The Parsley Data Description Language

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Problem

- What kinds of formal grammars can capture data formats?
  - ELF, OpenDocument, PDF
- How can untrusted data be parsed securely?
  - e.g. prevent parser exploits that manipulate parsing offsets

Limitations of Typical Formal Grammars

- Need for handling long-range context dependency
  - e.g. graph structures in document formats
- Very limited or no interface to parsing buffer
  - e.g. offset manipulations, buffer windowing, transformations

Issue: Handling Context Sensitivity

- Parsing and semantic actions can be controlled by context
- Distant context may need to be threaded through to current parsing operation
- Need a bounded mechanism to thread just the relevant context
- Relevant context can require structured datatypes

Issue: No First-class Parsing Buffers

- Binary data often specify offsets, lengths, etc.
  - Parsing cursor locations are data-dependent
- Network packet formats often require checksums
  - Requires windowed views into parsing buffer
- Data can often be optionally compressed, encrypted, etc.
  - Requires controlled transformations of windowed views into the parsing buffer

Design Goal: Adding Computation to Syntax

We are looking for a DDL that incorporates the computation needed

- to store and retrieve contextual information
- to evaluate contextual constraints
- to operate on parsing buffers

Other Design Goals

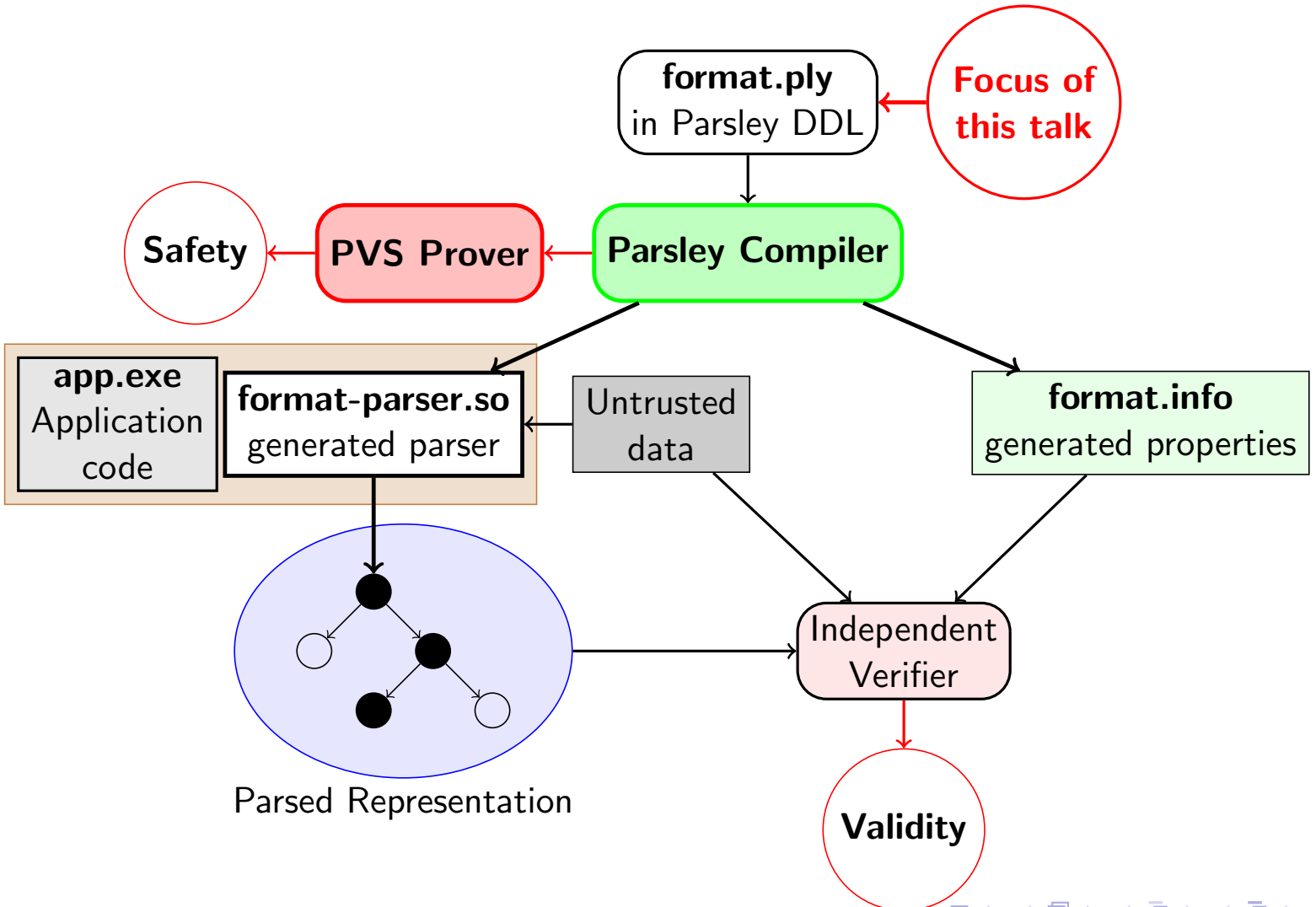
- Automatic extraction of parsers
- Construction of proofs-of-parse to validate correctness (Blaudeau, Shankar CPP 2020)

