Automated Extraction of Tree Adjoining Grammars from a Treebank for Vietnamese

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Abstract

In this paper, we present a system that automatically extracts lexicalized tree adjoining grammars (L TAG) from treebanks. We first discuss in detail extraction algorithms and compare them to previous works. We then report the first L TAG extraction result for Vietnamese, using a recently released Vietnamese treebank. The implementation of an open source and language independent system for automatic extraction of LTAG grammars is also discussed.

1 Introduction

Grammars in general and lexicalized tree adjoining grammars in particular are one of the most important elements in the natural language processing (NLP). Since the development of hand-crafted grammars is a time consuming and labor intensive task, many studies on automatic and semi-automatic grammar development have been carried out during last decades.

After decades of research in NLP mostly concentrated on English and other well-studied languages, recent years have seen an increased interest in less common languages, notably because of their growing presence on the Internet. Vietnamese, which belongs to the top 20 most spoken languages, is one of those new focuses of interest. Obstacles remain, however, for NLP research in general and grammar development in particular: Vietnamese does not yet have vast and readily available constructed linguistic resources upon which to build effective statistical models, nor reference works against which new ideas may be experimented.

Moreover, most existing research so far has been focused on testing the applicability of existing methods and tools developed for English or other Western languages, under the assumption that their logical or statistical well-foundedness guarantees cross-language validity, while in fact assumptions about the structure of a language are always made in such tools, and must be amended to adapt them to different linguistic phenomena. For an isolating language such as Vietnamese, techniques developed for flexional languages cannot be applied “as is”.

The primary motivation to develop a system that can automatically extract an LTAG grammar for the Vietnamese language is the need of a rich statistical information and wide-coverage grammar which may contribute more effectively in the development of basic linguistic resources and tools for automatic processing of Vietnamese text.

We present in this article a system that automatically extracts lexicalized tree adjoining grammars from treebanks. We first discuss in detail the extraction algorithms and compare them to previous works. We then report the first LTAG extraction result for Vietnamese, using the recently released Vietnamese treebank. The implementation of an open source and language independent system for automatic extraction of LTAG grammars from treebanks is also discussed.

2 Previous works on extracting grammars from treebanks

There has been much work done on extracting treebank grammars in general and LTAG grammars in particular from annotated corpora, all of these works are for common languages. Xia developed the uniform method of grammar extraction for English, Chinese and Korean (Xia et al., 2000; Xia, 2001). Chiang developed a system for extracting an LTAG grammar from English Penn Treebank and used it for statistical parsing with LTAG (Chiang, 2000). Chen extracted TAGs from English Penn Treebank (Chen and Vijay-Shanker, 2000; Chen et al., 2006) and there are other works
based on Chen’s approach such as Johansen (Johansen, 2004) and Nasr (Nasr, 2004) for French, and Habash for Arabic (Habash and Rambow, 2004). Neumann extracted lexicalized tree grammars for English from English Penn Treebank and for German from NEGRA treebank (Neumann, 2003). Bäcker extracted an LTAG grammar for German, also from the NEGRA corpus and used it for supertagging (Bäcker and Harbusch, 2002). Park extracted LTAG grammars for Korean from Korean Sejong Treebank (Park, 2006).

3 Vietnamese treebank

Recently, a group of Vietnamese computational linguists has been involved in developing a treebank for Vietnamese (Nguyen et al., 2009), and it is also the first treebank on which our extraction system was used.

The construction of a Vietnamese treebank is a branch project of a national project which aims to develop basic resources and tools for Vietnamese language and speech processing1. The raw texts of the treebank are collected from the social and political sections of the Youth online daily newspaper. The corpus is divided into three sets corresponding to three annotation levels: word-segmented, POS-tagged and syntax-annotated set. The syntax-annotated corpus, a subset of the POS-tagged one, is currently composed of 10,471 sentences (225,085 tokens). Sentences range from 2 to 105 words, with an average length of 21.75 words. There are 9,314 sentences of length 40 words or less. The tagset of the treebank has 38 syntactic labels (18 part-of-speech tags, 17 syntactic category tags, 3 empty categories) and 17 function tags. For details, please refer to (Nguyen et al., 2009).

