C2Rust

Migrating Legacy Code to Rust

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Acknowledgements & Disclaimer

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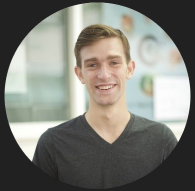
Who am I?

- Per Larsen
- Co-Founder at Immunant, Inc.
- From Denmark / Located in Irvine, CA
- Background in C/C++ exploit mitigation

Who?

Eric Mertens
Galois



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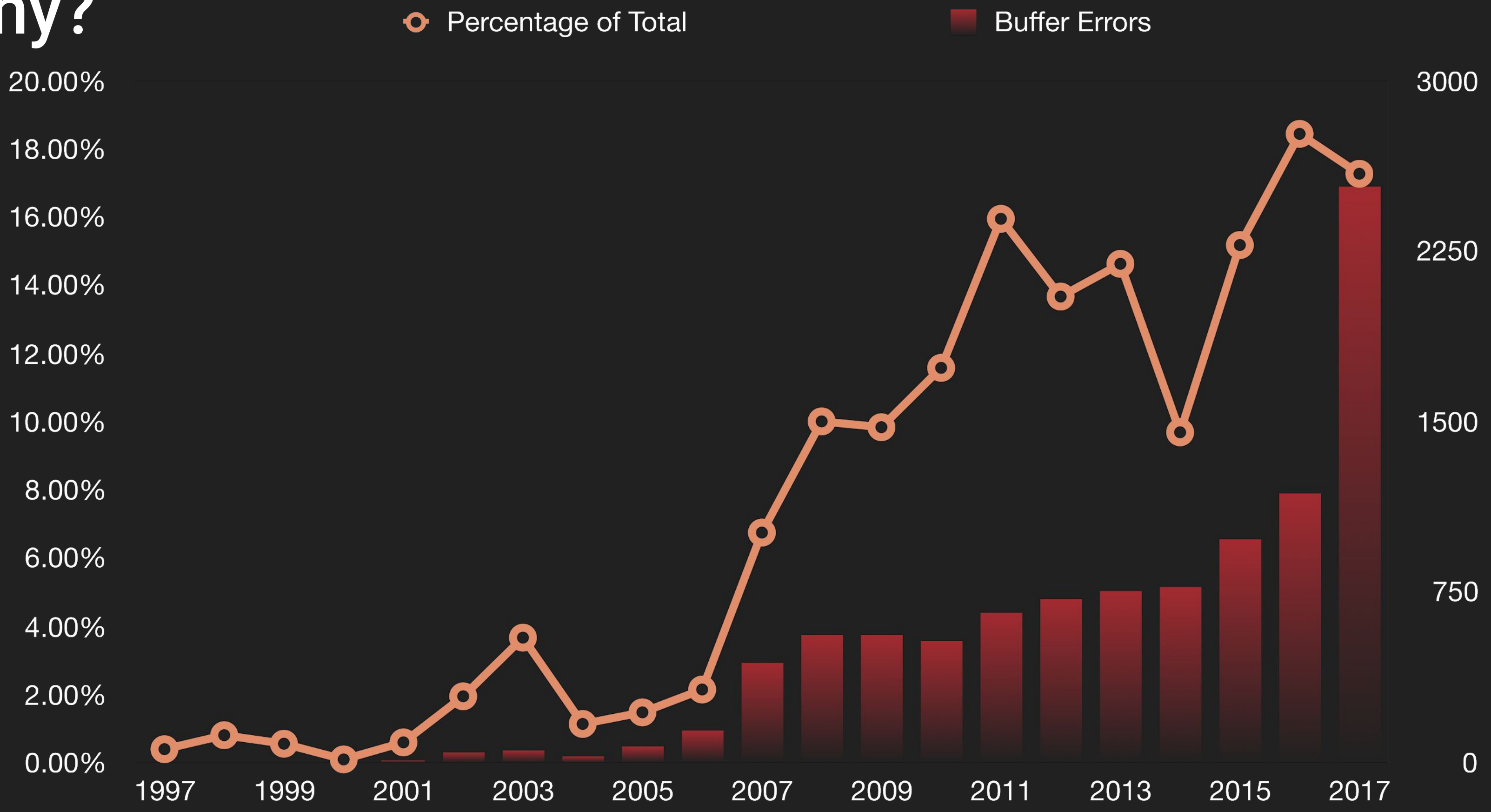
Why?



