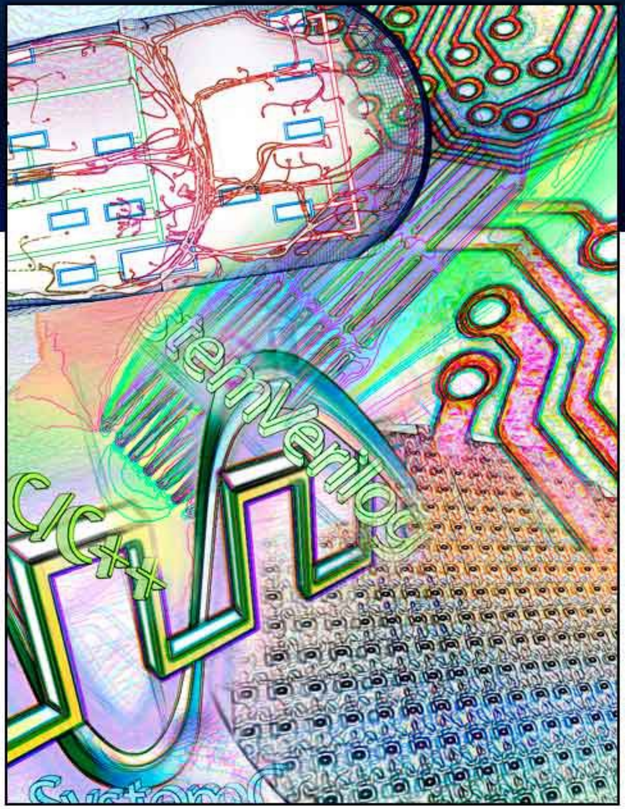

Integrated Tcl/C Performance Profiling

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“The purpose of computing is insight, not numbers”

Richard Hamming

Integrated Tcl/C Performance Profiling

- What is the problem?
- Why is it interesting and important?
- Key components of approach
- Results
- Example of analysis
- Notes and limitations
- Future work

What is the problem?

- We want our programs to produce correct results and run fast. Once we have it correct, how to make it fast?
- Profiling activity of a running program shows where it is spending time.
- Statistical profilers provide this information by periodically sampling the call stack of a running program and collating the results.
- To be most useful, the “where” in the program needs to be provided in terms of the source code that makes up that program.

Example of profiler use:

```
void main(int limit)  {
  int i;
  for (i=0; i<limit; i++)  {
    doSum(i);
    doProd(i);
  }
}

int doSum(int i)  {
  int j, sum = 0;
  for (j=0; j<i; j++)  {
    sum += j;
  }
  return sum;
}

int doProd(int i)  {
  int j, prod = 0;
  for (j=0; j<i; j++)  {
    prod *= j;
  }
  return prod;
}
```

- Possible call stacks:

```
main    main        main
           doSum       doProd
```

- Profile results - call tree is combination of call stacks:

```
main         1489 100.0%
   doSum      688  46.2%
   doProd     801  53.8%
```

But using same approach with a Tcl program

```
proc main { limit }  {
  for {set i 0} {$i<$limt} {incr i} {
    doSum $i
    doProd $i
  }
}

proc doSum { i }  {
  set sum 0
  for {set j 0} { $j<$i} {incr j}  {
    incr sum $j
  }
  return $sum;
}

proc doProd { i }  {
  set prod  0
  for {set j 0} { $j<$i} {incr j}  {
    set prod [expr {$prod * $j}]
  }
  return $prod;
}
```

- Possible call stack (portion):

```
Tcl_Eval
 Tcl_EvalEx
  TclEvalObjvInternal
   Tcl_IfObjCmd
    Tcl_EvalObjEx
     TclCompEvalObj
      TclExecuteByteCode
       TclEvalObjvInternal
        Tcl_CatchObjCmd
         Tcl_EvalObjEx
```

Why is it interesting and important?

