Interfacing ITP to the Real World

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Motivation

We would like to use ITP to reason about

- Software
- Hardware
- Control systems

The Weakest Link

There is a potential semantic gap. These are typically given as

- Software: C, C++, Java, maybe UML State Machine Diagrams
- Hardware: Verilog, VHDL
- Control systems: Simulink, ...

✘ITPs don't accept these as inputs. Semantics?

Possible Answers

A. Don't

- Instead: model in ITP's language, and then refine to target system
  (e.g., B, PVS $\rightarrow$ Verilog, ...)

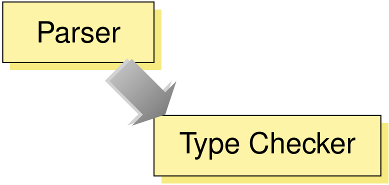
✔ Translation may be buggy, but this is usually a small tool

✔ Semantics question can be limited to a small subset of the target langauge

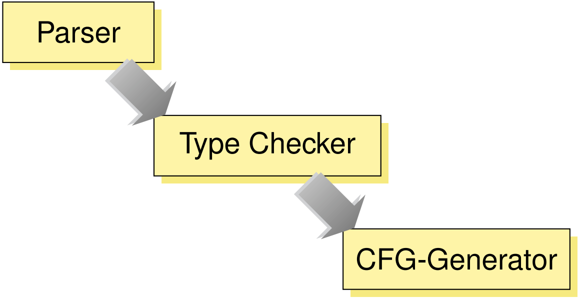
Models from Source Code: Overview

Parser

Models from Source Code: Overview



Models from Source Code: Overview



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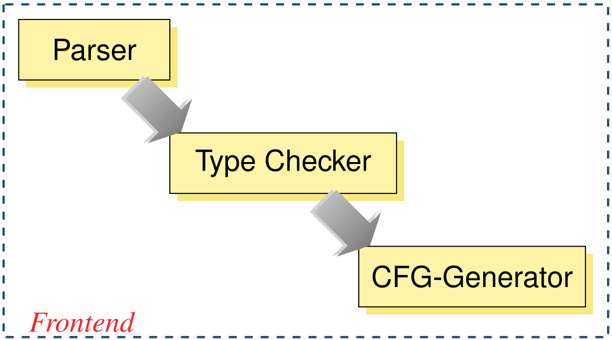

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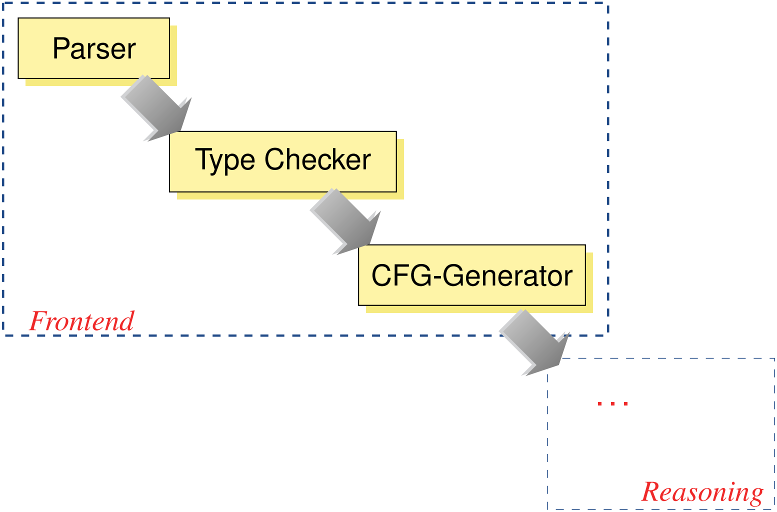


Scanner and Parser

Some overlap with compiler course here.

- A program is a sequence of tokens, which follows a grammar.
- A token is a sequence of characters drawn from an alphabet.

