SIGMA - Normalization

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***Abstract*—Introduction:**
Objective:
Methods:
Results: What are the main findings? Practical implications?
Limitations: What are the weaknesses of this research?
Conclusions: What is the conclusion?
***Index Terms*—Island Grammars, Automated Grammar Formation, Software Language Engineering**

I. Introduction

Multilingual parsing is an open problem that is currently being worked on. One method of multilingual parsing that has been developed is by creating island grammars for the combined grammars [1]. An automated method for doing this is currently being developed [SIGMA REFERENCE HERE]. One challenge to automating the creation of island grammar based multilingual parsers is detecting similar parts of grammars and combining them. This process becomes easier with an appropriate normalization process and normal form.

Outline:

1. Mention current SIGMA tool.
2. Normalization section is untested.

RG Design a normalization process for grammars that is conducive to identifying and merging similar parts across grammars to be used for merging grammars for the automated creation of multilingual parserss.

Organization

The remainder of this paper is organized as follows. Sec. II discusses the theoretical foundations of this work while also discussing other related studies. Sec. IV details the design of experiments which evaluate the normalization steps of SIGMA. Sec. V details the threats to the validity of this study. Finally, this paper is concluded in Sec. VI.

II. Background and Related Work

A. Theoretical Foundations

Context-free grammars are defined as $G = (V, \Sigma, P, S)$, where V is the set of non-terminal symbols, Σ is the set of terminal symbols, P is the set of productions, and S is the start production [@haoxiangLanguagesMachinesIntroduction1988].

Island Grammars are a type of grammar designed for extracting out features of interest. Island Grammars are composed of two types of rules: land/island rules which identify the features of interested, and water rules which are catch all rules for everything that is not of interest [@moonenGeneratingRobustParsers2001]. Island grammars are advantageous to regular grammars for several reasons, including being easier/faster to write, lower complexity, and better tolerance of errors in the input [@moonenGeneratingRobustParsers2001]. Because of this, island grammars have been used for the development of multilingual parsers [@synytskyyRobustMultilingualParsing2003].

In this paper, we evaluate the normalization process of SIGMA. SIGMA uses a unique

B. Related Studies

C. Research Contributions

III. Approach

A. Normalization

Next, the trivially merged grammar is normalized to a unique normal form wherein every production is one of the following two forms:

$\langle A \rangle$ ::= $\langle B \rangle$ ‘a’ ...
$\langle B \rangle$ ::= $\langle A \rangle$ | ‘b’ | ... | ε

Where production $\langle A \rangle$ represents form F_1 and production $\langle B \rangle$ represent form F_2. These forms were selected to ease comparison of similar productions. Note, as per this normalization, neither form may be recursively defined. The rational behind this, is to ensure that regardless of how productions are nested they will normalize to the same form, for example: Given grammar EG_1

$\langle A \rangle$ ::= ‘a’ $\langle B \rangle$
$\langle B \rangle$ ::= ‘b’ ‘c’

and grammar EG_2

$\langle A \rangle$ ::= $\langle B \rangle$ ‘c’
$\langle B \rangle$ ::= ‘a’ ‘b’

both EG_1 and EG_2 normalize to the same grammar, as follows:

$\langle A \rangle$ ::= ‘a’ ‘b’ ‘c’

Normalization continues, repeatedly, through the following six processes until stabilization: eliminating unused rules, simplifying productions, merging equivalent rules, eliminating unit rules, expanding productions, and collapsing compatible productions.

⟨S⟩ ::= <S_1> | <S_2>
⟨S_1⟩ ::= <A> | <B>
⟨A⟩ ::= ‘a’ ε <B> <C_1>
⟨C_1⟩ ::= ‘c’
⟨B⟩ ::= ‘b’ ‘d’
⟨S_2⟩ ::= <C_2> | <D>
⟨C_2⟩ ::= ‘c’
⟨D⟩ ::= ‘a’ ‘d’ (‘e’ | ‘c’) | (<C_2> | ‘b’)

(a) Grammar G_4.

⟨S⟩ ::= <S_1> | <S_2>
⟨S_1⟩ ::= <A> | <B>
⟨A⟩ ::= ‘a’ <B> <C_1>
⟨C_1⟩ ::= ‘c’
⟨B⟩ ::= ‘b’ ‘d’
⟨S_2⟩ ::= <C_2> | <D>
⟨C_2⟩ ::= ‘c’
⟨D⟩ ::= ‘a’ ‘d’ (‘e’ | ‘c’) | (<C_2> | ‘b’)

(b) Grammar G_5.

⟨S⟩ ::= <S_1> | <S_2>
⟨S_1⟩ ::= <A> | <B>
⟨A⟩ ::= ‘a’ <B> <C>
⟨C⟩ ::= ‘c’
⟨B⟩ ::= ‘b’ ‘d’
⟨S_2⟩ ::= <C> | <D>
⟨D⟩ ::= ‘a’ ‘d’ (‘e’ | ‘c’) | (<C> | ‘b’)

(c) Grammar G_6.

⟨S⟩ ::= <S_1> | <S_2>
⟨S_1⟩ ::= <A> | <B>
⟨A⟩ ::= ‘a’ <B> ‘c’
⟨B⟩ ::= ‘b’ ‘d’
⟨S_2⟩ ::= ‘c’ | <D>
⟨D⟩ ::= ‘a’ ‘d’ (‘e’ | ‘c’) | (‘c’ | ‘b’)

(d) Grammar G_7.

