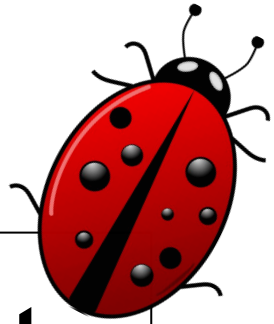
Coccinelle For Rust



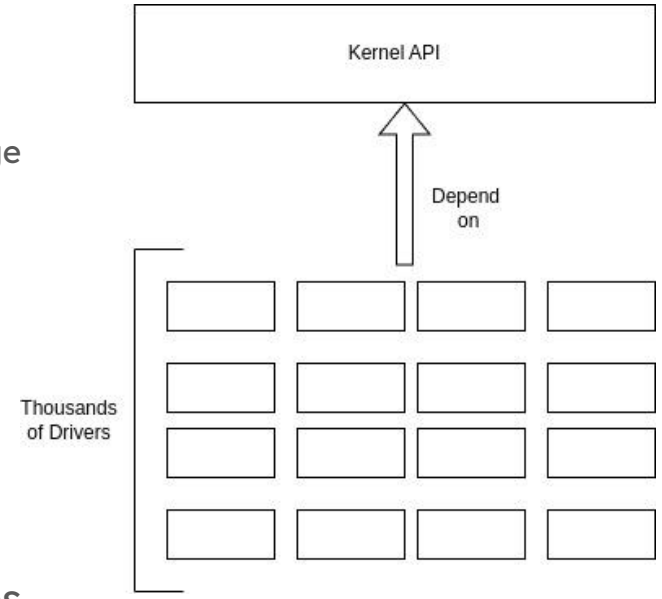
Tathagata Roy, Julia Lawall

What is Coccinelle?

1. Performs repetitive transformations at a large scale
   a. Rust is 1.6 MLOC
   b. Linux Kernel is 23 MLOC
   c. Collateral evolution - a change in the main API leads to change in all clients

2. Provide a transformation language for expressing these changes

3. Changes + Developer Familiarity = (semantic) patches



An example change (Rust repository)

```
commit d822b97a27e50f5a091d2918f6ff0ffd2d2827f5
Author: Kyle Matsuda <kyle.yoshio.matsuda@gmail.com>
Date:   Mon Feb 6 17:48:12 2023 -0700

    change usages of type_of to bound_type_of

diff --git a/compiler/rustc_borrowck/src/diagnostics/conflict_errors.rs b/compiler/.../conflict_errors.rs
@@ -2592,4 +2592,4 @@ fn annotate_argument_and_return_for_borrow(
             } else {
-                let ty = self.infcx.tcx.type_of(self.mir_def_id());
+                let ty = self.infcx.tcx.bound_type_of(self.mir_def_id()).subst_identity();
                 match ty.kind() {
                     ty::FnDef(_, _) | ty::FnPtr(_) => self.annotate_fn_sig(
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@@ -1185,4 +1185,4 @@ fn explain_captures(
                         matches!(tcx.def_kind(parent_did), rustc_hir::def::DefKind::Impl { .. })
                             .then_some(parent_did)
-                            .and_then(|did| match tcx.type_of(did).kind() {
+                            .and_then(|did| match tcx.bound_type_of(did).subst_identity().kind() {
                                 ty::Adt(def, ..) => Some(def.did()),
...
```

136 files changed, 385 insertions(+), 262 deletions(-)

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Creating a semantic patch: Step 1: remove irrelevant code

```
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```

```
-                     .and_then(|did| match tcx.type_of(did).kind() {
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```

Creating a semantic patch: Step 2: pick a typical example

```
@@

@@

- self.infcx.tcx.type_of(self.mir_def_id())
+ self.infcx.tcx.bound_type_of(self.mir_def_id()).subst_identity()
```

Creating a semantic patch: Step 3: abstract over subterms using metavariables

```
@@
expression tcx, arg;
@@

- tcx.type_of(arg)
+ tcx.bound_type_of(arg).subst_identity()
```

Creating a semantic patch: Step 3: abstract over subterms using metavariables

```
@@
expression tcx, arg;
@@

- tcx.type_of(arg)
+ tcx.bound_type_of(arg).subst_identity()
```

Updates over 200 call sites.

Latest Developments

1. Addition of the **CTL-VW** engine. Which is the same engine as Coccinelle For C.

    a. Gives us a standard way (Computation Tree logic formulas) to represent complex control flow paths

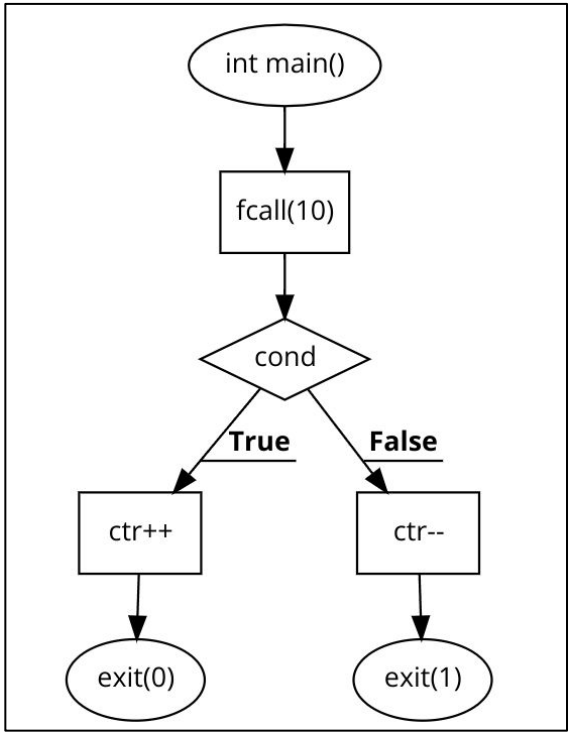
    b. C control flow is simple. Conditional nodes only in the function level or inside other conditionals (for the most part)

    c. Rust, not so much

C CFGs

```
int main() {
  fcall(10);

  if (cond) {
    ctr++;
    exit(0);
  }
  else {
    ctr--;
    exit(1);
  }
}
```