The meanings of the tags that appear in this paper are listed in Table 1.

4 Extraction algorithms

In general, our work on extracting an LTAG grammar for Vietnamese follows closely the method of grammar extraction originally proposed by Xia (Xia, 2001). The extraction process has three steps: first, phrase-structure trees are converted into LTAG derived trees; second, the derived trees are decomposed into a set of elementary trees conforming to their three predefined prototypes; and third, invalid extracted elementary trees are filtered out using linguistic knowledge.

4.1 Building LTAG derived trees

The phrase structures in the Vietnamese treebank follow the English Penn Treebank bracketed style format which are not based on the LTAG formalism. They may have different formats from the LTAG derived trees which distinguish heads, arguments and adjuncts. Therefore, we first have to convert the phrase structures of the treebank into derived trees.

In this step, we first classify each node in a phrase-structure tree into three types, head, argument or modifier, and then build a derived tree by adding intermediate nodes so that at each level of the tree, the nodes satisfy exactly one of the following relations (Xia, 2001):

- predicate-argument relation: there are one or more nodes, one is the head, the rest are its arguments;
- modification relation: there are exactly two nodes, one node is modified by the other;
- coordination relation: there are exactly three nodes, in which two nodes are coordinated by a conjunction.

In order to find heads of phrases, we have constructed a head percolation table (Magerman, 1995; Collins, 1997) for the Vietnamese treebank. This table is used to select the head child of a node. In addition, we have also constructed an argument table to determine the types of arguments that a head child can take. The argument table helps explicitly mark each sibling of a head child as either an argument or an adjunct according to the tag of the sibling, the tag of the head child, and

<table>
<thead>
<tr>
<th>No.</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>S</td>
<td>simple declarative clause</td>
</tr>
<tr>
<td>2.</td>
<td>VP</td>
<td>verb phrase</td>
</tr>
<tr>
<td>3.</td>
<td>NP</td>
<td>noun phrase</td>
</tr>
<tr>
<td>4.</td>
<td>PP</td>
<td>preposition phrase</td>
</tr>
<tr>
<td>5.</td>
<td>N</td>
<td>common noun</td>
</tr>
<tr>
<td>6.</td>
<td>V</td>
<td>verb</td>
</tr>
<tr>
<td>7.</td>
<td>P</td>
<td>pronoun</td>
</tr>
<tr>
<td>8.</td>
<td>R</td>
<td>adverb</td>
</tr>
<tr>
<td>9.</td>
<td>E</td>
<td>preposition</td>
</tr>
<tr>
<td>10.</td>
<td>CC</td>
<td>coordinating conjunction</td>
</tr>
</tbody>
</table>

Table 1: Treebank tags in examples.

1Project “Vietnamese Language and Speech Processing”
Algorithms information that is required for the extraction algorithms constitute the Vietnamese treebank-specific tables are published for the Vietnamese treebank.

The position of the sibling with respect to the head child. Together with the tagset table, these three tables constitute the Vietnamese treebank-specific information that is required for the extraction algorithms.

Since the conjunction structures are different from the argument and modifier structures, we first recursively bracket all conjunction groups of a treebank tree by Algorithm 1 and then build the full derived tree for the resulting tree by Algorithm 2.

Figure 1 shows a tree with conjunction groups before and after being processed by Algorithm 1 where $c_i$ are coordinating conjunctions and $X_i$ are conjunction groups. Figure 2 shows a realisation of Algorithm 2 where $A_i$ are arguments of the head child $H$ of $T$ and $M_i$ are modifiers of $H$.

These two algorithms use the function INSERT-NODE($T, L$) shown in Algorithm 3 to insert an intermediate node between a node $T$ and a list of its child nodes $L$. This new node is a child of $T$, has the same label as $T$ and has $L$ as the list of its kids. The function CONJ-GROUPS($L$) returns $k$ groups of components $C_i$ of $L$ which are separated by $k - 1$ conjunctions $c_1, \ldots, c_{k-1}$. The function NEW-NODE($l$) returns a new node with label $l$.