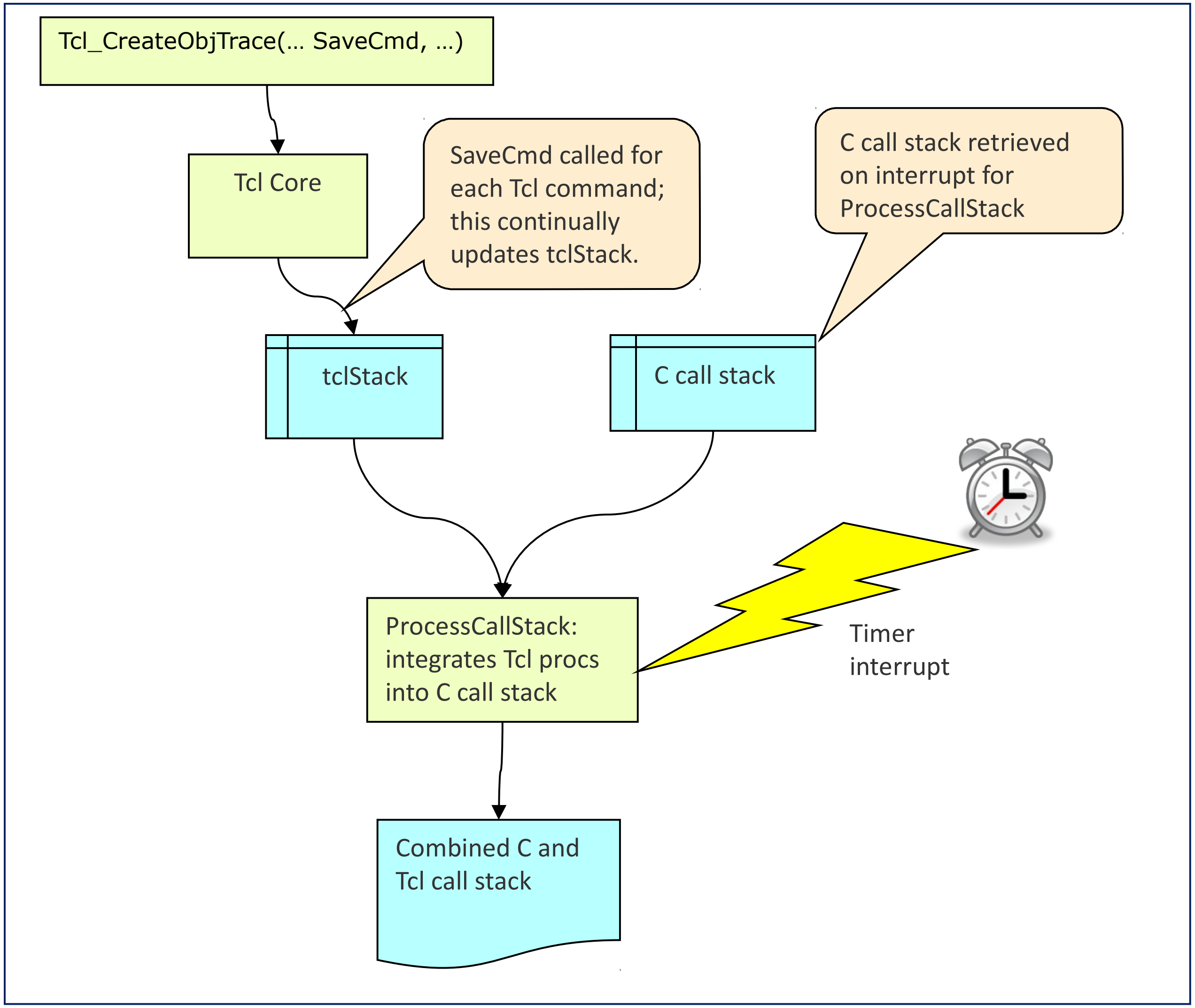
- Would like profile results in terms of original source code. C and Tcl used in our application.
- Existing profilers do either C or Tcl, but not both together.

Key components of combined profiling.

- We need to convert entries like **`TclExecuteByteCode`** and **`TclEvalObjvInternal`** on the call stack to the actual Tcl command that is being executed.
- Information on the C call stack is insufficient.

- Maintain a copy of the Tcl call stack during program execution.
- During processing of C call stack, do mapping from C functions to appropriate Tcl command.

Overview of profiling operation


Tcl_CreateObjTrace(… SaveCmd, …)
Tcl Core
SaveCmd called for each Tcl command; this continually updates tclStack.
C call stack retrieved on interrupt for ProcessCallStack
tclStack
C call stack
ProcessCallStack: integrates Tcl procs into C call stack
Timer interrupt
Combined C and Tcl call stack

