Leveraging Rust Types for Modular Specification and Verification

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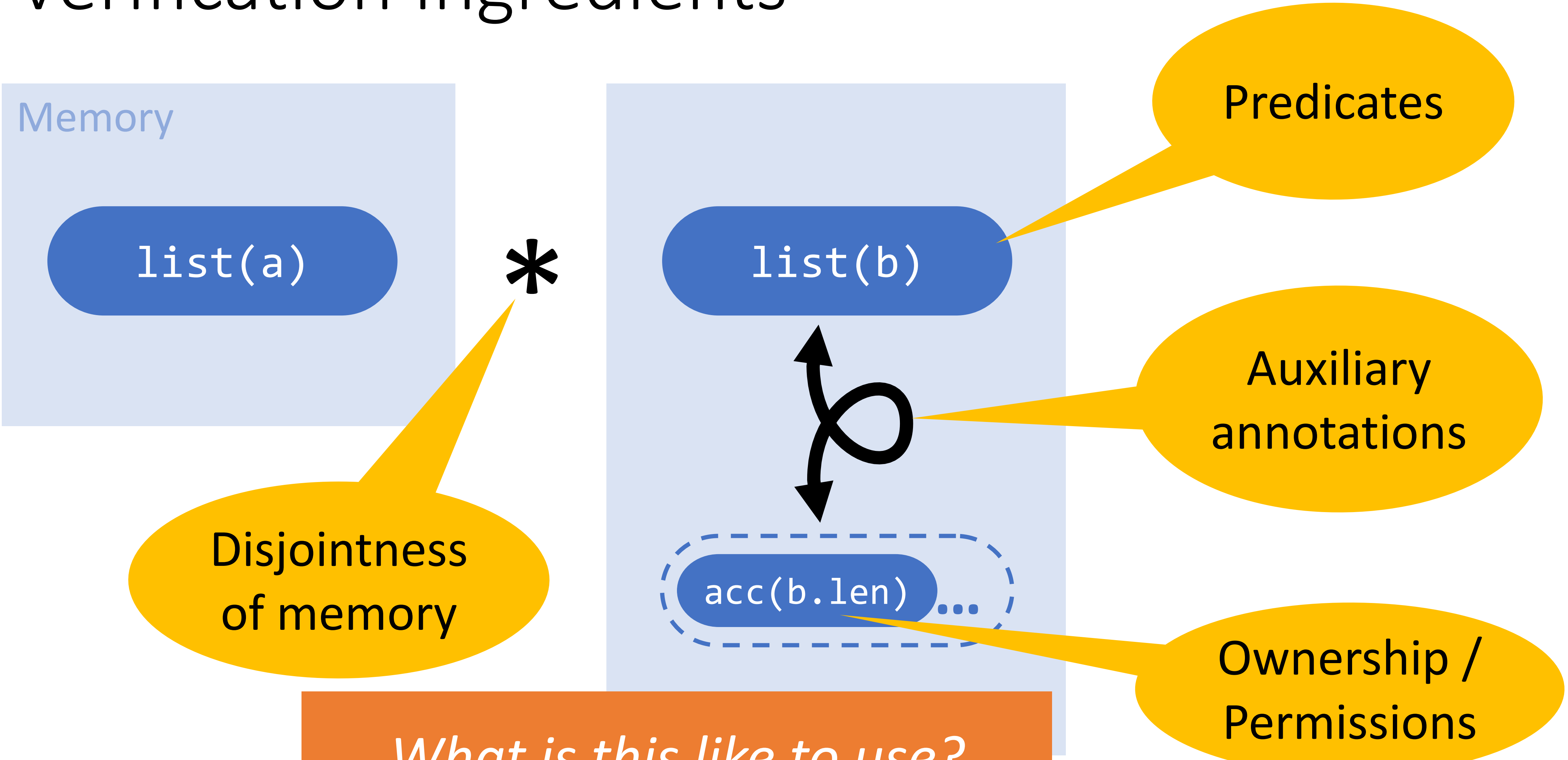
Analogy with C verification

```c
void client(list *a, list *b)
{
  int old_len = b->len;
  append(a, 100);
  assert(b->len == old_len);
}
```

