Finding and Fixing Bugs in Systems Code using Coccinelle

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Properties of large, legacy infrastructure software

- Low-level code
- Variable code quality
- May evolve rapidly
- May support many configurations
- Example: The Linux kernel

Problems of large, legacy infrastructure software

Bugs and defects:

- NULL pointer dereferences.
- Memory leaks, double free, use after free.
- Invalid lock management.
- Unreachable code.

Collateral evolutions:

- Changes in client code entailed by changes in API interfaces.
- Change of function name.
- Construction of new function arguments.
- Changes in the required order of operations.

Bug: dereference of a possibly NULL value

```
Author: Mariusz Kozlowski <m.kozlowski@tuxland.pl>

    tun/tap: Fix crashes if open() /dev/net/tun and
    then poll() it.

diff --git a/drivers/net/tun.c b/drivers/net/tun.c
@@ -486,12 +486,14 @@
- struct sock *sk = tun->sk;
+ struct sock *sk;
  unsigned int mask = 0;

  if (!tun)
    return POLLERR;

+ sk = tun->sk;
```

Collateral evolution: Refactoring of an API interface

```
Author: Jan Blunck <jblunck@suse.de>

    d_path: Make seq_path() use a struct path argument

    seq_path() is always called with a dentry and a vfsmount from a
    struct path.  Make seq_path() take it directly as an argument.

diff --git a/drivers/md/md.c b/drivers/md/md.c
@@ -5197,8 +5197,7 @@
-    seq_path(seq, bitmap->file->f_path.mnt,
-             bitmap->file->f_path.dentry," \t\n");
+    seq_path(seq, &bitmap->file->f_path, " \t\n");

diff --git a/mm/swapfile.c b/mm/swapfile.c
@@ -1394,7 +1394,7 @@
-  len = seq_path(swap, file->f_path.mnt, file->f_path.dentry, " \t\n\\");
+  len = seq_path(swap, &file->f_path, " \t\n\\");
```

Our goals

- Automatically find code containing bugs or defects, or requiring collateral evolutions.
- Automatically fix bugs or defects, and perform collateral evolutions.
- Provide a system that is accessible to software developers.

Requirements for automation

The ability to abstract over irrelevant information:

- Bug case: `struct sock *sk = tun->sk;`
- CE case: `bitmap->file->f_path.mnt` vs `file->f_path.mnt`

The ability to match scattered code fragments:

- Bug case: `struct sock *sk = tun->sk;` is a defect if followed by a NULL test on `tun`.

The ability to transform code fragments:

- CE case: Replace function arguments `X->Y.mnt` and `X->Y.dentry` by `&X->Y`.

Coccinelle

Program matching and transformation for unpreprocessed C code.

Fits with the existing habits of C programmers.

- C-like, patch-like notation

Semantic patch language (SmPL):

- Metavariables for abstracting over subterms.
- "..." for abstracting over code sequences.
- Patch-like notation ($-$/$+$) for expressing transformations.

Bug finding (and fixing)

```
@@
type T;
identifier i,fld;
expression E;
statement S;
@@

  T i = E->fld;

  ...

  if (E == NULL) S
```