ProcessCallStack

```
void ProcessCallStack()
{
  char *name, *proc, lcmd[80];

  while (name = next C call stack entry) {
    if (name == "TclEvalObjvInternal") {
      strcpy(lcmd, tclStack[tclStackLoc]);
      ++tclStackLoc;
      proc = FormatTclCmd(lcmd);
    }
    else if ((name == "Tcl.*")  ||
             (name == "Itcl.*")) {
      /* Ignore these functions in call stack */
      proc = NULL;
    }
    else {
      /* Save other C function names verbatim */
      proc = name;
    }
    if (proc) addToDisplayedCallStack(proc);
  }
}
```

```
char *FormatTclCmd(char *lcmd)
{
  /* Manipulate names for better info
   * in displayed call stack. */
  char *cmd[0:3] = tokensOf(lcmd);
  if (cmd[0] == “if"  ||
      cmd[0] == “for“ ||
      cmd[0] == ...    ) {
    /* Ignore these Tcl commands */
    return NULL;
  } else if (cmd[0] == “info"   ||
             cmd[0] == “winfo"  ||
             cmd[0] == ...    ) {
    return format("%s++%s", cmd[0], cmd[1]);
  } else if (cmd[0] == "string" ||
             cmd[0] == "switch" ||
             cmd[0] == ...       ) {
    if ((cmd[1][0]=='-')) {
      return format("%s++%s++%s",
                    cmd[0], cmd[1], cmd[2]);
    } else {
      return format("%s++%s", cmd[0], cmd[1]);
    }
  } else if (cmd[0] == ...) {
    return format("...", cmd[0], ...);
  } else {
    return cmd[0];
  }
}
```

Profiling Example

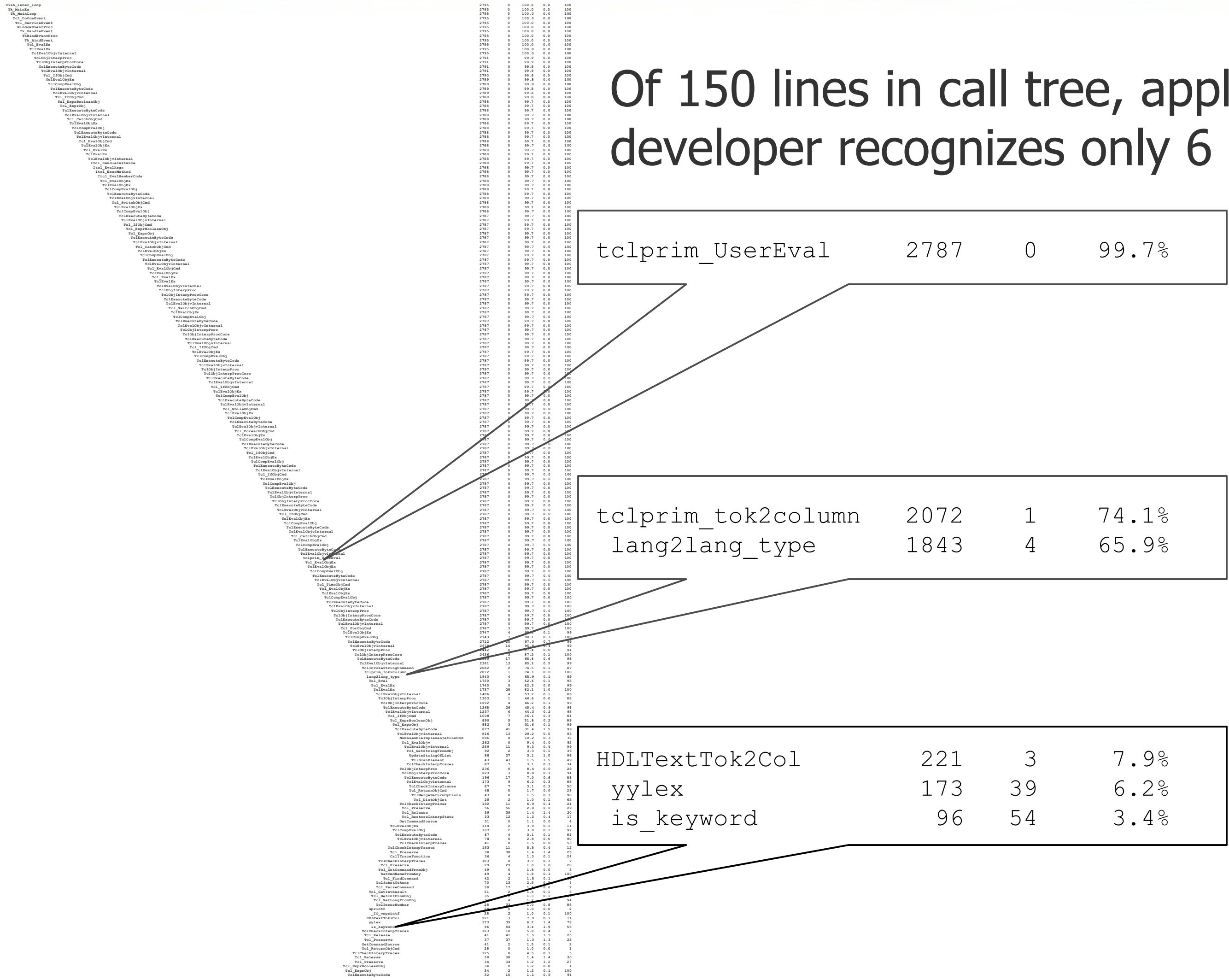
```
time { doWork 1000000 }

proc doWork { limit }  {
  set l [list]
  for {set i 0} {$i<$limit} {incr i} {
    set l [doWork2  $i]
  }
  puts $l
}

proc doWork2 { i  }  {
  set line "The quick brown fox jumps
              over the lazy dog."
  set l [tok2column Verilog 23 $line]
  return $l
}
```

- Test case from Questa code.
- `tok2column` tokenizes input string based on language and column number specified.
- Exercise `tok2column` to determine where time is spent in it.

