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/*******************************************************************************
File:           mcfTrace tool User Manual
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Description:    This document describes the use and features of mcfTrace.
                mcfTrace is a Pin tool developed to capture and record
                control-flow of multithreaded programs running under Pin.
                Each control flow instruction and exception is captured and its
                descriptor is recorded into a trace file.

Date:           July 10, 2013
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1. Tool Setup (Compilation)

a) Requirements: Linux computer with Pin installed.
To learn more about Pin and to download the latest version visit
http://software.intel.com/en-us/articles/pin-a-dynamic-binary-instrumentation-tool.
Examples in this manual are prepared on a x86_64 quad core machine running CentOS 6.3 OS with pin-2.12-58423.

b) Download source code files for mcfTrace:
mcfTrace.cpp
mcfTrace.h.
McfTraceAssist.h

c) Copy source code files into Pin directory
    pin-2.12-58423-gcc.4.4.7-linux/source/tools/ManualExamples
d) create obj-intel64 directory in
    pin-2.12-58423-gcc.4.4.7-linux/source/tools/ManualExamples
e) Add mcfTrace to the TEST_TOOL_ROOTS line in
    pin-2.12-58423-gcc.4.4.7-linux/source/tools/ManualExamples/makefile.rules
f) Add -std=c++0x to the TOOL_CXXFLAGS_NOOPT line in
    pin-2.12-58423-gcc.4.4.7-linux/source/tools/Config/makefile.unix.config

g) Build tool/tools

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// build mcfTrace only
[milenka@EB245-mhealth3 ManualExamples]$ make obj-intel64/mcfTrace.so

// build all tools in the ManualExamples directory
[milenka@EB245-mhealth3 ManualExamples]$ make all
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2. Instrumenting Programs With mcfTrace

a) To instrument binaries with mcfTrace tool use the command line as follows:

pin -t obj-intel64/mcfTrace.so -- executable args

b) mcfTrace tool switches

mcfTrace tool offers a rich set of switches to control instrumentation, capturing, and recording of control flow traces.

You can see the instrumentation options by running the following command.

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[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so -h -- ls

Pin tools switches

-a  [default 0]
       use ASCII output file isntead of binary
-c  [default 0]
       Allows you to compress the control trace. Supports bzip2, pbzip2,
       gzip, and pigz
-d  [default 0]
       Annotate descriptors with disassembly (only works when output is ASCII
-f  [default 50000]
       Output file size limit in MB. Tracing will end after reaching this
       limit. Default is 50000 MB
-filter_no_shared_libs  [default ]
       Do not instrument shared libraries
-filter_rtn
       Routines to instrument
-h  [default 0]
       Print help message (Return failure of PIN_Init() in order to allow the
       tool                             to print help message)
-help  [default 0]
       Print help message (Return failure of PIN_Init() in order to allow the
       tool                             to print help message)
-l  [default 0]
       Number of instructions to profile (default is no limit)
-logfile  [default pintool.log]
       The log file path and file name
-o  [default mcfTrace.out]
       specify trace output file name
-s  [default 0]
       Begin emitting branch descriptors after executing a specified number
       of instructions
-unique_logfile  [default 0]
       The log file names will contain the pid

Line information controls

-discard_line_info
       Discard line information for specific module. Module name should be a
       short name without path, not a symbolic link
-discard_line_info_all  [default 0]
       Discard line information for all modules.

Symbols controls

-short_name  [default 0]
       Use the shortest name for the RTN. Names with version substrings are
       preferred over the same name without the substring.
-unrestricted_rtn_size  [default 0]
       Use the unrestricted RTN size. When set the RTN size defined by the
       distance between RTN start to the beginning of next RTN.