Figure 1: Conjunction groups transformation by Algorithm 1.

Algorithm 1 Process-Conj($T$)

Require: A tree $T$
Ensure: $T$ with conjunctions processed
1: for $K \in T.kids$ do
2: if IS-PHRASAL($K$) then
3: $K \leftarrow$ PROCESS-Conj($K$);
4: end if
5: end for
6: $(C_1, \ldots, C_k) \leftarrow$ CONJ-GROUPS($T.kids$);
7: for $i = 1$ to $k$ do
8: if $\|C_i\| > 1$ then
9: INSERT-NODE($T, C_i$);
10: end if
11: end for
12: if $k > 2$ then
13: for $i = k$ downto 3 do
14: $L \leftarrow C_{i-1} \cup c_{i-1} \cup C_i$;
15: $T^* \leftarrow$ INSERT-NODE($T, L$);
16: $C_{i-1} \leftarrow T^*$;
17: end for
18: end if
19: return $T$;

Algorithm 2 Build-Derived-Tree($T$)

Require: A tree $T$ whose conjunctions have been processed
Ensure: A derived tree whose root is $T$
1: if (not IS-PHRASAL($T$)) then
2: return $T$;
3: end if
4: $H \leftarrow$ HEAD-CHILD($T$);
5: if not IS-LEAF($H$) then
6: for $K \in T.kids$ do
7: $K \leftarrow$ Build-Derived-Tree($K$);
8: end for
9: $A \leftarrow$ ARG-NODES($H, L$);
10: $M \leftarrow$ MOD-NODES($H, L$);
11: $m \leftarrow ||M||$;
12: if $m > 0$ then
13: $L \leftarrow \{H\} \cup A$;
14: $T^* \leftarrow$ INSERT-NODE($T, L$);
15: end if
16: $(M_1, M_2, \ldots, M_m) \leftarrow M$;
17: for $i = 1$ to $m - 1$ do
18: $L \leftarrow \{M_i, T^*\}$;
19: $T' \leftarrow$ INSERT-NODE($T, L$);
20: $T^* \leftarrow T'$;
21: end for
22: end if
23: return $T$;

2To our best knowledge, this is the first time such tables are published for the Vietnamese treebank.

3A phrasal node is defined to be a node which is not a leaf or a preterminal. This means that it must have two or more children, or one child that is not a leaf.
Algorithm 3  
\text{INSERT-NODE}(T, \mathcal{L})

\textbf{Require:}  A tree \(T\) and its children list \(\mathcal{L}\)

\textbf{Ensure:} A new child node \(T^*\) of \(T\) whose kids are \(\mathcal{L}\)

1: \(T^* \leftarrow \text{NEW-NODE}(T.\text{label});\)
2: \(T^*.\text{kids} \leftarrow \mathcal{L};\)
3: \(T.\text{kids} \leftarrow T.\text{kids} \cup \{T^*\};\)
4: \(\text{return } T^*;\)

spectively modifiers) of a node \(H\). The list \(\mathcal{L}\) contains all sisters of \(H\).

Figure 2: An example of derived tree realisation

For example, Figure 3 shows the phrase structure of a sentence extracted from the Vietnamese treebank “Họ sẽ không chuyển hàng xuống thuyền vào ngày mai.” The head children of phrases are circled.

The derived tree of the sentence given by Algorithm 2 is shown in Figure 4, the inserted nodes are squared.

\subsection{4.2 Building elementary trees}

At this step, each derived tree is decomposed into a set of elementary trees. The recursive structures of the derived tree are factored out and will become auxiliary trees, the remaining non-recursive structures will be extracted as initial trees.