`tok2column` profile results using C call stack only



```
vish_inner_loop  2795  0  100.0  0.0  100
 Tk_MainEx  2795  0  100.0  0.0  100
  Tk_MainLoop  2795  0  100.0  0.0  100
   Tcl_DoOneEvent  2795  0  100.0  0.0  100
    Tcl_ServiceEvent  2795  0  100.0  0.0  100
     WindowEventProc  2795  0  100.0  0.0  100
      Tk_HandleEvent  2795  0  100.0  0.0  100
       TkBindEventProc  2795  0  100.0  0.0  100
        Tk_BindEvent  2795  0  100.0  0.0  100
         Tcl_EvalEx  2795  0  100.0  0.0  100
          TclEvalEx  2795  0  100.0  0.0  100
           TclEvalObjvInternal  2795  0  100.0  0.0  100
            TclObjInterpProc  2791  0  99.9  0.0  100
             TclObjInterpProcCore  2791  0  99.9  0.0  100
              TclExecuteByteCode  2791  0  99.9  0.0  100
               TclEvalObjvInternal  2791  0  99.9  0.0  100
                Tcl_IfObjCmd  2790  0  99.8  0.0  100
                 TclEvalObjEx  2789  0  99.8  0.0  100
                  TclCompEvalObj  2789  0  99.8  0.0  100
                   TclExecuteByteCode  2789  0  99.8  0.0  100
                    TclEvalObjvInternal  2789  0  99.8  0.0  100
                     Tcl_IfObjCmd  2789  0  99.8  0.0  100
                      Tcl_ExprBooleanObj  2788  0  99.7  0.0  100
                       Tcl_ExprObj  2788  0  99.7  0.0  100
                        TclExecuteByteCode  2788  0  99.7  0.0  100
                         TclEvalObjvInternal  2788  0  99.7  0.0  100
                          Tcl_CatchObjCmd  2788  0  99.7  0.0  100
                           TclEvalObjEx  2788  0  99.7  0.0  100
                            TclCompEvalObj  2788  0  99.7  0.0  100
                             TclExecuteByteCode  2788  0  99.7  0.0  100
                              TclEvalObjvInternal  2788  0  99.7  0.0  100
                               Tcl_EvalObjCmd  2788  0  99.7  0.0  100
                                TclEvalObjEx  2788  0  99.7  0.0  100
                                 Tcl_EvalEx  2788  0  99.7  0.0  100
                                  TclEvalEx  2788  0  99.7  0.0  100
                                   TclEvalObjvInternal  2788  0  99.7  0.0  100
                                    Itcl_HandleInstance  2788  0  99.7  0.0  100
                                     Itcl_EvalArgs  2788  0  99.7  0.0  100
                                      Itcl_ExecMethod  2788  0  99.7  0.0  100
                                       Itcl_EvalMemberCode  2788  0  99.7  0.0  100
                                        Tcl_EvalObjEx  2788  0  99.7  0.0  100
                                         TclEvalObjEx  2788  0  99.7  0.0  100
                                          TclCompEvalObj  2788  0  99.7  0.0  100
                                           TclExecuteByteCode  2788  0  99.7  0.0  100
                                            TclEvalObjvInternal  2788  0  99.7  0.0  100
                                             Tcl_SwitchObjCmd  2788  0  99.7  0.0  100
                                              TclEvalObjEx  2788  0  99.7  0.0  100
                                               TclCompEvalObj  2788  0  99.7  0.0  100
                                                TclExecuteByteCode  2787  0  99.7  0.0  100
                                                 TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                  Tcl_IfObjCmd  2787  0  99.7  0.0  100
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                                                    Tcl_ExprObj  2787  0  99.7  0.0  100
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                                                             TclEvalObjEx  2787  0  99.7  0.0  100
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                                                                  TclObjInterpProcCore  2787  0  99.7  0.0  100
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                                                                    TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                     Tcl_SwitchObjCmd  2787  0  99.7  0.0  100
                                                                      TclEvalObjEx  2787  0  99.7  0.0  100
                                                                       TclCompEvalObj  2787  0  99.7  0.0  100
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                                                                                          TclExecuteByteCode  2787  0  99.7  0.0  100
                                                                                           TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                                            Tcl_WhileObjCmd  2787  0  99.7  0.0  100
                                                                                             TclEvalObjEx  2787  0  99.7  0.0  100
                                                                                              TclCompEvalObj  2787  0  99.7  0.0  100
                                                                                               TclExecuteByteCode  2787  0  99.7  0.0  100
                                                                                                TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                                                 Tcl_ForeachObjCmd  2787  0  99.7  0.0  100
                                                                                                  TclEvalObjEx  2787  0  99.7  0.0  100
                                                                                                   TclCompEvalObj  2787  0  99.7  0.0  100
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                                                                                                                      TclCompEvalObj  2787  0  99.7  0.0  100
                                                                                                                       TclExecuteByteCode  2787  0  99.7  0.0  100
                                                                                                                        TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                                                                         Tcl_CatchObjCmd  2787  0  99.7  0.0  100
                                                                                                                          TclEvalObjEx  2787  0  99.7  0.0  100
                                                                                                                           TclCompEvalObj  2787  0  99.7  0.0  100
                                                                                                                            TclExecuteByteCode  2787  0  99.7  0.0  100
                                                                                                                             TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                                                                              tclprim_UserEval  2787  0  99.7  0.0  100
                                                                                                                               Tcl_EvalObjEx  2787  0  99.7  0.0  100
                                                                                                                                TclEvalObjEx  2787  0  99.7  0.0  100
                                                                                                                                 TclCompEvalObj  2787  0  99.7  0.0  100
                                                                                                                                  TclExecuteByteCode  2787  0  99.7  0.0  100
                                                                                                                                   TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                                                                                    Tcl_TimeObjCmd  2787  0  99.7  0.0  100
                                                                                                                                     Tcl_EvalObjEx  2787  0  99.7  0.0  100