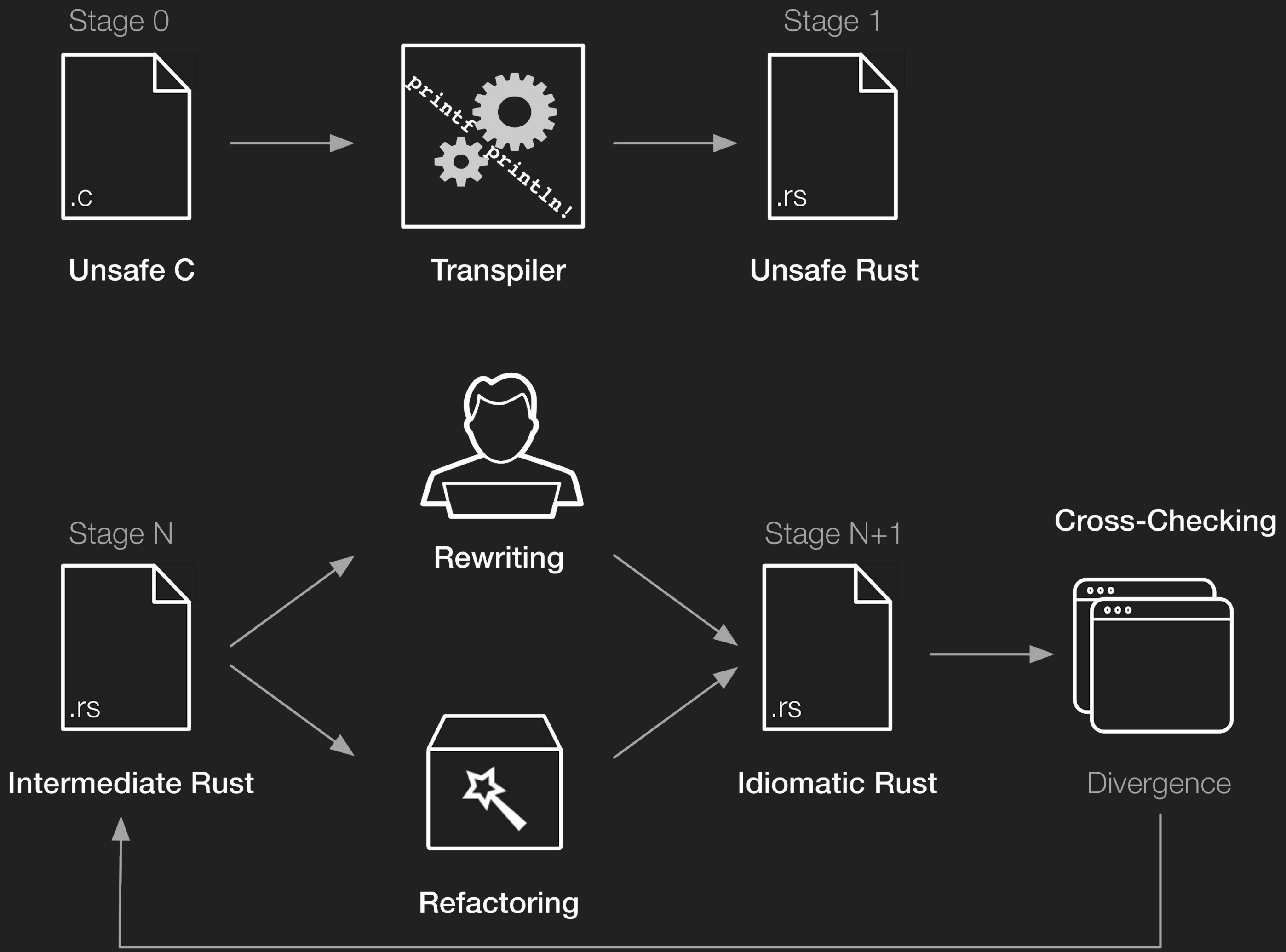
Source: NIST National Vulnerability Database

Why?

C/C++ mitigations are far from perfect.

Rust is an attractive migration target. Can we make migration easier?

1. reduce the tedium of initial translation
2. help catch errors during refactoring



Stage 0

Unsafe C

Transpiler

Stage 1

Unsafe Rust

Rewriting

Stage N

Intermediate Rust

Refactoring

Stage N+1

Idiomatic Rust

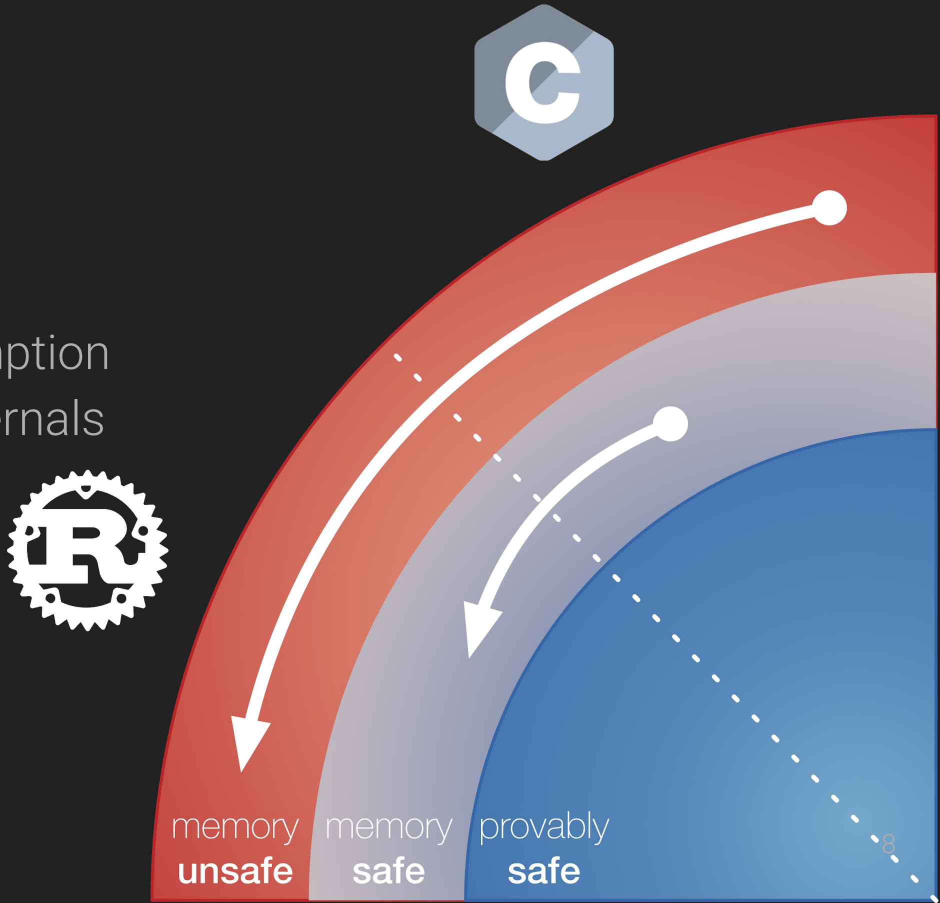
Cross-Checking

Divergence

Transpiling

Design Goals:

- Robust C and C++ parsing
- Preserve functionality of input code
- Generate output fit for human consumption
- Write back end in Rust; reuse Rust internals

