SMACC: BEHIND THE REFACTORINGS

Jason Lecerf & Thierry Goubier

May 17, 2017

TABLE OF CONTENTS

SMACC

- The Smalltalk Compiler Compiler is a parser generator for Smalltalk
- Originally developed by John Brant & Don Roberts
- Used in Moose, Synectique, CEA, RefactoryWorkers

CONTEXT

- Architecture to generate the front-end of compilers
  - for DSL parsing
  - for program analysis
  - for program migration
  - for refactoring and transformation of source code
  - for compiler front-end implementation
- SmaCC is written in Smalltalk and generate parsers in Smalltalk
- It has the infrastructure for generating parsers in other programming languages

EXAMPLE OF USE

What you want to do:

- Find pattern in code written in a (niche) language
- Refactor these patterns into something new

What you will need:

- The grammar for your language (if it does not already exists in SmaCC)
- Your patterns and related transformations
- Your program

TABLE OF CONTENTS

CAPABILITIES

Automated generation of LR parsers

- Input: the specification of the grammar
- Output: parser for the grammar
  - can create arbitrary code run at parse time
  - can create an AST[1]

[1] Abstract Syntax Tree

SMACC GENERATION PIPELINE

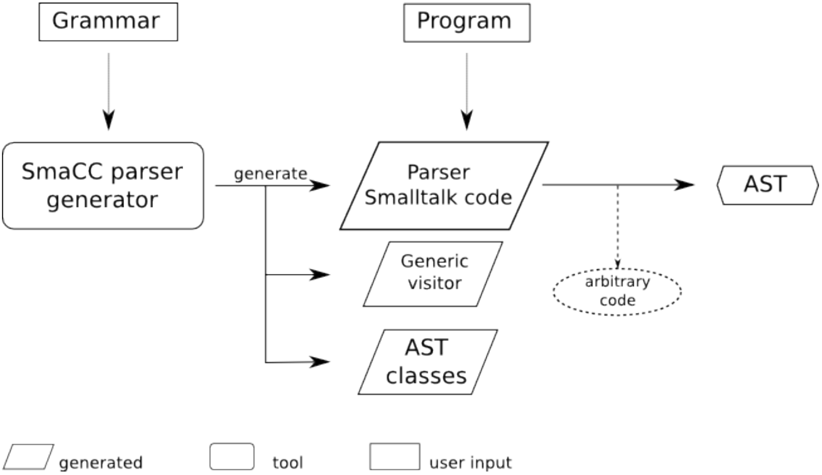


Figure: SmaCC overall pipeline

SMACC INPUT: THE GRAMMAR

- In a slightly modified BNF[2] form

```
CondExp
    : ArithExp
    | BitwiseExp
    | RelationalExp
    | BoolExp
    | TernaryExp
    | <lpar> CondExp <rpar>
    | "defined(" Id <rpar>
    | Id
    | Number
    ;
```

```
#if NB_BITS < 16
#elif NB_BITS < 32
#else
#endif
```

[2] Bachus-Naur Form: a meta-grammar

SMACC PARSER GENERATION

The generation:

- Produces a DFA lexer (the scanner)
- Produces either LR(1) or LALR(1) parsers
- Can be augmented to support GLR parsing
- Generate methods for parse table transitions
  - not exactly the parse tables themselves (optimizations were done)
  - no tables, just methods for the lexer

LR Standard parser for context-free grammars

LALR Merge states resulting in a smaller memory footprint

GLR Try all the possible transitions for a state

SMACC PARSER GENERATION OUTPUT

The generated parser is a Smalltalk package containing:

- a Scanner class
- a Parser class
- the AST node classes
- a generic AST visitor

Running the parser on an input pogram:

- produce AST nodes instances
- execute arbitrary code given to the grammar

GRAMMAR WITH ARBITRARY CODE EXECUTION

```
Expression
        : Expression 'left' "+" Expression 'right'
          {left + right}
        | Expression 'left' "-" Expression 'right'
          {left - right}
        | Expression 'left' "*" Expression 'right'
          {left * right}
        | Expression 'left' "/" Expression 'right'
          {left / right}
        | Expression 'left' "^" Expression 'right'
          {left raisedTo: right}
        | "(" Expression 'expression' ")" {expression}
        | Number 'number' {number}
        ;
Number
        : <number> 'numberToken'
          {numberToken value asNumber}
        ;
```