Tokenization

A scanner (lexical analyzer) turns a sequence of characters into a sequence of tokens.
Example: `flex`.

```
digit          [0-9]
octdigit       [0-7]
hexdigit       [0-9a-fA-F]
letter         ([A-Z]|[a-z])
identifier     (({letter}|"_")({letter}|{digit}|"_")*)
integer        {digit}+
decinteger     [1-9]{digit}*
octinteger     "0"{octdigit}*
hexinteger     "0"[xX]{hexdigit}+
decinteger_u   {decinteger}[uU]
octinteger_u   {octinteger}[uU]
hexinteger_u   {hexinteger}[uU]
```

Grammars

- Grammars are typically given in *Backus Normal Form* (BNF)
- Distinguishes terminals (from scanner) and non-terminals

Example from ISO/IEC 9899:1999 (ANSI–C)

(6.5.1) *primary-expression:*

identifier
constant
string-literal
(*expression* **)**

(6.5.2) *postfix-expression:*

primary-expression
postfix-expression **[** *expression* **]**
postfix-expression **(** *argument-expression-list*$_{opt}$ **)**
postfix-expression **.** *identifier*
postfix-expression **->** *identifier*
postfix-expression **++**
postfix-expression **--**
(*type-name* **)** **{** *initializer-list* **}**
(*type-name* **)** **{** *initializer-list* **,** **}**

(6.5.2) *argument-expression-list:*

assignment-expression
argument-expression-list **,** *assignment-expression*

Example: bison Grammar

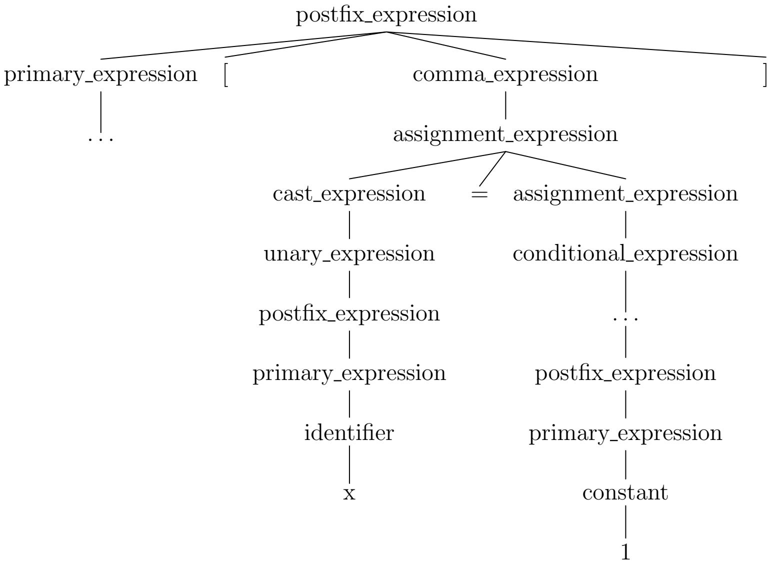
```
primary_expression:
    identifier
  | constant
  | '(' comma_expression ')'
  ;

postfix_expression:
    primary_expression
  | postfix_expression '[' comma_expression ']'
  | postfix_expression '(' ')'
  | postfix_expression '(' argument_expression_list ')'
  | postfix_expression '.' member_name
  | postfix_expression TOK_ARROW member_name
  ...
```

Parse Trees

Each rule is typically associated with some code fragment that constructs a parse tree.