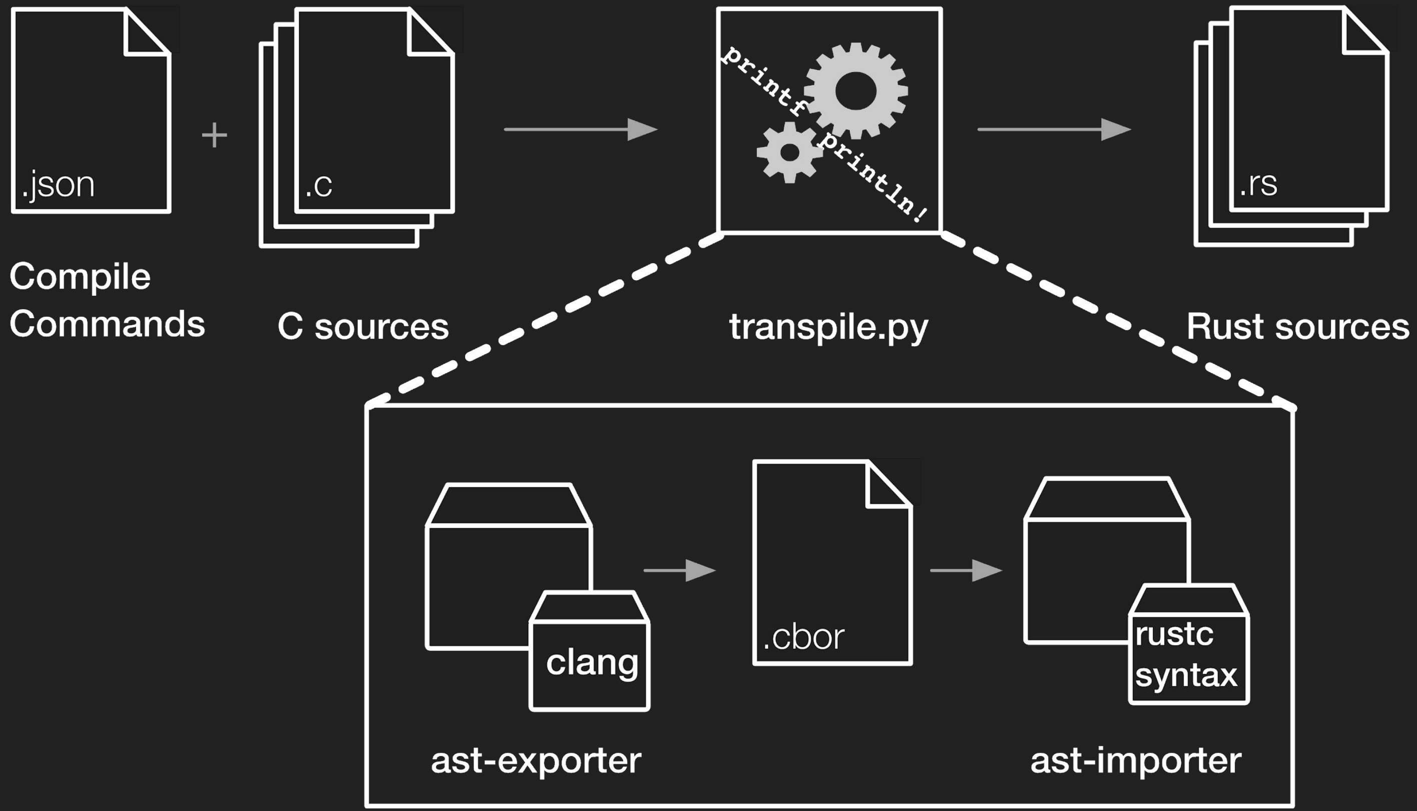


Other efforts

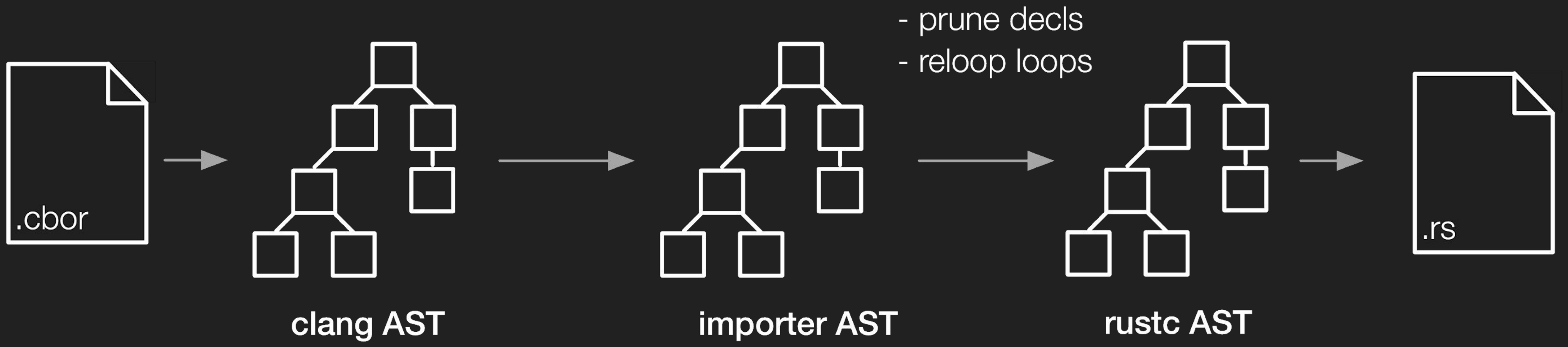
- Corrode
    - uses Haskell C parsing library
    - **`https://github.com/jameysharp/corrode`**
- Citrus-rs
    - uses clang for parsing
    - “transforms C syntax to Rust syntax, but ignores C semantics”
    - **`https://gitlab.com/citrus-rs/citrus`**

Transpiler

Transpiler


.json
+
.c
printf
println!
.rs
Compile
Commands
C sources
transpile.py
Rust sources
clang
.cbor
rustc
syntax
ast-exporter
ast-importer