Rust CFG

In rust, if and while/loop statements are expressions. Therefore a control flow branch/loop can occur anywhere.

```
fcall(if cond { args1 } else { args2 });
```

```
let _ = while true {
    if cond {
        ...
    }
};
```

Rust Madness

```
if if if a == b {
    b == c
} else {
    a == c
} {
    a == d
} else {
    c == d
} {
    println!("True!");
} else {
    println!("False!");
}
```

unearthly
control
flow

Snippet source: u/ZZaaaccc

Rust CFG

How to represent rust CFG from the Rust AST without remaking the compiler?

Rust CFG

How to represent rust CFG from the Rust AST without remaking the compiler?

```
fcall(10);
```

```
EXPR_STMT
  CALL_EXPR
    PATH_EXPR
      PATH
        PATH_SEGMENT
          NAME_REF
            IDENT
    ARG_LIST
      L_PAREN
      LITERAL
        INT_NUMBER
      R_PAREN
  SEMICOLON
```

Rust CFG

How to represent rust CFG from the Rust AST without remaking the compiler?

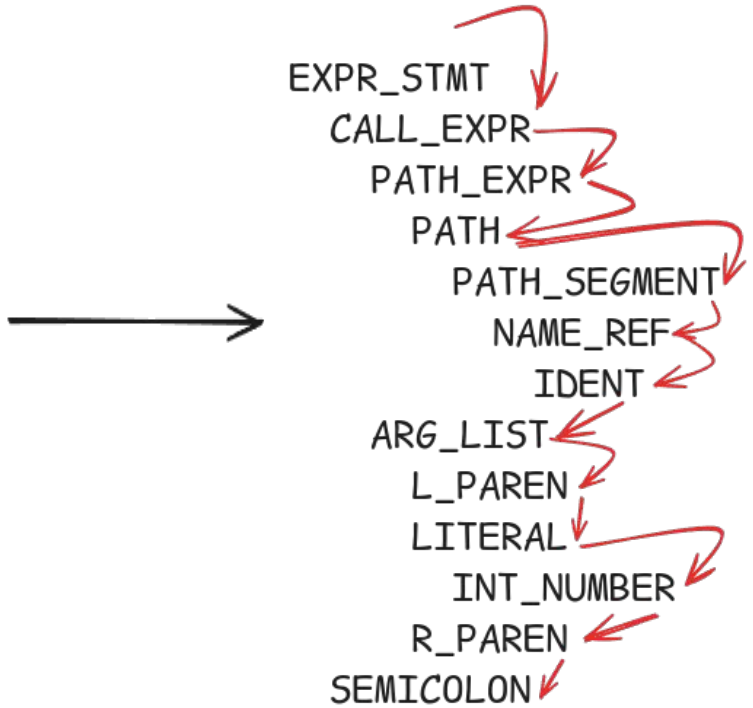
For simple non-branching nodes:-

```
f(node) {
    print(node.name);
    node.children.for_each(f);
}
```

Rust CFG

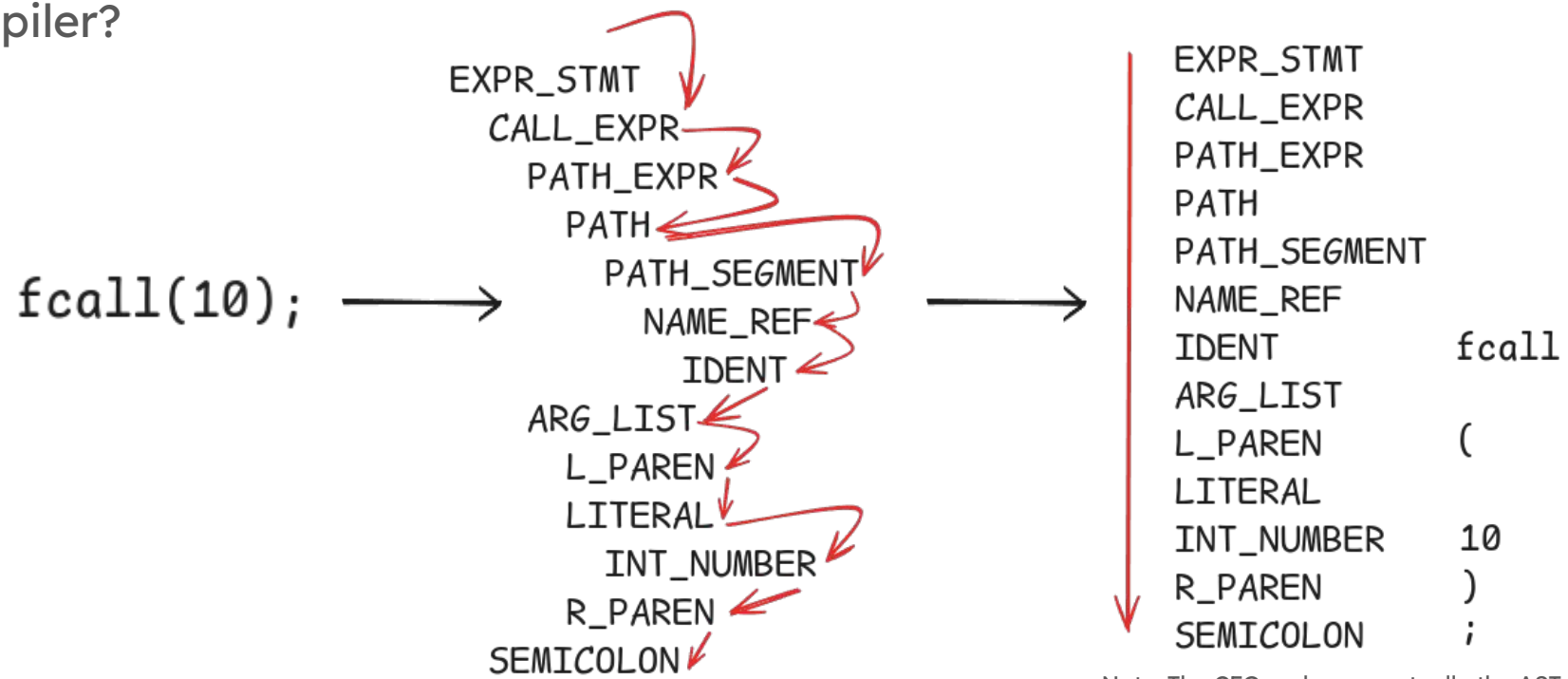
How to design a Rust CFG from the Rust AST without making remaking the compiler?

```
fcall(10);
```