C

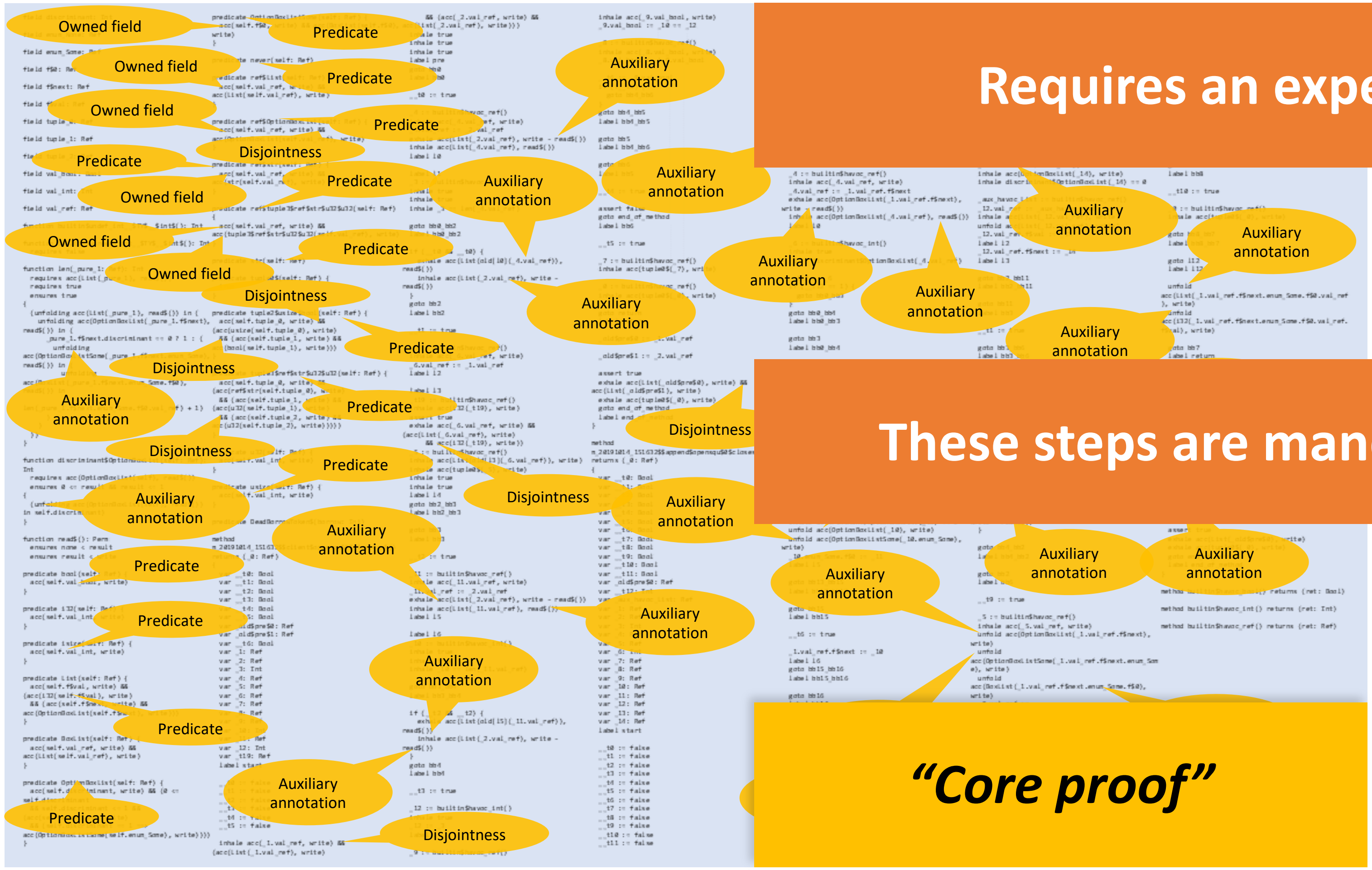
- Functional properties
- Memory Errors
- Aliasing
- Data Races

Verification Ingredients



What is this like to use?

Verification Ingredients at Scale



Requires an expert

These steps are mandatory

"Core proof"

Rust, and its type system

```rust
fn client(a: &mut List, b: &mut List)
{
  let old_len = b.len();
  append(a, 100);
  assert!(b.len() == old_len);
}
```

