Correcting Errors in a Treebank Based on Tree Mining

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Abstract
This paper provides a new method to correct annotation errors in a treebank. The previous error correction method constructs a pseudo parallel corpus where incorrect partial parse trees are paired with correct ones, and extracts error correction rules from the parallel corpus. By applying these rules to a treebank, the method corrects errors. However, this method does not achieve wide coverage of error correction. To achieve wide coverage, our method adopts a different approach. In our method, we consider that an infrequent pattern which can be transformed to a frequent one is an annotation error pattern. Based on a tree mining technique, our method seeks such infrequent tree patterns, and constructs error correction rules each of which consists of an infrequent pattern and a corresponding frequent pattern. We conducted an experiment using the Penn Treebank. We obtained 1,987 rules which are not constructed by the previous method, and the rules achieved good precision.

Keywords: error correction, synchronous tree substitution grammar, FREQT

1. Introduction
It is inevitable for annotated corpora to contain errors caused by manual or semi-manual annotation process. So, detecting and correcting errors in annotated corpora are important tasks. Many studies suggest methods of detecting or correcting errors in various kinds of annotated corpora (see (Dickinson, 2015) for a survey). There are several methods of detecting annotation errors in a phrase structure treebank (Dickinson and Meurers, 2003; Ule and Simov, 2004; Dickinson and Meurers, 2005; Boyd et al., 2007; Dickinson, 2009; Przepiórkowski and Lenart, 2012; Kulick et al., 2013; Faria, 2014). However, there is little work on treebank error correction.

One exception is the work of Kato and Matsubara (2010). Their method constructs a pseudo parallel corpus where incorrect parse trees are paired with correct ones, and extracts error correction rules from the parallel corpus. The rules transform incorrect tree patterns to correct ones. By applying these rules to a treebank, the method corrects errors. However, this method does not achieve wide coverage of error correction.

To solve this problem, we propose another approach to construct error correction rules. Our method does not construct a pseudo parallel corpus. In our method, we consider that an infrequent tree pattern which can be transformed to a frequent one is an annotation error pattern. Based on a tree mining technique, our method seeks such infrequent patterns efficiently. The method constructs error correction rules by pairing the infrequent tree patterns with the frequent ones. We conducted an experiment using the Penn Treebank. We obtained 1,987 rules which are not constructed by the previous method, and the rules achieved good precision.

This paper is organized as follows: Section 2 introduces the previous method of correcting errors in a treebank. Section 3 explains our method which is based on tree mining. Section 4 reports experimental results using the Penn Treebank.

2. Previous Work
Kato and Matsubara (2010) propose a method of correcting annotation errors in a treebank. Their method is based on synchronous tree substitution grammar (STSG) (Eisner, 2003). An STSG defines a tree-to-tree mapping, and consists of rules each of which is defined as a pair of trees called elementary trees. The one tree is called source, and the other is called target. Figure 1 shows an example of STSG rule. The rule transforms the structure which matches the source into the target’s structure. To correct annotation errors in a treebank, the method constructs STSG rules which transform incorrect structures to correct one and applies them to the treebank.

The STSG rules are constructed as follows:

1. Make a pseudo parallel corpus, which is a collection of pairs of partial parse trees which cover a same word sequence.

2. Extract STSG rules which represent a correspondence in the pseudo parallel corpus.

To select useful rules for error correction, they define a score function. Let \( \langle \tau_s, \tau_t \rangle \) be a rule whose source is \( \tau_s \) and whose target is \( \tau_t \). The score of \( \langle \tau_s, \tau_t \rangle \) is defined as follows:

\[
Score(\langle \tau_s, \tau_t \rangle) = \frac{f(\tau_t)}{f(\tau_s) + f(\tau_t)}
\]
Figure 2: Examples of parse trees

where \( f(\tau) \) is the frequency of an elementary tree \( \tau \) in a
treebank. They assume that the frequency of an incorrect
parse tree in a treebank is very low. The lower \( f(\tau_s) \) is, the
higher \( \text{Score}(\langle \tau_s, \tau_t \rangle) \) is. STSG rules with high scores are
useful for error correction.