GRAMMAR WITH AST PRODUCTION

```
Expression
        : Expression 'left' "+" 'op' Expression 'right'
            {{Expression}}
        | Expression 'left' "-" 'op' Expression 'right'
            {{Expression}}
        | Expression 'left' "*" 'op' Expression 'right'
            {{Expression}}
        | Expression 'left' "/" 'op' Expression 'right'
            {{Expression}}
        | Expression 'left' "^" 'op' Expression 'right'
            {{Expression}}
        | "(" Expression 'expression' ")" {{}}
        | Number
        ;
Number
        : <number> {{Number}}
        ;
```

TABLE OF CONTENTS

EXTENDED SMACC PIPELINE

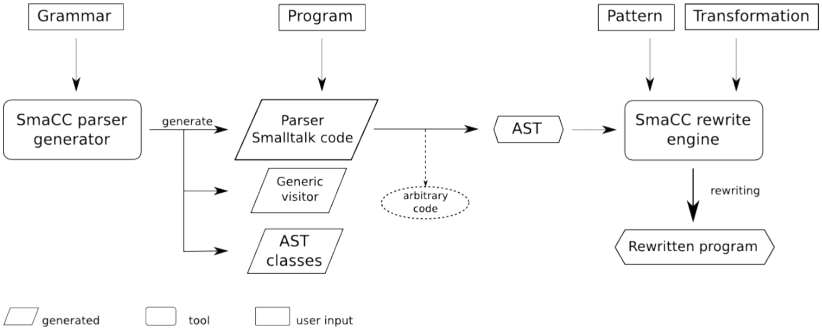


Figure: Extended SmaCC pipeline

PRECONDITIONS

- Parser for the language
- Enable GLR parsing in the grammar
- Declare a pattern token in the grammar
  - usually in between backquotes since they are used in barely any language

INPUT TO THE REWRITE ENGINE

- Pattern
- Metavariables
- Transformation

```
Parser: MyExpressionParser
>>>`a` + `b`<<<
->
>>>`a` `b` +<<<
```

REWRITTEN OUTPUT EXAMPLE

Input program:

```
(3 + 4) + (4 + 3)
```

Rewritten program using the rewrite engine:

```
3 4 + 4 3 + +
```

ANATOMY OF THE REWRITE ENGINE

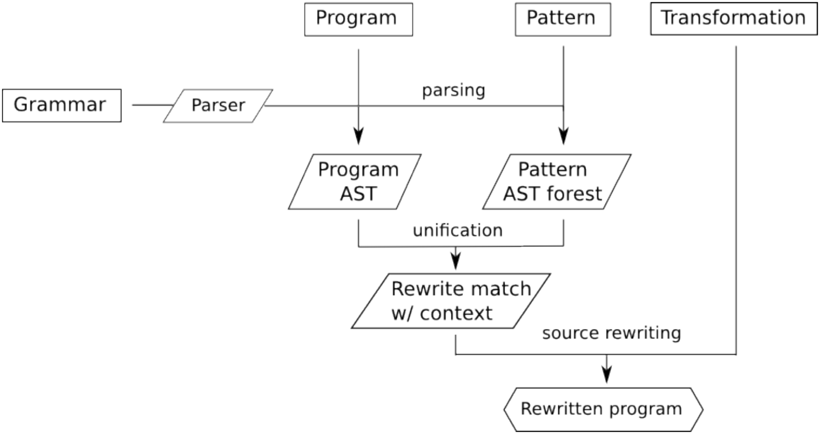


Figure: SmaCC rewriting process

PARSING OF THE PATTERN STRING

- Metavariables can match any nodes (unless specified otherwise)
  - can be modified to match list of nodes or specific types of nodes
- Use the GLR parser to parse the pattern
- Try all the possible starting symbols (entry points) of the grammar
  - ex: Methods, expressions, method call
  - not only the top entry point (often "Program")
- Get all the possible ASTs for the pattern

PRELIMINARY OPERATIONS

1. Parse *program* using the GLR parser
   - Produces the program AST
2. Parse *pattern* using the GLR parser
   - If there are conflicts: we get a forest of trees
   - If there are pattern nodes (metavariables): we get a forest of trees if valid for the grammar
   - Otherwise: we get a single tree