                                                                                                                                      TclEvalObjEx  2787  0  99.7  0.0  100
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                                                                                                                                           TclObjInterpProcCore  2787  0  99.7  0.0  100
                                                                                                                                            TclExecuteByteCode  2787  0  99.7  0.0  100
                                                                                                                                             TclEvalObjvInternal  2787  0  99.7  0.0  100
                                                                                                                                              Tcl_ForObjCmd  2787  3  99.7  0.1  100
                                                                                                                                               TclEvalObjEx  2747  4  98.3  0.1  99
                                                                                                                                                TclCompEvalObj  2743  7  98.1  0.3  100
                                                                                                                                                 TclExecuteByteCode  2712  20  97.0  0.7  99
                                                                                                                                                  TclEvalObjvInternal  2679  10  95.8  0.4  99
                                                                                                                                                   TclObjInterpProc  2442  0  87.4  0.0  91
                                                                                                                                                    TclObjInterpProcCore  2436  3  87.2  0.1  100
                                                                                                                                                     TclExecuteByteCode  2399  17  85.8  0.6  98
                                                                                                                                                      TclEvalObjvInternal  2381  13  85.2  0.5  99
                                                                                                                                                       TclInvokeStringCommand  2082  2  74.5  0.1  87
                                                                                                                                                        tclprim_tok2column  2072  1  74.1  0.0  100
                                                                                                                                                         lang2lang_type  1843  4  65.9  0.1  89
                                                                                                                                                          Tcl_Eval  1750  3  62.6  0.1  95
                                                                                                                                                           Tcl_EvalEx  1740  0  62.3  0.0  99
                                                                                                                                                            TclEvalEx  1737  28  62.1  1.0  100
                                                                                                                                                             TclEvalObjvInternal  1486  4  53.2  0.1  86
                                                                                                                                                              TclObjInterpProc  1303  1  46.6  0.0  88
                                                                                                                                                               TclObjInterpProcCore  1292  4  46.2  0.1  99
                                                                                                                                                                TclExecuteByteCode  1268  26  45.4  0.9  98
                                                                                                                                                                 TclEvalObjvInternal  1237  6  44.3  0.2  98
                                                                                                                                                                  Tcl_IfObjCmd  1008  7  36.1  0.3  81
                                                                                                                                                                   Tcl_ExprBooleanObj  890  5  31.8  0.2  88
                                                                                                                                                                    Tcl_ExprObj  882  3  31.6  0.1  99
                                                                                                                                                                     TclExecuteByteCode  877  41  31.4  1.5  99
                                                                                                                                                                      TclEvalObjvInternal  816  13  29.2  0.5  93
                                                                                                                                                                       NsEnsembleImplementationCmd  286  8  10.2  0.3  35
                                                                                                                                                                        Tcl_EvalObjv  262  0  9.4  0.0  92
                                                                                                                                                                         TclEvalObjvInternal  259  11  9.3  0.4  99
                                                                                                                                                                          Tcl_GetStringFromObj  92  2  3.3  0.1  36
                                                                                                                                                                           UpdateStringOfList  88  27  3.1  1.0  96
                                                                                                                                                                            TclScanElement  43  43  1.5  1.5  49
                                                                                                                                                                          TclCheckInterpTraces  87  7  3.1  0.3  34
                                                                                                                                                                       TclObjInterpProc  236  0  8.4  0.0  29
                                                                                                                                                                        TclObjInterpProcCore  223  3  8.0  0.1  94
                                                                                                                                                                         TclExecuteByteCode  196  17  7.0  0.6  88
                                                                                                                                                                          TclEvalObjvInternal  173  9  6.2  0.3  88
                                                                                                                                                                           TclCheckInterpTraces  87  7  3.1  0.3  50
                                                                                                                                                                           Tcl_ReturnObjCmd  48  0  1.7  0.0  28