For example, let us consider a treebank which includes the
parse trees shown in Figure 2. The parse tree (a) is correct,
but (b) and (c) include a same annotation error. In (a) and
(b), the word sequence “to sell at the same time” has different
partial parse trees enclosed within the dotted line. The
method makes a pair of these partial parse trees and extracts
the STSG rule shown in Figure 1 from the pair. Applying
this rule to the treebank, we can correct the error in (b).
Moreover, the error in (c) can be corrected by this rule.

However, this method has a problem. It cannot extract
any rule from a partial parse tree assigned to a word se-
quence which occurs only once in a treebank. So, annotation
errors included in only such partial parse tree cannot
be corrected by the method. Let us consider another case
where the treebank does not include (b). In (c), the word
sequence “to trade on Nasdaq” has incorrect partial parse
tree. But, the method can not makes a pair of partial parse
trees enclosed within the dotted lines in (a) and (c). This

is because these partial parse trees have different word se-
quences. This means that it constructs no rule. As the re-
sult, the method fails to correct the annotation error in (c).

3. Correcting Errors by Tree Mining

To solve the problem described in Section 2, we adopt a
different approach. Our method does not construct a pseudo
parallel corpus. STSG rules are constructed based on a tree
mining technique.

3.1. Definition

In this section, we give some definitions.

3.1.1. Derivation Tree

In our method, a parse tree is represented by a \textit{derivation}
tree. Figure 3 shows the derivation tree corresponding to
the partial parse tree enclosed within the dotted line in Figure
2(a). A derivation tree for a parse tree is defined as follows:
for each inner node \( v \) of a parse tree, there exists a
node \( v' \) which corresponds to \( v \). \( v' \) preserves the parent-
child relations on \( v \). The label of \( v' \) is the following gram-
mar rule:

\[
l(v) \rightarrow l(c_1) l(c_2) \ldots l(c_n)
\]

where \( l(v) \) is the label of \( v \) and \( c_1, c_2, \ldots, c_n \) are the chil-
dren of \( v \). We label the edge between \( v' \) and \( c_i \) with \( i \) in
order to indicate that a grammar rule \( l(c_i) \) is applied to the
\( i \)-th element of the right-hand side of \( l(v') \).

3.1.2. Pattern

We define a \textit{pattern} as a connected subgraph included in a
tree. Figure 4 shows examples of patterns. \( \tau_1, \tau_2 \) and \( \tau_3 \) are
included in the derivation tree shown in Figure 3. A pattern
with \( k \) nodes is called \( k \)-pattern.

In a derivation tree pattern, if no grammar rule is applied
to an element in the right-hand side of a grammar rule as-
signed to a node, we call such element \textit{leaf element}. A leaf
element corresponds to a leaf node of the original parse tree
pattern. In Figure 4, leaf elements are underlined.

3.1.3. Error Correction Rule

As described in Section 2, Kato and Matsubara (2010) as-
sume that the frequency of an incorrect pattern is very low.
According to this assumption, we consider that an infre-
quent pattern which can be transformed to a frequent one is
an annotation error pattern. Our method seeks such patterns
in a treebank and constructs STSG rules which transform
them to corresponding frequent ones.
3.2. Outline of Our Method

The following formula represents whether or not two patterns \( \tau \) and \( \tau' \) can be transformed to each other:

\[
\text{Trans}(\tau, \tau') \equiv \left( \text{root}(\tau) = \text{root}(\tau') \right)
\]

where \( \text{root}(\tau) \) is the left-hand side of the grammar rule of \( \tau \)’s root and \( \text{yield}(\tau) \) is the list of \( \tau \)’s leaf element. \( \tau_3 \) and \( \tau_4 \) shown in Figure 4 can be transformed to each other since \( \text{Trans}(\tau_3, \tau_4) \) is satisfied.