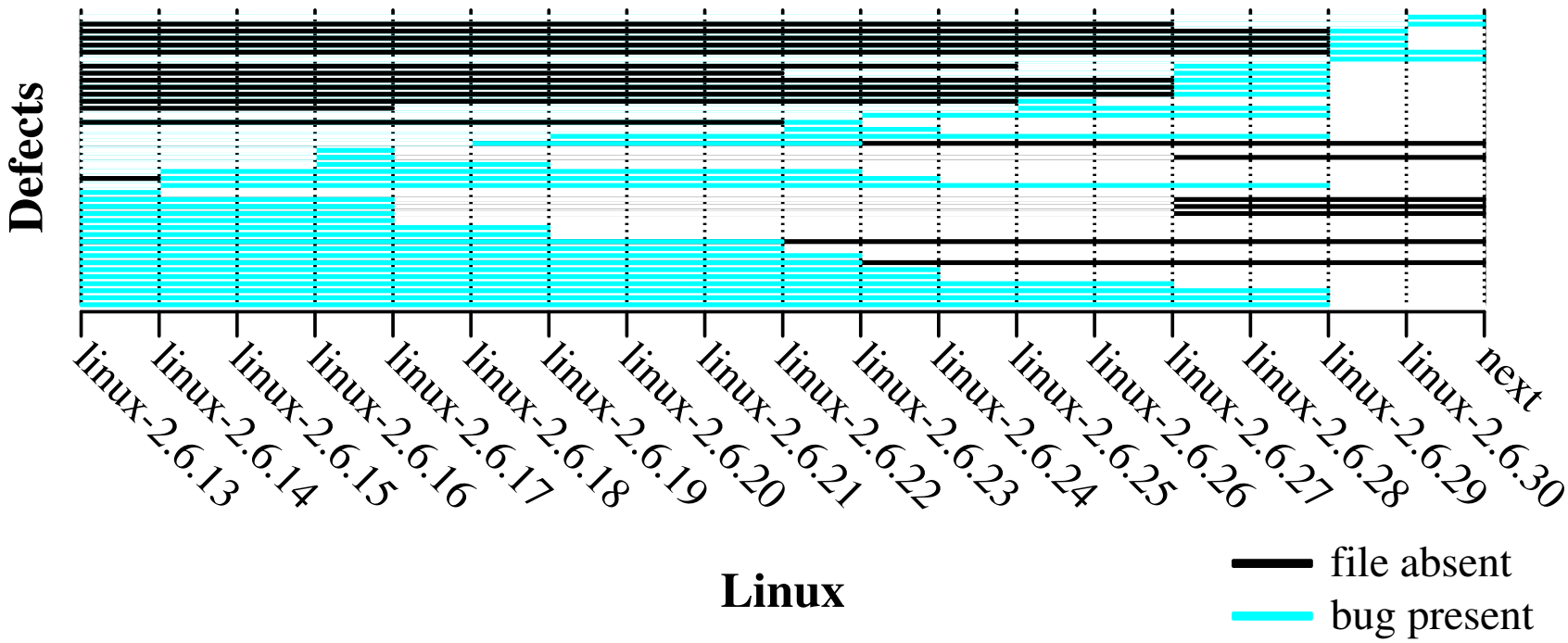
Bug finding (and fixing)

```
@@
type T;
identifier i,fld;
expression E;
statement S;
@@

  T i = E->fld;

  ... when != E
      when != i
  if (E == NULL) S
```

Bug finding (and fixing)

```
@@
type T;
identifier i,fld;
expression E;
statement S;
@@

- T i = E->fld;
+ T i;
  ... when != E
      when != i
  if (E == NULL) S
+ i = E->fld;
```

Potential impact of the semantic patch



Collateral evolution

```
@@
expression file,E1,E2;
identifier fld;
@@

 seq_path(E1,
-             file->fld.mnt,file->fld.dentry
+             &file->fld
          ,E2)
```

Updates 11/12 relevant code sites.

This rule can be automatically generated from examples.

Current status

- Over 750 patches based on Coccinelle accepted into the Linux kernel.
- A collection of semantic patches integrated into the Linux kernel source tree.
- Several LWN articles by Linux developers.
- Seems to be "easy" to learn.
- Used by developers of Linux and other software.
- Articles in EuroSys, DSN, POPL, ASE, AOSD, etc. on the language and methodology.

Conclusion

- Coccinelle provides a declarative language for program matching and transformation.
- Coccinelle semantic patches look like patches; fit with Linux programmers' habits.
- Quite "easy" to learn; already accepted by the Linux community.
- Future work will build on Coccinelle to develop tools motivated by problems observed in Linux development.

http://coccinelle.lip6.fr