interactive code checking with Cobra

a Tutorial

Gerard Holzmann
Nimble Research
gholzmann@acm.org

this course

Code Browser
and Analyzer

- why was it built?
- what can it do?
- how does it work?
- how can you use it?

schedule

- Day 1
  - background and principle of operation
    - installation, configuration
    - guide to online documentation
  - *pattern queries*
  - regular expressions
  - exercises with pattern queries
  - command-line and *interactive queries*
  - exercises with query commands

~20 minute breaks after about 90 minutes each day

- Day 2
  - query commands
    - token attributes
    - sets and ranges
  - query functions, reading files
  - the *scripting language*
    - recursive functions
    - associative arrays
    - using concurrency
  - building *standalone checkers*
    - using multi-threading
  - wrapup

background: a challenge project

designing & building an interactive code query system

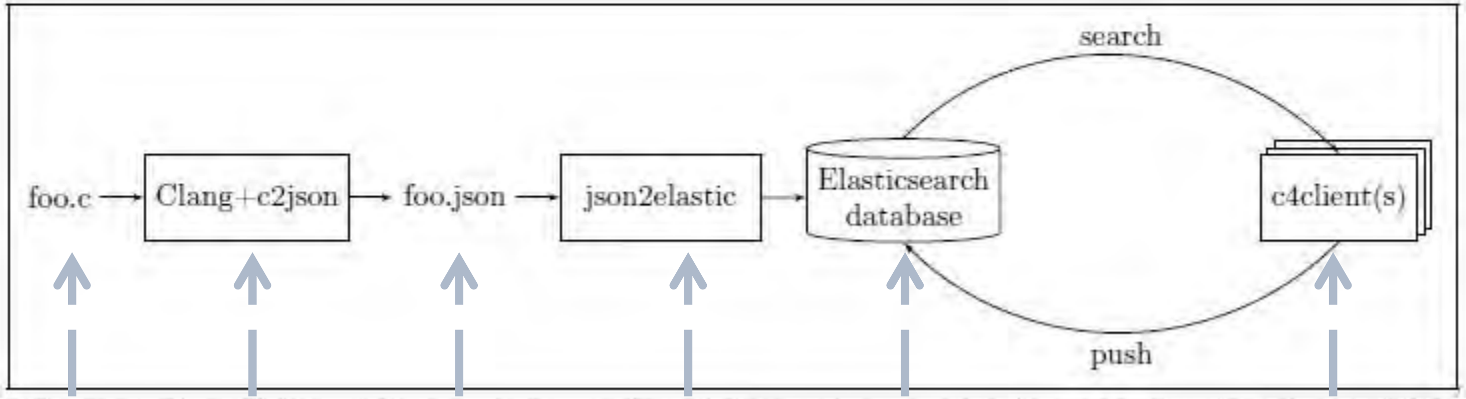

Figure 1: Overall C4 architecture. c2json and json2elastic are responsible for generating the indexing ASTs into an Elasticsearch database. Users use the c4client API to ask questions about the codebase (search) and store conclusions (push).

code ***compile*** ***AST*** ***convert*** ***web database*** ***query processing***

the challenge project

summer internship project report

4 Results

We tested C4's capabilities by first writing a generic call graph analysis. This analysis pushes a 2 directional call graph into C4.

Second we wrote analyses that leveraged the result of the call graph to determine which public interface functions of Europa's Core FSW codebase and the MSL codebase sent which interprocess messages. Although we did not record times for Europa's Core FSW codebase, we did record times for certain modules in the MSL codebase (table 1). For these benchmarks, C4 used a single node (12 shard) Elasticsearch database running on a 12-core processor with 30 gigabytes of heap space.

Lines of Code	Functions	Call Graph Time	Interprocess Message Time
13321	297	8.16 min	18.28 sec
56429	812	1.28 hr	2.55 min
64843	1159	1.33 hr	1.92 min

Table 1: Call graph and interprocess message times for three MSL modules. As expected, analysis time increased as the number of lines of code / functions increased. Most work was done during the CallGraph analysis.

much too slow, especially when targeting millions of lines of code

the challenge project

it doesn’t have to be that slow: computing the function call graph

MSL Module	Lines of Code	Functions	Call Graph Time	Interprocess Message Time
files	13321	297	8.16 min	18.28 sec
cbm	56429	812	1.28 hr	2.55 min
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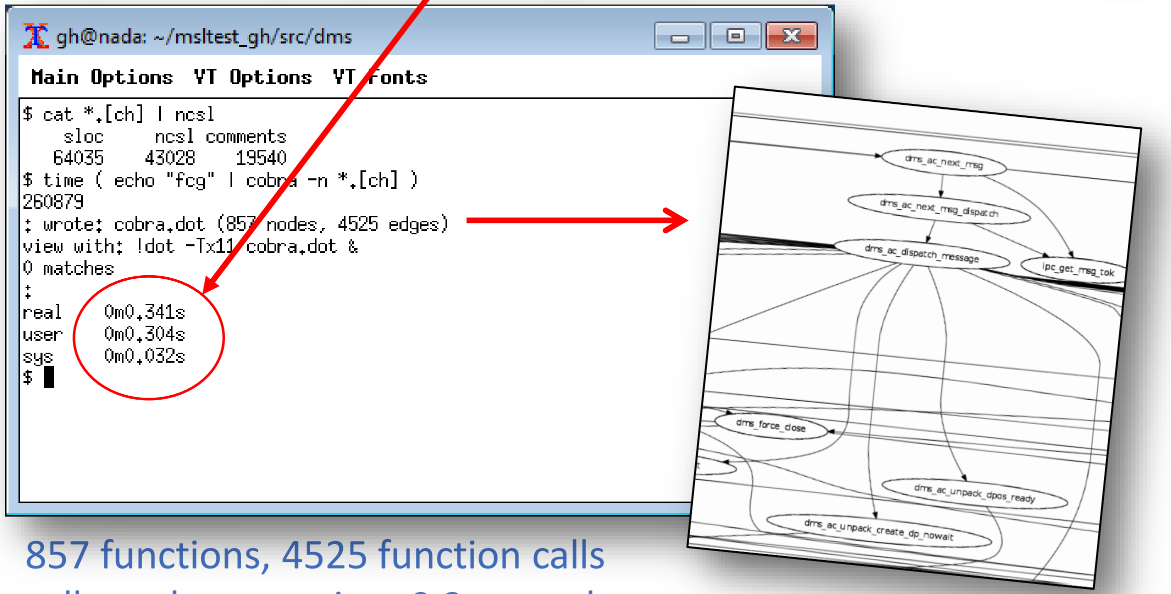
Cobra on the MSL dms source code



857 functions, 4525 function calls
call graph generation: 0.3 seconds

the challenge project

it doesn't have to be that slow: checking which MSL IPC message types are sent

MSL Module	Lines of Code	Functions	Call Graph Time	Interprocess Message Time
files	13321	297	8.16 min	18.28 sec
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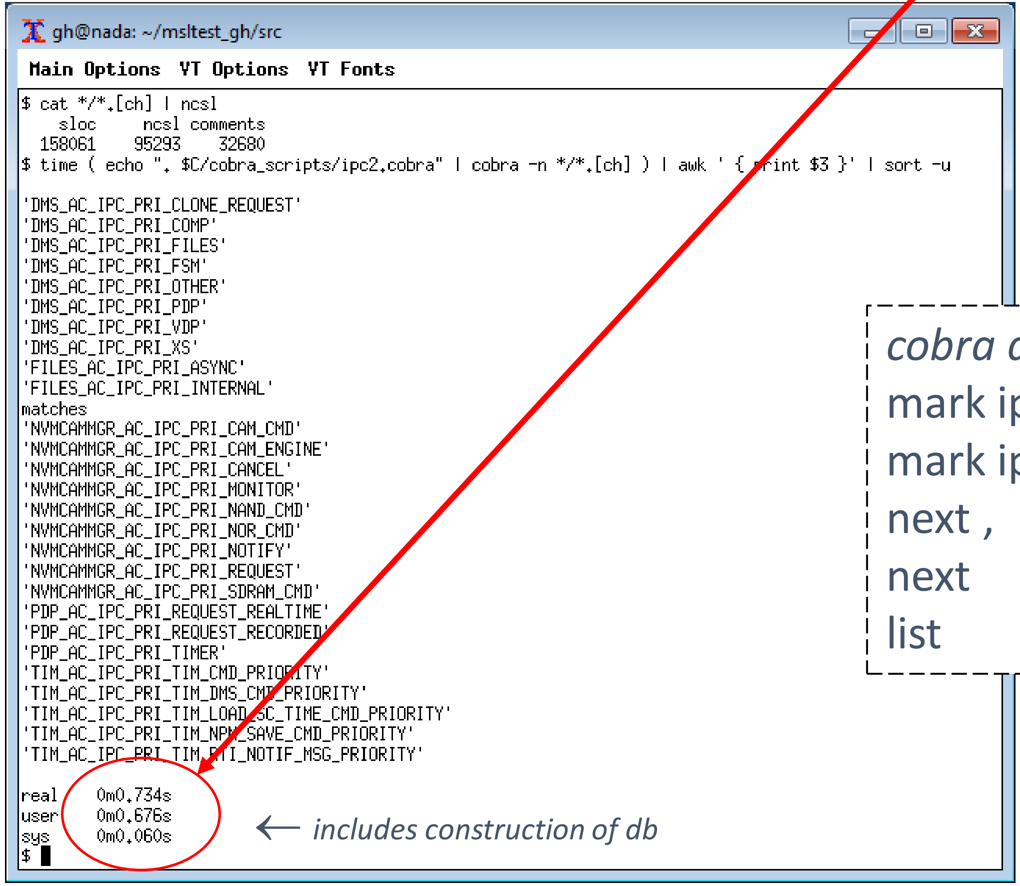
Cobra

these



← *includes construction of db*

cobra query commands sequence:
mark ipc_send
mark ipc_check_and_send
next ,
next
list

performance can be critical

consider this real scenario from early in the MSL mission

- an in-flight anomaly occurs
  - manual analysis reveals the cause:
  - a function call passes an array argument of the wrong size
    - function expects an array of 16 elements
    - the call passes an array of 8 elements
    - data corruption results (compilers don’t catch this)
- *does this happen anywhere else in the 2.8 MLOC?*
  - old method:
    - develop a new checker for (one of) the static analyzers
    - wait 15 hours for the cumulative check to be run
    - meanwhile, a few million miles away…..