SIMPLIFIED SPLITFORPATTERNTOKEN

if *currentToken* = *patternToken* **then**
  for all *symbol* in {tokens OR non-terminal nodes} **do**
    actionsToProcess ←all possible LR actions for *symbol*
    for all LR *action* in *actionsToProcess* **do**
      Check if *action* was not already performed
      if *symbol* = *Token* OR (*symbol* = *Node* AND *action* = *reduction*) **then**
        Add a token interpretation to the current token
        Try to perform current LR *action*
      else if *symbol* = *Node* AND *action* = *shift* **then**
        stateStack add new ambiguous state
      end if
    end for
  end for
  Remove current pattern token state
end if

MATCHING OF THE PATTERN

Based on ambiguity handling by GLR

- Reuses the parser for your grammar
- Based on the parse tables of said parser
- When parsing a pattern token:
  - Try all the valid action-token combinations (transitions) for the current state
  - When conflicts arise (i.e. more than one transition is possible), fork the parser

ANATOMY OF THE REWRITE ENGINE

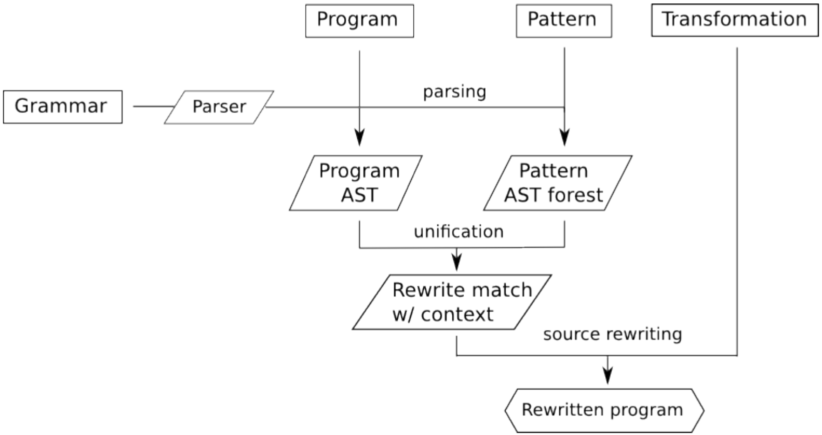


Figure: SmaCC rewriting process

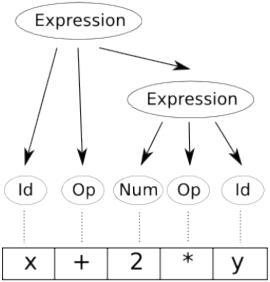
UNIFICATION ALGORITHM

```
Require: patternForest, programTree
  for all programNode in programTree do
  ▷ Depth first traversal
    for all patternTree in patternForest do
      for all patternNode in patternTree do
        if patternNodeclass = programNodeclass then
          Tries to match patternNode subnodes with programNode subnodes
        else
          continue
        end if
      end for
    end for
  end for
```

UNIFICATION ALGORITHM

Program

x + 2 * y



Pattern matching

\`a\` \`op{nodeClassName: #Op}\` \`b\`

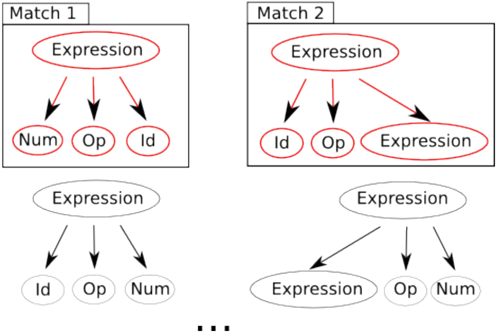


Figure: SmaCC rewriting process

EQUALITY

```
ArgumentListPar
    : "(" (Expression 'argument'
        ("," Expression 'argument')* )? ")"
```

Node equality Class are identical and every subnodes, subtokens match

Token equality Both values are identical (same string)