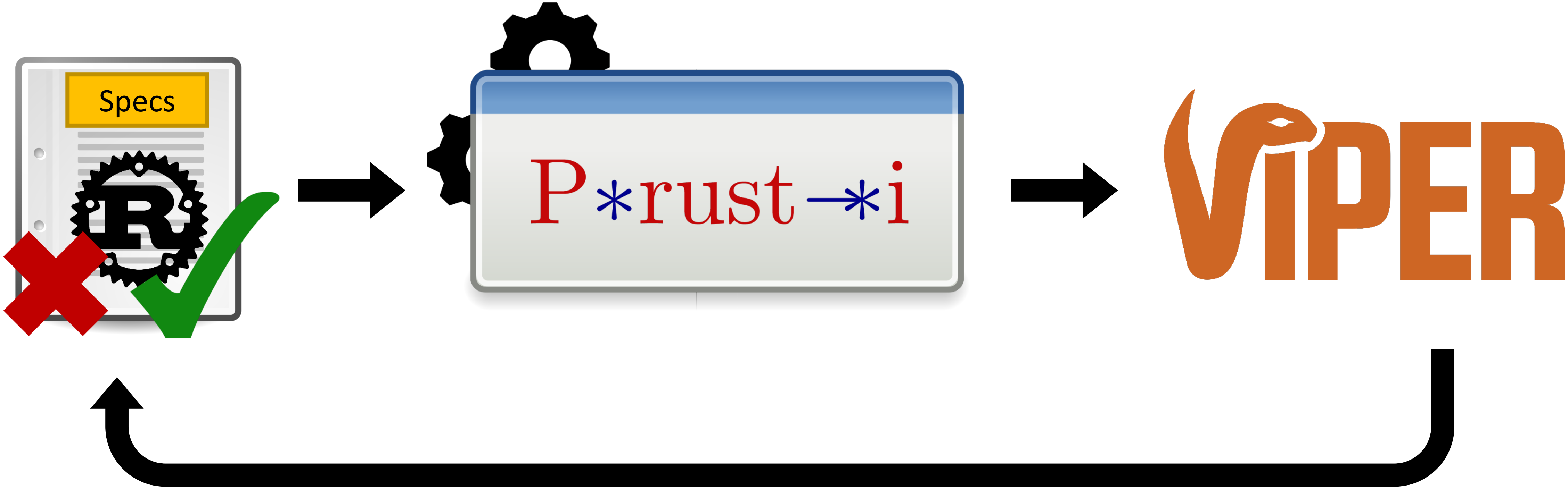
Rust

Can we exploit this type system for *verification*?

- Functional properties
- No Memory Errors
- Controlled Aliasing
- No Data Races

What would we like?

Prusti: An Overview



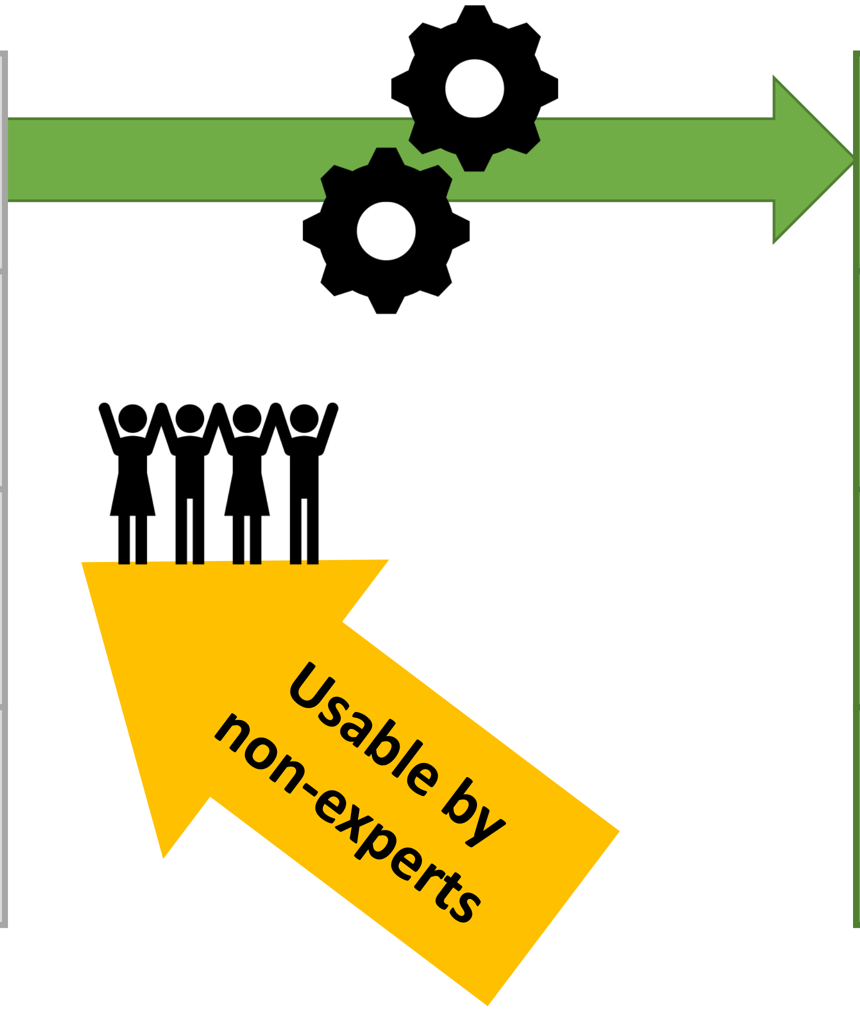
Leveraging Rust Types for Modular Specification and Verification

