Prequel: A Patch-Like Query Language for Commit History Search

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Our focus: the Linux kernel

Linux is critical software.

- Used in embedded systems, desktops, servers, etc.

Linux is very large.

- Over 22 000 .c files
- Over 13.6 million lines of C code in Linux 4.4.
- Increase of 44% since July 2011 (Linux 3.0).

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– Maintainers, contributors, developers of proprietary drivers

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Developers need reliable and precise information...

Our first effort: Coccinelle

Goal: Automating evolutions in C code

Find once, fix everywhere.

Approach: Coccinelle: `http://coccinelle.lip6.fr/`

- Static analysis to find patterns in C code.
- Automatic transformation to perform evolutions and fix bugs.
- User scriptable, based on patch notation (semantic patches).

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Approach: Coccinelle: `http://coccinelle.lip6.fr/`

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- Automatic transformation to perform evolutions and fix bugs.
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Goal: Be accessible to C code developers.

Example

Evolution: A new function: kzalloc (Linux 2.6.14)

⟹ Collateral evolution: Merge kmalloc and memset into kzalloc

```
fh = kmalloc(sizeof(struct zoran_fh), GFP_KERNEL);
if (!fh) {
  dprintk(1,
    KERN_ERR
    "%s: zoran_open(): allocation of zoran_fh failed\n",
    ZR_DEVNAME(zr));
  return -ENOMEM;
}
memset(fh, 0, sizeof(struct zoran_fh));
```

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A kmalloc → kzalloc semantic patch

```
@@
expression x, E;
identifier f;
@@

x =
-   kmalloc
+   kzalloc
        (...)
  ...

- memset(x, 0, ...);
```

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  ...  when != (<+...x...+>) = E
       when != f(...,x,...)
- memset(x, 0, ...);
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```

Updates 45 occurrences
(for 20, the allocated and zeroed sizes may differ)

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We can see how the code is today...

... but how did it get that way?

... and what were the alternatives?

Example code development question

We know that kmalloc + memset can be converted to kzalloc.

$\Longrightarrow$ Can it be converted into anything else?

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We know that kmalloc + memset can be converted to kzalloc.
⟹ Can it be converted into anything else?

- `git log -G kmalloc v3.0..v4.4`: 4076 results in 305 sec
- `git log -G memset v3.0..v4.4`: 6913 results in 296 sec
- `git log -S kmalloc v3.0..v4.4`: 3100 results in 212 sec
- `git log -S memset v3.0..v4.4`: 5662 results in 231 sec
- Don't know replacement function, so can't specify a line range for `git log -L` or `git blame`
- Don't know what commit to show.

Prequel idea

Find patches that closely resemble a patch query:

```
@@
expression x;

@@

  x =
-   kmalloc
+   kzalloc
       (...)
  ...
- memset(x, 0, ...);
```

Prequel idea

Or rather...

```
@@
expression x;
identifier f != kzalloc;
@@

  x =
-   kmalloc
+   f
        (...)
  ...
- memset(x, 0, ...);
```

Our proposal

Prequel: Patch Query Language

- Code-like pattern-based query language for describing patched code.
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- Code-like pattern-based query language for describing patched code.
  - Builds on the Coccinelle pattern language (SmPL).
- Approximate querying:
  - − and + lines must match changes.
  - Changes also allowed in matches of context lines.
  - Configurable with constraints on the amount of other changes in the commit.

Implementation strategy

How to match:

```
@@ expression x; identifier f != kzalloc; @@
  x =
-   kmalloc
+   f
      (...)
  ...
- memset(x, 0, ...);
```

against:

```
@@ -418 +418 @@ static void fnic_fcoe_process_vlan_resp(
- vlan = kmalloc(sizeof(*vlan),
+ vlan = kzalloc(sizeof(*vlan),
@@ -426 +426,0 @@ static void fnic_fcoe_process_vlan_resp(
- memset(vlan, 0, sizeof(struct fcoe_vlan));
```

Our solution: Reuse matching features of Ccocinelle

Split the patch query into:

- minus slice: – code and unannotated code.
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Split the patch query into:

- minus slice: - code and unannotated code.
- plus slice: + code and unannotated code.