Extracted elementary trees fall into one of three prototypes according to the relation between the anchor and other nodes, as shown in Figure 5.

\[ X^m \quad W \quad X \]
\[ Y \downarrow X^{m-1} \quad W^* \quad X^m \quad X \quad CC \quad X^* \]
\[ X^1 \quad Y \downarrow X^{m-1} \quad \text{anchor} \]
\[ X \quad Z \downarrow \quad X^1 \]
\[ \text{anchor} \quad X \quad Z \]

Figure 5: Prototypes of spine trees (predicate-argument relation) and auxiliary trees (modification and coordination relation).

The extraction process involves copying nodes from the derived tree for building elementary trees. The result of extraction process is three sets of elementary trees: \(S\) contains spine trees, \(M\) contains modifier trees and \(C\) contains conjunction trees.

To build elementary trees from a derived tree \(T\), we first find the head path\(^5\) \(\{H_0, H_1, \ldots, H_n\}\) of \(T\). For each parent \(P\) and its head child \(H\), we get the list \(\mathcal{L}\) of sisters of \(H\) and determine the relation

\[ A \quad \text{head path starting from a node } T \quad \text{is the unique path from } T \quad \text{to a leaf node where each node except } T \quad \text{is the head child of its parents. Here } H_0 \equiv T \quad \text{and } H_1 \quad \text{is the parent of its head child } H_{j+1}. \quad \text{A node on the head path is called a link node if its label is the same as that of its parent.} \]

Figure 4: The derived tree of the treebank tree in Figure 3.

Figure 3: A treebank tree.
between $H$ and $\mathcal{L}$. If the relation is coordination, a conjunction tree will be extracted; if the relation is modification, a modifier tree will be extracted; otherwise, the relation is predicate-argument and an spine tree will be extracted. Algorithm 4 shows the extraction algorithm.

Algorithm 5 shows the function for building a spine tree. The function BUILD-SPINE-TREE($T$) merges all link nodes of a spine tree into one node (see Figure 7). Algorithms 6 and 7 are functions which respectively build modifier and conjunction trees.

### 4.3 Filtering out invalid trees

Annotation errors are inevitable for any treebank. The errors in parse trees will result in wrong elementary trees. An elementary tree is called invalid if it does not satisfy some linguistic requirement.
4.4 Comparison with previous work

As mentioned above, our approach for LTAG extraction follows the uniform method of grammar extraction proposed by Xia (Xia, 2001). Nevertheless, there are some differences between our design and implementation of extraction algorithms and that of Xia.

First, in the building derived tree step, we first recursively bracket all conjunction groups of the tree before fully bracketing the arguments and modifiers of the resulting tree. We think that this approach is easier to understand and implement since conjunction structures are different from argument and modifier structures. Second, in the elementary tree decomposition step, we do not split each node in the derived tree into the top and bottom parts as it was done in the approach of Xia. In our implementation, the nodes are directly copied to build extracted trees. Third, the tree extraction process is broken into functions, each function builds a type of elementary trees and they can be called mutually by each other to repeat the extraction process for the subtrees whose roots are not yet visited. In spite of using recursive functions, our extraction algorithms are carefully designed so that there is no redundant or repeating function calls: each node is assured to be visited one time. The “divide and conquer” approach in algorithm design has been shown to be efficient and easy to optimise.

5 Experiments

We ran extraction algorithms on the Vietnamese treebank and extracted two treebank grammars. The first one, $G_1$, uses the original tagset of the treebank. The second one, $G_2$, uses a reduced tagset, where some tags in the treebank are merged into a single tag, as shown in Table 2. The grammar $G_2$ is smaller than $G_1$ and it is presumable that the sparse data problem is less severe when $G_2$ is used. Furthermore, it was shown that the size of the extracted grammar is important for Lightweight Dependency Analysis (LDA) and supertagging (Bangalore and Joshi, 1999).

We count the number of elementary trees and tree templates. The sizes of the two grammars are in Table 3. Recall that a template is an elementary tree without the anchor word.
Table 2: Some tags in the Vietnamese treebank tagset are merged into a single tag.

