testProfile(void)	1,740	0	100.00	0.00

Doubleclick to move into Function Details view

46 % of time spend in gf_alog function

Function Code View

d:\documents\develop\pb173\pb173_aes\pb173_aes\aes32.cpp

```
                /* ------------------------------------------------------------------------ */
                uint8_t gf_alog(uint8_t x) // calculate anti-logarithm gen 3
  1.4 %         {
< 0.1 %             uint8_t atb = 1, z;

 42.0 %             while (x--) {z = atb; atb <<= 1; if (z & 0x80) atb^= 0x1b; atb ^= z;}

< 0.1 %             return atb;
  0.3 %         } /* gf_alog */
```

- How to speed up `gf_alog` function?

aestab.c

```
AES_RETURN aes_init(void)
{   uint_32t  i, w;

#if defined(FF_TABLES)

    uint_8t  pow[512], log[256];

    if(init)
        return EXIT_SUCCESS;
    /*  log and power tables for GF(2^8) finite field with
        WPOLY as modular polynomial - the simplest primitive
        root is 0x03, used here to generate the tables
    */

    i = 0; w = 1;
    do
    {
        pow[i] = (uint_8t)w;
        pow[i + 255] = (uint_8t)w;
        log[w] = (uint_8t)i++;
        w ^=  (w << 1) ^ (w & 0x80 ? WPOLY : 0);
    }
    while (w != 1);
// ...
```

MS VS Profiler – save results

- You can save results and compare later
- To check the real impact of your optimization
- Don’t forget to eventually stop the optimization ☺

GCC `gcov` tool

- http://gcc.gnu.org/onlinedocs/gcc/Gcov.html#Gcov

1. Compile program by GCC with additional flags
   - gcc -Wall -fprofile-arcs -ftest-coverage main.c
   - gcc -Wall --coverage main.c
   - additional monitoring code is added to binary
2. Execute program
   - files with “.bb" ".bbg" and ".da" extension are created
3. Analyze resulting files with **`gcov`**
   - gcov main.c
   - annotated source code is created

- Lcov - graphical front-end for gcov
  - http://ltp.sourceforge.net/coverage/lcov.php

LCOV - code coverage report

		Hit	Total	Coverage
Current view:	top level - example/methods - iterate.c (source / functions)			
Test:	Basic example (view descriptions)			
Date:	2012-10-12			
Legend:	Lines: hit not hit | Branches: + taken - not taken # not executed			
Lines:		8	8	100.0 %
Functions:		1	1	100.0 %
Branches:		4	4	100.0 %

```
                Branch data     Line data    Source code
       1                  :              :  /*
       2                  :              :   *  methods/iterate.c
       3                  :              :   *
       4                  :              :   *  Calculate the sum of a given range of integer numbers.
       5                  :              :   *
       6                  :              :   *  This particular method of implementation works by way of brute force,
       7                  :              :   *  i.e. it iterates over the entire range while adding the numbers to finally
       8                  :              :   *  get the total sum. As a positive side effect, we're able to easily detect
       9                  :              :   *  overflows, i.e. situations in which the sum would exceed the capacity
      10                  :              :   *  of an integer variable.
      11                  :              :   *
      12                  :              :   */
      13                  :              :
      14                  :              :  #include <stdio.h>
      15                  :              :  #include <stdlib.h>
      16                  :              :  #include "iterate.h"
      17                  :              :
      18                  :              :
      19                  :            3 :  int iterate_get_sum (int min, int max)
      20                  :              :  {
      21                  :              :          int i, total;
      22                  :              :
      23                  :            3 :          total = 0;
      24                  :              :
      25                  :              :          /* This is where we loop over each number in the range, including
      26                  :              :             both the minimum and the maximum number. */
      27                  :              :
      28        [ +   + ]:        67548 :          for (i = min; i <= max; i++)
      29                  :              :          {
      30                  :              :                  /* We can detect an overflow by checking whether the new
      31                  :              :                     sum would become negative. */
      32                  :              :
      33        [ +   + ]:        67546 :                  if (total + i < total)
      34                  :              :                  {
      35                  :            1 :                          printf ("Error: sum too large!\n");
      36                  :            1 :                          exit (1);
      37                  :              :                  }
      38                  :              :
      39                  :              :                  /* Everything seems to fit into an int, so continue adding. */
      40                  :              :
      41                  :        67545 :                  total += i;
```

Taken from http://ltp.sourceforge.net/coverage/lcov/output/example/methods/iterate.c.gcov.html

Memory consumption profiling

- Not provided by MSVS Profiler for native apps
  - unfortunately, available only for managed code
- Visual Studio is detecting memory leaks!
  - _CrtDumpMemoryLeaks()
  - run program in debug mode (possibly without any breakpoint)
  - let it finish and watch Output pane
- Valgrind *-v --leak-check=full*
- Write your own new and delete
  - and log the allocated/freed memory

Assignment – performance analysis

- Produce detailed speed estimation for:
  - New user registration
  - User authentication to server
  - Obtain list of other users
  - Prepare protected message for another user
  - Unprotect message from another user
- Which function(s) is consuming most of the CPU?
  - provide a list with %, discuss possible improvements
- Improve performance of the most significant bottleneck twice (resulting time 50%, document)

Submissions, deadlines

- Upload application source codes as single zip file into IS Homework vault (Crypto - 6. homework (Performance))
  - 2xA4 with performance analysis
- DEADLINE 10.4. 12:00
  - 0-10 points assigned