Rust CFG

How to design a Rust CFG from the Rust AST without making remaking the compiler?



Note: The CFG nodes are actually the AST types of the tree

Rust CFG

How to design a Rust CFG from the Rust AST without making remaking the compiler?

But what about branching instructions?

```
fcall(if cond { 10 } else { 0 });
```

Rust CFG

How to design a Rust CFG from the Rust AST without making remaking the compiler?

But what about branching instructions?

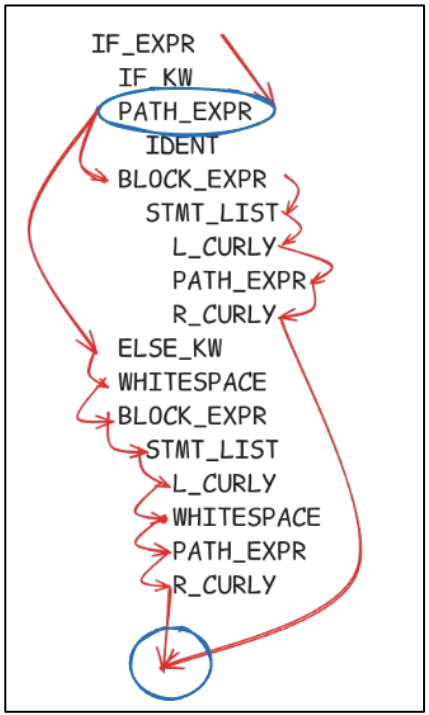
```
if cond { d1 } else { d2 }
```

```
IF_EXPR
  IF_KW
  PATH_EXPR
    IDENT
  BLOCK_EXPR
    STMT_LIST
      L_CURLY
      PATH_EXPR
      R_CURLY
  ELSE_KW
  WHITESPACE
  BLOCK_EXPR
    STMT_LIST
      L_CURLY
      WHITESPACE
      PATH_EXPR
      R_CURLY
```

Rust CFG

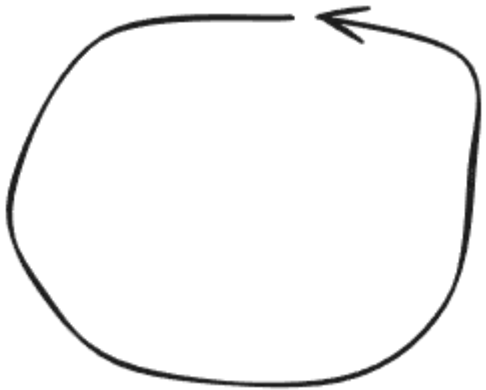
How to represent rust CFG from the Rust AST without making remaking the compiler?

```
f(node) {
    if node.kind() == IF_EXPR {
        branch_if(node);
    }
    else {
        add_seq(node.name);
        node.children.for_each(f);
    }
}
```

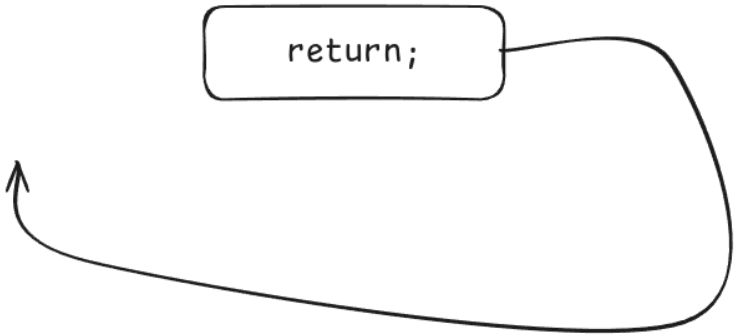


Rust CFG

Similarly we can define CFGs for loops and return statements.



