Langkit

source code analyzers for the masses

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Langkit: A meta compiler

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High level vision

A DSL to implement language analysis front ends (parsing & more).

Front ends generated by Langkit could be the basis for:

- compilers
- debuggers (e.g. expression evaluator)
- interactive code browsers
- static analyzers
- automatic code refactoring tools

Original use case: Libadalang

- The Ada ecosystem lacks a good library to create code-aware tools
- Several partial analyzers in various tools (e.g. GPS, the main IDE)
- Libadalang = Langkit-generated library for Ada-aware tools

The DSL

Syntax

- Python-based DSL for now
- Uses the Python syntax to create data structures that are then compiled
- Will have its own syntax one day!

DSL Episode 1: Lexing

```
from langkit.lexer import LexerToken, WithText, WithSymbol

class MyTokens(LexerToken):
    Def = WithText()
    Identifier = WithSymbol()
    # ...

my_lexer = Lexer(MyTokens)
my_lexer.add_rules(
    (Literal('def'), MyTokens.Def),
    (Pattern(r'[a-zA-Z][a-zA-Z0-9]*',
     MyTokens.Identifier)),
    # ...
)
```

- Define a list of token kinds
- Provide regexp-based scanning rules to produce them

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DSL Episode 2: Tree

```python
from langkit.dsl import ASTNode, Field, abstract

@abstract
class RootNode(ASTNode):
    pass

class Name(RootNode):
    token_node = True

class Def(RootNode):
    name = Field()

# ...
```

- Define tree nodes the parser can produce
- Uses a Python class hierarchy to describe the *generated* node hierarchy
- Nodes can be abstract

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DSL Episode 3: Parsing

```python
from langkit.parsers import Grammar, List

g = Grammar('main_rule')
g.add_rules(
    main_rule=List(g.def_rule),
    name=Name(MyTokens.Identifier),
    def_rule=Def('def', g.name),
    # ...
)
```

- Recursive descent parser combinators (sequences, lists, optional parts, alternatives, …), based on Packrat
- Compiling the grammar:
    - Infers node types `Field` if type not specified
    - Checks consistency otherwise

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DSL Episode 4: Scoping

```
class Function(RootNode):
    local_vars = Field()
    env_spec = EnvSpec(
        add_env() # Associate an env to this node
    )

class VariableDeclaration(RootNode):
    name = Field()
    env_spec = EnvSpec(
        add_to_env(
            mappings=New(T.env_assoc, key=Self.name.symbol, val=Self)
            # In the current env, add a mapping from the name of this var to
            # the node itself.
        )
    )
```

- Foundation for semantic analysis
- Create name/nodes mappings: lexical environments

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DSL Episode 5: Semantic analysis

```python
from langkit.expressions import langkit_property

class VariableReference(FooNode):
    name = Field()

    @langkit_property(public=True)
    def var_decl():
        return Self.node_env.get_first(Self.name)
```

- Create methods on nodes (called “properties”)
- Public properties: user API for semantic analysis
- Private ones: implementation detail, hidden from users
- Functional programming language

DSL Episode 6: Logic DSL

- Hard problems in semantic analysis:
    - Overload resolution
    - Type inference
- Require non local knowledge

```
def f1 (i : int) -> int;
def f1 (f : float) -> int;

def f2 (c : char) -> int;
def f2 (c : char) -> char;

f1 (1);
f1 (0.3);
f2 (2);

f1 (f2 (f2 ('C')));
```

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DSL Episode 6: Logic DSL

```
  f1 (f2 (f2 ('C')));
#        ^ Call A
#    ^ Call B
# ^ Call C
```

```
A.args[0].type = char
A.returns.type = B.args[0].type
B.returns.type = C.args[0].type
A is in [f2 (c : char) -> int,
         f2 (c : char) -> char]
B is in [f2 (c : char) -> int,
         f2 (c : char) -> char]
C is in [f1 (i : int) -> int,
         f1 (f : float) -> float]
```

Solution:

```
A = f1 (i : int) -> int
B = f2 (c : char) -> int
C = f2 (c : char) -> char
```

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The generated libraries

Base library: Ada (W00T!)