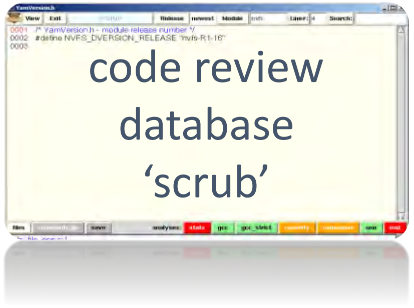
performance can be critical

JPL tool-based code review process

Nightly Build Log
~3K compiler calls

Static Code Analysis for
Defect Detection &
Coding Rule Compliance Checking

gcc –Wall –pedantic | coverity | codesonar | semmle | uno

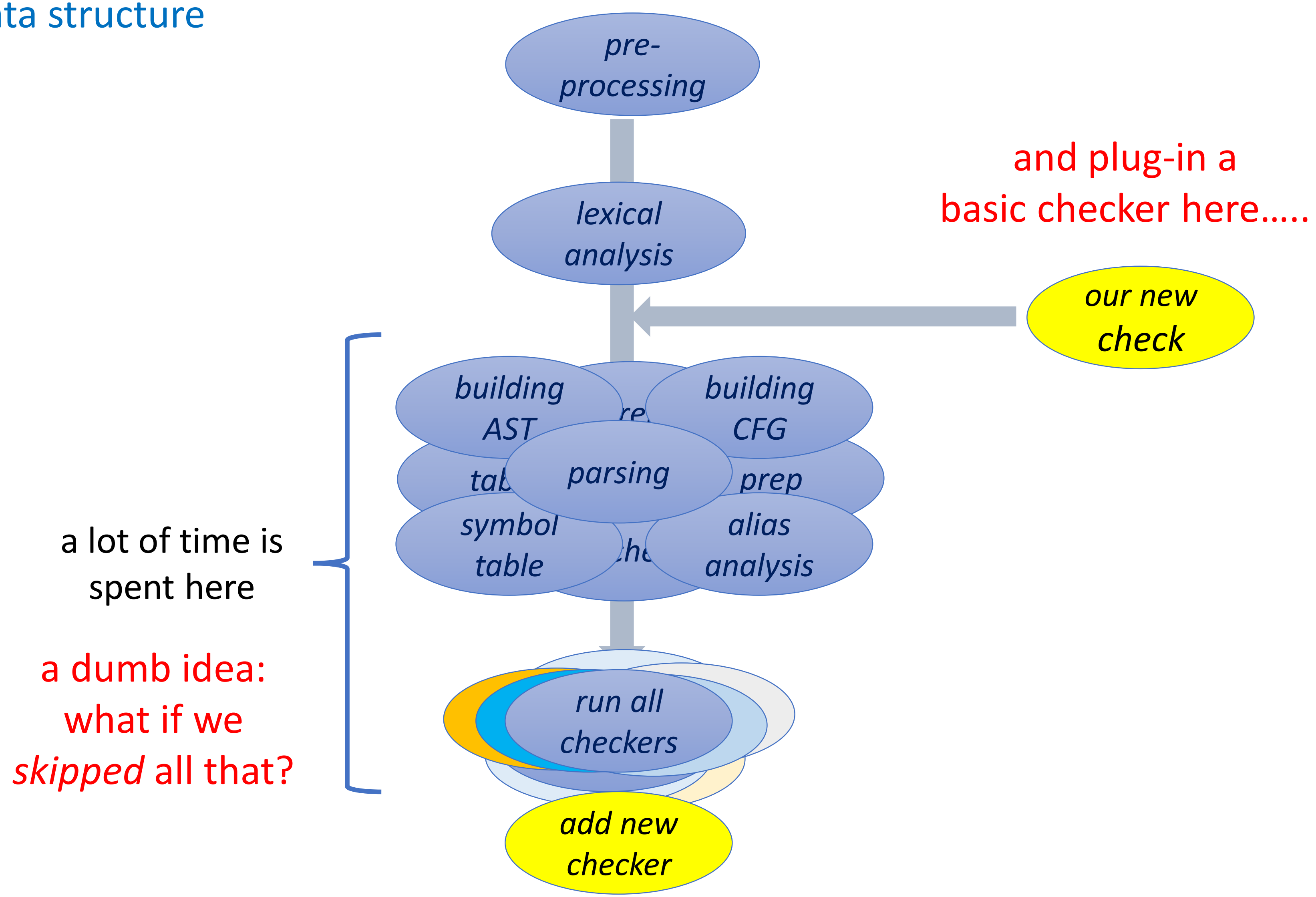


analysis time for
2.8 MLOC of C
~15hrs

in this case, we asked semmle
to build a new checker for us,
which they delivered the next day
so that we could add it to the nightly check

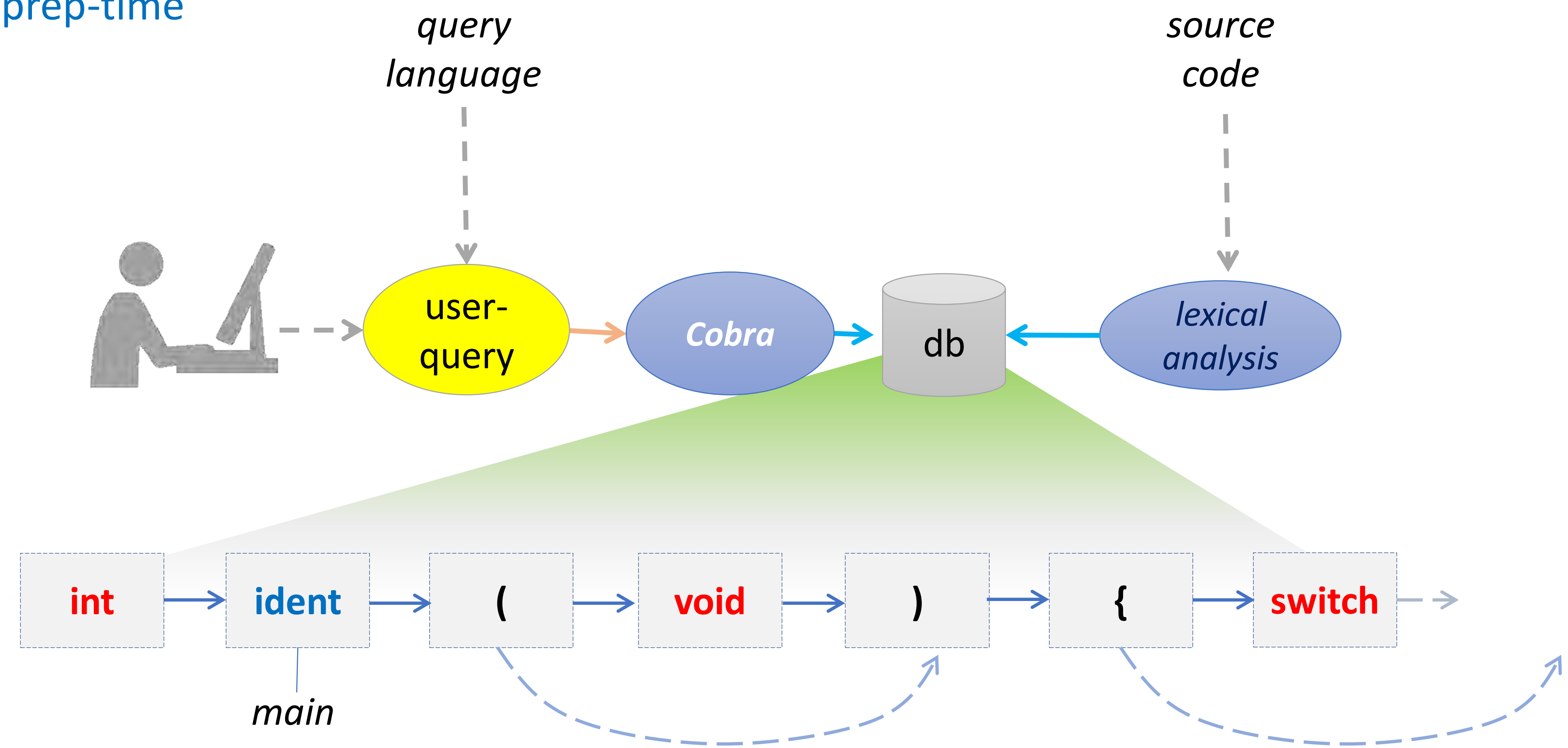
why does the analysis take so long?

building data structure



cobra's design

minimize prep-time

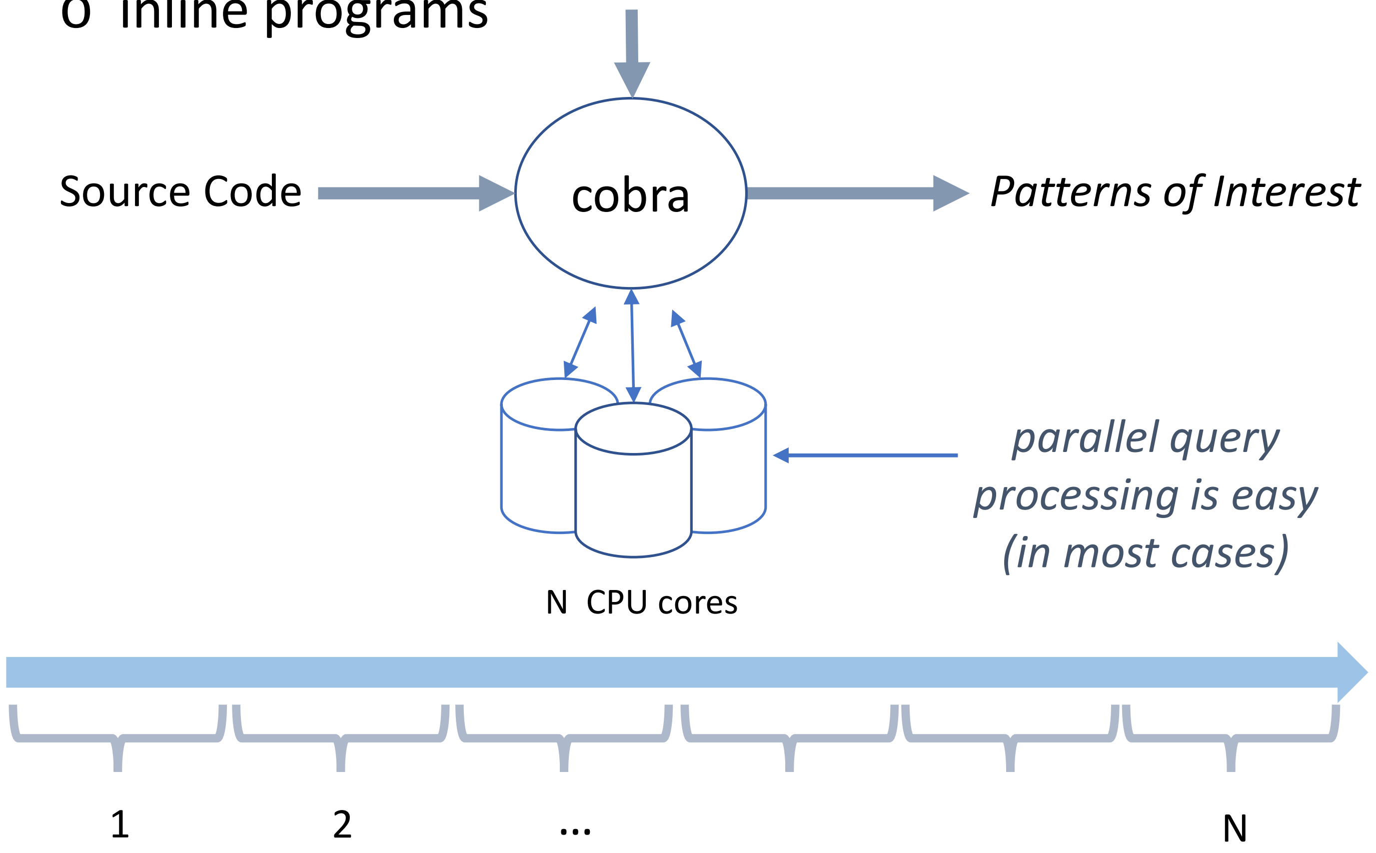


a linked list of lexical tokens with annotations
(token types, ranges, levels of nesting for parentheses, brackets, and braces, etc.)

cobra's design

minimizing query response time

- interactive query commands over sets & ranges
- pattern matching commands
- inline programs



getting started

installation and configuration

```
$ # pick the directory where you'll install the cobra files
$ git clone https://github.com/nimble-code/Cobra
$ ls –l
drwxrwxr-x 2 gh gh 4096 May 16 12:59 bin_linux      # executables for linux
drwxrwxr-x 2 gh gh 4096 May 16 12:59 bin_cygwin     # executables for cygwin
drwxrwxr-x 2 gh gh 4096 May 16 12:59 bin_mac        # executables for macs
drwxrwxr-x 2 gh gh 4096 May 16 10:03 doc            # change history, manpage, license
drwxrwxr-x 2 gh gh 4096 May 16 10:03 gui            # optional small tcl/tk script
drwxrwxr-x 8 gh gh 4096 May 16 15:55 rules          # cobra checker libraries
drwxrwxr-x 1 gh gh 4096 May 16 12:43 src            # cobra source files
drwxrwxr-x 1 gh gh 4096 May 16 12:43 src_app        # standalone cobra checkers
$ cd src
$ sudo make install_mac    # or install_cygwin, install_linux
$ cd ..
$ export PATH=$PATH:`pwd`/bin_mac     # or bin_cygwin, bin_linux
$ cobra –configure `pwd`/rules
```

optional,
to compile from scratch

recommended:
install also tcl/tk
install also graphviz
on ubuntu:
sudo apt-get install graphviz
on mac:
brew install graphviz

getting started

all manual pages are online

http://spinroot.com/cobra

Cobra Static Code Analyzer

about papers manpages downloads

Cobra is a structural source code analyzer, fast enough that it can be used interactively. The tool prototype (Version 1.0) was developed at NASA's Jet Propulsion Laboratory late 2015, and released for general distribution about a year later.

Versions 2 and 3 of the tool are extended versions that can handle interactive analyses of code bases with up to millions of lines of code, while supporting a significantly richer online query scripting language. It also comes with multi-core support for many types of queries, including a new set of cyber-security related checks.

Starting with Version 3, the Cobra code is distributed in open source form at github.com/nimble-code.

Cobra can analyze C, C++, Ada, and Python, and can relatively easily be retargeted for other languages. The distribution includes sample query libraries and scripts.