Loops



Jump statements

Problems with this approach

1. HUGE Control Flow Graphs.
2. All the CFGs shown in the slides are highly compressed. This is how a CFG looks for

```
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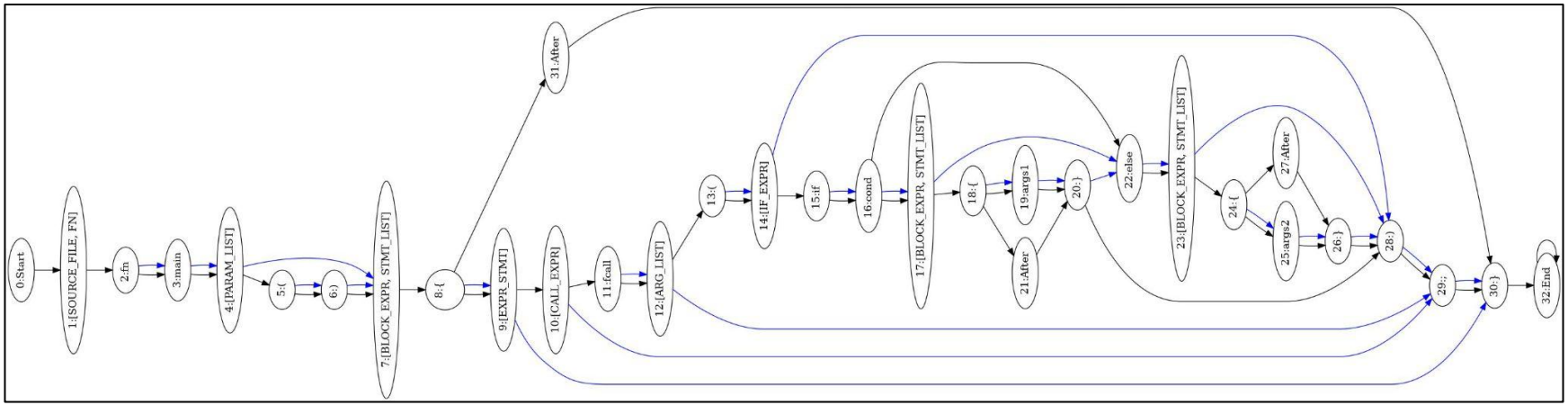
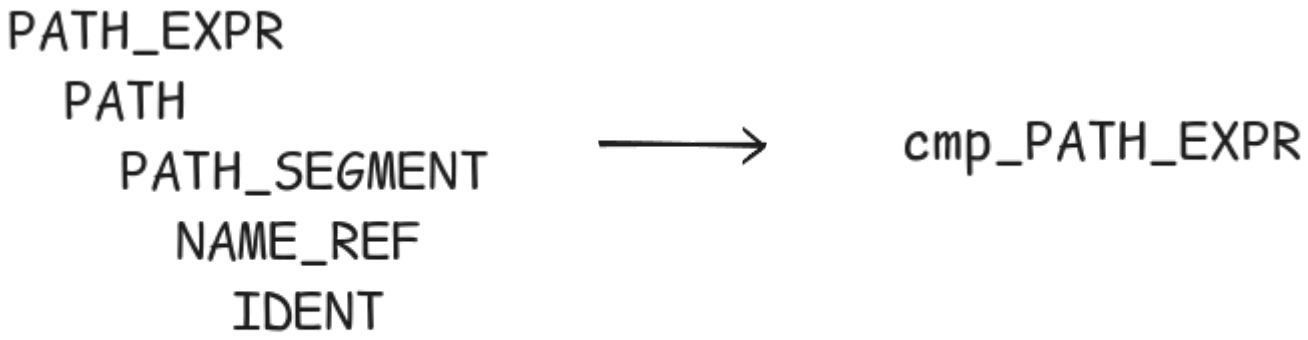


Problems with this approach

1. HUGE Control Flow Graphs.

Solution :- Compress nodes with nodes with only one child.



Problems with this approach

2. Representation of metavariables

Special edges for metavariables and blocks.