                                                                                                                                                                            TclMergeReturnOptions  43  8  1.5  0.3  90
                                                                                                                                                                             Tcl_DictObjGet  28  2  1.0  0.1  65
                                                                                                                                                                       TclCheckInterpTraces  192  11  6.9  0.4  24
                                                                                                                                                                        Tcl_Preserve  56  56  2.0  2.0  29
                                                                                                                                                                        Tcl_Release  39  39  1.4  1.4  20
                                                                                                                                                                        Tcl_RestoreInterpState  33  12  1.2  0.4  17
                                                                                                                                                                       GetCommandSource  31  0  1.1  0.0  4
                                                                                                                                                                   TclEvalObjEx  110  2  3.9  0.1  11
                                                                                                                                                                    TclCompEvalObj  107  2  3.8  0.1  97
                                                                                                                                                                     TclExecuteByteCode  87  4  3.1  0.1  81
                                                                                                                                                                      TclEvalObjvInternal  78  0  2.8  0.0  90
                                                                                                                                                                       TclCheckInterpTraces  41  0  1.5  0.0  53
                                                                                                                                                                  TclCheckInterpTraces  153  11  5.5  0.4  12
                                                                                                                                                                   Tcl_Preserve  38  38  1.4  1.4  25
                                                                                                                                                                   CallTraceFunction  36  4  1.3  0.1  24
                                                                                                                                                              TclCheckInterpTraces  103  8  3.7  0.3  7
                                                                                                                                                               Tcl_Preserve  29  29  1.0  1.0  28
                                                                                                                                                              Tcl_GetCommandFromObj  49  0  1.8  0.0  3
                                                                                                                                                               SetCmdNameFromAny  49  4  1.8  0.1  100
                                                                                                                                                                Tcl_FindCommand  42  2  1.5  0.1  [illegible]
                                                                                                                                                             TclSubstTokens  70  13  2.5  0.5  4
                                                                                                                                                             Tcl_ParseCommand  38  17  1.4  0.6  2
                                                                                                                                                          Tcl_GetIntResult  51  2  1.8  0.1  3
                                                                                                                                                           Tcl_GetIntFromObj  35  2  1.3  0.1  [illegible]
                                                                                                                                                            Tcl_GetLongFromObj  33  4  1.2  0.1  94
                                                                                                                                                             TclParseNumber  28  23  1.0  0.8  85
                                                                                                                                                          sprintf  28  0  1.0  0.0  2
                                                                                                                                                           _IO_vsprintf  28  2  1.0  0.1  100
                                                                                                                                                         HDLTextTok2Col  221  3  7.9  0.1  11
                                                                                                                                                          yylex  173  39  6.2  1.4  78
                                                                                                                                                           is_keyword  96  54  3.4  1.9  55
                                                                                                                                                       TclCheckInterpTraces  163  10  5.8  0.4  7
                                                                                                                                                        Tcl_Release  41  41  1.5  1.5  25
                                                                                                                                                        Tcl_Preserve  37  37  1.3  1.3  23
                                                                                                                                                       GetCommandSource  41  2  1.5  0.1  2
                                                                                                                                                       Tcl_ReturnObjCmd  28  0  1.0  0.0  1
                                                                                                                                                   TclCheckInterpTraces  125  8  4.5  0.3  5
                                                                                                                                                    Tcl_Release  38  38  1.4  1.4  30
                                                                                                                                                    Tcl_Preserve  34  34  1.2  1.2  27
                                                                                                                                               Tcl_ExprBooleanObj  34  0  1.2  0.0  1
                                                                                                                                                Tcl_ExprObj  34  2  1.2  0.1  100
                                                                                                                                                 TclExecuteByteCode  32  15  1.1  0.5  94
```