AST importer



Preprocessor directives

- Translating **after** preprocessing

Preprocessor directives

- Translating after preprocessing
- How was compiler invoked?
  - `compile_commands.json`
- Recording compile commands
  - Use `cmake` 2.8.5 or later
  - Use `intercept-build` for makefile projects
  - … or `bear` (Linux only)

https://github.com/rizsotto/bear

```
[
    {
        "arguments": [
            "cc",
            "-c",
            "-std=c99",
            "-o",
            "test",
            "test.c"
        ],
        "directory": "/tmp/buffer",
        "file": "test.c"
    }
]
```

Simple loops

Simple loops

```
int x = 0;
while (x < 42) { x++; }


for (x = 0; x < 42; x++)
{  }
```

```
let mut x: libc::c_int = 0i32;
while x < 42i32 { x += 1 }


x = 0i32;
while x < 42i32 { x += 1 };
```

Relooping

```c
int sum(int count) {
   goto a;

   b:
   --count;
   goto d;

   a:;
   int x = 0;
   goto d;

   c:
   return x;

   d:
   if(count <= 0)
   goto c;
   goto e;

   e:
   x += count;
   goto b;
}
```

```rust
pub unsafe extern "C" fn sum(mut
count: libc::c_int)
   -> libc::c_int {
   let mut x: libc::c_int = 0i32;
   while !(count <= 0i32)
   { x += count; count -= 1 }
   return x;
}
```

https://github.com/kripken/emscripten

Translator limitations

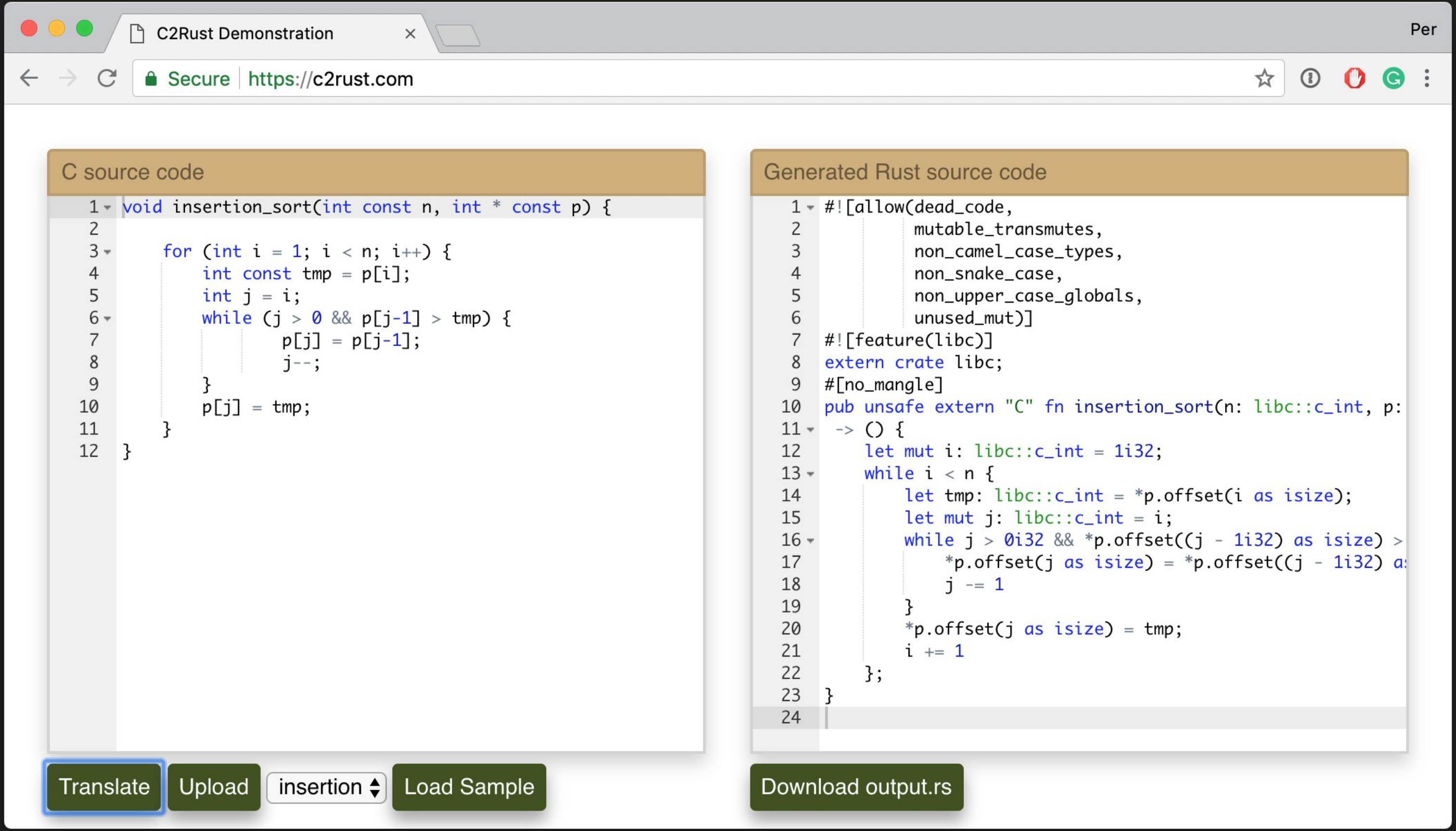
Unimplemented

- variadic function definitions (Rust RFCs blocking issue #2137)
- bitfields (Rust RFCs blocking issue #314)
- `long double` and _Complex types (Rust libc blocking issue #355)
- macros