```
f( g ( 0 ), 2);
h();
```

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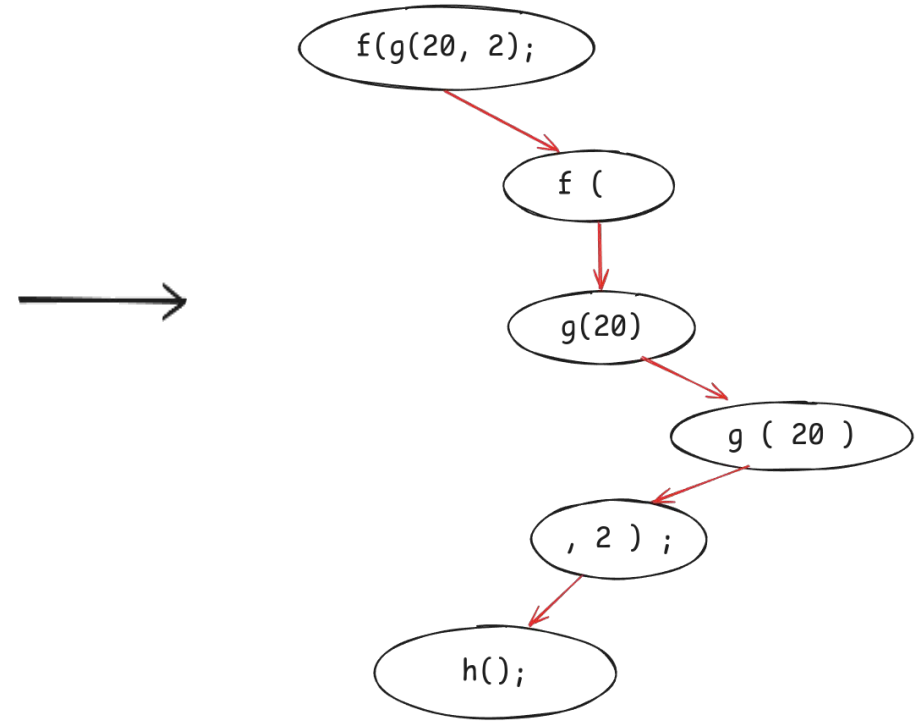

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2. Representation of metavariables

Special edges (sibling) for metavariables and blocks.

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f( g ( 0 ), 2);
h();
```
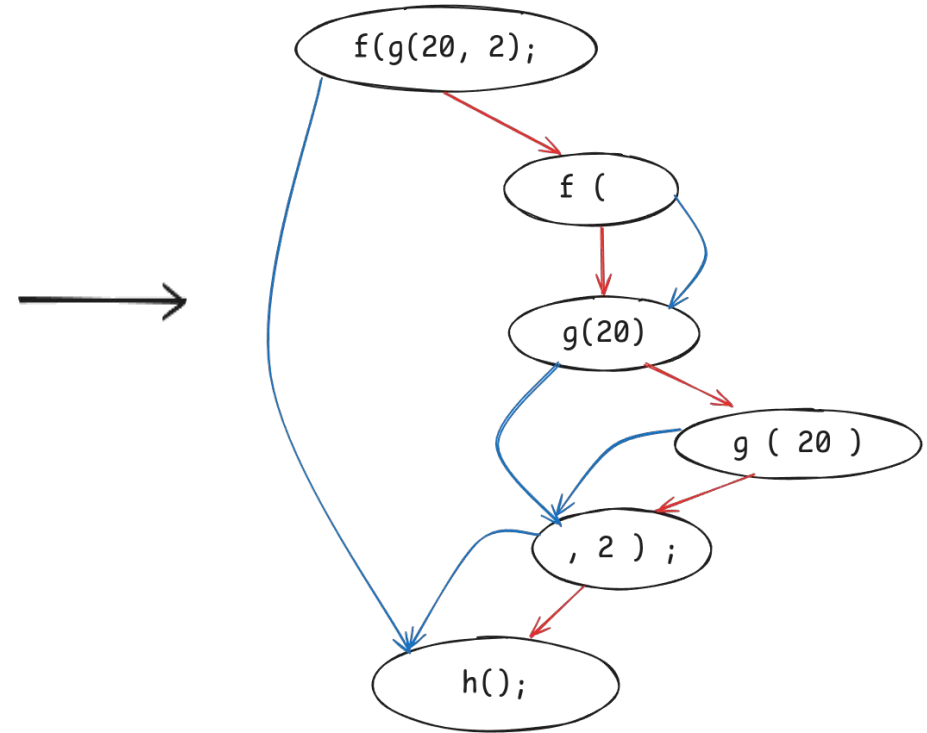
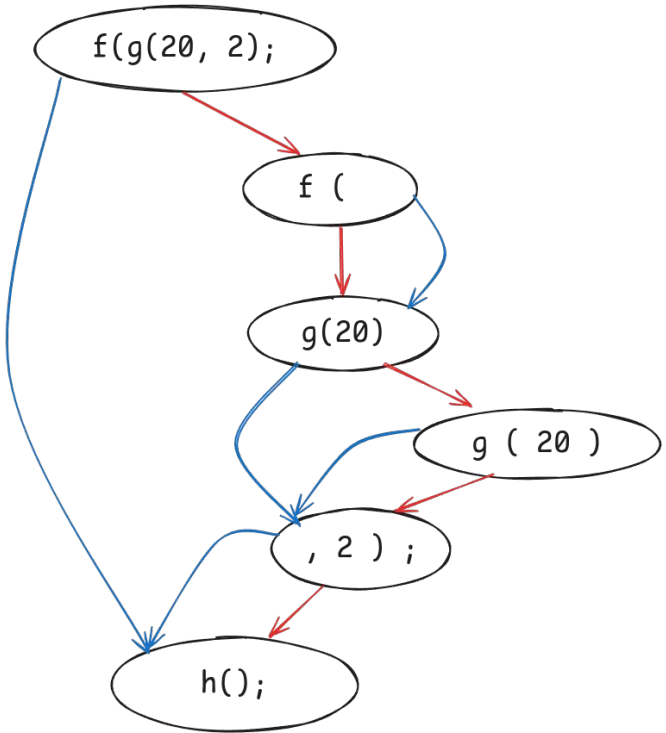



Problems with this approach

2. Representation of metavariables

Special edges (sibling) for metavariables and blocks.

```
@@
expression x;
@@

f(x, 2);
h();
```



Other points

CTL formulas are very verbose and hard to read in their current state. For example…

