Backus-Naur Form

Announcements

Describing Code

Languages with Recursive Structure

Programming languages often have recursive **structure** (even if they do not support recursion).

E.g., the calculator language was a tiny subset of Scheme that had only built-in procedures.

- Expressions are either numbers or call expressions.

- A call expression is +, -, *, or / followed by zero or more expressions.

```
(+ (* 3 (+ (* 2 4) (+ 9 3))) (+ (* 0 2) 1))
```

All calculator programs are sequence of these characters: ( ) + - * / . 0 1 2 3 4 5 6 7 8 9

But a valid calculator program must also have a tree structure and balanced parentheses.

Limitations of Regular Expressions

The parentheses language: an expression is zero or more expressions surrounded by <>

E.g., **<<<><<>><<<>>><><>>>**

The regular expression **[<>]+** is too expressive; it matches **><** and **<<>.**

(Demo)

<(<>)*> matches **<>**, **<<>>**, and **<<><>>**, but not **<<<>>>** or **<<><<>>>**

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Regular expressions cannot describe recursive structures of arbitrary depth.

(Therefore, a regular expression cannot describe the set of valid regular expressions!)

Context-Free Grammars

Grammars

A language has:

- **Syntax:** the set of allowed expressions in the language
- **Semantics:** the meaning of an expression

A *grammar* is a compact description of the syntax of a language.

A *regular language* is a language whose syntax can be described by a regular expression.

A *context-free language* has syntax that can be described by a **context-free grammar.**

- All of the features of a regular expression
- Can ensure that parentheses are balanced and properly nested

Backus-Naur Form

Backus-Naur form is a particular syntax for describing context-free grammars.

- Something like it was invented by John Backus to describe the syntax of ALGOL.
- Describing languages via context-free grammars is an older idea, formalized by Chomsky.

```
?start: expr
expr: OPEN CLOSE | OPEN exprs CLOSE
exprs: expr | expr exprs
OPEN: "<"
CLOSE: ">"
```

The Lark Python module is available on code.cs61a.org and has its own flavor of BNF.

Create a file on code.cs61a.org that starts with **?start:**, and it will be processed by Lark.

(Demo)

Details of Backus-Naur Form in Lark

A special symbol ?start corresponds to a complete expression.

Symbols in all caps are called terminals:

- Can only contain /regular expressions/, "text", and other TERMINALS
- No recursion is allowed within terminals

Unnamed literals within non-terminals do not show up in the parse tree.

```
?start: numbers
numbers: INTEGER | numbers "," INTEGER
INTEGER: "0" | /-?[1-9]\d*/
```

The **%ignore** directive omits those terminals in the final parse. E.g., **%ignore /\s+/**

(Demo)

Extended BNF

Extended BNF Operators

Extended BNF is not more expressive than BNF, but the grammar descriptions are shorter.

From the docs (lark-parser.readthedocs.io/en/latest/grammar.html#rules):

- (item item ..) - Group items
- [item item ..] - Maybe. Same as (item item ..)?
- item? - Zero or one instances of item (”maybe”)
- item* - Zero or more instances of item
- item+ - One or more instances of item
- item ~ n - Exactly *n* instances of item
- item ~ n..m - Between *n* to *m* instances of item

EBNF notation appears in Python docs (docs.python.org/3/reference/expressions.html):

```
dict_display       ::=  "{" [key_datum_list | dict_comprehension] "}"
key_datum_list     ::=  key_datum ("," key_datum)* [","]
key_datum          ::=  expression ":" expression | "**" or_expr
dict_comprehension ::=  expression ":" expression comp_for
```

Example: Calculator Language

A few more Lark specifics:

- Lark supports some common terminal types, such as numbers, via the **%import** directive.
- Symbol starting with ? do not show up in the parse tree if they have exactly one child.

A grammar for Calculator:

```
?start: expr
?expr: NUMBER | call
call: "(" OPERATOR expr* ")"
OPERATOR: "+" | "-" | "*" | "/"

%ignore /\s+/
%import common.NUMBER
```

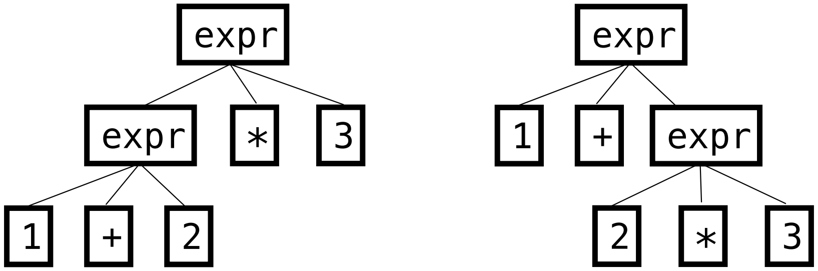
(Demo)

Ambiguity

Two Parses for the Same String

This grammar is ambiguous for 1+2*3:

```
?start: expr
?expr: NUMBER | expr OPERATOR expr
OPERATOR: "+" | "*"
%import common.NUMBER
```



Introducing symbols can eliminate ambiguity:

```
?start: expr
?expr: mul_expr | expr PLUS mul_expr
?mul_expr: NUMBER | mul_expr TIMES NUMBER
PLUS: "+"
TIMES: "*"
%import common.NUMBER
```

(Demo)