Parsley Design

- Composition of conventional techniques
  - Parsing expression grammars (PEG)
    - for determinism and unambiguity
  - Attribute grammars
    - for structured handling of context-sensitivity
    - specifying semantic actions
  - Functional languages
    - for type-safe computation of constraints and semantic actions

- Capture syntax using PEG and attribute grammars
- Capture computation using a functional language
- Capture contextual and computational state using attributes

Overall Parsley Architecture



Sublanguages of the Parsley DDL

- Parsing expression grammar for production rules
  - Specified in notation similar to EBNF
    `NonTerm := rule1 ; rule2 ; ... ;;`
- Typed functional expression language
  - Used for constraint expressions
    `[guard1(args) && (guard2(args) || guard3(args))]`
  - and semantic actions
    `{let val := expr(args) in nt.syn_attr := val}`

Grammar sublanguage

- Standard attribute system
  - `NonTerm (inh_attr:type)` := *rules*
    Communicates context-sensitive information using inherited attributes
  - `NonTerm {syn_attr:type}` := *rules*
    Stores information computed during *local* parsing in synthesized attributes
- Boolean constraints can guard parsing progress of a rule

  ... := *prev rule* ; ... `[bool_expr(attrs)]` ... ; *next rule*
  - Expressed in terms of the computed attributes in scope
  - Rewinds on guard failure to the last ordered choice (;) and continues with the next choice
- Standard library contains basic primitives like character classes

  `[:ascii:]`, `[:alphanum:]`

Expression sublanguage

- Simple typed functional language with user-defined types and functions

  ```
  fun f(a: arg_type) -> result_type = {...}
  ```

- Types of grammar non-terminals are represented by records with synthesized attributes as field names

  ```
  type non_term_type = {attrname: type}
  ```

- Standard library contains basic functions such as conversions of parsed data into typed values, and basic data structures like lists, sets, and maps

  `string_to_int()`, `byte_to_int()`, ...

  `List.append`, `Map.extend`, `Set.add`, ...

PDF Examples

- Null

```
Null := "null" ;;
```

- Comments

```
Comment := "%" ([:char:] \ "\n")* "\n" ;;
```

- Booleans

```
Boolean b {val : bool} := "true"  { b.val := true }
                        ;  "false" { b.val := false } ;;
```

- Name object

```
Name n {val : string} :=
  "/" s=([:alphanum:]+)
  { n.val := normalize_name(s) } ;;
```

PDF Examples

- Context-sensitive Whitespace

```
Whitespace (allow_empty : bool) :=
  [allow_empty]  // boolean constraint
  (" " | "\0" | "\t" | "\r" | "\n"
   | "\x0c" // form-feed
   | Comment
  )*
; [!allow_empty]
  (" " | "\0" | "\t" | "\r" | "\n"
   | "\x0c" // form-feed
   | Comment
  )+
;;
```

Tagged-Length-Value (TLV) constructs

```
type tlv =
   TTL  of int
 | Port of int
 | Unknown of byte * [byte]
fun ttl_to_int(b : [byte; 1]) -> int =
{ byte_to_int(b[0]) }
fun port_to_int(b : [byte; 2]) -> int =
{ 256* byte_to_int(b[1]) * byte_to_int(b[0]) }

TLV t { val: tlv } :=
tg=([:byte:]) l=([:byte:]) v=([[:byte:] * byte_to_int(l)])
 ( [tg = 1] [l = 1] { t.val := tlv::TTL(ttl_to_int(v))   }
 | [tg = 2] [l = 2] { t.val := tlv::Port(port_to_int(v)) }
 |                  { t.val := tlv::Unknown(tg, v)       }
 )
```

ELF Fragment

```
type elf_file_hdr = {ph_offset : int}

ELF_File := e=ELF_File_Hdr
            [e.ph_offset < ParseBuffer.size($buffer)]
            @(ParseBuffer.start($buffer) + e.ph_offset)
            p=ELF_Prog_Hdr
            ...
```

Design challenges

- Backtracking in ordered choice requires rewinding attribute updates
  - This is easier with *L*-attributed grammars
- Defining how backtracking composes with operations on the parsing buffer

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Questions?

Thank you!