Statistic switches
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-profile  [default 0]
       print amount of memory dynamically allocated but not yet freed by the
       tool
-statistic  [default 0]
       print general statistics

General switches (available in pin and tool)

-slow_asserts  [default 0]
       Perform expensive sanity checks
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The mcfTrace tool options allow users to specify the following:

- format of the output trace file (ASCII or binary, default is binary);
- captured control flow traces can be piped into a selected general-purpose compressor (e.g., bzip2, pbzip2, gzip,...);
- control flow descriptors can be annotated with disassembled instructions;
- control flow descriptors can be recorded during entire benchmark execution
  or during a selected program segment
  (-l specifies the number of instructions to trace and
  -s specifies the number of instructions to skip
  from the beginning before recording is turned on).
- output trace file can be specified (switch -o).

c) Example run to trace /bin/ls shell command.
In this example mcfTrace captures the control flow of ls (list) shell command.
The control trace of the entire execution of the /bin/ls is captured in binary a file.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so -- ls
mcfTrace: Writing to binary file:mcfTrace.out2013_8_31_14.52.17.bin
mcfTrace Descriptor encoding: ThreadID ( 1 bytes ), Instruction address ( 8 bytes ),
Branch target ( 8 bytes ), Branch type and outcome ( 1 bytes )
mcfTrace: thread begin 0 29031
makefile  makefile.rules  Matrix_Multiplication_OpenMP.cpp  mcfTraceAssist.h
mcfTrace.cpp  mcfTrace.h   mcfTrace.out2013_8_31_14.52.17.bin  obj-intel64
[myersar@EB245-mhealth3 ManualExamples]$ ls
makefile  makefile.rules  Matrix_Multiplication_OpenMP.cpp  mcfTraceAssist.h
mcfTrace.cpp  mcfTrace.h  mcfTrace.out2013_8_31_14.52.17.bin
mcfTrace.out2013_8_31_14.52.17.Statistics  obj-intel64
[myersar@EB245-mhealth3 ManualExamples]$ cat mcfTrace.out2013_8_31_14.52.17.Statistics
mcfTrace: Traced 461689 instructions
mcfTrace: Skipped 0 instructions
mcfTrace: Recorded 100935 control transfer instructions.
       11052 ( %10.95 ) Unconditional Direct
       38943 ( %38.58 ) Conditional Direct Taken
       44588 ( %44.17 ) Conditional Direct Not Taken
       6352 ( %6.29 ) Unconditional Indirect
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d) Example run to trace ls shell command, with ASCII output and no compression.
In this example mcfTrace captures the control flow of ls (list) shell command.
The entire execution is captured in an ASCII file.