Likely won't ever support

- `longjmp` and `setjmp`
- jumps in and out of GNU C statement expressions

Web Demo



```c
void insertion_sort(int const n, int * const p) {

    for (int i = 1; i < n; i++) {
        int const tmp = p[i];
        int j = i;
        while (j > 0 && p[j-1] > tmp) {
                p[j] = p[j-1];
                j--;
        }
        p[j] = tmp;
    }
}
```

```rust
#![allow(dead_code,
         mutable_transmutes,
         non_camel_case_types,
         non_snake_case,
         non_upper_case_globals,
         unused_mut)]
#![feature(libc)]
extern crate libc;
#[no_mangle]
pub unsafe extern "C" fn insertion_sort(n: libc::c_int, p:
 -> () {
    let mut i: libc::c_int = 1i32;
    while i < n {
        let tmp: libc::c_int = *p.offset(i as isize);
        let mut j: libc::c_int = i;
        while j > 0i32 && *p.offset((j - 1i32) as isize) >
            *p.offset(j as isize) = *p.offset((j - 1i32) a
            j -= 1
        }
        *p.offset(j as isize) = tmp;
        i += 1
    };
}

```

Running locally

```
$ git clone git@github.com:immunant/c2rust
```

```
$ c2rust/scripts/docker_build.sh
```

```
$ cd c2rust/vagrant && vagrant up
```

Building

```
$ c2rust/scripts/build_translator.py --with-clang
```

```
$ c2rust/scripts/build_cross_checks.py
```

```
$ cd c2rust/rust-refactor && cargo build
```

Transpiling

```
$ git clone git@github.com:immunant/buffer.git


$ cd buffer && bear make

  ✓ ok

$ path/to/transpile.py -m=test compile_commands.json


$ cd c2rust-build && RUSTFLAGS=-Awarnings cargo run

  ✓ ok
```

Example C input

```c
/*
* Allocate a new buffer with `n` bytes.
*/
buffer_t *
buffer_new_with_size(size_t n) {
 buffer_t *self = malloc(sizeof(buffer_t));
 if (!self) return NULL;
 self->len = n;
 self->data = self->alloc = calloc(n + 1, 1);
 return self;
}
```

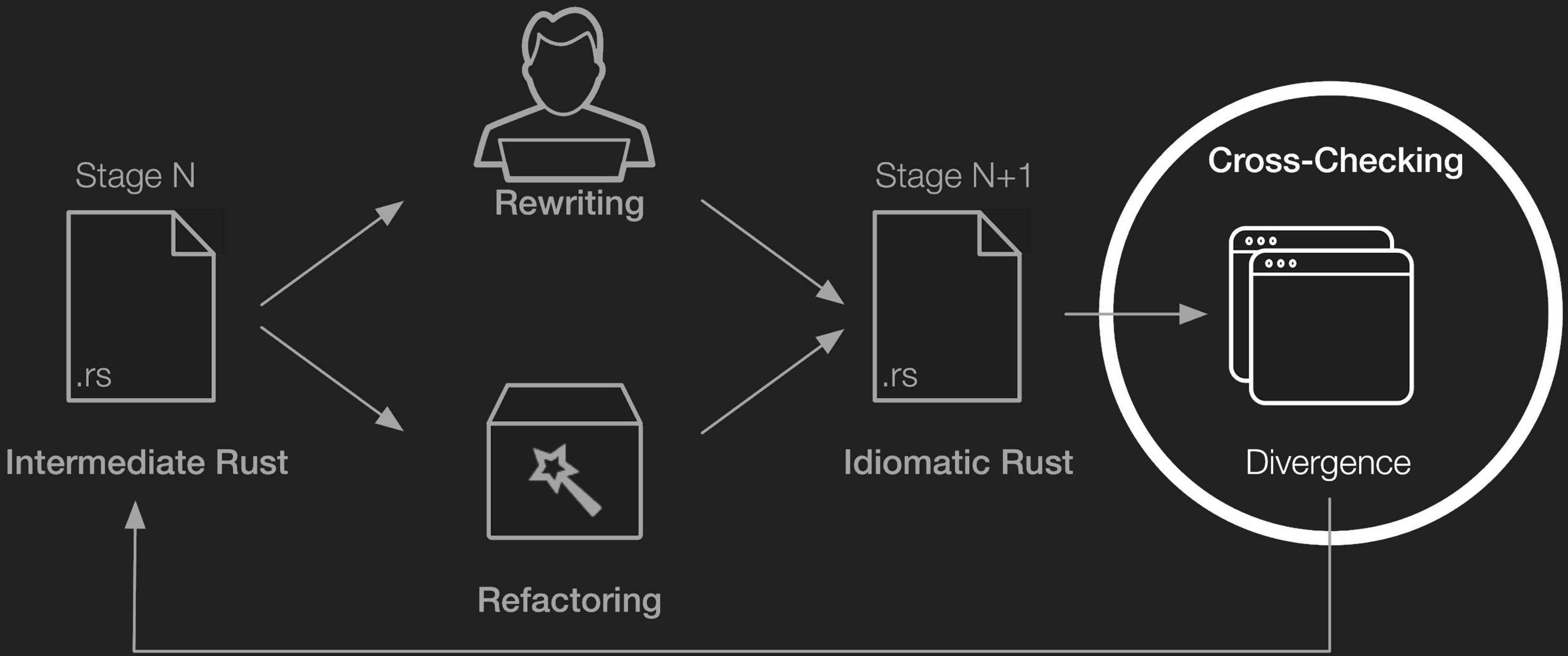
Example Rust output

```
#[no_mangle]
pub unsafe extern "C" fn buffer_new_with_size(mut n: size_t)
-> *mut buffer_t {
   let mut self_0: *mut buffer_t =
       malloc(::std::mem::size_of::<buffer_t>() as libc::c_ulong) as
           *mut buffer_t;
   if self_0.is_null() {
       return 0 as *mut buffer_t
   } else {
       (*self_0).len = n;
       (*self_0).alloc =
           calloc(n.wrapping_add(1i32 as libc::c_ulong),
                  1i32 as libc::c_ulong) as *mut libc::c_char;
       (*self_0).data = (*self_0).alloc;
       return self_0
   };
}
```