To appear at OOPSLA 2019, Athens, Greece (next week)

The Prusti Approach

Rust

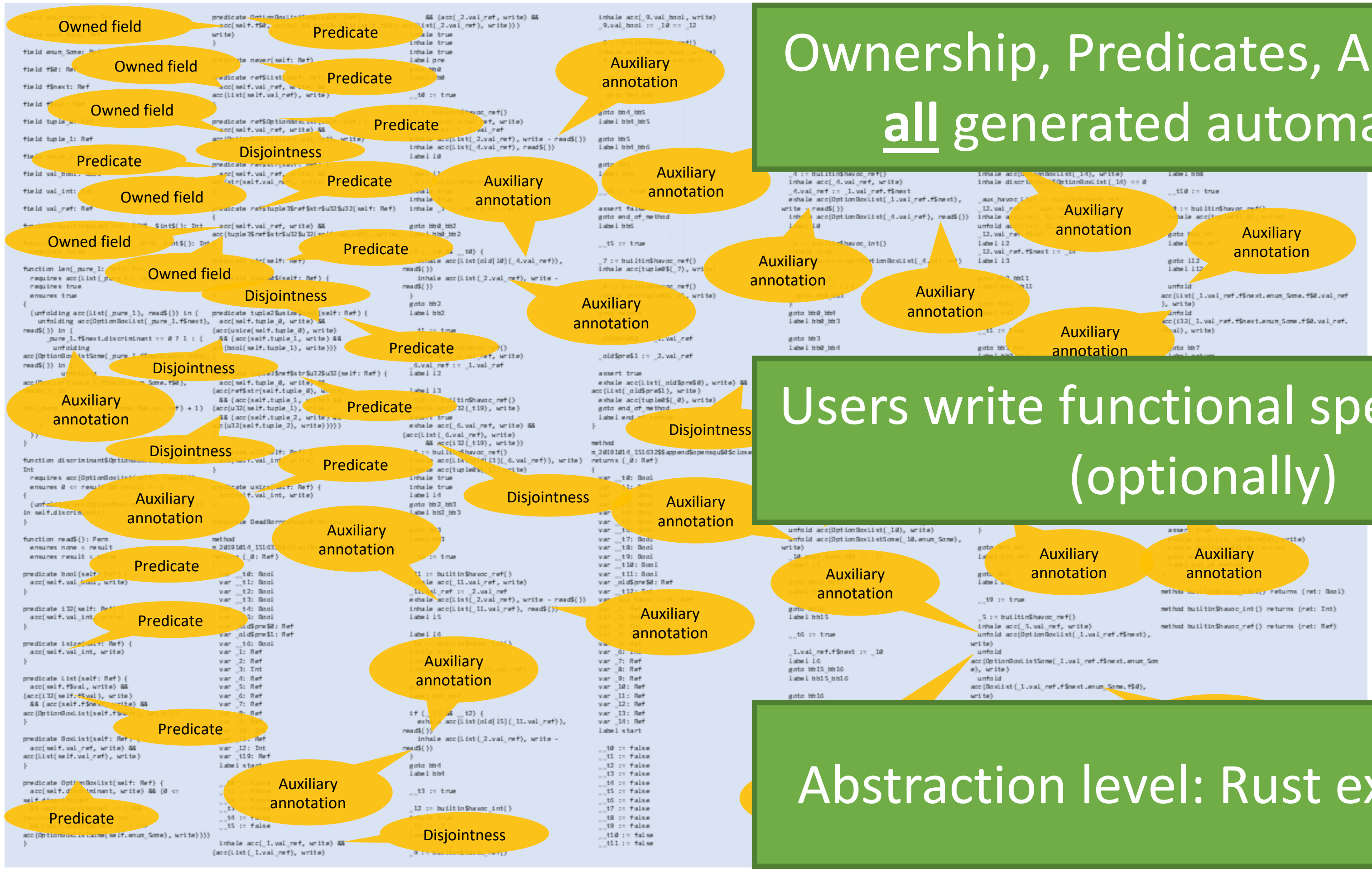
- Types
- Signature
- Compiler analyses (e.g. borrow checker)
- User specifications (optional)