- Here: the left and right parenthesis tokens

Node collection equality Every individual node matches

- Here: the list of $n-1$ commas

Token collection equality Every individual token matches

- Here: the list of n Expression arguments

CONTEXT & METAVARIABLE BINDING

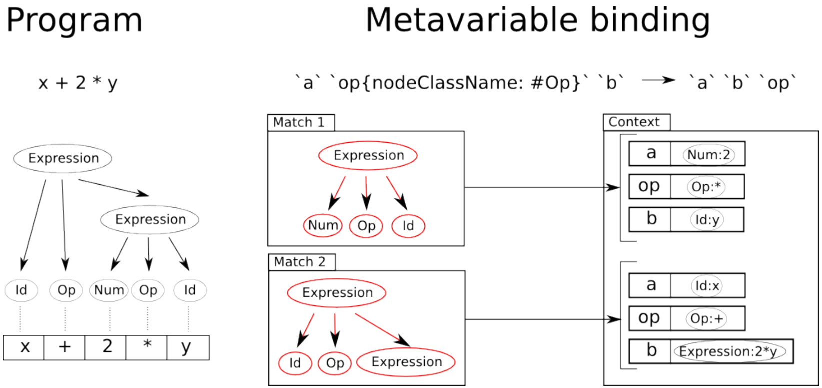


Figure: SmaCC binding & rewriting process

ANATOMY OF THE REWRITE ENGINE

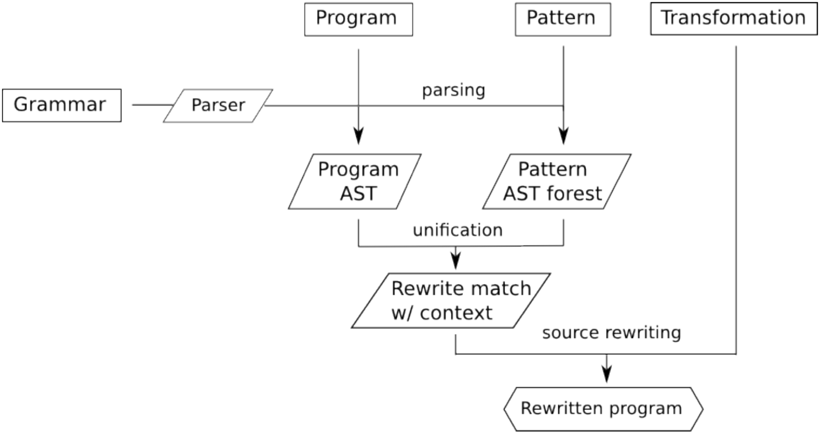


Figure: SmaCC rewriting process

REWRITING

- When nodes match, they are stored in the *context*
- Even if it seems intuitive, SmaCC does not perform AST rewriting
  - Is rewriting a part of a tree really that simple ?
  - And what if I rewrite in another programming language ?
- When rewriting, only transform the source of the nodes to the source of the transform
  - i.e.: the source of the transform is not parsed

WHAT ABOUT RB ?

- RB and SmaCC share the same creators
- But Smalltalk is a very simple language (to parse)
  - It is simple to specify a pattern tree directly
  - Use a bit the parser to complete the pattern tree
  - Rule: a pattern is valid Smalltalk code
  - But may match a slightly different tree (message)
- Subtree matching algorithm is exactly the same as in SmaCC
  - For example, see
  - RBPatternMethodNode>>#match:inContext:

TABLE OF CONTENTS

SMACC APPROACH

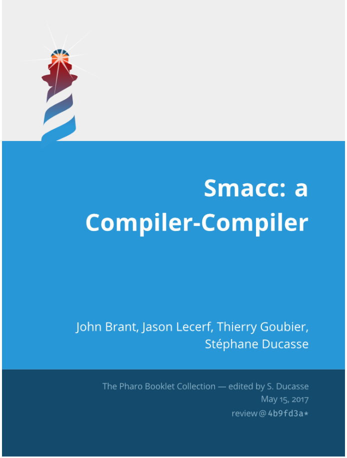
- Put some (most) of the complexity in the parser
- Use reflexivity on the grammar
  - The grammar specify all correct phrases (all valid sequences of tokens)
  - The AST directives specify all possibles nodes and trees of nodes (complete type specification)
  - The parser contains all that information in the state tables
  - Query it!
- Match and rewrite (on a large scale... over a million lines of code)

CONCLUSION

- SmaCC is a parser generator extended with pattern matching and rewriting capabilities
- Uses the parser as a way to reflect on the grammar and build pattern trees
- Tree traversal for matching is depth first (ASTs are not very deep)
- Generalization of the Refactoring Browser in the case of an "arbitrary" grammar
- Used extensively by John Brant, Thierry Goubier and others...

WIP: SMACC BOOKLET

Tutorial and documentation book for SmaCC



Thank you!

Commissariat à l'énergie atomique et aux énergies alternatives
Campus Saclay Nano-Innov | F-91191 Gif-sur-Yvette Cedex
www-list.cea.fr