For bug reports and additional information:
gholzmann atsign acm dot org

getting started

all manual pages are online

http://spinroot.com/cobra/manual.html

COBRA Reference Manual
Code Browser and Analysis Tool

Principle of Operation

Cobra uses a lexical analyzer to scan in the source code in the files given as arguments on the command-line. It then builds a data structure that can be used for querying that source code, either interactively or with predefined scripts.

The internal data structure dat Cobra builds is a basic linked list of lexical tokens, annotated with some basic information and links to other tokens, for instance to identify matching pairs of parentheses, brackets and braces. The tool does not attempt to parse the code, which means that it can handle a broad range of possible inputs. Despite the simplicity of the data structure, the tool can be remarkably powerful in quickly locating complex patterns in a code base to assist in peer review, code development, or structural code analysis.

There are several ways to write queries. You can use:

- Interactive queries (overview below, or see the index),
- Inline programs (described separately),
- Standalone checkers (described separately).

Interactive queries are written in a simple command language that can support the most frequent types of searches. When more complex queries need to be handled, requiring anything other than a sequential scan of the

getting started

all manual pages are online

http://spinroot.com/cobra/commands/index.html

Cobra Command Overview

Commands with short-hand:

a	append a source file
b	move marks back one token
B	browse a source file (cf V)
:	(colon) execute a named script
c	contains: query a range
d	display
.	(dot) read a command file
e	extend match
F	list of open files
G	grep in source files
?	help
h	command history
=	print something
i	inspect lexical tokens
j	jump
l	list
m	mark tokens

Commands without short-hand:

cfg	cfg
context	context
cpp	preprocessing
def...end	define named scripts
default	default
fcg	fcg
fcts	fcts
ff	ff
ft	ft
map	map
ncore	set nr of cores to use
nowindow	disable window popups for display commands (default)
%{...%}	inline programs
pat	pattern token expression
pe	same as pat
re	regular token expression

getting started

all manual pages are online

http://spinroot.com/cobra/commands/mark.html

Cobra **Interactive Query Language** **mark**

NAME

mark — mark tokens if they match one or two patterns

SYNTAX

```
m[ark] [qualifier]* pattern [pattern2]
pattern:   string | @string | /re | (expr)
qualifier: ir | no | &
```

DESCRIPTION

If used without qualifiers, the mark command can only add additional marks, but not remove them. The qualifiers can be used to restrict an existing set of marks to a subset.

A pattern can be one of the following:

- a string (without quotes) to match the token text precisely,
- a token type (when prefixed with a @ symbol),
- a regular expression (when preceded by a / symbol), or
- a pattern expression (when enclosed in round braces).

A qualifier is one of the three terms **ir**, **no**, or **&**. Qualifiers can be escaped as \no, \&, or \ir if a literal match is intended, as can the **/** that would otherwise identify a regular expression, or a round brace **(** that would otherwise indicate a pattern expression.

getting started

the query libraries

try, for instance:
$ cobra –f basic *.c

or for summary output:
$ cobra –terse –f basic *.c

```
$ cd $COBRA/rules
$ ls –l
total 60
drwxr-xr-x+ 1 gh None 0 May  1 16:31 cwe
drwxr-xr-x+ 1 gh None 0 Oct 11  2018 jpl
drwxr-xr-x+ 1 gh None 0 May  6 17:16 main
drwxr-xr-x+ 1 gh None 0 Oct 11  2018 misra
drwxr-xr-x+ 1 gh None 0 Oct 11  2018 pedantic
drwxr-xr-x+ 1 gh None 0 Jun  1 14:18 play
drwxr-xr-x+ 1 gh None 0 Mar 20 15:49 stats
$ ls -l main/*.cobra
total 89
-rwxr-xr-x+ 1 USER None 1017 May 12  2017 basic.cobra
-rwxr-xr-x+ 1 USER None 3513 May 13  2017 binop.cobra
-rwxr-xr-x+ 1 USER None   21 May  6 17:16 cwe.cobra
-rwxr-xr-x+ 1 USER None  793 Apr 20  2017 extern.cobra
-rwxr-xr-x+ 1 USER None 2490 May 13  2017 iridex.cobra
-rwxr-xr-x+ 1 USER None 4004 May 15  2017 jpl.cobra
-rwxr-xr-x+ 1 USER None  589 May 12  2017 metrics.cobra
-rwxr-xr-x+ 1 USER None  714 May 12  2017 misra1997.cobra
-rwxr-xr-x+ 1 USER None  725 May 12  2017 misra2004.cobra
-rwxr-xr-x+ 1 USER None  658 May 12  2017 misra2012.cobra
-rwxr-xr-x+ 1 USER None  501 May 12  2017 p10.cobra
-rwxr-xr-x+ 1 USER None 1008 May 31 09:02 reverse_null.cobra
-rwxr-xr-x+ 1 USER None  585 May  6 17:09 stats.cobra
```

getting started

languages supported

- Cobra is designed to be language neutral, which means that:
  - it can be targeted to a broad range of languages, by providing it with the relevant set of lexical tokens
  - the token categories for C, C++, Java, Ada, and Python are predefined
  - the default is C, the alternatives:

    $ cobra –Ada …
    $ cobra –Java …
    $ cobra –C++ …
    $ cobra –Python …
  - other languages can be added by using the *map* command
- to see all currently recognized cobra flags:

    $ cobra --

cobra pattern searches

pattern searches

so what's wrong with using "grep"?

```
$ grep  -e x *.c | wc
   1136    7251   57700
```

sample match: `prefix = s;`

```
$ cobra -pat x *.c | wc
     96     549    3647
```

matches ***tokens*** named x,

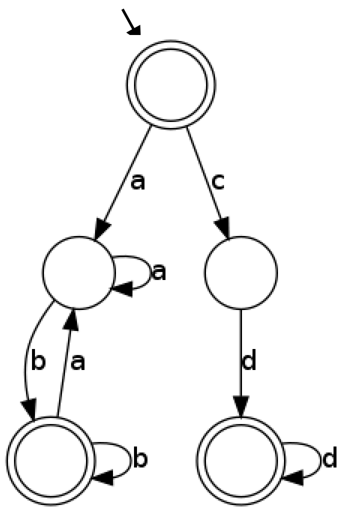
sample match: `strcmp(x->txt, "x"))`

note: the pattern search does not match either the word prefix or the string "x"

pattern searches

pattern expressions are a simplified form of regular expressions

- Regular expressions are used in many tools and applications for pattern matching *text strings*
- Examples include the well-known Unix™ tools:
  - grep, sed, awk, lex, ed, sam, etc.
  - Google search patterns can also contain regular expressions
- Regular expressions define *finite state automata*
  - the automata accept precisely those text strings that match the regular expression
  - example: "(a+ b+)* | c d+“ defines the finite state automaton (FSA) shown on the right.
    - the FSA *accepts* input if it terminates in an accepting state (indicated by the double circles)



(,), +, *, and | are regular expression meta-symbols)

pattern searches

cobra pattern expressions are defined over *lexical tokens* instead of *text*

```
$ cobra –pat x *.[ch]                                # a very simple ‘pattern’

$ cobra –pat ‘{ .* malloc ^free* }’ *.c        # don’t-cares, negation, repetition
```

cobra guarantees that in all these patterns
the nesting level of all brace pairs matches

```
$ cobra –pat ‘{ .* [static STATIC] .* }’ *.c       # choice

$ cobra –pat ‘{ .* @type x:@ident ^:x* }’ *.c      # types and name-binding

$ cobra –pat ‘x:@ident -> .* if ( :x  /=  NULL )’ *.c   # /regex embedded
```

without spaces:
this matches a single token

think about this one….
to match the *token* /= write: \/=

pattern searches

matching for-loops not followed by a compound statement

```
$ cobra -pat `for ( .* ) ^{`  *.c                     # first try
  5814    for (n = v_names[ix]; n; lastn = n, n = n->nxt) // mk_var
  5815    {       if (n->h2 > h2)

$ cobra -pat `for ( .* ) ^[{ @cmnt]*' *.c             # second try
  2834    for (i = 0; i < Ncore; i++)
  2835    for (n = a_tbl[i].n[h1]; n; n = n->nxt) // sum_array

$ cobra -pat `for ( .* ) ^[{ @cmnt for switch if]*' *.c  # third try
   793    for (yylen = 0; yystr[yylen]; yylen++)
   794      continue;
```

pattern searches

adding preprocessing with -cpp

```
$ cobra –cpp -pat 'for ( .* ) ^{' *.c
```

pattern searches

adding preprocessing with -cpp

```
$ cobra –cpp -pat 'for ( .* ) ^{' *.c
cobra_ctok.c:
  1:   2483   for ( i = 0; i < nr; ++i )
  2:   2484          *(dst++) = *(src++);

  3:   2538   YY_INPUT((& ... ), ...        ?
...
```

pattern searches

adding preprocessing with -cpp

```
$ cobra –cpp -pat 'for ( .* ) ^{' *.c
cobra_ctok.c:
  1:   2483   for ( i = 0; i < nr; ++i )
  2:   2484        *(dst++) = *(src++);

  3:   2538   YY_INPUT((& ... ), ...
...
```

```
…
for (n=0; n < max_size && \
   (c = getc(yyin))!= EOF && c != '\n'; ++n ) \
   buf[n] = (char) c; \
…
```

traditional regular expressions are also supported,

but only rarely useful

note the required spaces to separate tokens

- example

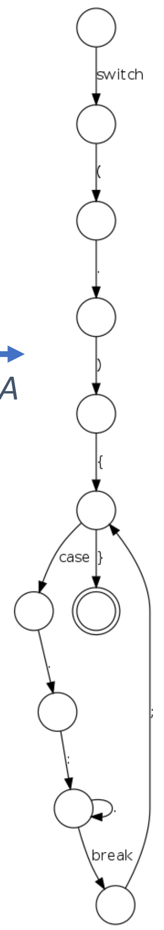
  $ cobra –regex ‘switch \(. \) { (case . : .* break ;)* }’ *.c

  FSA

  (and) are now *meta-symbols* (used for grouping)

  as are +, ?, and |

a plain (or) must now be written \(and \) to distinguish them from the *meta-symbols*



regular expressions vs pattern expressions

the key differences

(and)	grouping
|	choice, e.g. "(a | b)" matches a *or* b
+	one or more repetitions
?	zero or *one* repetition
*	zero or more repetitions
.	match any token
@type	match a particular token class, e.g., @ident
x:@type	bind the variable-name x to a specific token *name*
:x	refer to a previously bound name
[and]	define a set of options, e.g., [a b c] matches one of a b or c

not meta-symbols in pattern expressions

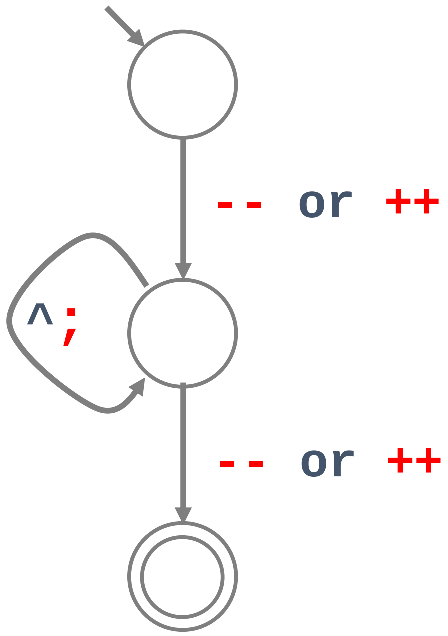
* and]	when *preceded* by a space is a regular symbol
[	when *followed* by a space is a regular symbol
/re	match token if the *token-text* matches re

in pattern expressions

pattern searches

find multiple side-effects without a *sequence point* in between

```
$ cobra -pat '[-- ++] ^;* [-- ++]' *.c
   sml_dsa.c:
    16: 212  for (; k >=0; k--) {
    17: 213    lA1 = (ulong) (*p++)*(*q--);
    18: 230  for (; j < len; j++) {
    19: 231    lA1 = (ulong) (*p++)*(*q--);
```



pattern searches

interactive use of pattern queries

$ cobra –N8 \`cat thousands_of_filenames\` # e.g., linux-4.3

```
8 cores 39133 files 84,111,645 tokens
: # if/else/if chains must end with else
: pat else if ( .* ) { .* } ^else
```

matched braces

```
: # every non-void fct must have a return stmnt
: pat ^void @ident ( .* ) { ^return* }
```

no quotes around the pattern are required but now a “;” token match must be protected with “\;” to prevent interpretation as a query-command separator

pattern searches

interactive use of pattern queries

```
:  # check the sanity of for-statements
: pat for ( .* \; .* [< <=] .* ; .* ^[++ +=] )
   memtest.c: 108:  # linux-4.3
        for (i = memtest_pattern-1; i < UINT_MAX; --i) {
   timeconv.c:120
        for (y = 11; days < ip[y]; y--)

:  # or with regular expressions on token texts
: pat for ( .* /^< .* /^-[-=]$ .* )
```

pattern searches

using name binding

find assignments to the control variable of a for-loop, inside the loop body

```
$ cobra –pat “for ( x:@ident .* ) { .* :x = .* }” *.c
```

matching braces *matching braces*

find local variable declarations that aren’t used in the function body

```
$ cobra –pat “) { .* @type x:ident ^:x* }” *.c
```

to avoid matching on structure declarations

note: *all* individual *tokens* in the pattern must be separated by *spaces*

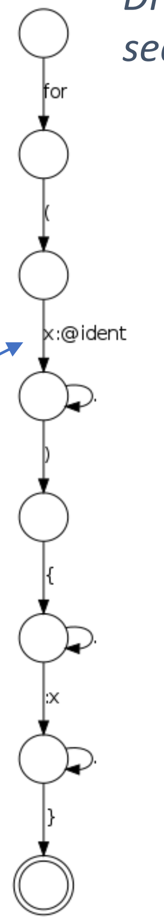
pattern searches

find uses of the control variable of a for-statement inside the body of the loop, using variable binding