Rewritten Rust

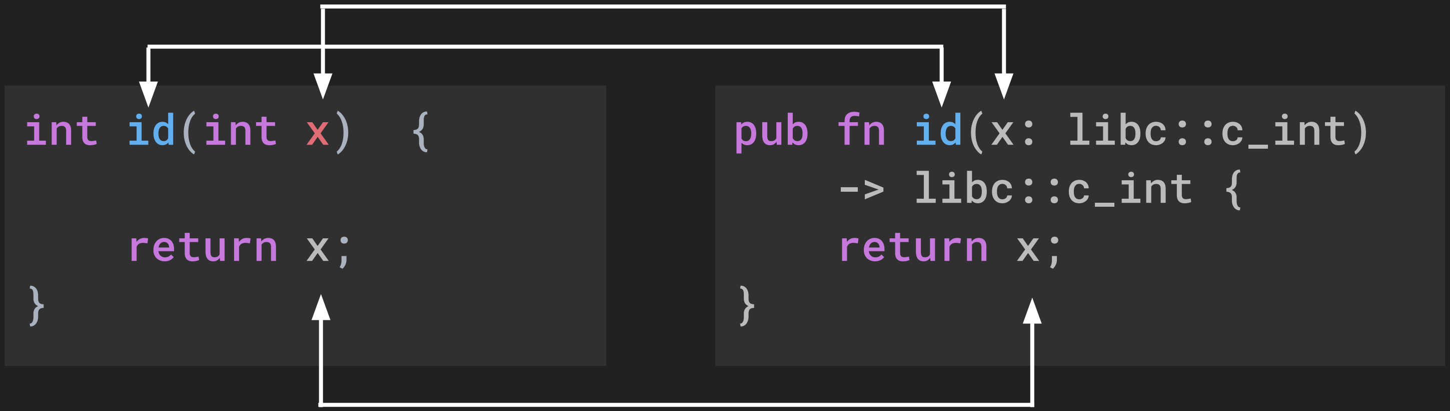
```
#[no_mangle]
pub extern "C" fn buffer_new_with_size(mut n: size_t)
                                     -> *mut buffer_t {
  let mut v = vec![0; n + 1];
  let mut b = Box::new(buffer_t {
      len: n,
      data: v.as_mut_ptr(),
      alloc: v,
  });
  Box::into_raw(b)
}
```

Cross checking



Cross checking

1. Instrument original C and translated Rust
2. Run programs with identical inputs
3. **Optional:** Configure cross checking



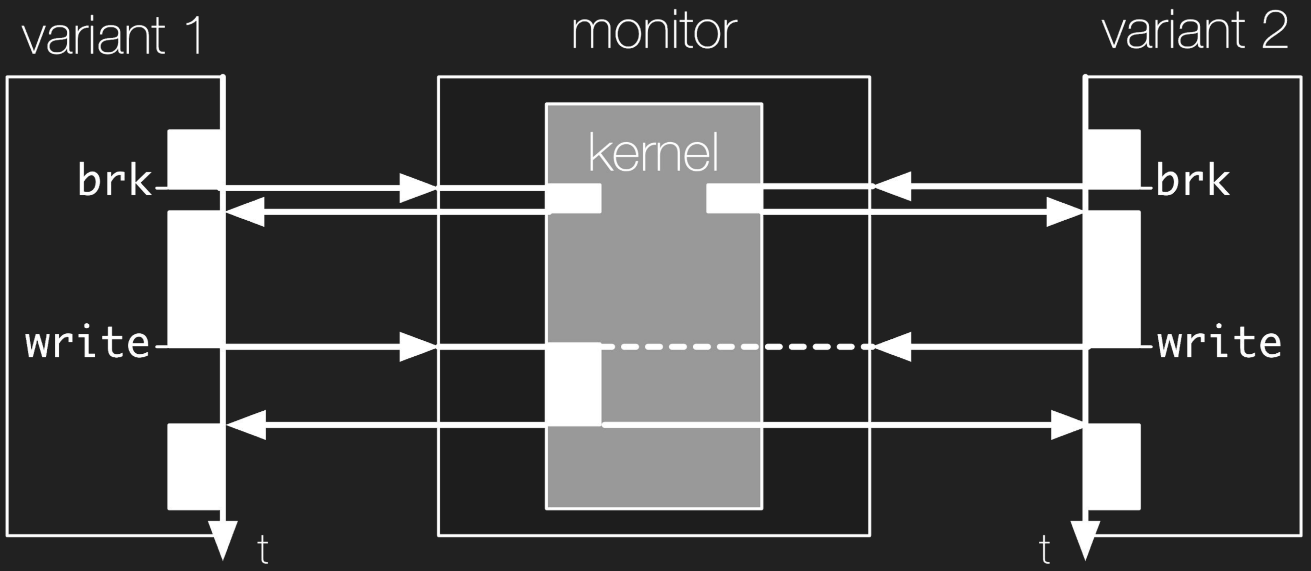
```c
int id(int x)  {

    return x;
}
```

```rust
pub fn id(x: libc::c_int)
    -> libc::c_int {
    return x;
}
```

Cross checking options

1. **Online**
   - Using **ReMon** MVEE*
   - + no log files
   - + replicates program input
   - - limited compatibility
2. **Offline**
   - + broad compatibility
   - - user must ensure identical inputs
   - - log files grow quickly

Multi-variant execution environment



https://github.com/stijn-volckaert/ReMon

Cross checking instrumentation

1. `clang` plug-in for C code
2. `rustc` plug-in for Rust code
3. Cross-checking runtimes
   a. MVEE-based
   b. log-based
4. Zeroing `malloc` replacement
5. `ptrace`-based segfault handler