- The internal nodes are non-terminals of the grammar
- The leaf nodes are terminals of the grammar

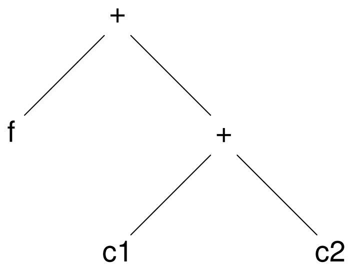
Parse Trees


postfix_expression
primary_expression
[
comma_expression
]
. . .
assignment_expression
cast_expression
=
assignment_expression
unary_expression
conditional_expression
postfix_expression
. . .
primary_expression
postfix_expression
identifier
primary_expression
x
constant
1

Type Checker

- Parse tree to symbol table: maps identifiers to types

- Expressions are annotated with types
  $\rightarrow$ promotion rules in the case of C



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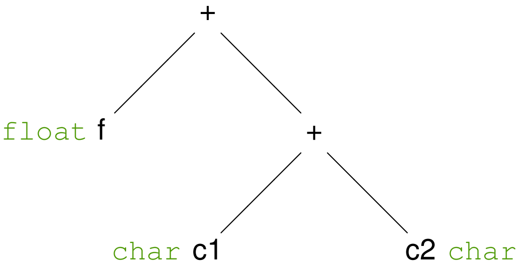

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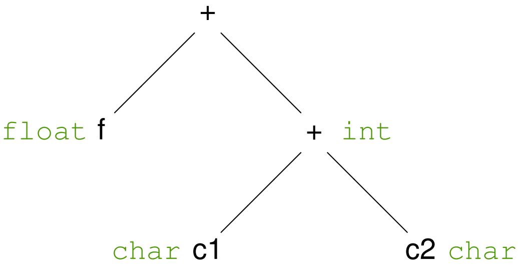

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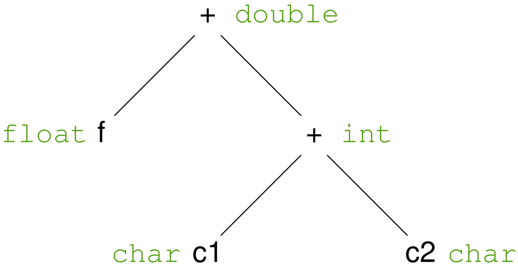


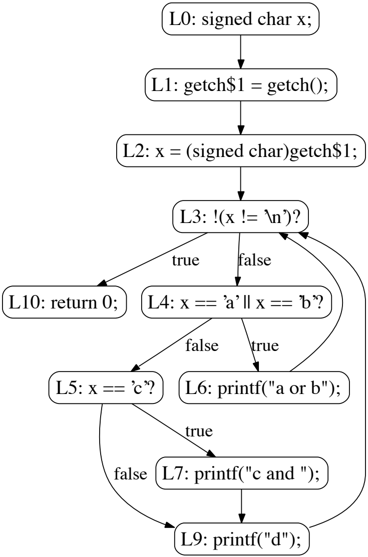
Control Flow Graph

- The code of each procedure is converted to a Control Flow Graph (CFG)

- Think of this as a program with GOTOs

Control Flow Graph

```
int main( void ) {
  char x;
  x = getch();
  while (x!='\n') {
    switch(x) {
      case 'a':
      case 'b':
        printf("a or b");
        break;
      case 'c':
        printf("c and ");
        /* fall-through */
      default:
        printf("d");
        break;
    }
  }
  return 0;
}
```



Where and How?

- All of this can be done inside the ITP
- A tool like ACL2 might even be fast
- Or: do externally, and grab any of the intermediate stages (possibly verify the external tool)

STL

- Standard Template Library
- Encapsulates complex data structures and algorithms

```
typedef std::hash_map<
  std::string, symbolt, string_hash> symbolst;
...

typedef std::vector<nodet> nodest;
```

STL

- "Interesting" programs using STL
  have $>$1000 data structures

- STL implementation highly complex and optimized
- Don't want to verify STL together with program

- Let's *assume the STL is correct*,
  and let's map these to theorem prover types!

Simulink

- We have models from Airbus, Ford, ...

- This looks like a dataflow description, but it isn't
- This looks like there are modules, but there aren't
- This looks like there is concurrency, but there isn't

$\longrightarrow$ Use sequential semantics

✔ We are building a converter to CFGs