Cobra converts the pattern into an NDFA, converts that into a minimized DFA, and uses that to performs the search

```
$ cobra *.c
: pat  for ( x:@ident .* ) { .* :x .* }
  program.c:
    1:    37    for (i = 0; i < 10; i++)
    2:    38    {      i++;
    3:    39    }
    4:    48    for (i = 0; i < 10; i++)
    5:    49    {      stmnt6();
    6:    50           i = 12;
    7:    51    }
```

name binding & reference



pattern searches

the matching algorithm

Regular Expression Matching Can Be Simple And Fast
(but is slow in Java, Perl, PHP, Python, Ruby, ...)

Russ Cox
rsc@swtch.com
January 2007

Introduction

This is a tale of two approaches to regular expression matching. One of them is in widespread use in the standard interpreters for many languages, including Perl. The other is used only in a few places, notably most implementations of awk and grep. The two approaches have wildly different performance characteristics:

Time to match $a?^n a^n$ against a^n

pattern searches

the matching algorithm

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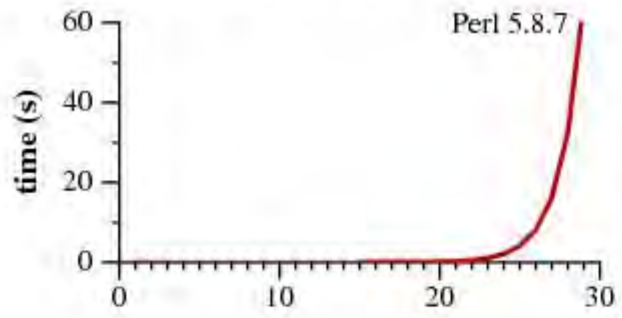

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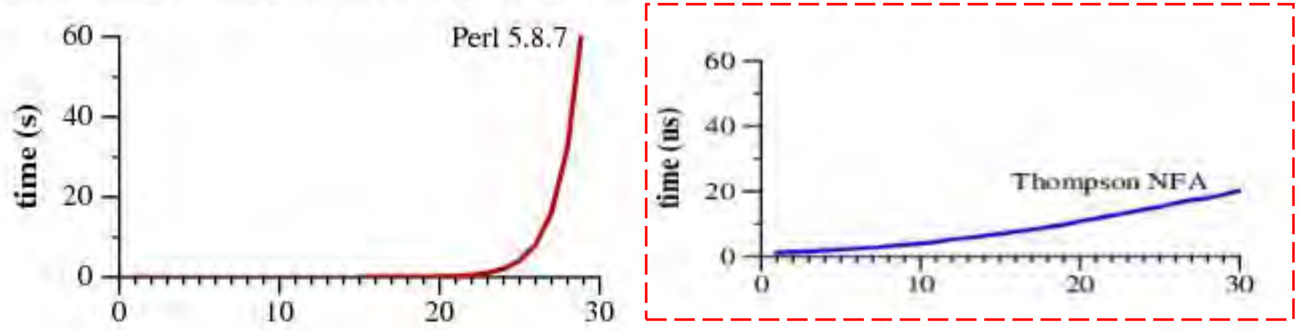


Time to match $a?^n a^n$ against a^n

pattern searches

thompson’s algorithm

pattern searches

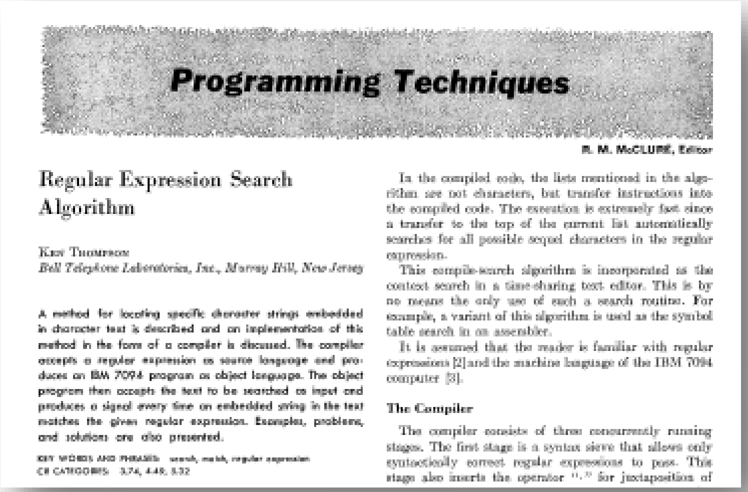
thompson’s algorithm

example: find expressions with multiple side-effects

$ cobra -pat “[-- ++] ^;* [-- ++]” *.c

sml_dsa.c:

213   lA1 = (ulong) (*p++)*(*q--);



Programming Techniques

R. M. McCLURE, Editor

Regular Expression Search Algorithm

Ken Thompson
Bell Telephone Laboratories, Inc., Murray Hill, New Jersey

A method for locating specific character strings embedded in character text is described and an implementation of this method in the form of a compiler is discussed. The compiler accepts a regular expression as source language and produces an IBM 7094 program as object language. The object program then accepts the text to be searched as input and produces a signal every time an embedded string in the text matches the given regular expression. Examples, problems, and solutions are also presented.

KEY WORDS AND PHRASES: search, match, regular expression
CR CATEGORIES: 3.74, 4.49, 5.32

In the compiled code, the lists mentioned in the algorithm are not characters, but transfer instructions into the compiled code. The execution is extremely fast since a transfer to the top of the current list automatically searches for all possible sequel characters in the regular expression.

This compile-search algorithm is incorporated as the context search in a time-sharing text editor. This is by no means the only use of such a search routine. For example, a variant of this algorithm is used as the symbol table search in an assembler.

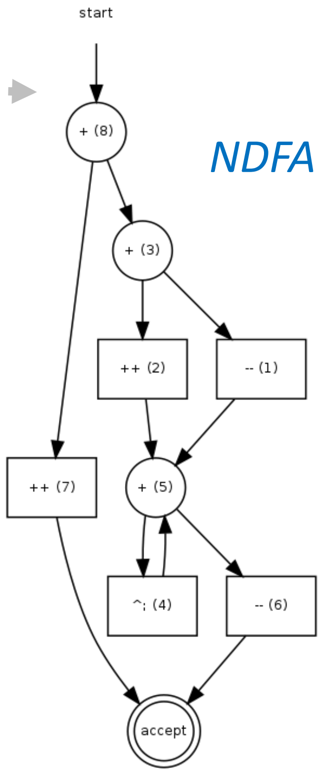
It is assumed that the reader is familiar with regular expressions [2] and the machine language of the IBM 7094 computer [3].

The Compiler

The compiler consists of three concurrently running stages. The first stage is a syntax sieve that allows only syntactically correct regular expressions to pass. This stage also inserts the operator “·” for juxtaposition of

(CACM 11:6 1968)

NDFA



$ cobra –view –pat ‘…’ *.c

(requires graphviz and x11)

pattern searches

examples and some exercises with pattern searches

```
: pat @type /restore ( .* ) { .* = false .* }              # find function names containing "restore"

: pat x:@ident += snprintf ( ^,* :x .* /%s .* )            # using result of snprintf in first arg

: pat /define @ident ( x:@ident ) ^[EOL (]* :x             # macro args must be enclosed in braces
```

exercises:

```
: pat                                                      # there can be no _ in a typedef names

: pat                                                      # typedefs for ptrs must have a _ptr suffix
                          ?
: pat                                                      # no ptr derefencing preceding a NULL check

: pat                                                      # body of if statement not enclosed in { … }
```

the query command language

the query language

overview

there are about 40 query commands predefined,
though 4 or 5 suffice for handling most queries.
they can be used for:

A. Setting, Moving, or Removing Marks
B. Setting Ranges
C. Output
D. Meta Commands
E. Defining Sets of Marks

examples:

- A: mark, next, back, jump, contains, extend, undo, reset
- B: stretch
- C: display, list, pre, =, help
- D: history (h), browse (B), files (F), system (!), cfg, fcg, fcts
- E: save (>), restore (<)

try:
 $ cobra –c help < /dev/null
and note that the output is different from:
 $ cobra -help

the query language

an example of an interactive session: find switch statements without a default clause

```
$ cobra *.[ch]          # start an interactive session on the cobra 3.0 sources
1 core, 13 files, 58381 tokens
: mark switch (         # mark all switch statements
29 matches
: next {                # move mark to the start of the body
29 matches
: contains no default # check the range from { to }, no is a qualifier
6 matches
: display 2 +8          # display the 2nd match with 8 lines after it
cobra_lib.c:538:
  2: >  538   {     switch (*s) {
  2:    539           case '&':
  2:    540           case '|':
  2:    541           case '^':
  2:    542                 tmp = t;
  2:    543                 t = s;
  2:    544                 s = tmp;
  2:    545                 break;
  2:    546   }       }
: quit
$
```

the query language

shorthands

instead of writing:

```
: mark switch (
: next {
: contains no default
: display
```

we can also use shorthands:

```
: m switch (
: n {
: c no default
: d
```

and we can combine commands on a single line:

```
: m switch (; n {; c no default; d
```

or execute everything from *the command line*:

```
$ cobra –c ‘m switch (; n {; c no default; d’ *.c
```

m[ark]	defines a set of matches
n[ext]	moves all current marks forward
d[isplay]	displays the current marks
c[contains]	checks a token range
{ … }	defines a token range, as do:
[…]	
(…)	

the query language

command-line use

$ cobra –c “m switch (; n {; c top no default; d” *.[ch]

```
          switch (f->n->ntyp) {
          case UNLESS:
                    attach_escape(f->sub->this, e);
                    break;
          case IF:
          case DO:
                    for (z = f->sub; z; z = z->nxt)
                              attach_escape(z->this, e);
                    break;
          case D_STEP:
                    /* attach only to the guard stmnt */
                    escape_el(f->n->sl->this->frst, e);
                    break;
          case ATOMIC:
          case NON_ATOMIC:
                    /* attach to all stmnts */
                    attach_escape(f->n->sl->this, e);
                    break;
          }
```

$

another query *qualifier* to restrict the check to the *top level* of nesting

# with a –runtimes flag (and without the ‘d’):
$ cobra -runtimes -c 'm switch; n {; c top no default' *.c
(0.0404 sec)
(0.00338 sec)
(0.000523 sec)
(0.000344 sec)
(0.0005 sec)
$

the query language

the stretch command

we've already covered *five* commands: mark, next, contains, display, and quit
three other useful commands are stretch, list, and pre:

```
$ cobra *.c
1 core, 10 files, 56450 tokens
: mark for (                # mark all for statements
206 matches
: next \;                   # move mark to the first ; after for
206 matches
: stretch \;                # define a range from here to the next semi-colon
206 matches
: contains ->               # restrict to ranges that contain a -> token
45 matches
: pre 1                     # show the first matched range with pre (or p)
cobra_cfg.c:38<->cobra_cfg.c:38
  1:    38  for ( cur = ( Prim * ) n ; rval && cur && cur -> seq <= n -> jmp -> seq ; cur = cur -> nxt )
  1:                                 ^ ^^^^ ^^ ^^^ ^^ ^^^ ^^ ^^^ ^^ ^ ^^ ^^^ ^^ ^^^ ^
```

try using display (d), or list (l) commands instead of pre (p)

the query language

using command qualifiers

we've used two qualifiers so far: top and no
there are two more: & and ir

- top # restrict to matching at the same nesting level as the mark (contains and stretch)
- no # to find non-matches (mark and contains)
- ir # mark *all* matching tokens inside the current range (mark)
- & # restrict to *marks* that also match a new pattern (mark)
- & # restrict to *ranges* that also match a new pattern, and move the mark to *the first* (contains)

to see how it works, at the end of the last example, type:

: c & seq
: p 1

try instead: m ir seq

note: only the first match is marked

```
cobra_cfg.c:38:
  1:    38  for ( cur = ( Prim * ) n ; rval && cur && cur -> seq <= n -> jmp -> seq ; cur = cur -> nxt )
  1:                                                        ^^^
```

the query language

find if-else-if chains not ending with 'else' (another MISRA rule violation)

we earlier expressed this with a search pattern: else if (.*) { .* } ^else

we can also do it with a sequence of query commands

```
$ cobra *.c
: mark else if
40 matches
: next (
40 matches
: jump                  # to the other end of the range
40 matches
: next
40 matches
: mark & {              # restrict the set of matches
33 matches
: jump
33 matches
: next
33 matches
: mark no else
11 matches
: display 1 -5
```

try: adding d[isplay] or l[ist] commands to see which tokens are matched at different steps, e.g., list 1 2

```
cobra_fcg.c:151:
 1:    146                 }
 1:    147          } else if (r->curly > 0)
 1:    148          {      continue;
 1:    149          }
 1:    150
 1: >  151           ptr = r;
```

the one-line version:

: m else if; n (; j; n; m & {; j; n; m no else; d 1 -5

exercises

the query language

exercises

1: find global variables with fewer than 3 characters
2: find loops that contain gotos but no labels
3: find recursive functions
4: find goto statements immediately followed by the label

.range	# nr of lines in a range
.fnm	# source filename (a string)
.lnr	# source line-number
.curly	# level of {…} nesting
.round	# level of (…) nesting
.bracket	# level of […] nesting
.len	# length of token text
.typ	# token type (a string)
.txt	# token text (a string)
.seq	# token sequence number
.mark	# marked value

answer 1

answer 2

answer 3

answer 4

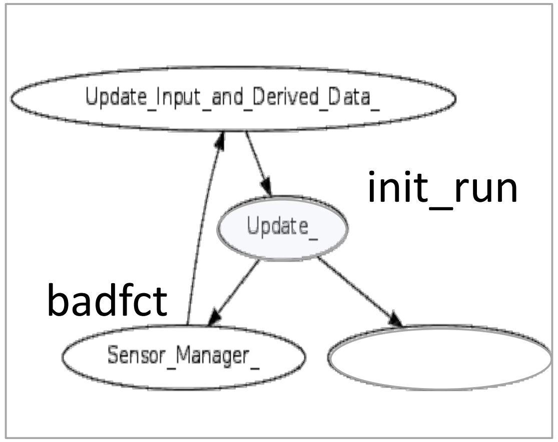
day 2

the query language

using sets

is there memory allocation ever used after system initialization in C++ code?

```
$ cobra –C++ *.cpp
: fcts                  # mark all fct names
: next {                # move to fct body
: contains new          # restrict to these
: back (                # back to fct parameter list
: back                  # back to fct name
: >1                    # store these names in set 1
: reset                 # clear all marks
: fcg init_run *        # mark all fcts reachable from init_run
: <&1                   # check intersection with set 1
: fcg init_run badfct   # show call graph connecting init_run and badfct
```



the query language

operations on sets, and the use of set qualifiers

>n # save all current marks and ranges in set n

<n # restore current marks and ranges from set n
<|n # add marks from set n to current (set union)
<&n # keep only marks also in set n(set intersection)
<^n # keep only marks not in set n (set difference)

where n is 1..3

two additional sets are used internally for
storing the current and the previous set of marks
(allowing a fast ‘undo’ on most operations)

the query language

stretch and extend

the *stretch* command can refer to the current token name as $$

example, MISRA 2012 rule 2.7: *there should be no unused parameters in function declarations*

```
$ cobra –cpp *.c      # preprocessed cobra sources
1 core, 10 files, 56450 tokens
: fcts                # mark all function definitions (at the names)
: n (                 # move mark to start of parameter list
: m ir @ident         # mark all identifiers in the list (c & @ident would just mark the first)
: e /^[,)]$           # retain only those marks that are followed by , or ) (the extend command)
: >1                  # store these names in set 1
: s $$                # try to stretch each marked identifier to the next occurrence
: >2                  # store the names for which this succeeds in set 2
: <1                  # recover set 1
: <^2                 # omit all the ones also stored in set 2
4 matches
: = “misra r2.7: there should be no unused parameters:”
: d
```

pattern searches

extend and stretch: find unused parameters

```
4 matches
: d
cobra_heap.c:313:
  1:    313  stop_timer(int cid, int always, const char *s)?
cobra_lib.c:2900:
  2:   2900  history(char *unused1, char *unused2)
  3:   3209  cleanup(int unused)
: d 1 +30
cobra_heap.c:313:
  1: >  313  stop_timer(int cid, int always, const char *s)
  1:      ...
  1:    326  #if 0
  1:    327      if (always
  1:    328      ||  delta_time[cid] > 0.1)
  1:    329  #endif
  1:    330      {  if (Ncore > 1)
  1:    331         {       printf("%d: ", cid);
  1:    332         }
  1:    ...
```

the query language

defining named functions, with parameters

```
: def p10_rule4(rn, nr)
	fcts			# mark function names
	n {			# move to fct body
	m & (.range > nr)	# restrict to fcts longer than nr lines
	b
	= "=== rn: functions exceeding 75 physical source lines:"
	d
end
: p10_rule4(R4, 75)
```

.range is a predefined token attribute

other token attributes that can be referenced:

```
.fnm      # source filename (a string)
.lnr      # source line-number
.curly    # level of {…} nesting
.round    # level of (…) nesting
.bracket  # level of […] nesting
.len      # length of token text
.typ      # token type (a string)
.txt      # token text (a string)
.seq      # token sequence number
.mark     # marked value
```

the query language

refining pattern matches using .mark

using the .mark token attribute
we can also conveniently refine *pattern* searches

by default all tokens in a matched pattern are marked with 1
there are two special cases:

- the first token in each pattern is marked with value 2
- any bound variables in the pattern is marked with value 3

```
$ cobra *.c
: pat for ( x:@ident .* ) { .* :x = .* }
bound variables matched:
      1: cobra_te.c:1579: q_now
      2: cobra_te.c:1358: m
      3: cobra_te.c:881: b
      4: cobra_sym.c:105: r
      5: cobra_sym.c:51: r
      6: cobra_prep.c:339: c
      7: cobra_lib.c:2492: r
      8: cobra_lib.c:2122: z
      9: cobra_lib.c:1202: s
      10: cobra_lib.c:782: r
      11: cobra_fcg.c:156: r
      12: cobra_cfg.c:171: cur
      13: cobra_cfg.c:67: cur
13 patterns matched
3929 matches
: m & (.mark == 2)
12 matches
: undo
: m & (.mark == 3)
14 matches
```

the query language

reading commands or definitions from files

- for instance, to read a query function from the “play” library use the dot command **.** :

  $ cobra *.c
  : **.** play/declarations.cobra

- we can do the same from the command line:

  $ cobra –f play/declarations.cobra *.c

- cobra query files stored in rules/main can be read without the directory prefix
- try, for instance:

  $ cobra -terse –f basic *.c
  $ cobra –terse –f stats *.c
  $ cobra –terse –f metric *.c
  $ cobra –terse –f cwe *.c

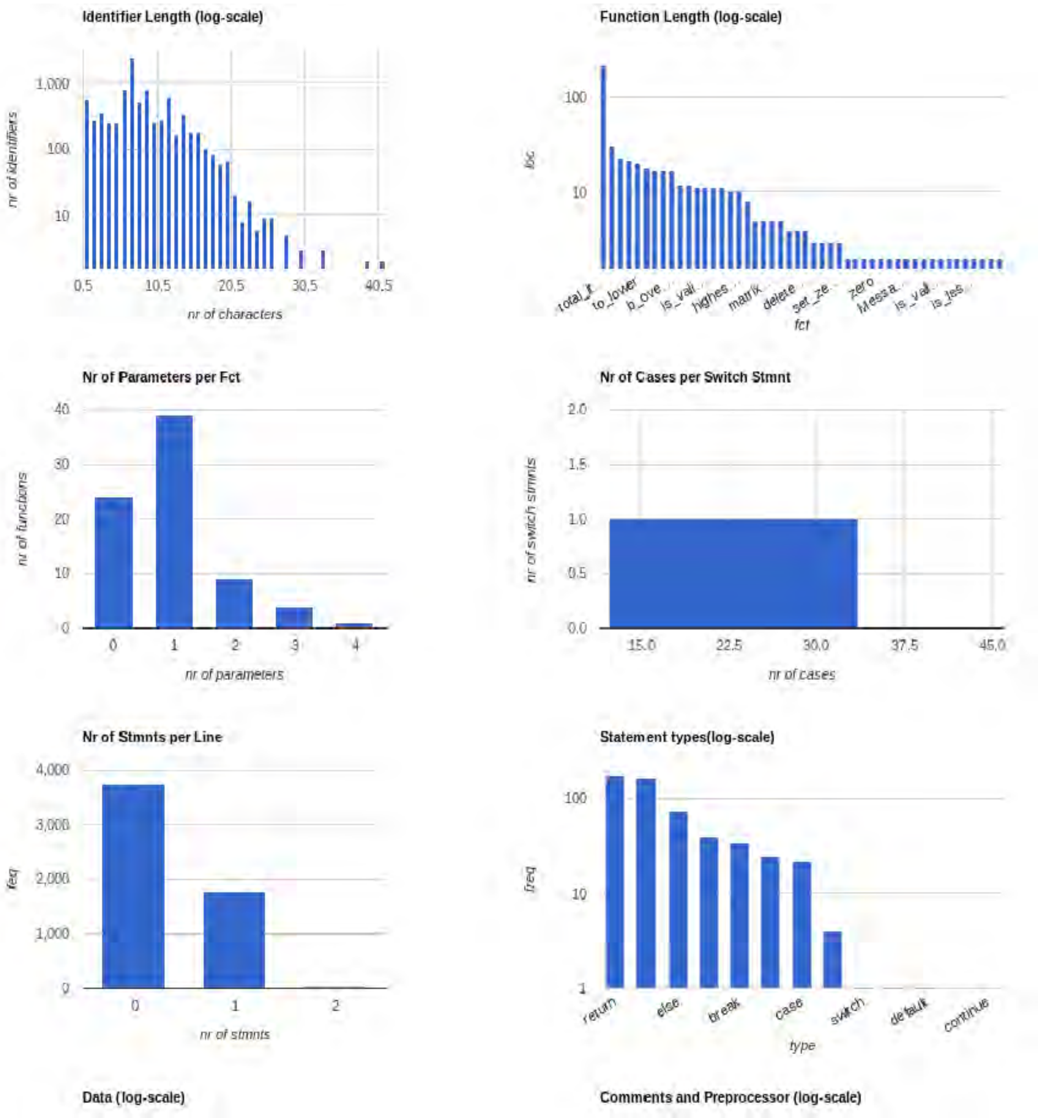
the query language

generating stats: e.g., tabulate the length of switch statements

```
$ cobra –c ‘m switch; n {; = (.range)’ *.c | sort –k3 -n
cobra_prog.c:999        value 3
cobra_eval.c:1125       value 4
...
cobra_lib.c:1030        value 200
cobra_prog.c:1688       value 437
cobra_ctok.c:1361       value 1076
```