We say that a pattern \( \tau \) is frequent if \( f(\tau) \geq \sigma \) where \( \sigma \) is a threshold. Let \( T \) be a treebank. Let \( F(T) \) be the set of frequent patterns in \( T \). The following set \( Rule(T) \) is the set of rules our method constructs from \( T \):

\[
\text{Rule}(T) = \{ \langle \tau_s, \tau_t \rangle \mid \tau_s \notin F(T) \land \tau_t \in F(T) \land \text{Trans}(\tau_s, \tau_t) \}
\]

3.3. FREQT

In this section, we explain FREQT (Asai et al., 2004), which is the basis of our method. FREQT efficiently enumerates all frequent patterns in a tree set. Figure 5 shows the algorithm of FREQT. First, FREQT creates the set \( F_1 \) of all frequent 1-patterns by traversing a treebank \( T \). Next, the algorithm generates candidate 2-patterns by expanding each frequent 1-pattern \( \tau \in F_1 \) by attaching a new node \( \text{root}(\tau) \) to \( \text{yield}(\tau) \). For each candidate 2-pattern \( \tau' \), if \( f(\tau') \geq \sigma \), \( \tau' \) is added to \( F_2 \). The algorithm iteratively expands frequent \((k-1)\)-patterns, and adds frequent \(k\)-patterns to \( F_k \). By continuing this process until no patterns are generated, FREQT enumerates all frequent patterns.

FREQT uses the rightmost expansion technique. When FREQT expands a pattern, a new node must be attached to a node on the rightmost branch of the pattern. This enables FREQT to enumerate all candidate pattern without overlapping. Figure 6 shows examples of expansions.

3.4. Constructing Error Correction Rules

After calculating \( F(T) \) by FREQT, our method seeks infrequent source patterns by expanding infrequent patterns.
3.4.1. Efficient Enumeration of Infrequent Source Patterns

For an infrequent pattern \( \tau_s \), if there exists some \( \tau_i \in F(T) \) s.t. \( Trans(\tau_s, \tau_i) \), our method constructs the rule \( (\tau_s, \tau_i) \).

\(...

\begin{algorithm}
\begin{algorithmic}
\STATE \textbf{Enumerate infrequent patterns}
\end{algorithmic}
\end{algorithm}

\textbf{Input:} A threshold \( \sigma > 0 \), a treebank \( T \), the set \( F \) of all frequent patterns in \( T \).

\textbf{Output:} The set \( I \) of infrequent patterns which includes all source patterns.

\begin{algorithmic}
\STATE \( C_1 := \emptyset \)
\STATE \( I_1 := \emptyset \)
\FOR{each 1-pattern \( \tau \) which appears in \( T \)}
\IF{there exists \( \tau_i \in F \) s.t. \( \text{root}(\tau) = \text{root}(\tau_i) \)}
\STATE \( C_1 := C_1 \cup \{ \tau \} \)
\IF{\( f(\tau) < \sigma \)}
\STATE \( I_1 := I_1 \cup \{ \tau \} \)
\ENDIF
\ENDIF
\STATE \( k := 2 \)
\WHILE{\( C_{k-1} \neq \emptyset \)}
\FOR{each \( \tau \in C_{k-1} \)}
\IF{there exists \( \tau_i \in F \) s.t. \( \text{root}(\tau) = \text{root}(\tau_i) \) and \( dl(\tau) \) is a prefix of \( \text{yield}(\tau_i) \)}
\STATE \( C_k := C_k \cup \{ \tau \} \)
\IF{\( f(\tau') < \sigma \)}
\STATE \( I_k := I_k \cup \{ \tau \} \)
\ENDIF
\ENDIF
\STATE \( k := k + 1 \)
\ENDFOR
\ENDWHILE
\RETURN \( I = I_1 \cup I_2 \cup \cdots \cup I_{k-1} \).
\end{algorithmic}

\end{algorithm}

\end{document}

Figure 7: The algorithm of enumerating infrequent patterns

For an infrequent pattern \( \tau_s \), if there exists some \( \tau_i \in F(T) \) s.t. \( Trans(\tau_s, \tau_i) \), our method constructs the rule \( (\tau_s, \tau_i) \).