Verification Ingredients

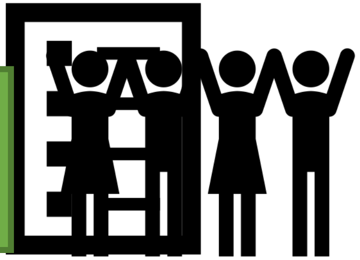
- Predicates and Ownership
- Pre/postconditions
- Auxiliary annotations
- Functional specification

Core Proofs: Behind the Scenes



Ownership, Predicates, Annotations **all** generated automatically

Users write functional specifications (optionally)

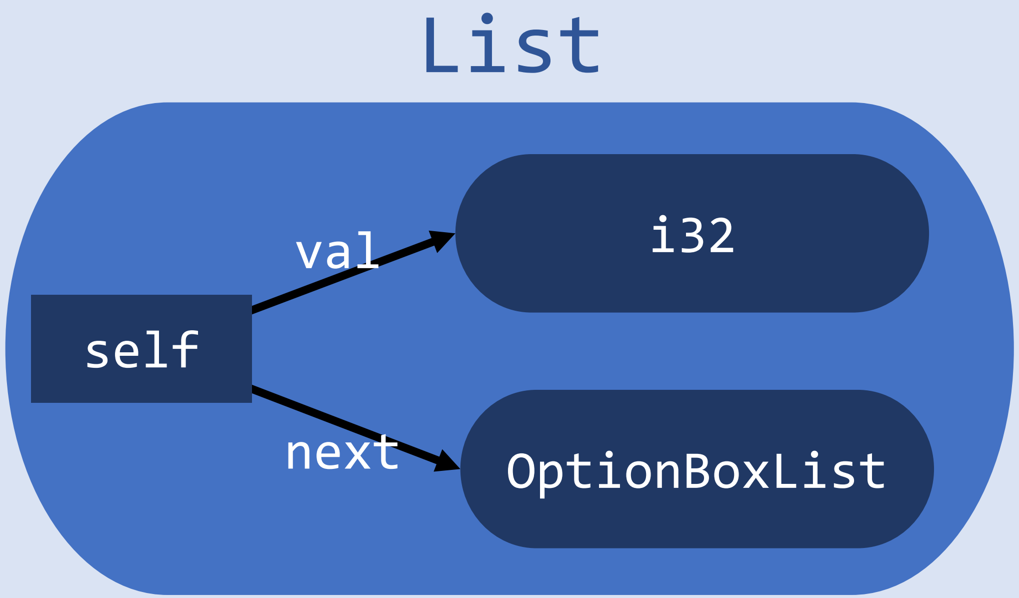


Abstraction level: Rust expressions

Type Encoding

```
struct List { val: i32, next: Option<Box<List>> }
```

Rust



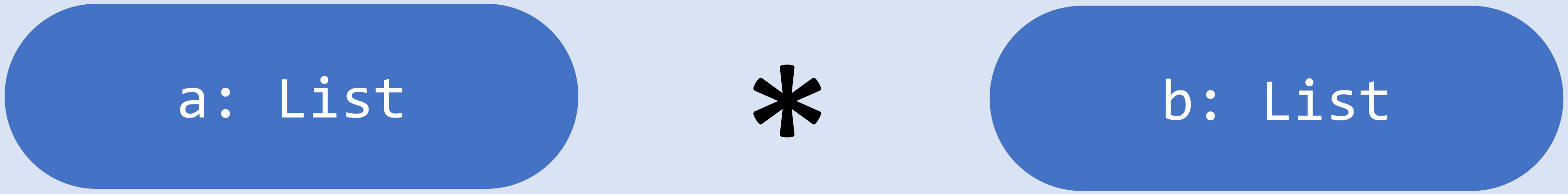

```
predicate List(self: Ref)
{
  acc(self.val) *
  acc(self.next) *
  i32(self.val) *
  OptionBoxList(self.next)
}
```

Viper

Signature Encoding

```
fn client(a: &mut List, b: &mut List)
```

Rust




```
method client(a: Ref, b: Ref)
  requires List(a) * List(b) && a.sorted() && …
  ensures List(a) * List(b) && a.sorted()
```

