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# RE-TARGETABLE GRAMMAR BASED TEST CASE GENERATION

**TESTING PARSERS IS  
HARD**

## HOW WE GOT HERE

- ▶ Mostly black box (ish) implementation of complex languages (context-free-ish)
- ▶ ~35k lines of grammar in total (ANTLR)
- ▶ Implemented from incomplete, inaccurate, and contradictory documentation
- ▶ Radically different parsing algorithm(s) from original implementations
- ▶ Lack of public test cases for most dialects

# PROBLEM AREAS FOR PARSING

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## OVERFIT/UNDERFIT GRAMMAR DEFINITION

- ▶ Does the parser accurately recognize the language?
- ▶ Lack of access to real grammars
- ▶ Poor documentation
- ▶ Differences in parsing algorithms means differences in grammar definition
- ▶ Ambiguity, recursion, precedence differences
- ▶ Universally proving CFG equivalence is undecidable

## TREE GENERATION FLAWS

- ▶ Does the parse tree accurately represent the sentence?
- ▶ Shows the syntactic relationship between tokens
- ▶ Most parser generators require manual tree construction
- ▶ Typically this stage translates string data to its real type representation

```
lexer_body_part: ast::Operation = {
  <r:UpperId> <q:Quantifier*> => ast::unroll_quantifier(q, ast::Operation::Token(r)),
  <l:StringLiteral> ".." <r:StringLiteral> => ast::Operation::Range((l, r)),
  <r:StringLiteral> <q:Quantifier*> => ast::unroll_quantifier(q, ast::Operation::StringLiteral(r)),
  "(" <r:LexerBody> ")" <q:Quantifier*> => ast::unroll_quantifier(q, ast::Operation::Group(r)),
  "." <q:Quantifier*> => ast::unroll_quantifier(q, ast::Operation::Any),
  CharacterClass <q:Quantifier*> => ast::unroll_quantifier(q, ast::Operation::CharacterClass),
};
```

## UNSAFE/INCORRECT VALIDATED INPUT

- ▶ Have we validated that the input is safe and correct?
- ▶ Correct parsing proves validity but doesn't ensure future proper handling
- ▶ Syntactic/Semantic correctness doesn't ensure safety
- ▶ Opaque handling of tokens is fairly common due to language complexity
- ▶ Once you're past the parser it's back to smashing the stack/logic flaws/etc

**HOW DO WE TEST THIS?**

## GETTING MORE TEST CASES

- ▶ Write by hand
- ▶ Crawl the web/open source project pulling out examples
- ▶ Automatically generate test cases with a fuzzer

# STYLES OF FUZZING

## INSTRUMENTATION + RANDOM MUTATION

- ▶ Focus on path exploration and code coverage
- ▶ No concept of syntax/semantics
- ▶ Wont necessarily provide lot's of coverage for variations of a specific parse tree
- ▶ Might spend a lot of time on uninteresting/non-relevant code paths
- ▶ Not immediately clear how to build a proper test harness
- ▶ Example of this strategy is AFL (American Fuzzy Lop)
- ▶ <https://lcamtuf.blogspot.com/2014/11/pulling-jpegs-out-of-thin-air.html>

**“THE FIRST IMAGE, HIT AFTER  
ABOUT SIX HOURS ON AN 8-CORE  
SYSTEM...”**

**“...CERTAIN TYPES OF ATOMICALLY EXECUTED CHECKS WITH A LARGE SEARCH SPACE MAY POSE AN INSURMOUNTABLE OBSTACLE TO THE FUZZER...”**



**“IN PRACTICAL TERMS, THIS MEANS THAT AFL-FUZZ WON'T HAVE AS MUCH LUCK ‘INVENTING’ PNG FILES OR NON-TRIVIAL HTML DOCUMENTS FROM SCRATCH...”**

## INSTRUMENTATION + SOLVING

- ▶ Focus on path exploration and code coverage
- ▶ Instrument the code and solve for new paths
- ▶ Still doesn't care about syntax/semantics
- ▶ Still not clear how to build a more customer test harness
- ▶ Not necessarily easy to gate off specific paths that are uninteresting
- ▶ Example of this is KLEE

## GRAMMAR BASED

- ▶ Uses a grammar to generate syntactically correct sentences
- ▶ Typically provide their own grammar language
- ▶ Mostly targeted at regular/context-free text based languages
- ▶ Example of this is Mozilla Dharma
- ▶ <https://github.com/MozillaSecurity/dharma>

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## PROBLEMS WITH TRADITIONAL TEST CASE GENERATION

- ▶ Inflexibility with using test cases
- ▶ Inflexibility with providing feedback
- ▶ Existing tools solve many cases but as you deviate they become less useful