⟨S⟩ ::= <S_1> | <S_2>
⟨S_1⟩ ::= <A> | <B>
⟨A⟩ ::= ‘a’ <B> ‘c’
⟨B⟩ ::= ‘b’ ‘d’
⟨S_2⟩ ::= ‘c’ | <D>
⟨D⟩ ::= <D_1> | <D_3>
⟨D_1⟩ ::= ‘a’ ‘d’ <D_2>
⟨D_2⟩ ::= ‘e’ | ‘c’
⟨D_3⟩ ::= ‘c’ | ‘b’

(e) Grammar G_8.

⟨S⟩ ::= <A> | <B> | ‘c’ | <D>
⟨A⟩ ::= ‘a’ ‘b’ ‘d’ ‘c’
⟨B⟩ ::= ‘b’ ‘d’
⟨D⟩ ::= <D_1> | ‘c’ | ‘b’
⟨D_1⟩ ::= ‘a’ ‘d’ <D_2>
⟨D_2⟩ ::= ‘e’ | ‘c’

(f) Grammar G_9.

Fig. 1. Transformed grammars produced during the normalization of grammar G_3.

1) Eliminating Unused Rules: Remove all rules that are not produced, directly or indirectly, from the start rule. This is accomplished by marking all rules enumerated via a depth first search, and then dropping unmarked rules. When applied to G_3 the grammar is transformed into grammar G_4, as depicted in Fig. 1a.

2) Simplifying Productions: To simplify in-memory grammar representations, the process removes ε embedded inside terms. Next, productions containing one term are replaced with that term. When this step is applied to grammar G_4, it is transformed into grammar G_5, as depicted in Fig. 1b

3) Merging Equivalent Rules: Rules that have identical productions are replaced by a single rule. This new rule is given a name derived from the rules that were merged to create it. In the following example of this step, rules a and b are merged into the rule a+b:

⟨s⟩ ::= ⟨a⟩ | ⟨b⟩
⟨a⟩ ::= ‘a’ ‘b’ ⟨a⟩
⟨b⟩ ::= ‘a’ ‘b’ ⟨a⟩

Which after equivalent rules are merged yields:

⟨s⟩ ::= ⟨a+b⟩
⟨a+b⟩ ::= ‘a’ ‘b’ ⟨a+b⟩

When this step is applied to grammar G_5, it is transformed into grammar G_6, as depicted in Fig. 1c.

4) Eliminating Unit Rules: All non-terminals with productions of one of the following two forms will have their non-terminal symbols replaced by their rules, and their productions eliminated.

⟨a⟩ ::= ⟨b⟩
⟨a⟩ ::= ‘a’

Elimination of productions of the first form, is derived from Chomsky Normal Form (CNF) [X]. Eliminations of productions of the second form, a derivation from CNF, allows the simplification process to simplify rules of the following form:

⟨a⟩ ::= ⟨b⟩ ‘a’ ‘b’
⟨b⟩ ::= ε

When this step is applied to grammar G_6, it is transformed into grammar G_7, as depicted in Fig. 1d.

5) Expanding Productions: Productions that have nested rules have all nested content replaced by with a non-terminal. The new non-terminal defines a production pointing to their content. When this step is applied to grammar G_7, it is transformed into grammar G_8, as depicted in Fig. 1e.

6) Collapsing Compatible Productions: The final step of the normalization process combines productions that are compatible with each other. This ensures that any non-terminal symbols referenced in a rule will not define a duplicate production. The following provides an example:

⟨A⟩ ::= ‘a’ ⟨B⟩
⟨B⟩ ::= ‘b’ ‘c’
⟨C⟩ ::= ‘c’ | ⟨D⟩
⟨D⟩ ::= ‘d’ | ‘e’

would then collapse to form:

⟨A⟩ ::= ‘a’ ‘b’ ‘c’
⟨C⟩ ::= ‘c’ | ‘d’ | ‘e’

When this step is applied to grammar G_8, it is transformed into grammar G_9, as depicted in Fig. 1f.

IV. Experimental Design

A. Goals, Hypotheses, and Variables

Goals: - Evaluate each step of normalization

Hypotheses: - Null hypothesis: each step has no effect on the halstead effort for MCC.

Variables: - Size of grammar as chosen in SIGMA - Blocking, - Halstead/MCC - The steps that the normalization goes through. (2^#numSteps)

B. Design

Blocked factorial design

Reasons - Effect from size found in SIGMA - Interactions from size also seen in SIGMA

C. Experimental Units

D. Data Collection Procedures

E. Analysis Procedures

F. Evaluation of Validity

Conclusion Validity:

Internal Validity:
Construct Validity:
External Validity:

V. Threats to Validity

VI. Conclusions and Future Work

The timeline to complete this study is as follows:

We intend to publish these results at one of the following conferences:

Acknowledgements

References

[1] N. Synytskyy, J. R. Cordy, and T. R. Dean, "Robust multilingual parsing using island grammars," in *Proceedings of the 2003 Conference of the Centre for Advanced Studies on Collaborative Research*. IBM Press, 2003, pp. 266–278.