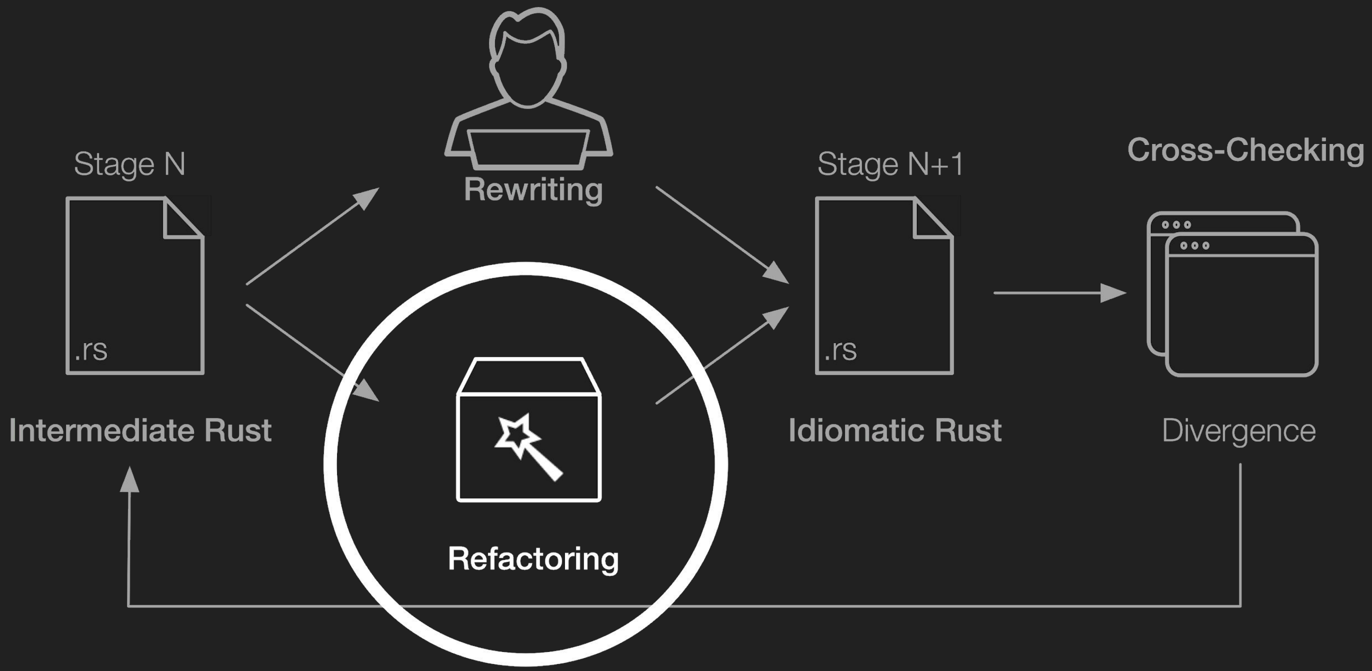
Cross-checking a library (1/2)

```
$ cd buffer && bear make
  ✓ ok
$ path/to/transpile.py -x -u -m=test compile_commands.json


$ cd c2rust-build && RUSTFLAGS=-Awarnings cargo build
```

Cross-checking a library (2/2)

```
$ export LD_LIBRARY_PATH=path/to/libfakechecks.so

$ cargo run --quiet 2> ../buffer.rust.xchecks

$ cd .. && make test_xcheck 2> buffer.c.xchecks

$ diff buffer.rust.xchecks buffer.c.xchecks || echo “fail”
```

Refactoring



Reconstruct for range

```rust
fn main() {
  let mut i;

  i = 0;
  'a: while (i < 10) {
      println!("{}", i);
      i = i + 1;
  }

  i = 0;
  'a: while (i < 10) {
      println!("{}", i);
      i = i + 2;
  }
}
```

Reconstruct for range

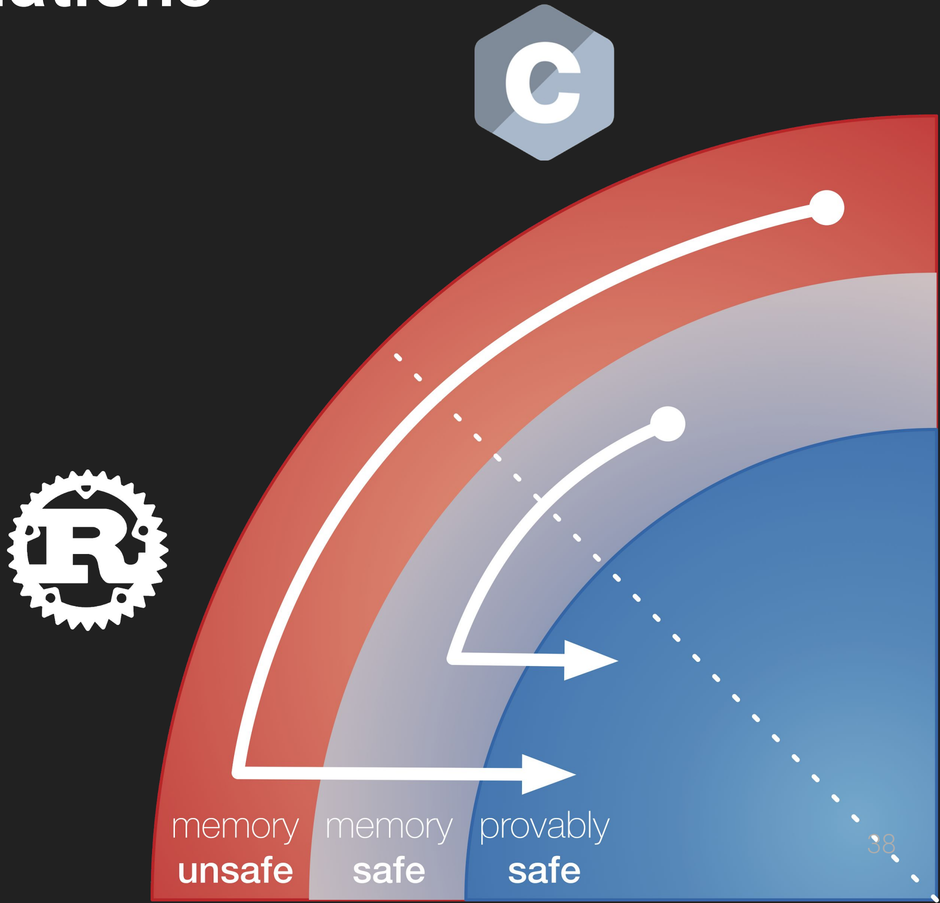
```rust
fn main() {
  let mut i;

  'a: for i in 0..10 {
      println!("{}", i);
  }

  'a: for i in (0..10).step_by(2) {
      println!("{}", i);
  }
}
```