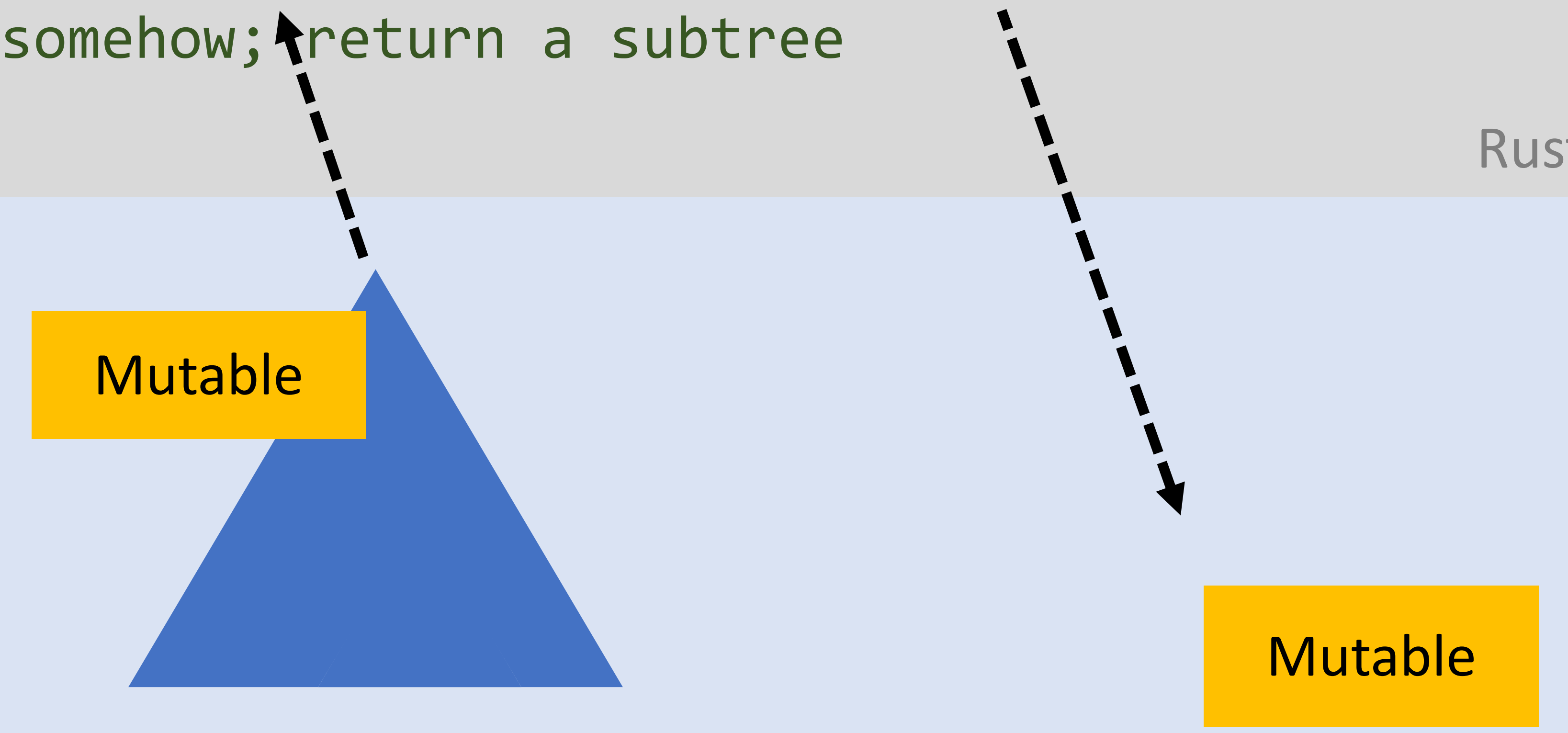
Viper

Reborrowing Challenges

```
fn get(t: &mut BinaryTree) -> &mut BinaryTree {
  // traverse somehow; return a subtree
}
```

Rust

For the caller:



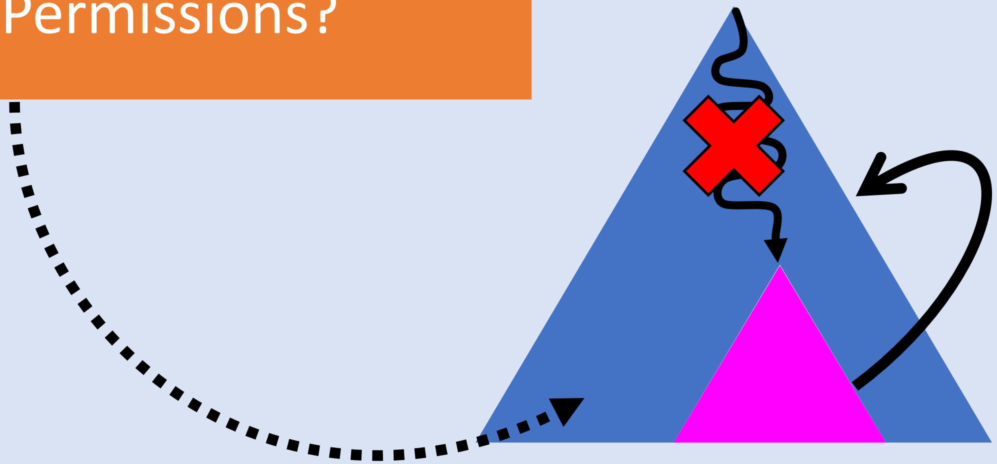
Reborrowing Challenges

```rust
fn get(t: &mut BinaryTree) -> &mut BinaryTree {
  // traverse somehow; return a subtree
}
```

Rust

Permissions?

Combined effect?



Reborrowing Challenges

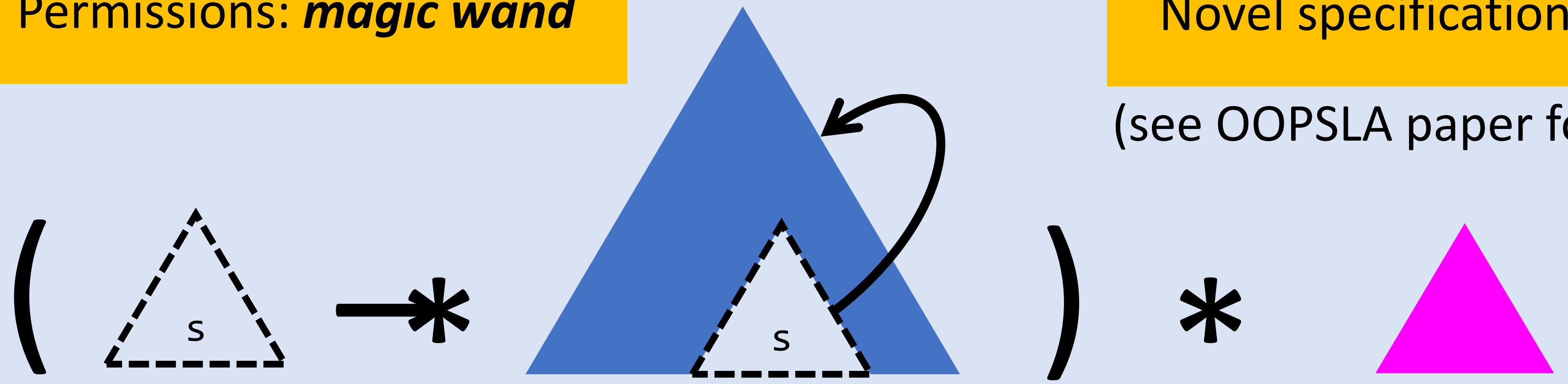
```rust
fn get(t: &mut BinaryTree) -> &mut BinaryTree {
  // traverse somehow; return a subtree
}
```

Rust

Permissions: ***magic wand***

Novel specification: ***pledges***

(see OOPSLA paper for details…)



Evaluation (no specifications)

500 most downloaded packages (crates)