Of 150 lines in call tree, application developer recognizes only 6 of them

```
tclprim_UserEval       2787    0     99.7%
```

```
tclprim_tok2column   2072    1     74.1%
 lang2lang_type      1843    4     65.9%
```

```
HDLTextTok2Col         221    3      7.9%
 yylex                 173   39      6.2%
 is_keyword             96   54      3.4%
```

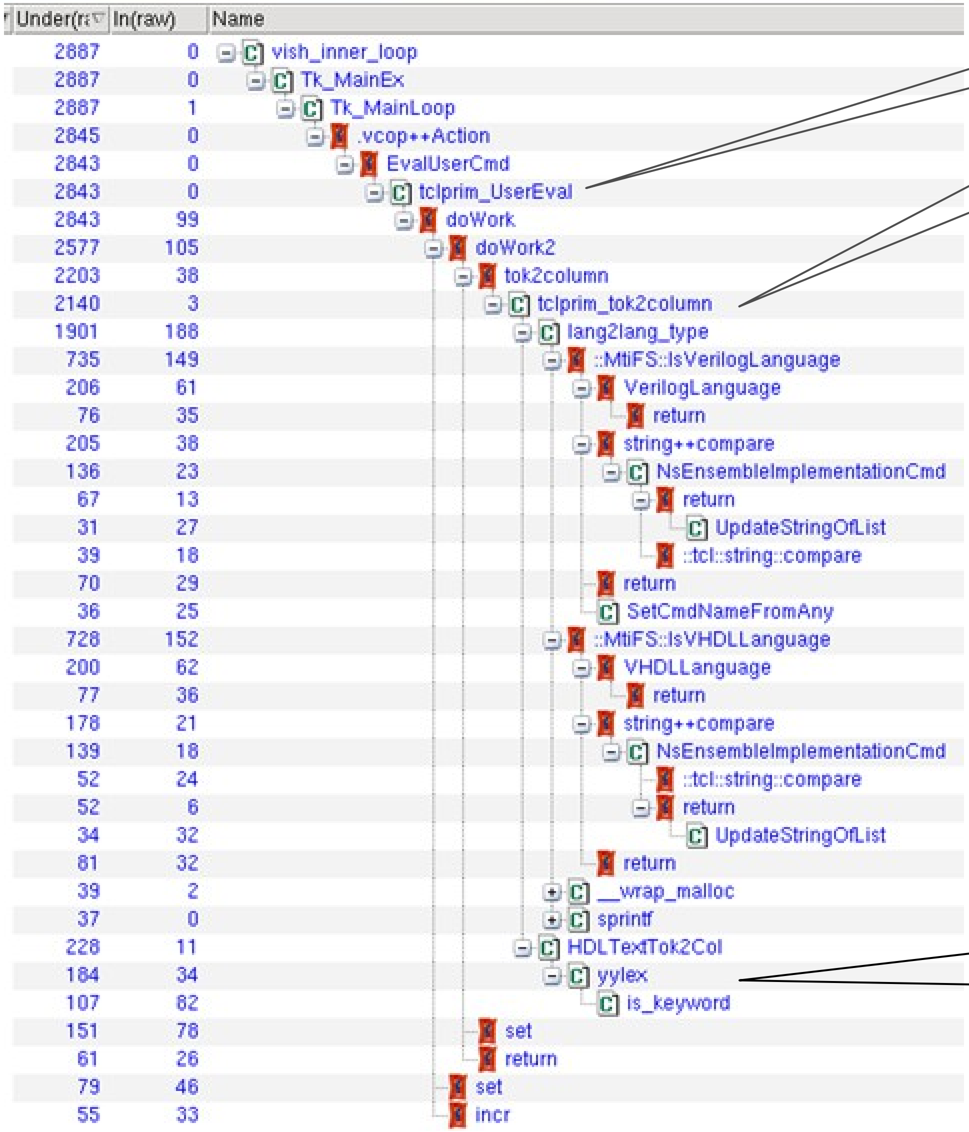
Call stack mapping detail

C function only call stack entry	ProcessCallStack action	Combined C and Tcl call stack entry
vish_inner_loop	-->	vish_inner_loop
Tk_MainEx	-->	Tk_MainEx
Tk_MainLoop	-->	Tk_MainLoop
Tcl_DoOneEvent	X	
Tcl_ServiceEvent	X	
WindowEventProc	X	
Tk_HandleEvent	X	
TkBindEventProc	X	
Tk_BindEvent	X	
Tcl_EvalEx	X	
(lines of Tcl*)	X	
TclEvalObjvInternal	map to Tcl command	.vcop++Action
(lines of Tcl*)	X	
Tcl_CatchObjCmd	X	
TclEvalObjEx	X	
TclCompEvalObj	X	
TclExecuteByteCode	X	
TclEvalObjvInternal	map to Tcl command	EvalUserCmd