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[EXPR_STMT] & (AX ([CALL_EXPR] & (AX (f & (AX ([ARG_LIST] & (AX (Exnk l1 ((& (Paren(l1)) & (AX (Ex x (x & (AX ()(M) & (Paren(l1)) & (AX (; & (AX (A[NOT ([EXPR_STMT] & (AX ([CALL_EXPR] & (AX (f & (AX ([ARG_LIST] & (AX (Exnk l1 ((& (Paren(l1)) & (AX (Ex x (x & (AX ()(M) & (Paren(l1)) & (AX (;))))) OR After)))))))))) OR [EXPR_STMT] & (AX ([CALL_EXPR] & (AX (Ex _v (g) & (AX ([ARG_LIST] & (AX (Exnk l1 (Ex _v (( ) & (Paren(l1)) & (AX (Ex _v (x) & (AX (Ex _v ()(M)) & (Paren(l1)) & (AX (Ex _v (;))))) OR After)))))))))) U [EXPR_STMT] & (AX ([CALL_EXPR] & (AX (Ex _v (g modif) & (AX ([ARG_LIST] & (AX (Exnk l1 (Ex _v ((modif) & (Paren(l1)) & (AX (Ex _v (x modif) & (AX (Ex _v ()(M) modif) & (Paren(l1)) & (AX (Ex _v (; modif))))) OR After)))))))))]))))))) OR After))))))))))

Other points

CTL formulas are very verbose and hard to read in their current state

```
@@
@@

f(x)
...
-g(x);
```

Thankfully the CfR user does not have to deal with CTL formulas :)

Latest Developments

Ellipses (…)

a. The ellipses operator
b. Matches any control flow path connecting two nodes
c. Helpful for when we don’t care about intermediate statements
d. Finds all paths by default

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```
let mut a = Buffer::make(params);
/*
Do some work
*/
a.flush();
// more work
```

```
let mut a =
  Buffer::make_auto_flush(params);
/*
Do some work
*/
-a.flush();
// more work
```

Latest Developments

Ellipses (...)

```
@@
identifier i;
expression options;
@@

-let mut i = Buffer::make(options);
+let mut i = Buffer::make_auto_flush(options);
...
-i.flush();
```

elipses operator

Latest Developments

Disjunctions

1. Conditional Matching
2. Matches either one of the branches

Disjunctions

Example

write() needs to be flushed always,

writeln() is self flushing.

```
let mut a = Buffer::make(params);
/*
Do some work
*/
a.writeln(info);
```

```
let mut a = Buffer::make(params);
/*
Do some work
*/
a.write(info);

//NO FLUSHHH????
```

Disjunctions

```
@@
identifier i;
expression x;
@@

-let mut i = Buffer::make();
+let mut i = Buffer::make_nl_flush();
...
(
i.write(x);
+i.flush();
|
i.writeln(x);
-i.flush();
|
i.writeln(x);
)
```

```
let mut a = Buffer::make(params);
/*
Do some work
*/
a.writeln(info);
```

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let mut a = Buffer::make(params);
/*
Do some work
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a.write(info);

//NO FLUSHHH????
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Disjunctions

WHAT'S NEW?????

Disjunctions

Disjunction branches can now be anything as long as the whole patch makes sense.

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Disjunction branches can now be anything as long as the whole patch makes sense.

```
(
expression1
|
expression2
)
```

Previously

Disjunctions

Disjunction branches can now be anything as long as the whole patch makes sense.

```
(
expression1
|
expression2
)
```

Previously

```
t1 t2
(
t3
|
t4 t5 t6
)
t7
```

This is valid as long as

t1 t2 t3 t7, and
t1 t2 t4 t5 t6 t7

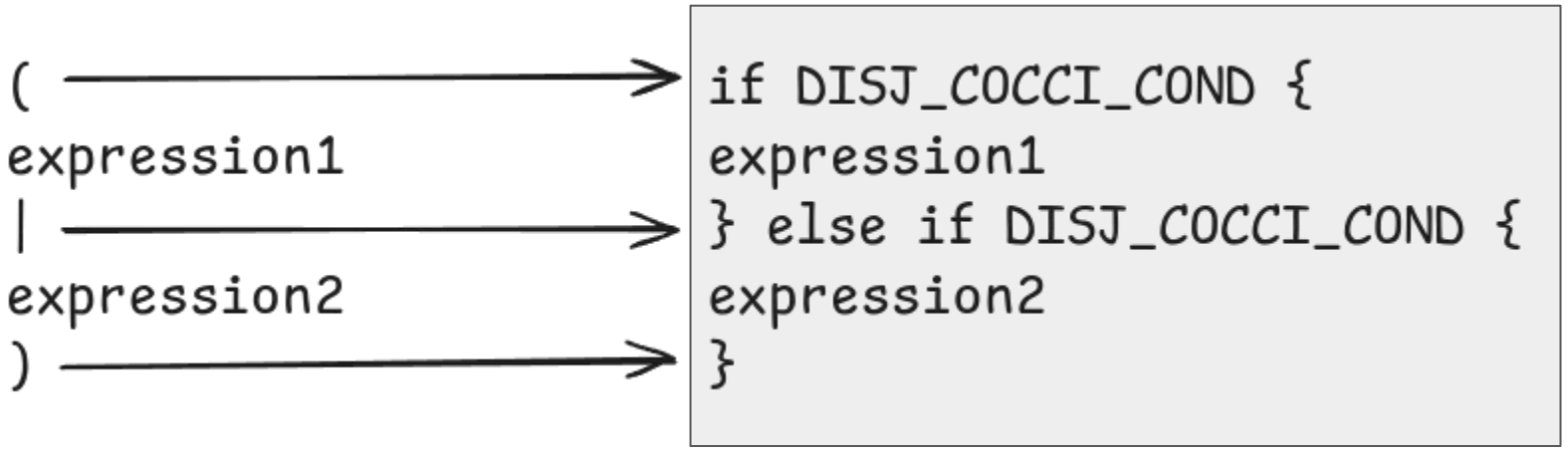
make sense*

* For the most part

Disjunctions

Previously on Coccinelle For Rust…

1. Disjunctions -> If statements



Disjunctions

Non-expression disjunctions

```
let x:
(
Tcx<usize>
|
Tcx<u32>
);
```

```
f(
(
1, 2
|
3
)
 );
```

Disjunctions

Previously on Coccinelle For Rust…

1. Disjunctions -> If statements

   Problem: Cannot parse anything other than expressions.