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<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so -a -- ls
```

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mcfTrace: Writing to text file: mcfTrace.out2013_8_31_14.53.48.txt
mcfTrace descriptor: tid, instruction address, target address, conditional or
unconditional, direct or indirect, outcome
mcfTrace: thread begin 0 29053
makefile  makefile.rules  Matrix_Multiplication_OpenMP.cpp  mcfTraceAssist.h
mcfTrace.cpp  mcfTrace.h   mcfTrace.out2013_8_31_14.53.48.txt  obj-intel64
[myersar@EB245-mhealth3 ManualExamples]$ ls
makefile  makefile.rules  Matrix_Multiplication_OpenMP.cpp  mcfTraceAssist.h
mcfTrace.cpp  mcfTrace.h  mcfTrace.out2013_8_31_14.53.48.Statistics
mcfTrace.out2013_8_31_14.53.48.txt  obj-intel64
[myersar@EB245-mhealth3 ManualExamples]$ head mcfTrace.out2013_8_31_14.53.48.txt
0, 0x0000003f83200b03, 0x0000003f83201130, U, D, T
0, 0x0000003f83201182, 0x0000003f832011f7, C, D, NT
0, 0x0000003f832011ae, 0x0000003f832011c4, U, D, T
0, 0x0000003f832011c8, 0x0000003f832011b0, C, D, T
0, 0x0000003f832011c2, 0x0000003f832011f0, C, D, NT
0, 0x0000003f832011c8, 0x0000003f832011b0, C, D, T
0, 0x0000003f832011c2, 0x0000003f832011f0, C, D, NT
0, 0x0000003f832011c8, 0x0000003f832011b0, C, D, NT
0, 0x0000003f832011d4, 0x0000003f832014d0, C, D, T
0, 0x0000003f832014d8, 0x0000003f832014f0, C, D, T
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e) Example run to trace ls shell command, ASCII output with compression using gzip.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so -a -c gzip --
ls
mcfTrace: Writing to text file: mcfTrace.out2013_8_31_14.54.52.txt
mcfTrace descriptor: tid, instruction address, target address, conditional or
unconditional, direct or indirect, outcome
mcfTrace: thread begin 0 29073
makefile  makefile.rules  Matrix_Multiplication_OpenMP.cpp  mcfTraceAssist.h
mcfTrace.cpp  mcfTrace.h   mcfTrace.out2013_8_31_14.54.52.txt.gz  obj-intel64
[myersar@EB245-mhealth3 ManualExamples]$ ls
makefile  makefile.rules  Matrix_Multiplication_OpenMP.cpp  mcfTraceAssist.h
mcfTrace.cpp  mcfTrace.h  mcfTrace.out2013_8_31_14.54.52.Statistics
mcfTrace.out2013_8_31_14.54.52.txt.gz  obj-intel64
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f) Tracing a multithreaded program

Use our Matrix_Multiplication_OpenMP.cpp as a test program as follows.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
# compile program
[myersar@EB245-mhealth3 ManualExamples]$ g++ -fopenmp Matrix_Multiplication_OpenMP.cpp
-o Matrix_Multiplication_OpenMP
[myersar@EB245-mhealth3 ManualExamples]$ export OMP_NUM_THREADS=4

# trace program
[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so -a --
./Matrix_Multiplication_OpenMP 32
mcfTrace: Writing to text file: mcfTrace.out2013_8_31_14.56.34.txt
mcfTrace descriptor: tid, instruction address, target address, conditional or
unconditional, direct or indirect, outcome
mcfTrace: thread begin 0 29119
mcfTrace: thread begin 1 29127
mcfTrace: thread begin 2 29128
mcfTrace: thread begin 3 29129
193
```

```
# trace program, skip 3,000,000 instructions, then trace 1,000,000
[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so -a -s 3000000
-l 1000000 -- ./Matrix_Multiplication_OpenMP 32
mcfTrace: Writing to text file: mcfTrace.out2013_8_31_15.4.1.txt
mcfTrace descriptor: tid, instruction address, target address, conditional or
unconditional, direct or indirect, outcome
mcfTrace: thread begin 0 29399
mcfTrace: thread begin 1 29407
mcfTrace: thread begin 2 29408
mcfTrace: thread begin 3 29409
277
mcfTrace: Detaching...
[myersar@EB245-mhealth3 ManualExamples]$ head mcfTrace.out2013_8_31_15.4.1.Statistics