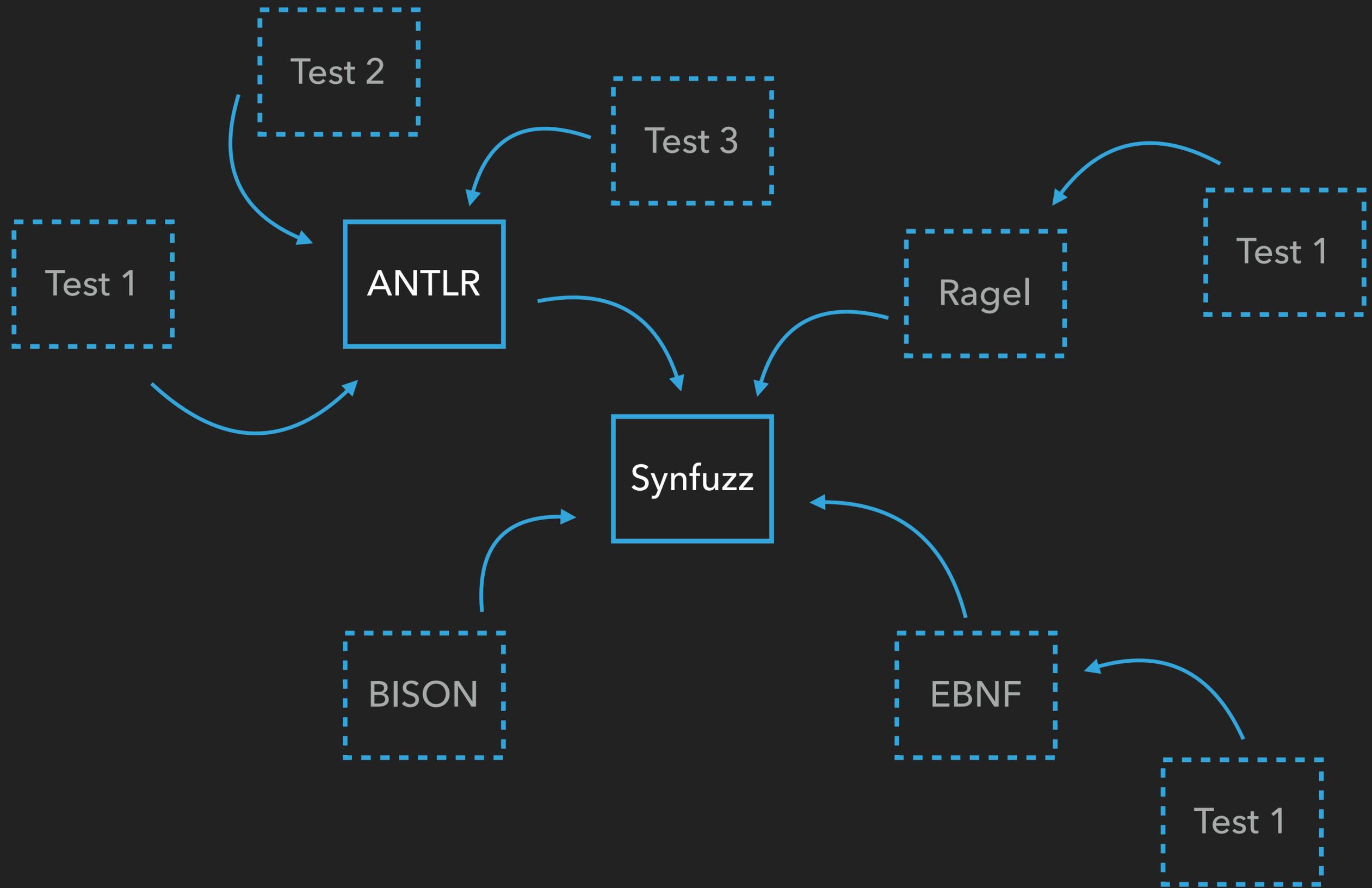
## HOW CAN WE DO BETTER?

- ▶ Easy to build flexible test harnesses
- ▶ Directly use grammar definition without manual translation
- ▶ Expressive enough for regular, context-free, and context-sensitive languages both text and binary
- ▶ Embeddable into and usable from any language
- ▶ As much code re-use as possible to avoid duplication

A GRAMMAR BASED TEST CASE GENERATION  
PLATFORM

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**SYNFUZZ**



Values

Quantification

Logical

Grouping

CharLiteral

RepeatN

Choice

Sequence

Byte

Many

Not

JoinWith

String

Many1

SepBy

CharRange

Range

SepBy1

Optional

```
let mut f = File::open("bnf.g4").unwrap();
let mut buf = String::new();
f.read_to_string(&mut buf).unwrap();

let rules = antlr4::generate_rules(&buf).unwrap();

let r = rules.read().unwrap();
let root = r.get("rulelist").unwrap();
let generated = root.generate();
let s = String::from_utf8_lossy(&generated);
println!("{}", s);
```

DEMO

# DESIGNING TEST HARNESSES

## DOES IT CRASH?

1. Start process
2. Generate input and feed it
3. Listen for SIGSEGV/SIGABRT

# OVERFIT

1. Generate test case
2. Find oracle that specifies whether a syntax or runtime error
3. Feed test case
4. Categorization
  1. If failure and syntax error parser is overfit
  2. If failure and runtime error may or may not be overfit



# UNDERFIT

1. Generate test case from reference implementation grammar
2. Parse with re-implementation
3. Categorization
  1. If fails re-implementation is underfit
  2. If succeeds re-implementation is correct

## WHAT'S READY TODAY

- ▶ Combinator library for regular and context-free grammars
- ▶ ANTLR4 frontend
- ▶ <https://www.github.com/jrozner/synfuzz>
- ▶ <https://www.github.com/jrozner/rust-antlr4>

## WHAT'S NEXT?

- ▶ Cycle detection + forced progression
- ▶ Expose a C-compatible API + language bindings
- ▶ Better negation logic
- ▶ Context-Sensitive/Introspective generators
- ▶ Bit level values
- ▶ Additional frontends
- ▶ Grammar coverage information

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HTTPS://WWW.GITHUB.COM/JROZNER/SYNFUZZ

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QUESTIONS?