Call stack mapping detail (continued)

Tcl_TimeObjCmd	X	
Tcl_EvalObjEx	X	
TclEvalObjEx	X	
TclCompEvalObj	X	
TclExecuteByteCode	X	
TclEvalObjvInternal	map to Tcl command	doWork
TclObjInterpProc	X	
TclObjInterpProcCore	X	
TclExecuteByteCode	X	
TclEvalObjvInternal	map to “for”, but suppress	
Tcl_ForObjCmd	X	
TclEvalObjEx	X	
TclCompEvalObj	X	
TclExecuteByteCode	X	
TclEvalObjvInternal	map to Tcl command	doWork2
TclObjInterpProc	X	

tok2column profile results with combined Tcl and C call tree



```
Under(ra  In(raw)  Name
 2887       0      vish_inner_loop
 2887       0        Tk_MainEx
 2887       1          Tk_MainLoop
 2845       0            .vcop++Action
 2843       0              EvalUserCmd
 2843       0                tclprim_UserEval
 2843      99                  doWork
 2577     105                    doWork2
 2203      38                      tok2column
 2140       3                        tclprim_tok2column
 1901     188                          lang2lang_type
  735     149                            ::MtiFS::IsVerilogLanguage
  206      61                              VerilogLanguage
   76      35                                return
  205      38                              string++compare
  136      23                                NsEnsembleImplementationCmd
   67      13                                  return
   31      27                                    UpdateStringOfList
   39      18                                  ::tcl::string::compare
   70      29                              return
   36      25                              SetCmdNameFromAny
  728     152                            ::MtiFS::IsVHDLLanguage
  200      62                              VHDLLanguage
   77      36                                return
  178      21                              string++compare
  139      18                                NsEnsembleImplementationCmd
   52      24                                  ::tcl::string::compare
   52       6                                  return
   34      32                                    UpdateStringOfList
   81      32                              return
   39       2                            __wrap_malloc
   37       0                            sprintf
  228      11                          HDLTextTok2Col
  184      34                            yylex
  107      82                              is_keyword
  151      78                        set
   61      26                        return
   79      46                      set
   55      33                      incr
```

```
tclprim_UserEval
```

```
tclprim_tok2column

 lang2lang_type
```

```
time { doWork 1000000 }

proc doWork { limit }  {
  set l [list]
  for {set i 0} {$i<$limit} {incr i} {
    set l [doWork2  $i]
  }
  puts $l
}

proc doWork2 { i  }  {
  set line "The quick brown fox
          jumps over the lazy dog."
  set l [tok2column Verilog 23 $line]
  return $l
}
```

```
HDLTextTok2Col
 yylex
 is_keyword
```

Why is lang2lang_type so slow?

```
static int lang2lang_type (Tcl_Interp *interp,const char *lang)
{
  char buf[256];
  sprintf(buf, "::MtiFS::IsVHDLLanguage %s", lang);
  if ( Tcl_Eval(interp, buf) == TCL_OK) {
    if (Tcl_GetIntResult(interp)) {
      Tcl_ResetResult(interp);
      return LANGVHDL;
    }
  }

  sprintf(buf, "::MtiFS::IsVerilogLanguage %s", lang);
  if ( Tcl_Eval(interp, buf) == TCL_OK) {
    if (Tcl_GetIntResult(interp)) {
      Tcl_ResetResult(interp);
      return LANGVERILOG;
    }
  }
     . . .
```

```
proc MtiFS::IsVerilogLanguage { type } {
  if {[string compare -nocase $type [VerilogLanguage]] == 0 } {return 1}
    return 0
}
proc MtiFS::VerilogLanguage {}       { return "verilog" }
```

Notes and limitations

- Performance – slower operation during profiling
- **`TCL_ALLOW_INLINE_COMPILATION`** to **`Tcl_CreateObjTrace()`** caused misalignment of Tcl call stack entries
- Changes to Tcl core code to get consistent values for **`numLevels`** used in callback routine.
- **`SaveCmd`** not always called for every level of Tcl command
- Filtering in **`ProcessCallStack`** suited our needs; other applications could use different rules.

Future work

- In Tcl 8.5, it would be useful to have lighter-weight function to record Tcl command calls.
- In Tcl 8.6, “stackless evaluation” has been introduced. This will require a different mechanism to correlate C and Tcl call stacks.

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