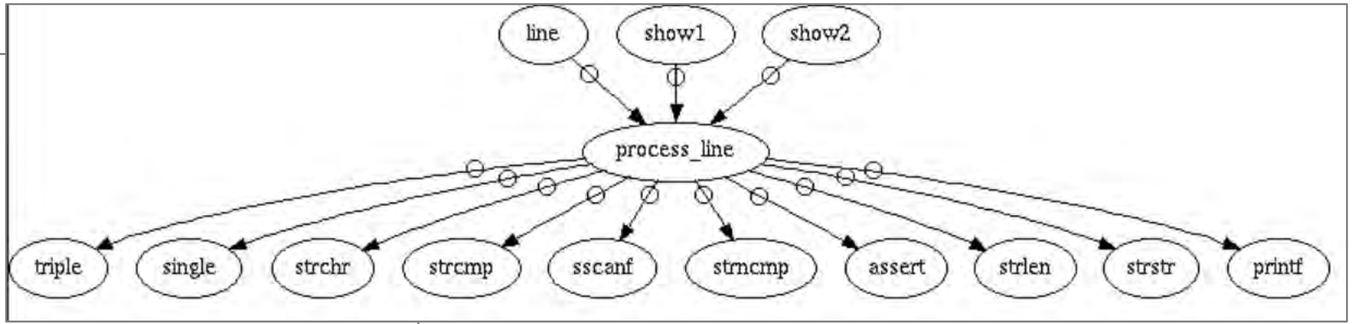
the query language

you can now input these data to google graphs to create dash-boards plotting quality metrics of a code base



the query language

computing the function call context (requires graphviz/dot)

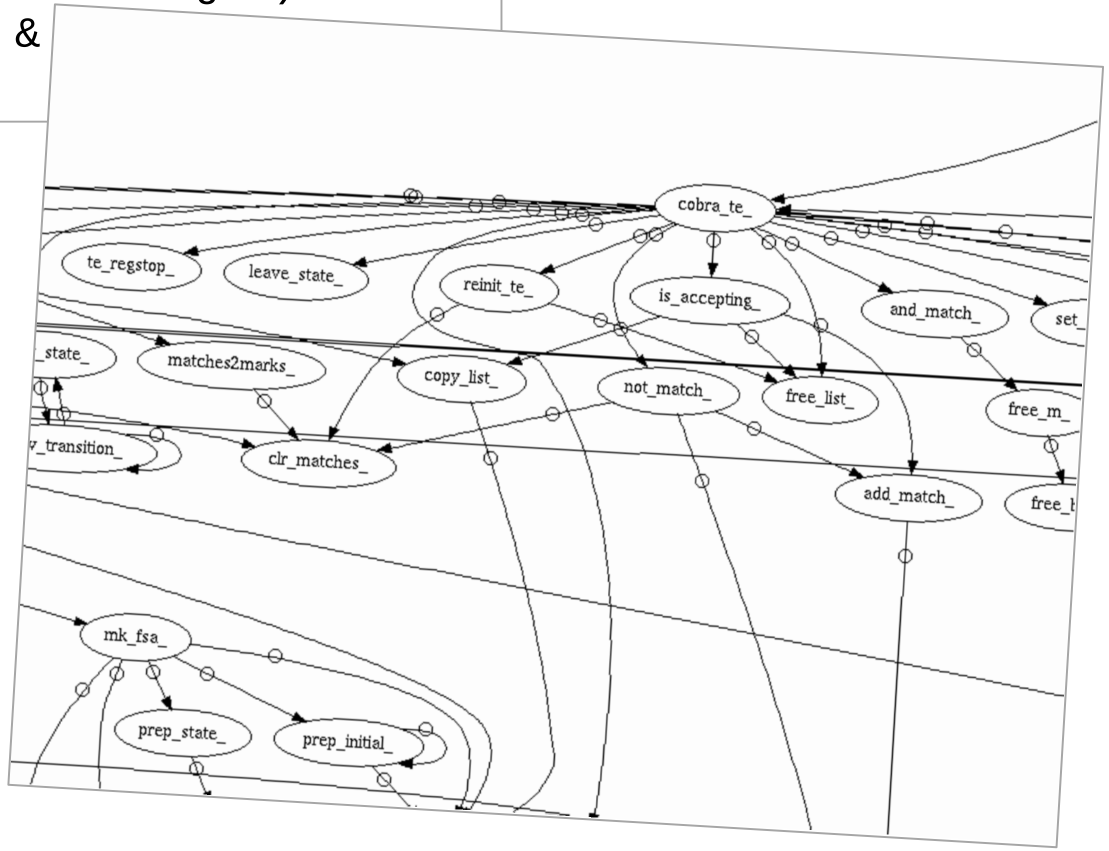



```
$ cobra *.c
1 core, 10 files, 56546 tokens
: context process_line
cobra_prim.c:626-673
calls:
        cobra_prim.c:671: triple()
        cobra_prim.c:669: single()
        cobra_prim.c:662: strchr()
        cobra_prim.c:649: strcmp()
        cobra_prim.c:647: sscanf()
        cobra_prim.c:646: strncmp()
        cobra_prim.c:644: assert()
        cobra_prim.c:640: strlen()
        cobra_prim.c:638: strstr()
        cobra_prim.c:631: printf()
is called by:
        cobra_lex.c:809: line()
        cobra_lex.c:279: show1()
        cobra_lex.c:288: show2()
:
```

the query language

or full or partial function call graphs (requires graphviz/dot)

```
$ cobra *.c
1 core, 10 files, 56546 tokens
: fcg
wrote: /tmp/cobra_dot_Sf8RAv (269 nodes, 499 edges)
view with: !dotty /tmp/cobra_dot_Sf8RAv &
: !dotty /tmp/cobra_dot_Sf8RAv &
```



the query language

browsing code

```
: B cobra_te.c 100   # show file starting at line 100
: B                  # browse forward in same file
: B 90               # browse same file from line 90
```

other sometimes useful short-hands:

```
: ff par_scan        # find function definition
: cpp on             # processes the header files
: ft Prim            # find a type definition
```

with tcl/tk installed:

```
: V cobra_te.c 100   # like B, but in a popup window
: window             # enable automatic window popups
: m while            # mark something
: d 1                # now pops up a tcl/tk window with the source text
: : window off       # disable window popups
```

with graphviz (dotty) installed:

```
$ cobra –view –pat "…." *.c    # pop up graph showing FSA for the pattern
```

the query language

defining new token categories: map

```
$ cat prepositions.map          # map token text to new user-defined token types
of        preposition
to        preposition
in        preposition
for       preposition
on        preposition
with      preposition
by        preposition
but       preposition
at        preposition
from      preposition
about     preposition
like      preposition
into      preposition
...
```

```
$ cobra *.txt          # some random English prose
: map prepositions.map
: m @preposition .
: = “a sentence should not end with a preposition:”
: d
```

the query language

now we're getting into the woods:
track_start, track_stop, and shell escapes

```
$ cobra *.[ch]
1 core, 15 files, 90063 tokens
: m while
127 matches
: track start file1   # redirect output
: list
: track stop          # end redirection
: !wc file1           # shell escape
: q
$
```

the query language

so does it scale?

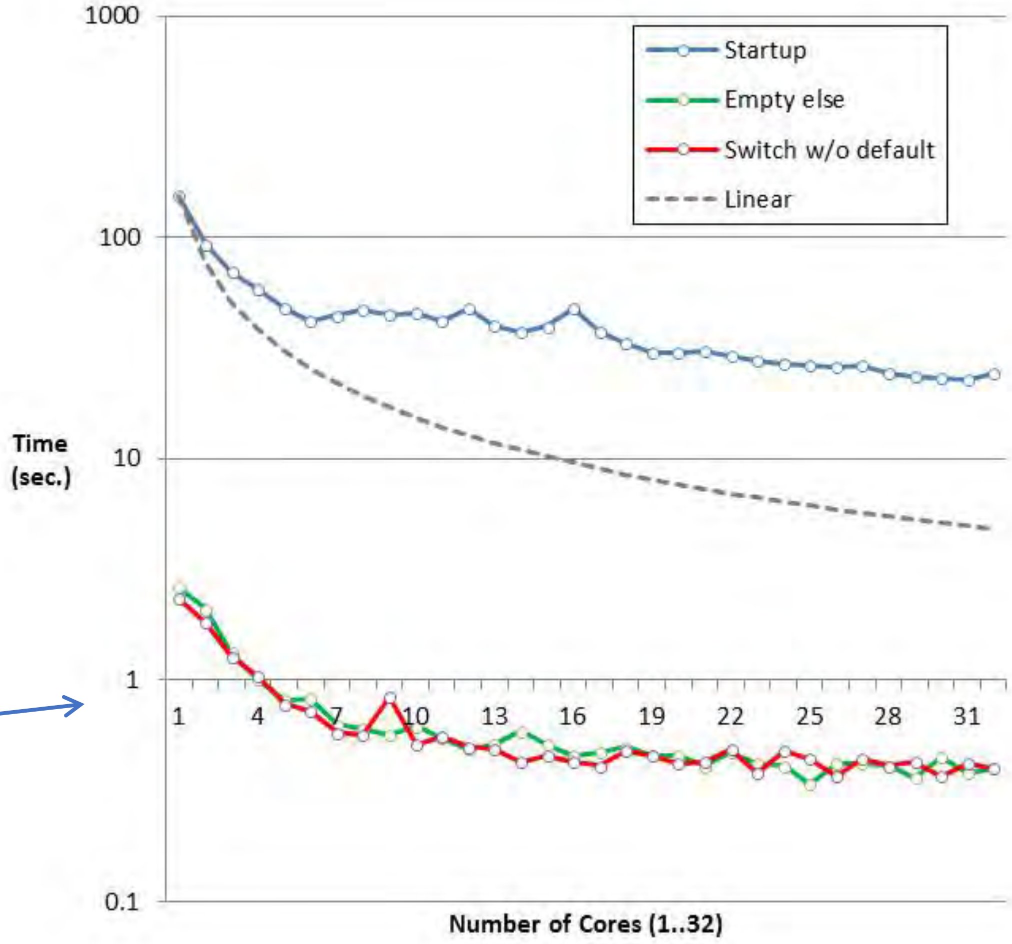
18,633,817 Lines of Code of the Linux 4.3 distribution, with 39,144 .c and .h files

checking 2 types of queries:

- find empty else stmnts
- find all switch stmnts without default clause

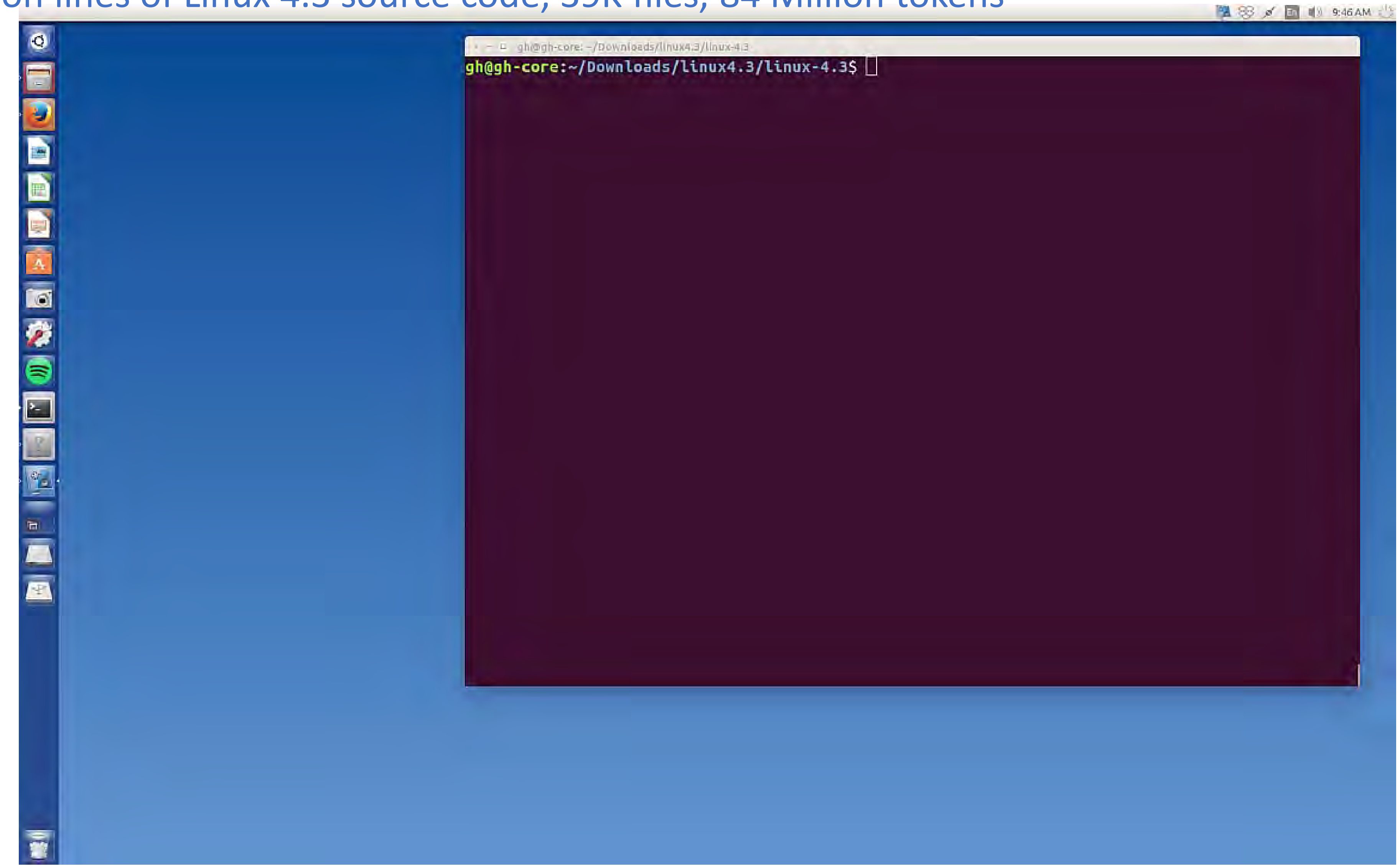
using 1..32 CPU cores

with 4 or more cores we get interactive query processing times < 1 sec.