```
Box<
    if cond { usize }
    else cond { u32 }
    >
```

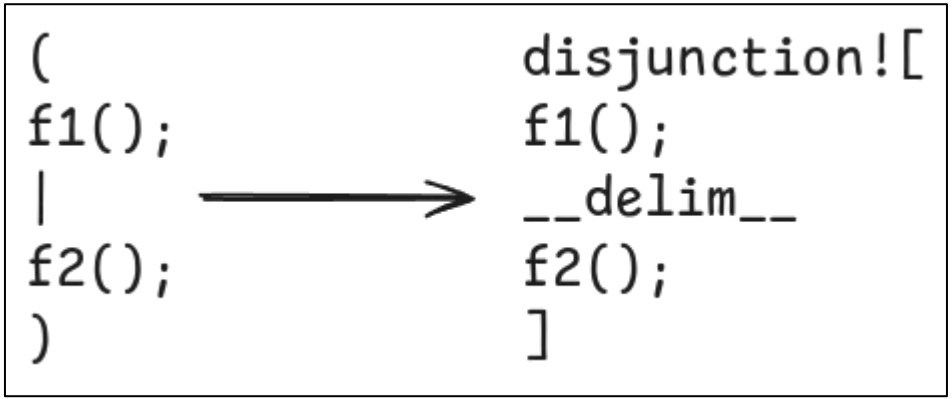
Disjunctions

HAIL OUR SAVIOUR :- ***MACROS***

1. Rust macros are very versatile. There are a few types of declarative rust macros :-
   a. MacroDef
   b. MacroCall
   c. MacroType
   d. …?
2. If we use macros to wrap our disjunctions, not only can we parse them, but also get what should be in their place.

Disjunctions

What we do now :-



Disjunctions

What we do now :-

```
t1 t2
(
t3
|
t4 t5 t6
)
t7
```

1. Parse disjunctions
2. Get all possible paths as a string but keep the disjunction information
3. Make sure that these branches are parsable
4. Parse the newly formed branches
5. Merge all the branches into one disjunction

Disjunctions

Note:-

There are still cases where disjunctions cannot be used. For example :-

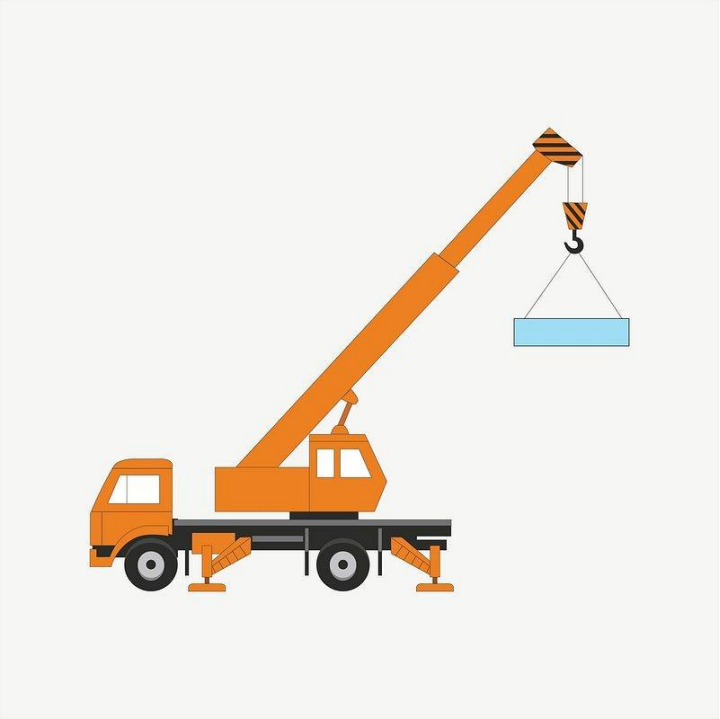
```
(
-#[inline]
|
#[no_mangle]
)
fn to_some_lib() {
...
}
```