Minus slice:

```
@@
expression x;

@@
  x =
-   kmalloc

      (...)
  ...
- memset(x, 0, ...);
```

Plus slice:

```
@@
expression x;
identifier f != kzalloc;
@@
  x =

+   f
      (...)
```

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- Match minus slice against complete before files
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Need to synchronize

- `x` should match the same term in before and after code.
- `kmalloc` and `kzalloc` should match tokens in the same hunk.
- Entire `memset` call should be in a hunk.

Generated code (simplified)

```
@r depends on before@
expression x;
position m1,m2,m3;
@@
x = kmalloc@m1(...)
...
memset@m2(x, 0, ...);@m3

@s depends on after@
expression r.x;
identifier f != kzalloc;
position p1;
@@
x = f@p1(...)

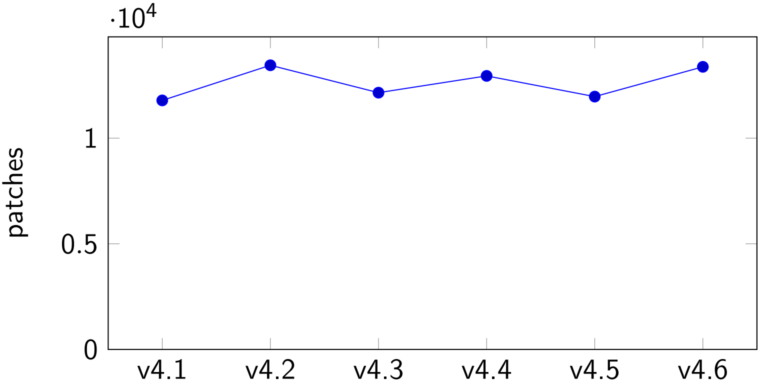
@script:ocaml@
m1 << r.m1; m2 << r.m2; m3 << r.m3; p1 << r.p1;
@@
match in_same_hunk_pair m1 m1 p1 p1 with
  Some hunkinfo1 ->
    (match in_same_hunk m2 m3 with
      Some hunkinfo2 -> output [hunkinfo1;hunkinfo2]
    | _ -> ())
| _ -> ()
```

Results: Linux v3.0..v4.4

Filtering options: –pct 0 –top 20 –all-lines

```
3d04fea: 100%
kcalloc
6d4ef68: 6%
kmalloc
1392402: 4%
rpcrdma_create_req
rpcrdma_create_rep
fe2fc9c: 4%
raw3215_alloc_info
180b138: 3%
kmalloc
10b1e0c: 0%
vmw_fifo_reserve
```

Scalability



Not practical to process all of them...

Filtering

Most patch queries don't need to be applied to all commits.

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       (...)
  ...
- memset(x, 0, ...);
```

Requires:

- Removed `kmalloc`
- Removed `memset`

Filtering

Idea:

- Search for `kmalloc` and `memset` in patches.
  - Much smaller than source files.
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Results:

- 270 selected commits
- 7 results
- $\sim$ 5 minutes

Another example

- `pn544_hci_i2c_probe` acquired an extra argument.
- What should the new value be?

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- What should the new value be?

Using Prequel:

```
@@
expression e;
@@

pn544_hci_probe(...,
+ e,
  ...)
```

What filtering is possible?

Filtering alterative

```
@@
expression e;
@@

pn544_hci_probe(...,
+ e,
  ...)
```

– Changed tokens give no information.

+ `pn544_hci_probe` may be nearby.

+ Patches contain some context code.

Inferred criteria

- Patch must contain some added code.
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Sample result:

```
  r = pn544_hci_probe(phy, &i2c_phy_ops, LLC_SHDLC_NAME,
                      PN544_I2C_FRAME_HEADROOM, PN544_I2C_FRAME_TAILROOM,
-                     PN544_HCI_I2C_LLC_MAX_PAYLOAD, &phy->hdev);
+                     PN544_HCI_I2C_LLC_MAX_PAYLOAD, NULL, &phy->hdev);
```

Inferred criteria

- Patch must contain some added code.
- Patch must contain pn544_hci_probe, in context or changed lines.

Results:

- 7 commits analyzed from Linux 3.0-4.6.
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```

Risk of false negatives.

Another example

- `gpio_chip` structure has no `dev` field.
- How to access the needed information?

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Using Prequel:

```
@@
struct gpio_chip *e;
@@
- e->dev
```

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```

24,707 commits remove dev

Taking into account non-local information

Observations:

- Patch must contain `dev`
- Files may contain `gpio_chip`.

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- Files may contain `gpio_chip`.

Approach:

- Checking files of all patches would be costly.
- Grep for `gpio_chip` in a reference version.
- Check patches that affect those files.

Taking into account non-local information

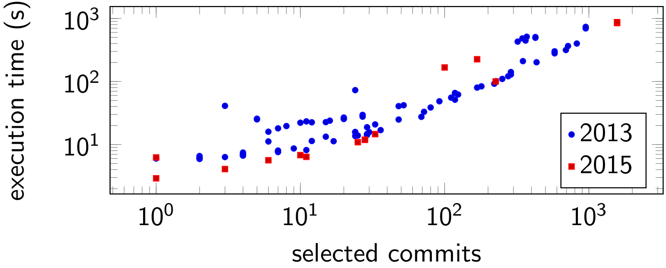
- 428 commits analyzed from Linux 3.0-4.6.
- 17 results.
- $\sim$15 minutes.
- Susceptible to false negatives

Evaluation

Driver porting:

- Dataset: 56 Linux drivers introduced in 2013 or 2015
- Compiled original versions in Linux v4.6 (May 2016)
- 103 patch queries to find commits illustrating fixes for the compiler errors.

Performance:



Comparison with git

	prior commits						prior lines					
	mn		avg		mx		mn		avg		max	
2013	git	prequel	git	prequel	git	prequel	git	prequel	git	prequel	git	prequel
Unknown function	0	0	1.3	1.3	7	8	0	0	163.2	38.1	1421	239
Unknown type	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0	0
Unknown field	3	0	852.7	0.7	2195	10	184	0	146K.1	63.1	411K	756
Unknown variable	0	0	2.6	0.0	6	0	0	0	202.6	0.0	452	0
Arg error	0	0	8.8	1.2	∞	10	0	0	1189.2	117.9	∞	943
Value type change	2	0	46.6	0.0	73	0	178	0	5691.9	0.0	8582	0
Context type change	∞	0	∞	0.1	∞	1	∞	0	∞	3.6	∞	29
2015	git	prequel	git	prequel	git	prequel	git	prequel	git	prequel	git	prequel
Unknown function	0	0	0.5	0.0	2	0	0	0	87.8	0.0	351	0
Unknown field	217	0	996.0	0.6	2243	1	31K	0	143K	15.6	318K	29
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Conclusion

- Pattern language for searching commit histories
  - Patterns include context information.
  - User controls rate of unmatched changes.
- Potential applications:
  - How to modernize old code
  - Finding potentially risky constructions
  - Automated bug fixing
  - Metrics
- Moderately efficient
  - Under 30 seconds in 60% of driver examples.
- Available soon...

Prequel performance by error type.

	Total time (sec.)			Commit selection time			# commits selected			Cocci time per commit		
2013	mn	avg	mx	mn	avg	mx	mn	avg	mx	mn	avg	mx
Unknown function	6	21	66	4	5	8	2	22	118	0	1	11
Unknown type	6	6	6	5	5	5	1	1	1	0	0	0
Unknown field	11	299	736	4	86	292	6	373	951	0	1	2
Unknown variable	7	15	28	4	5	5	4	24	69	0	1	2
Arg error	6	35	316	4	6	24	2	66	693	0	0	1
Value type change	6	30	92	4	6	10	2	43	221	0	1	1
Context type change	49	93	141	7	10	12	92	201	288	0	0	0
2015	mn	avg	mx	mn	avg	mx	mn	avg	mx	mn	avg	mx
Unknown function	4	6	7	2	2	3	1	6	11	0	1	3
Unknown field	100	443	875	4	59	147	100	726	1569	0	0	0
Arg error	3	10	15	2	3	3	1	23	33	0	0	0

mn = min, avg = average, mx = max. Times rounded to the nearest second.