Requirements for the target language:

- Fast
- Low level enough
- Memory management agnostic (no GC)
- Easy to bind to C and other languages

Candidates

- C, C++, Ada, Rust, ...

Chosen one: Ada

- Since the project is developed at AdaCore: no surprises :)

Bindings to other languages

Automatically generated C bindings

So that it is very easy to generate bindings to any languages the users wants

First class citizen Python bindings

- Python is the *de facto* scripting language of the Langkit ecosystem
- Everything possible in Ada is possible in Python

Easy to generate bindings to new languages

- No need for external bindings generators
- Knowledge about data types, functions, memory management -> Langkit

Crafted for incremental analysis

- Reloading happens a lot in IDE: performance required
- Avoid big recomputations for common operations
- No need to recompute *everything* when reloading one source file:
    - Keep source file-specific data as much isolated as possible
    - Reduced update process when removing/reloading source files

Syntactic analysis

- Small Ada syntactic analyzer
- Can be adapted to another language trivially

```
def has_same_operands(binop):
    def same_tokens(left, right):
        return len(left) == len(right) and all(
            le.is_equivalent(ri) for le, ri in zip(left, right)
        )
    return same_tokens(list(binop.f_left.tokens), list(binop.f_right.tokens))

def interesting_oper(op):
    return not op.is_a(lal.OpMult, lal.OpPlus, lal.OpDoubleDot,
                       lal.OpPow, lal.OpConcat))

for b in unit.root.findall(lal.BinOp):
    if interesting_oper(b.f_op) and has_same_operands(b):
        print 'Same operands for {} in {}'.format(b, source_file)
```

- Detected 4 serious bugs in AdaCore's own code

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Unparser

- Create a new source file *only from the tree* (not using original source information)
- Can also be used to create sources from completely synthetic trees
- Uses the grammar and the AST definition (no additional code needed)

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Rewriting (work in progress)

Source code:

```
procedure Main is
begin
    Put_Line ("Hello world");
end Main;
```

Let's rewrite:

```
call = unit.root.findall(lal.CallExpr) # Find the call
diff = ctx.start_rewriting() # Start a rewriting
param_diff = diff.get_node(call.f_suffix[0]) # Get the param of the call
# Replace the expression of the parameter with a new node
param_diff.f_expr = lal.rewriting.StringLiteral('"Bye world"')
diff.apply()
```

Result:

```
procedure Main is
begin
    Put_Line ("Bye world");
end Main;
```

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Generic tools shipping with the libraries

Small tools

./playground

- Command line tool based on IPython
- Allow interactive exploration of the tree/API in general

./parse

- Allow inspection of the AST
- Dump lexical environments

Code indenter (prototype)

- Provide a declarative data structure for indentation rules

```python
block_rule = field_rules(constant_increment=3)

indent_map = {
    lal.PackageDecl: Indent(
        field_rules=indent_fields(
            public_part=block_rule, private_part=block_rule
        )
    ),
    # ...
}
```

- Get auto indentation on tab in your favorite editor

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Syntax highlighter (not done)

- Auto generation of syntax highlighter
- Highlight keywords by default
- Custom rules to highlight more complex syntax based rules
- Automatic support in your editor

Language Server Protocol? (not done)

- Tentative plan: automatically generate basic LSP support from the plug-in
- We have a Neovim plug-in already doing for Ada:
  - Indentation
  - Go to definition
  - Tree editing and exploration
- In the future: more editors, more languages?

Existing Langkit-based libraries & prototypes

- **Ada** `https://github.com/AdaCore/libadalang`
- **Python** `https://github.com/AdaCore/langkit/tree/master/contrib/python`
- **JSON**
- **GPR** files (AdaCore's project description language) `https://github.com/AdaCore/gpr`
- **KConfig** (Linux kernel configuration description language) `https://github.com/Fabien-Chouteau/libkconfiglang`

Conclusion

- Sources are on GitHub: `https://github.com/AdaCore/langkit`
- Tutorial, too: `https://github.com/AdaCore/langkit/blob/master/doc/tutorial.rst`
- Still work in progress: APIs are moving and "doc is the code" (no separate documentation document)
- We gladly accept issues and pull requests, but our priority right now is Libadalang