mcfTrace: Traced 1000000 instructions
mcfTrace: Skipped 3000000 instructions
mcfTrace: Recorded 269334 control transfer instructions.
       4968 ( %1.84 ) Unconditional Direct
       129517 ( %48.09 ) Conditional Direct Taken
       131116 ( %48.68 ) Conditional Direct Not Taken
       3733 ( %1.39 ) Unconditional Indirect
[myersar@EB245-mhealth3 ManualExamples]$ head mcfTrace.out2013_8_31_15.4.1.txt
1, 0x00007f5a40996bbe, 0x00007f5a40996be4, C, D, NT
1, 0x00007f5a40996bc9, 0x00007f5a40996bb8, C, D, T
1, 0x00007f5a40996bbe, 0x00007f5a40996be4, C, D, NT
2, 0x00007f5a40996bc9, 0x00007f5a40996bb8, C, D, T
1, 0x00007f5a40996bc9, 0x00007f5a40996bb8, C, D, T
1, 0x00007f5a40996bbe, 0x00007f5a40996be4, C, D, NT
1, 0x00007f5a40996bc9, 0x00007f5a40996bb8, C, D, T
3, 0x00007f5a40996bc9, 0x00007f5a40996bb8, C, D, T
1, 0x00007f5a40996bbe, 0x00007f5a40996be4, C, D, NT
2, 0x00007f5a40996bbe, 0x00007f5a40996be4, C, D, NT
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g) Tracing a multi-threaded string search program from ParMiBench benchmark suite.

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
# mcfTrace will detach early here when it reaches a 50GB file limit. This limit can be
# changed by the user.
[myersar@EB245-mhealth3 ManualExamples]$ pin -t obj-intel64/mcfTrace.so --
/home/myersar/parmibench-master/stringsearch/parallel_stringsearch 2 4
/home/myersar/parmibench-master/stringsearch/testdata/SearchString16.txt
/home/myersar/parmibench-master/stringsearch/testdata/testpattern5.txt
mcfTrace: Writing to binary file:mcfTrace.out2013_8_31_15.5.35.bin
mcfTrace Descriptor encoding: ThreadID ( 1 bytes ), Instruction address ( 8 bytes ),
Branch target ( 8 bytes ), Branch type and outcome ( 1 bytes )
mcfTrace: thread begin 0 29431
Opening Input File:</home/myersar/parmibench-
master/stringsearch/testdata/SearchString16.txt>
Input File Size is:<16526618>
Done Reading Input File!
Opening Pattern File:</home/myersar/parmibench-
master/stringsearch/testdata/testpattern5.txt>
Done Reading Pattern File!
---***Case-sensitive Boyer-Moore-Horspool string search***---
mcfTrace: thread begin 1 29439
mcfTrace: thread begin 2 29440
mcfTrace: thread begin 3 29441
mcfTrace: thread begin 4 29442
mcfTrace: Detaching...
```

```
[myersar@EB245-mhealth3 ManualExamples]$ ls -l
total 48828232
-rw-r--r--. 1 myersar myersar         676 Feb  2  2013 makefile
-rw-r-----. 1 myersar myersar        7694 Aug 28 11:28 makefile.rules
-rwxrwxr-x. 1 myersar myersar       10870 Aug 31 14:55 Matrix_Multiplication_OpenMP
-rw-rw-r--. 1 myersar myersar        1730 Aug 28 18:34
Matrix_Multiplication_OpenMP.cpp
-rw-rw-r--. 1 myersar myersar       14202 Aug 31 15:03 mcfTraceAssist.h
-rw-rw-r--. 1 myersar myersar       12855 Aug 31 13:49 mcfTrace.cpp
-rw-rw-r--. 1 myersar myersar       14713 Aug 31 15:03 mcfTrace.h
-rw-rw-r--. 1 myersar myersar 50000000128 Aug 31 15:24
mcfTrace.out2013_8_31_15.5.35.bin
-rw-rw-r--. 1 myersar myersar         312 Aug 31 15:24
mcfTrace.out2013_8_31_15.5.35.Statistics
drwxrwxr-x. 2 myersar myersar        4096 Aug 31 15:03 obj-intel64
-rw-rw-r--. 1 myersar myersar       12088 Aug 31 15:04 temp
[myersar@EB245-mhealth3 ManualExamples]$ head mcfTrace.out2013_8_31_15.5.35.Statistics
mcfTrace: Traced 5350007983 instructions
mcfTrace: Skipped 0 instructions
mcfTrace: Recorded 1562500004 control transfer instructions.
       27277 ( %0.00 ) Unconditional Direct
       1082654058 ( %69.29 ) Conditional Direct Taken
       479795294 ( %30.71 ) Conditional Direct Not Taken
       23375 ( %0.00 ) Unconditional Indirect
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```