```
pub enum foo {
    e1,
(
    -e2
|
    e2,
    e3
)
}
```

Latest Developments

Disjunctions

Still a work in progress :)



Remaining Challenges

Macros

1. They are a pain in the AST
2. CfR uses rustfmt
3. rustfmt does not format macros and mods properly
4. Ambiguity as to what to do.

Parallelization

1. Limited parallelization capabilities due to the thread-unsafe structure of rowan syntax nodes.

Possible applications?

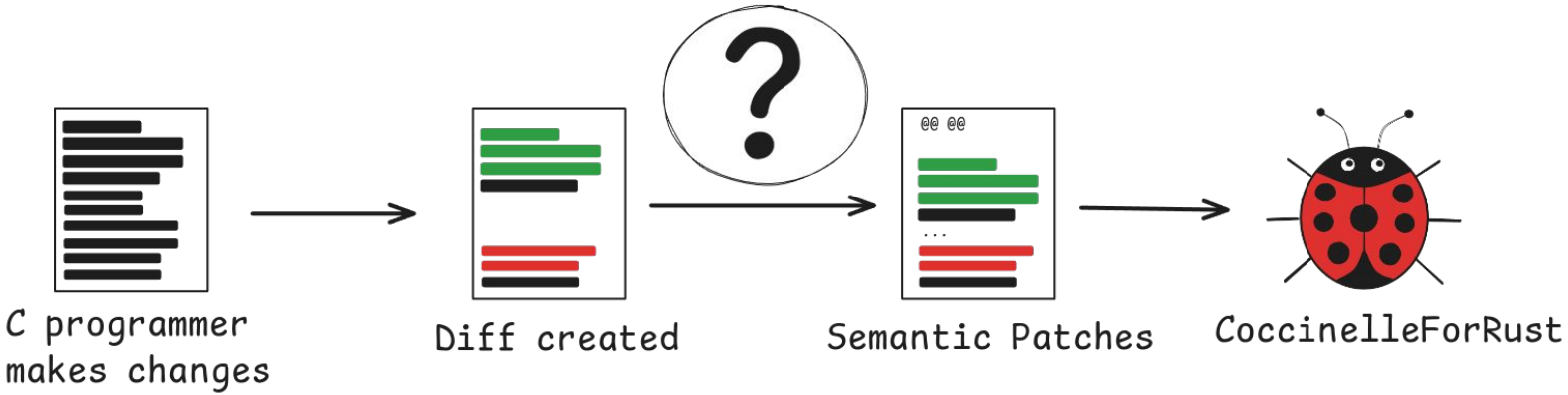
Interfacing C-Rust Code

a. Changes in C side of the code require the corresponding Rust code to be updated.

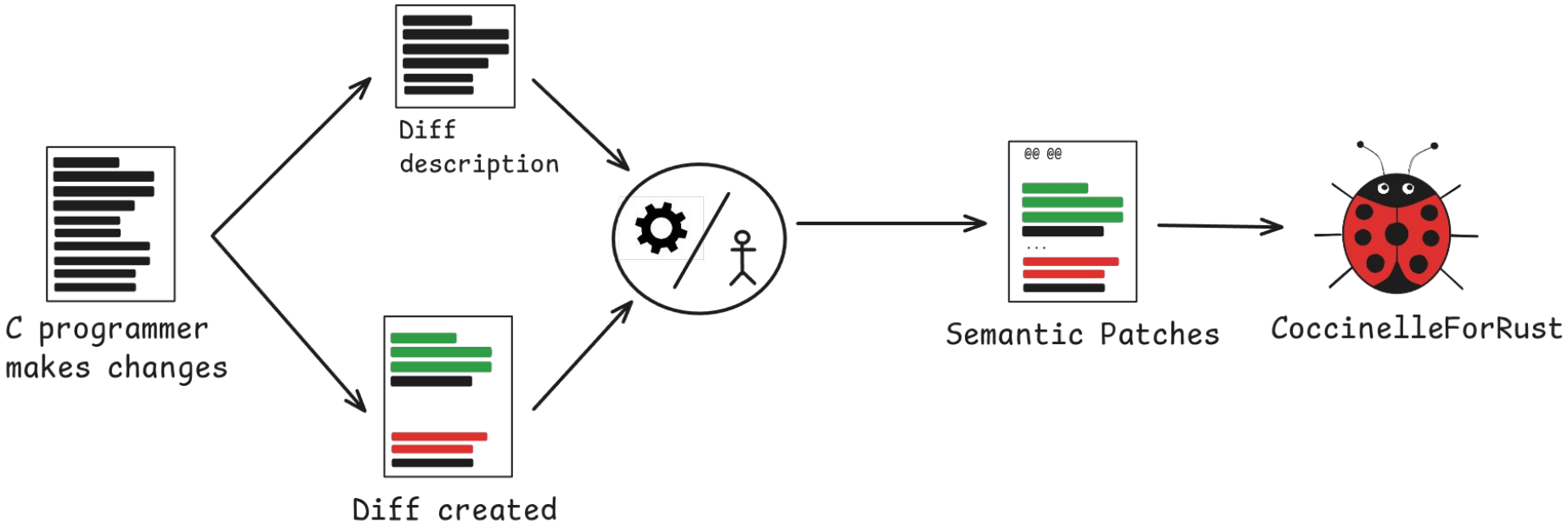
b. Questions in the community as to who should make the changes across languages.

Coccinelle For Rust could potentially act as a tool which automates the changes from C to Rust. This reduces the burden on both C and Rust developers.

Possible applications?



Possible applications?



Possible applications?

Some examples of the diff description -

1. arg2 is never NULL
2. struct foo *arg1 can only be dereferenced once
3. Size of `struct foo` has changed to 32 bytes from 48 bytes.
4. More...

Question to the audience

What kind of C-Rust interface changes are most common in the linux kernel and would benefit most from automation?

Support

Thank you Collabora for supporting the development of Coccinelle For Rust!

COCCINELLE FOR RUST LINKS

1. Main Page - https://rust-for-linux.com/coccinelle-for-rust

2. Gitlab Page - https://gitlab.inria.fr/coccinelle/coccinelleforrust/-/tree/main?ref_type=heads (Please use the ctl2 branch, as per the link)

3. Previous Talks - https://gitlab.inria.fr/coccinelle/coccinelleforrust/-/blob/ctl2/talks/lpc23.pdf?ref_type=heads

4. Contact: julia.lawall@inria.fr

   tathagata.roy1278@gmail.com