cobra performance

18.6 Million lines of Linux 4.3 source code, 39K files, 84 Million tokens



inline scripting language

cobra inline programs

the scripting language

An inline program is enclosed in delimiters:

```
%{
    …
%}
```

which can be used like any other query command, e.g. in a query function:

```
def prog1
    %{
        …
    %}
end
```

and invoked by name:

```
: prog1
```

If stored in a file, these scripts can be invoked from the command line as well:

```
$ cobra –f file.cobra *.[ch]
```

Simple example:

```
$ cat file.cobra
%{
    print .fnm “:” .lnr “: “ .txt “\n”;
%}
```

which prints the text of all tokens, each preceded by filename and linenumber

cobra inline programs

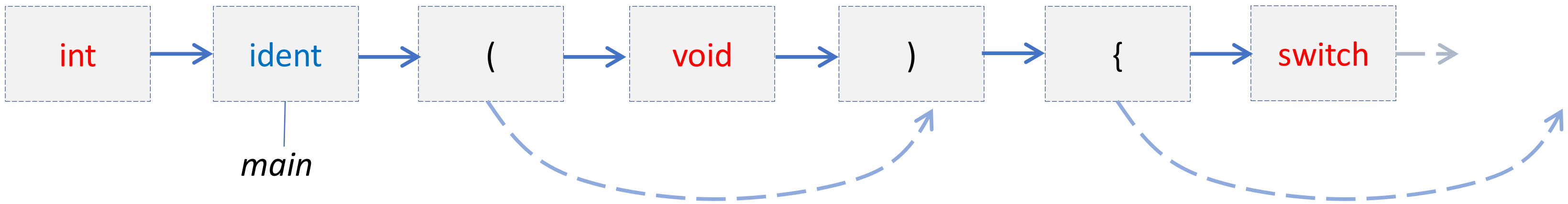
the scripting language

the main control-loop:

cobra inline programs are, like all other query commands, executed once for each token in the input sequence

but a cobra program can also take over control and navigate the token sequence in any way it wants

it can refer to any token attribute



cobra inline programs

keywords

control flow :

- if
- else
- while
- break
- continue
- goto
- for
- in
- return
- Next
- Stop

token references:

- Begin
- End
- .

example predefined functions:

- print
- assert()

user-defined functions:

```
function name (...) { ... }
```

a fairly standard grammar:

```
if (expr) { stmnt;+ } [ else { stmnt;+ } ]
while (expr) { stmnt;+ }
for (var in array) { stmnt;+ }
L:  goto L;
q = .;
array[expr] = expr;
```

variables:

can be introduced without declaration
the type is inferred from context, and
may change dynamically

cobra inline programs

two very simple examples, using print

```
%{
    print .fnm ":" .lnr ": " .txt "\n";
%}
```

```
%{
    print "hello world\n";
    Stop;    # no need to repeat this for every token…
%}
```

cobra inline programs

token attributes that can be referred to and modified

the *current* token is always referred to as dot: .   http://spinroot.com/cobra/commands/tokens.html

integer values:
- .round
- .bracket
- .curly
- .len
- .lnr
- .mark
- .seq
- .range

string values:
- .fct
- .fnm
- .txt
- .typ

token positions:
- .
- .nxt
- .prv
- .jmp
- .bound

reference rule:

token attributes can only be referenced directly, so instead of writing:

```
q = .nxt.jmp;
```

you have to split this in two steps:

```
q = .nxt;  q = q.jmp;
```

example-1 (using a variable q):

```
q = .nxt;
q.mark++;
q.fnm = “hello”;
q = q.prv;
```

example-2:

```
if (.txt == “{“)
{       q = .jmp;
        assert(q.seq  != 0);
        r = q.jmp;
        assert(r == .);
}
```

cobra inline programs

operators that can be used in expressions

binary operators:

+, -, *, /, %	arithmetic (integer operands)
>, <. <=, >=, ==, !=, ||, &&	Boolean (operands can be any type)

unary operators

!	Boolean, logical negation	
-	arithmetic, unary minus	
~	true if .txt contains a pattern	if (~yy) { … }
^	true if .txt starts with a pattern	if (^yy) { … }
#	true if .txt equals a pattern	if (#yy) { … }
@	true if .typ equals a pattern	if (@ident) { … }

regular expression matching of any token text:

match(s1, s2) true if s1 matches s2, where s2 can be a regex

if (match(q.txt, "/[Yy][Yy]")) { … }

comments: # when followed by another # or a space

cobra inline programs

associative arrays (“hash-maps”)

name [expr [, expr]*]	associates a (possible sequence of) values, or any type with another value, of any type (a “map”)

predefined functions for associative arrays:

retrieve(A, n)	retrieves the nth element of associative array A
size(A)	returns the number of elements stored in array A
unset A[v]	remove associative array element A[v]
unset A	remove variable or array A

cobra inline programs

example 1

find the 10 most frequently occurring trigrams of types

```
%{
    q = .nxt;
    r = q.nxt;
    if (.typ != "" && q.typ != "" && r.typ != "")
    {   Trigram[.typ, q.typ, r.typ]++;
    }
%}
track start _tmp_
%{
    for (i in Trigram)
    {   print i.txt "\t" Trigram[i.txt] "\n";
    }
    Stop;
%}
track stop
!sort -k2 -n < _tmp_ | tail -10; rm -f _tmp_
%{ unset Trigram; Stop; %}
```

```
const_int,oper,ident      157
key,chr,oper              177
oper,const_int,oper       180
oper,oper,ident           181
ident,oper,chr            185
storage,type,ident        263
type,oper,ident           541
ident,oper,const_int      739
oper,ident,oper          2342
ident,oper,ident         4197
```

cobra inline programs

example 2

count the number of cases in
a switch, taking into account that
switch statements may be nested.

```
$ cobra -f nr_cases_all cobra_lib.c | sort -n
    3 cobra_lib.c:173
    3 cobra_lib.c:1993
    3 cobra_lib.c:538
    3 cobra_lib.c:683
    4 cobra_lib.c:3450
    7 cobra_lib.c:3416
    8 cobra_lib.c:1717
    8 cobra_lib.c:583
    16 cobra_lib.c:1597
    27 cobra_lib.c:1546
```

```
 %{
    if (.curly > 0 && #switch)
    { q = .;
      . = .nxt;
      if (.txt != "(" )
      {        . = q;
              Next;
      }
      . = .forw;
      . = .nxt;
      if (.txt != "{")
      {        . = q;
               Next;
      }
      q.mark = 0;
      while (.curly >= q.curly)
      {        if (.curly == q.curly + 1
               &&  (#case || #default))
               {        q.mark++;
               }
               . = .nxt;
      }
      print q.mark " " .fnm ":" q.lnr "\n";
      . = q;
   }
%}
```

cobra inline programs

example 3

```
%{
    if (#float)
    {   . = .nxt;
        if (@ident)
        {       Store[.txt] = .;        # store current location
                print .fnm ":" .lnr ": declaration of '" .txt "'\n";
        }
        Next;
    }
    if (@ident)
    {   q = Store[.txt];
        if (q.seq != 0)
        {       print .fnm ":" .lnr ": use of float '" .txt "' ";
                print "declared at " q.fnm ":" q.lnr "\n";
    }   }
%}
```

cobra inline programs

example 4 – propagating data forward

```
%{      # check the identifier length for all tokens
        # and remember the longest in variable q

        if (@ident && .len > q.len)
        {       q = .;
        }
%}
# q holds its last value
%{
        print q.fnm ":" q.lnr ": " q.txt " = " q.len " chars\n";
        Stop;   # stops after the line is printed
%}
```

```
cobra_links.c:487: switch_links_range = 18 chars
```

cobra inline programs

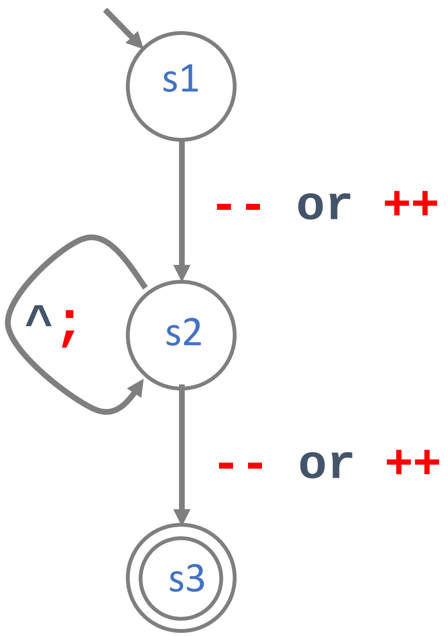
script for matching “[-- ++] ^;* [-- ++]”

in earlier versions of Cobra, the DFA was converted into an inline program (the current version uses the DFA directly)

```
%{
        q = .;
s1:     if (q.txt == "--" || q.txt == "++")
        { q = q.nxt; goto s2;
        } else { Next; }

s2:     if (q.txt == ';') { Next; }
        if (q.txt == "--" || q.txt == "++")
        { q = q.nxt; goto s3;
        } else { q = q.nxt; goto s2; }

s3:     r = .;
        while (r != q) { r.mark++; r = r.nxt; }
        Next;
%}
```



cobra inline programs

script for matching “**for (x:@ident .*) { .* :x .* }**”

```
%{
        q = .;
S0:
        if (q.txt == "for") {
                if (q == q.nxt) { Next; }
                q = q.nxt; goto S1;
        }
        Next;
S1:
        if (q.txt == "(") {
                if (q == q.nxt) { Next; }
                p_lft = q;
                q = q.nxt; goto S2;
        }
        Next;
S2:
        if (q.typ == "ident") {
                if (q == q.nxt) { Next; }
                x = q;
                q = q.nxt; goto S3;
        }
        Next;
S3:
        if (q.txt == ")") {
                if (q == q.nxt) { Next; }
                if (q.round != p_lft.round)
                { q = q.nxt; goto S3; }
                q = q.nxt; goto S4;
        }
        if (q == q.nxt) { Next; }
        q = q.nxt; goto S3;
```

name binding

```
S4:
        if (q.txt == "{") {
                if (q == q.nxt) { Next; }
                c_lft = q;
                q = q.nxt; goto S5;
        }
        Next;
S5:
        if (q.txt == x.txt) {
                if (q == q.nxt) { Next; }
                q = q.nxt; goto S6;
        }
        if (q == q.nxt) { Next; }
        q = q.nxt; goto S5;
S6:
        if (q.txt == "}") {
                if (q == q.nxt) { Next; }
                if (q.curly != c_lft.curly) { q = q.nxt; goto S6; }
                q = q.nxt; goto S7;
        }
        if (q == q.nxt) { Next; }
        q = q.nxt; goto S6;
S7:
        r = .;
        while (r != q)
        {       r.mark = 1;
                r = r.nxt;
        }
        Next;
%}
```

reference to the bound name x

cobra inline programs

recursive functions

```
$ cobra some_file.c
: %{
        function fact(n)
        {  if (n <= 1)
            {      return 1;
            }
            return n*fact(n-1);
        }

        print "10! = " fact(10) "\n";
        Stop;
  %}
10! = 3628800
:
```

remember:
inline programs are by default executed once for every token in the input stream

this has two consequences:

1. there has to be minimally one token to process
2. if something is meant to be executed only once, we need to explicitly Stop the control loop

cobra inline programs

creating new tokens

```
%{
        a = newtok();     # create 3 new empty tokens
        b = newtok();
        c = newtok();

        a.txt = "2";      # assign the .txt fields
        b.txt = "+";
        c.txt = "2";

        a.typ = "oper";   # assign the .typ field

        a.nxt = b;        # connect a to b
        b.nxt = c;        # and b to c
        set_ranges(a, c); # define a range from a to c
        Stop;
%}
%{
        print .txt "\n";  # scan the newly defined range
%}
```

running this program on arbitrary input, prints:

```
2
+
2
```

cobra inline programs

dealing with flow-sensitive properties: uninitialized variable use

```
$ cd Unix/V7/usr/src/cmd
$ cobra –f play/dfs_uninit *.c

...
cat.c:16 declaration of dev
cat.c:50 possible uninitialized use
```

dfs_uninit adds links to capture a basic control-flow graph information for each function (if/else/goto)

and then uses recursive calls to perform a depth-first search over the control-flow graphs to find the suspicious execution paths

```
main(argc, argv)
char **argv;
{
    ...
    int dev, ino = -1;
    struct stat statb;

    setbuf(stdout, stdbuf);
    ...
    statb.st_mode &= S_IFMT;
    if (statb.st_mode!=S_IFCHR && statb.st_mode!=S_IFBLK) {
       dev = statb.st_dev;
       ino = statb.st_ino;
    }
    ...
    while (--argc > 0) {
       ...
       if (statb.st_dev==dev && statb.st_ino==ino) {
          fprintf(stderr, "cat: input %s is output\n",
               fflg?"-": *argv);
          fclose(fi);
          continue;
       }
       ...
    }
```

159 .c files, 30 KLOC, 1 core, 0.8 seconds
5 accurate warnings + 1 false positive

cobra inline programs

dealing with flow-sensitive properties

play/goto_links.cobra
collects goto statements and labels and connects the .bound field of gotos to the corresponding target label

similarly break_links.cobra, else_links.cobra, and switch_links.cobra use the .bound token attribute to set shortcuts, e.g. from case label to case label, or from if to else, etc.

a relevant fragment from else_links.cobra:

```
if (.txt == "if")
{       q = .;
        skip_cond();
        while (.typ == "cmnt")
        {       . = .nxt;
        }
        if (.txt == "{")
        {       . = .jmp;
                . = .nxt;
        } else
        {       skip_stmnt();
        }
        if (.txt == "else")
        {       q.bound = .nxt;
        } else
        {       q.bound = .;
        }
        . = q;
        Next;
}
```

cobra inline programs

using multiple cores – extending the earlier Trigram program

```
: ncore 8          # use 8 cores, or: cobra –N8 *.c
```

```
%{
        q = .nxt;
        r = q.nxt;
        if (.typ != "" && q.typ != "" && r.typ != "")
        {       Trigram[.typ, q.typ, r.typ]++;
        }
%}
track start _tmp_
%{
        if (cpu != 0)
        {       Stop;
        }
        a_unify(0);
        for (i in Trigram)
        {       print i.txt "\t" sum(Trigram[i.txt]) "\n";
        }
        Stop;
%}
track stop
!sort -k2 -n < _tmp_ | tail -10; rm -f _tmp_
```

post-process on cpu 0 only

unify the associative array data from all cores and make it available to cpu 0

sum the collected results

cobra inline programs

concurrency control

```
$ cobra –N4 *.c        # cobra sources
4 cores, 10 files, 56546 tokens
%{
    if (.txt == “for”)  # for is a keyword, so #for doesn’t work here
    {   count++;        # { ... } braces always required
    }
%}
%{
    lock();
    print cpu “: my count = “ count “\n”;
    unlock();
    if (cpu == 0)
    {  print cpu “: total = “ sum(count) “\n”; # only 1 cpu gets here
    }
    Stop;
%}
```

```
0: my count = 54
0: total = 210
1: my count = 50
2: my count = 55
3: my count = 51
```

when multiple cores are used, each core scans part of the input sequence, so Begin and End refer to the local part

when needed, the very first and very last token can be accessed via first_t and last_t

cobra inline programs

concurrency control

when multiple cores are used, each core scans part of the input sequence, so Begin and End refer to the local part

when needed, the very first and very last token can be accessed via first_t and last_t

```
# let cpu 0 scan all tokens backwards
# for no good reason....
$ cobra –N4 *.c
4 cores, 10 files, 56546 tokens
%{
    if (cpu == 0)
    {   . = last_t;                # start at the end
        while (. != first_t)       # to the beginning
        {     .mark = .seq;        # something pointless
              . = .prv;            # backwards
        }
    }
    Stop;
%}
```

building standalone checkers

standalone checkers

linked to the cobra front-end

we can write standalone checkers using the infrastructure that is built by Cobra used as a front-end, to get the full power of C.

the structure of a standalone checker is defined as follows:

```
#include "c_api.h"

typedef struct Names Names;
struct Names {
        char *nm;
        int  cnt;
        Names *nxt;
} *names;

int
newname(char *s)
{
        …
}
```

example checkers of this type are included in the distribution in the src_app subdirectory, including checkers for a range of cwe properties defined multi-threaded

```
void
cobra_main(void)                 // the interface point
{
  for (cur = prim; cur; NEXT)  // main loop over the token sequence
  { if (TYPE("ident"))         // if (strcmp(cur->typ, "ident") == 0)
    { if (verbose)
      { printf("n_%d ", newname(cobra_txt()));
      } else
      {    printf("ident ");
      }
    } else
    {    printf("%s ", cur.txt);
    }
    if (MATCH(";")               // if (strcmp(cur->txt, ";") == 0)
    ||  MATCH("}")
    ||  TYPE("cpp"))
    {       printf("\n");
    }
  }
}
```

standalone checkers

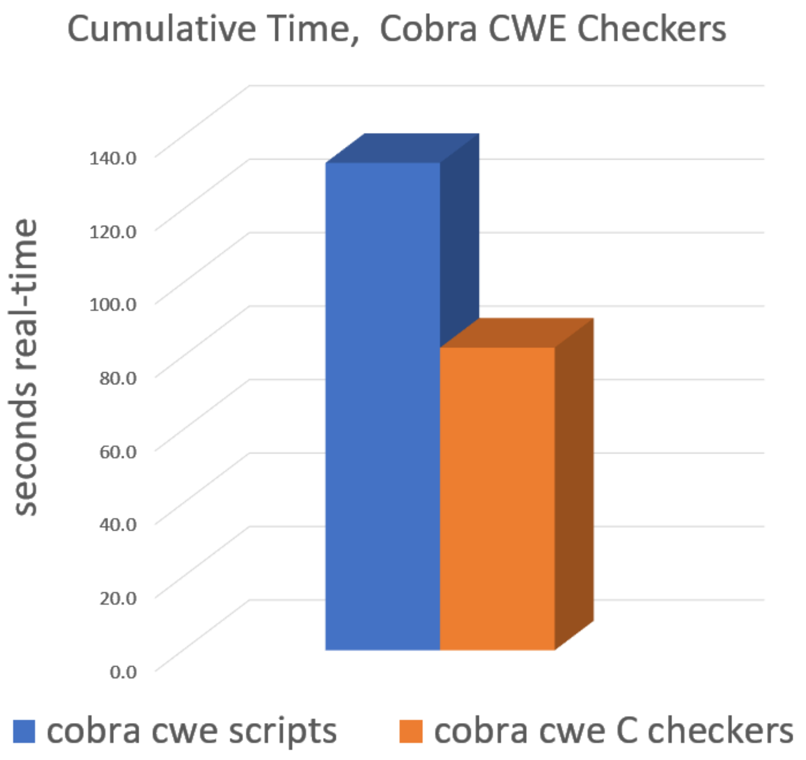
the multi-threaded cwe checkers in $COBRA/src_app
and the precompiled binary in $COBRA/bin_...

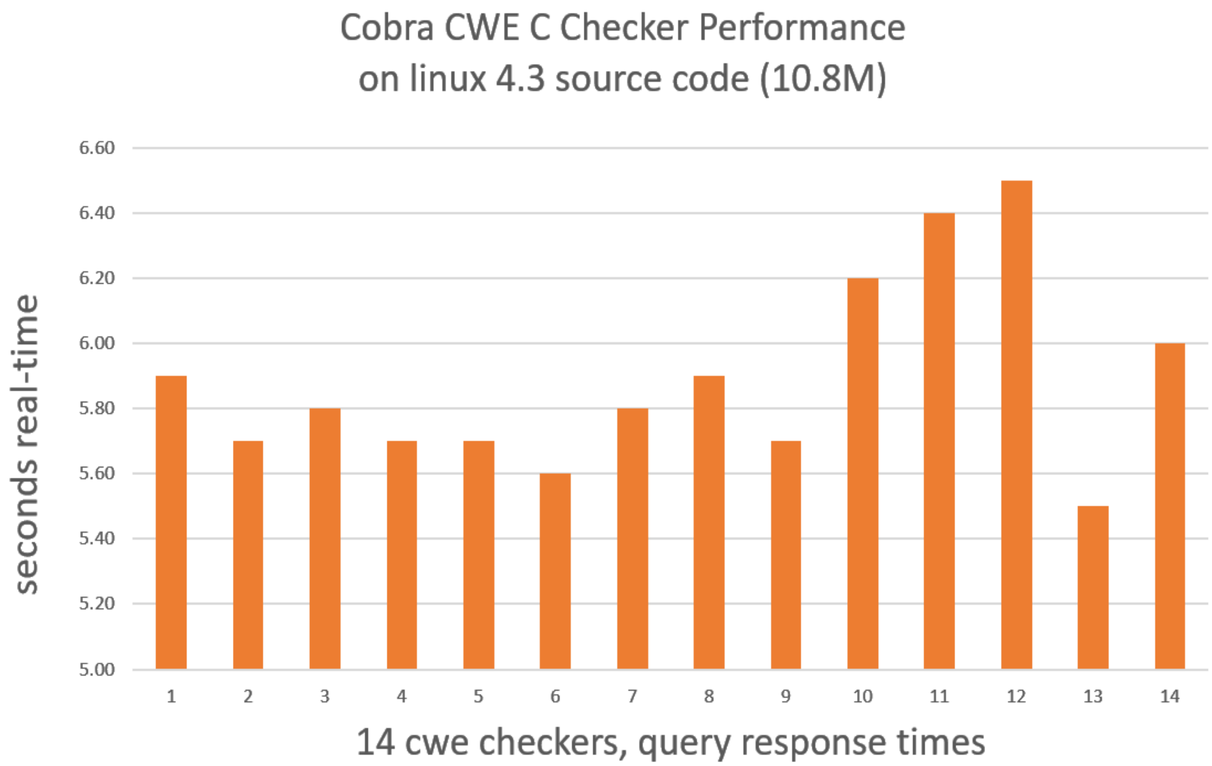
```
$ ls –l src_app/cwe*
-rw-r--r--+ 1 gh None  2587 Nov 29  2018 cwe.c
-rw-r--r--+ 1 gh None  1018 May  6 13:39 cwe.h
-rw-r--r--+ 1 gh None 12089 Apr 26 13:10 cwe_119.c
-rw-r--r--+ 1 gh None  9236 Apr 27 09:20 cwe_120.c
-rw-r--r--+ 1 gh None  5291 Mar 14 13:44 cwe_131.c
-rw-r--r--+ 1 gh None  3450 Apr 27 10:26 cwe_134.c
-rw-r--r--+ 1 gh None  4105 Mar 14 13:44 cwe_170.c
-rw-r--r--+ 1 gh None  6435 Mar 14 13:54 cwe_197.c
-rw-r--r--+ 1 gh None  8216 May  6 13:30 cwe_416.c
-rw-r--r--+ 1 gh None 10934 May  6 13:30 cwe_457.c
-rw-r--r--+ 1 gh None  1467 Mar  8 14:12 cwe_468.c
-rw-r--r--+ 1 gh None  4423 Mar  8 14:53 cwe_805.c
-rw-r--r--+ 1 gh None  6335 May  6 13:35 cwe_util.c
$ ls -l  bin_cygwin/cwe*
-rwxr-xr-x+ 1 USER None 271152 Jun  4 09:21 ../bin_cygwin/cwe.exe
```

for comparison:
the cobra scripted equivalents
for each cwe check are also available
in $COBRA/rules/cwe/...

standalone checkers

performance, compared with scripted checkers on 18.6 MLOC of source code (linux 4.3)





C standalone: response times: 5.5 – 6.5 seconds per CWE check (single core)
Cobra scripted: 1.6x slower
Startup time: ~10 seconds multi-core

thank you!

manual pages, tutorials, papers:
http://www.spinroot.com/cobra

source code, rule libraries, binaries:
https://github.com/nimble-code/Cobra