No specification

11’791 (21%) supported functions

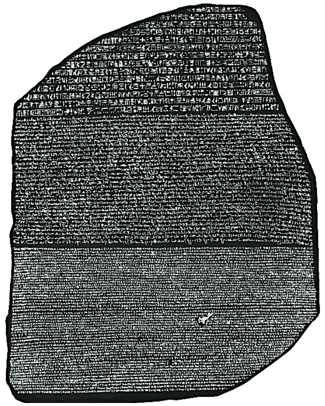
Total: **~40K** loc

100% of functions: core proof verifies

Total: **1M** lines of Viper

Auxiliary annotations: **100K**

Evaluation with specifications



rosettacode.org

+ Specification

Example	LOC	#Fns	Spec. LOC	Time (s) All	Time (s) Viper	No Panic	No Overflow	Verified Additional Properties
100 doors	19	2	7	10.9	7.4	✓	✓	
Binary Search (generic)	16	1	2	16.2	12.9	✓	✓	
Heapsort	39	3	18	30.6	26.2	✓	✓	
Knight's tour	89	6	71	127.6	120.2	✓	✓	
Knuth Shuffle	16	2	3	9.5	6.2	✓	✓	
Langton's Ant	58	4	22	16.7	11.8	✓	✓	
Selection Sort (generic)	20	2	8	19.2	15.2	✓	✓	
Ackermann Func.	16	2	17	7.4	4.4	-	×	Correct result
Binary Search (monomorphic)	16	1	29	25.5	21.4	✓	✓	Correct result
Fibonacci Seq.	46	6	26	9.1	5.7	-	-	Correct result
Knapsack Problem/0-1	27	1	86	139.4	131.6	✓	×	Correct computation
Linked List Stack	59	5	60	21.4	16.9	✓	-	Correct behaviour
Selection Sort (monomorphic)	20	2	34	29.6	24.2	✓	✓	Sorted result
Towers of Hanoi	10	2	5	5.9	3.2	-	✓	Correct param. range
Borrow First	7	1	1	6.6	3.6	✓	✓	
Message	13	1	0	7.2	4.2	×	-	

What else is in the paper?

VIPER ENCODING

AUTOMATION

PLEDGES

RUST SUBSET

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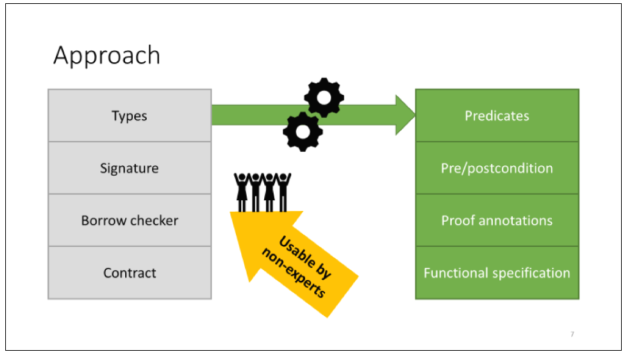
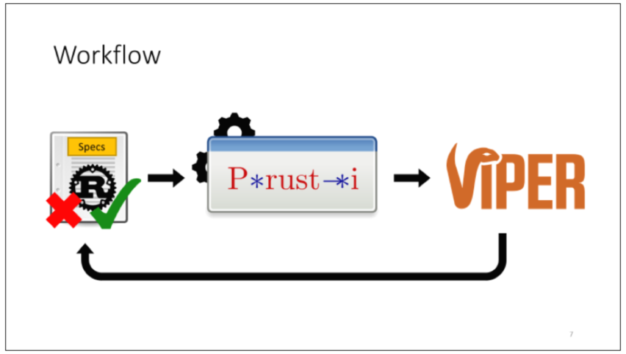
Conclusion

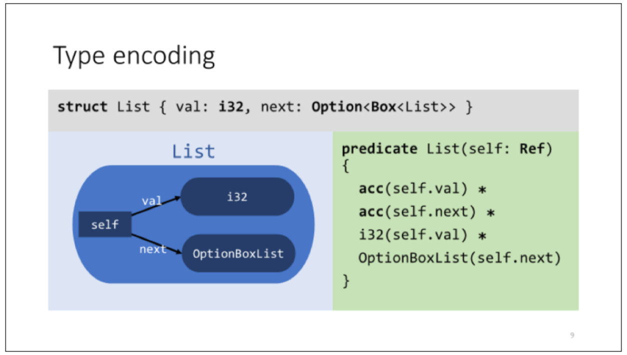


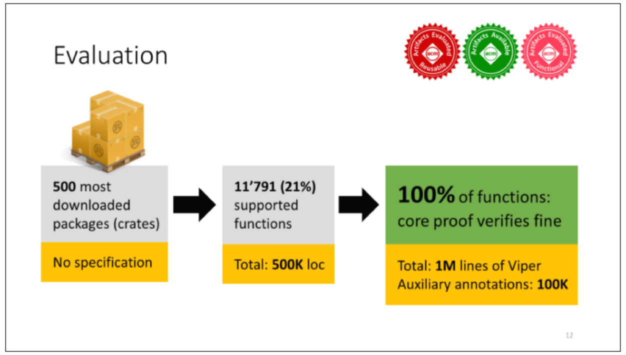


Plenty more to work on!
e.g. closures, unsafe code, reference counting, standard libraries, …

Dramatically simplifies Rust verification

Enables verification by developers





On the lookout for Master's (ETH/UBC) and PhD students (UBC)
- get in touch!

prusti.ethz.ch