3.4.1. Efficient Enumeration of Infrequent Source Patterns

To seek infrequent source patterns efficiently, we focus on leaf elements of patterns. According as pattern expansion proceeds from left to right, it is determined whether or not a grammar rule is applied to a leaf element. Once a leaf element is skipped, it never has a grammar rule. We call such element determined leaf. In Figure 4 and 6, determined leaves are marked with an asterisk. Our method expands a pattern \( \tau \) only if there exists a frequent pattern \( \tau_i \) which fulfills the following conditions:

\begin{enumerate}
\item \( \text{root}(\tau) = \text{root}(\tau_i) \).
\item \( dl(\tau) \) is a prefix of \( \text{yield}(\tau_i) \).
\end{enumerate}

where \( dl(\tau) \) is the list of determined leaves of a pattern \( \tau \). If a pattern \( \tau \) has no pattern \( \tau_i \) satisfying the above conditions, the pattern \( \tau \) does not contribute to constructing \( Rule(T) \). This is because there is no target pattern \( \tau_i \) for any \( \tau' \) s.t. \( \tau \Rightarrow \tau' \). That is, \( Trans(\tau', \tau_i) \) does not hold for any \( \tau' \) and \( \tau_i \). As an example, let us consider the patterns \( \tau_5 \) and \( \tau_6 \) shown in Figure 4. Here, \( dl(\tau_5) \) is \( \{\text{NP}, \text{VP}\} \) and \( \text{yield}(\tau_5) \) is \( \{\text{NP}, \text{TO}, \text{VB}, \text{PP}\} \). This pair does not fulfill the condition 2. For any \( \tau'_s \) s.t. \( \tau'_s \Rightarrow \tau'_d, dl(\tau'_d) \) and \( \text{yield}(\tau'_d) \) are in the form of \( \{\text{NP}, \text{VP}, \ldots\} \). Therefore, \( \text{yield}(\tau'_d) \neq \text{yield}(\tau_6) \). This also means that \( Trans(\tau'_s, \tau_6) \) does not hold.

Figure 7 shows our algorithm of enumerating infrequent patterns.

4. Experiment

We performed an experiment to evaluate our method. We applied our method to 49,208 sentences in Wall Street Journal section of the Penn Treebank (Marcus et al., 1993). We implemented our method in Java. The experiment was run on a PC (Intel core i7 3.40GHz) with 8GB main memory, running Windows 7 Professional. The threshold \( \sigma \) was set to 100. We obtained 2,379 rules. This took about 34 minutes\(^1\). In these rules, 1,987 rules can not be obtained by Kato and Matsubara’s method. To measure the precision of the rules, we applied rules to the WSJ section. Because it is time-consuming and expensive to evaluate all rules, we only evaluated the rules with the 300 highest scores. A person (not the authors) manually checks whether or not each rule corrects errors. The precision \( p \) is measured in the same way as (Kato and Matsubara, 2010):

\[ p = \frac{\# \text{of the positions where an error is corrected}}{\# \text{of the positions to which some rule is applied}} \]

The number of the positions to which 300 rules are applied is 605. The number of the positions where an error is corrected is 466. Therefore, the precision of our method is 77.0%. The precision of the previous method (Kato and Matsubara, 2010) is 71.6%. We measured the precision of each rule. The precision of 196 rules achieved 100% precision. 155 of the 196 rules could not be obtained by Kato and Matsubara’s method. This result shows that our method can obtain the useful error correction rules which the previous method can not obtain. Figure 8 shows some examples of correcting errors which our method correct but the previous method does not.
5. Conclusion

In this paper, we proposed a new method of correcting annotation errors in a treebank. Our method is based on tree mining. An experiment showed that our method can obtain rules which the previous method cannot obtain. The proposed method and the previous one are complementary. That is, by both methods, we can expect to achieve wider coverage of error correction. If a source pattern has several target patterns, our method simply transforms the source to the most frequent target. To improve the precision, we will explore how to select an appropriate target.

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