Major enhancements

- Automate safety transformations
- C++ subset support
- Translation of macros/preprocessor directives

Automate safety transformations

- 100% automation not possible
- Challenges
  - Lack of domain knowledge
  - Differences in type systems
    - Ownership
    - Mutability
  - Differences between C preprocessor macros and Rust macros.



Refactoring quicksort (1/4)

```
pub unsafe extern "C" fn swap(mut a: *mut libc::c_int,
                             mut b: *mut libc::c_int) -> () {
    let mut t: libc::c_int = *a;
    *a = *b;
    *b = t;
}

pub unsafe extern "C" fn partition(mut arr: *mut libc::c_int,
                                   mut low: libc::c_int,
                                   mut high: libc::c_int) -> libc::c_int {
    // elided
    swap(&mut *arr.offset(i as isize) as *mut libc::c_int,
         &mut *arr.offset(j as isize) as *mut libc::c_int);
    // elided
}
```

Refactoring quicksort (2/4)

```
pub extern "C" fn swap(mut a: &mut libc::c_int,
                       mut b: &mut libc::c_int) -> () {
   let t: libc::c_int = *a;
   *a = *b;
   *b = t;
}

pub unsafe extern "C" fn partition(mut arr: &mut [libc::c_int],
                                   mut low: libc::c_int,
                                   mut high: libc::c_int) -> libc::c_int {
   // elided
   // requires two mutable borrows, won't compile
   swap(&mut arr[i as usize],
        &mut arr[j as usize]);
   // elided
}
```

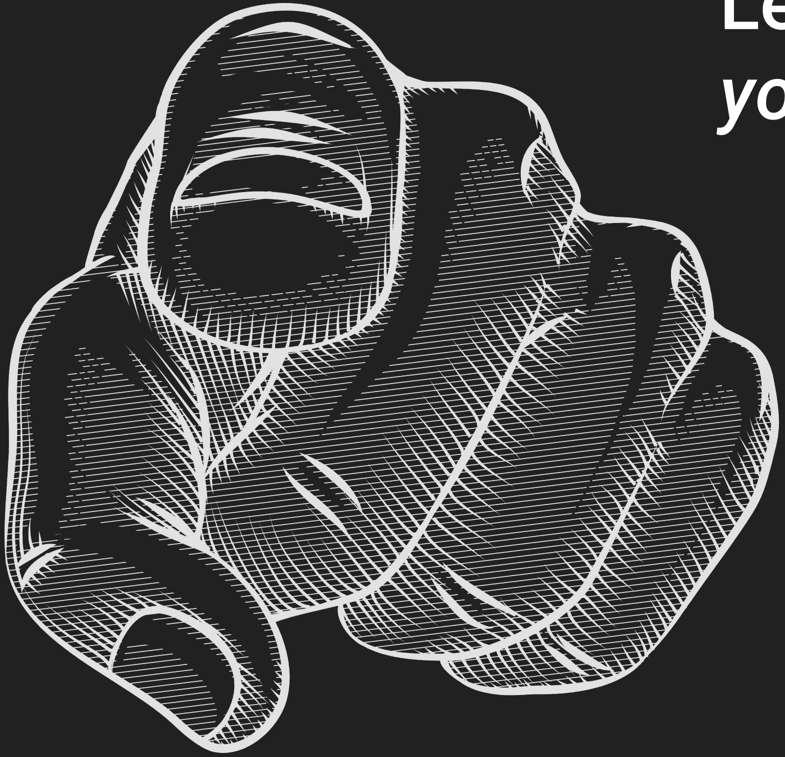
Refactoring quicksort (3/4)

```
~~pub extern "C" fn swap(mut a: &mut libc::c_int,~~
~~                       mut b: &mut libc::c_int) -> () {~~
~~    let t: libc::c_int = *a;~~
~~    *a = *b;~~
~~    *b = t;~~
~~}~~

pub unsafe extern "C" fn partition(mut arr: &mut [libc::c_int],
                                   mut low: libc::c_int,
                                   mut high: libc::c_int) -> libc::c_int {
    // elided
    // the idiomatic solution; requires human insight
    arr.swap(i as usize, j as usize);
    // elided
}
```

Refactoring quicksort (4/4)

```
pub extern "C" fn swap(mut a: &mut libc::c_int,
                       mut b: &mut libc::c_int) -> () {
    let t: libc::c_int = *a;
    *a = *b;
    *b = t;
}

pub unsafe extern "C" fn partition(mut arr: &mut [libc::c_int],
                                   mut low: libc::c_int,
                                   mut high: libc::c_int) -> libc::c_int {
    // elided
    let mut a = mem::replace(&mut arr[i as usize], 0);
    let mut b = mem::replace(&mut arr[j as usize], 0);
    swap(&mut a, &mut b);
    mem::replace(&mut arr[i as usize], a);
    mem::replace(&mut arr[j as usize], b);
    // elided
}
```

Let’s translate *your* code to Rust



www.c2rust.com

github.com/immunant/c2rust

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