<table>
<thead>
<tr>
<th>Category</th>
<th>Original tags</th>
<th>Tags in ( G_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>noun phrases</td>
<td>NP/WHNP</td>
<td>NP</td>
</tr>
<tr>
<td>adjective phrases</td>
<td>AP/WHAP</td>
<td>AP</td>
</tr>
<tr>
<td>adverbial phrases</td>
<td>RP/WHRP</td>
<td>RP</td>
</tr>
<tr>
<td>preposition phrases</td>
<td>PP/WHPP</td>
<td>PP</td>
</tr>
<tr>
<td>clauses</td>
<td>S/SQ</td>
<td>S</td>
</tr>
</tbody>
</table>

Table 3: Two LTAG grammars extracted from the Vietnamese treebank.

<table>
<thead>
<tr>
<th>Type</th>
<th># of trees</th>
<th># of templates</th>
</tr>
</thead>
<tbody>
<tr>
<td>( G_1 )</td>
<td>46,382</td>
<td>2,317</td>
</tr>
<tr>
<td>Spine trees</td>
<td>24,973</td>
<td>1,022</td>
</tr>
<tr>
<td>Modifier trees</td>
<td>21,309</td>
<td>1,223</td>
</tr>
<tr>
<td>Conjunction trees</td>
<td>100</td>
<td>72</td>
</tr>
<tr>
<td>( G_2 )</td>
<td>46,102</td>
<td>2,113</td>
</tr>
<tr>
<td>Spine trees</td>
<td>24,884</td>
<td>952</td>
</tr>
<tr>
<td>Modifier trees</td>
<td>21,121</td>
<td>1,093</td>
</tr>
<tr>
<td>Conjunction trees</td>
<td>97</td>
<td>68</td>
</tr>
</tbody>
</table>

Figure 8: The growth of tree templates. The \( x \) axis shows the percentage of the corpus used for extraction, the \( y \) axis shows the number of extracted templates (\( \triangle \)), initial templates (\( o \)) and auxiliary templates (\( \diamond \)).

6 Conclusions

We have presented a system that automatically extracts LTAGs from treebanks. The system has been used to extract an LTAG for the Vietnamese language from the recently released Vietnamese treebank. The extracted Vietnamese LTAG covers the corpus, that is the corpus can be seen as a collection of derived trees for the grammar and can be used to train statistical LTAG parsers directly.

The number of templates extracted from the current Vietnamese treebank converges slowly. This implies that there are many new templates outside the corpus and the current Vietnamese treebank is not large or typical enough to cover all the grammatical templates of the Vietnamese language.

We have developed a software package that implements the presented algorithms for extracting an LTAG for Vietnamese. The software is written in the Java programming language and is freely distributed under the GNU/GPL license\(^6\). The software is very efficient in terms of extraction speed: it takes only 165 seconds to extract the entire grammar \( G_1 \) on an ordinary personal computer. It is very easy to extend the software for use to extract LTAGs from treebanks of other languages since the language-specific information is intentionally factored out of the general framework. In order to use the software on a treebank of a language, user needs to provide the treebank-specific information for that language: a tagset, a head percolation table, and an argument table.

\[^6\]http://www.loria.fr/~lehong/tools/vnLEntractor.php
Table 4: Head percolation rules for the Vietnamese treebank.

<table>
<thead>
<tr>
<th>Tags</th>
<th>Direction</th>
<th>Priority List</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Left</td>
<td>S VP AP NP</td>
</tr>
<tr>
<td>SBAR</td>
<td>Left</td>
<td>SBAR S VP AP NP</td>
</tr>
<tr>
<td>SQ</td>
<td>Left</td>
<td>SQ VP AP NP</td>
</tr>
<tr>
<td>NP</td>
<td>Left</td>
<td>NP Nc Nu Np N P</td>
</tr>
<tr>
<td>VP</td>
<td>Left</td>
<td>VP V A AP N NP S</td>
</tr>
<tr>
<td>AP</td>
<td>Left</td>
<td>AP A N S</td>
</tr>
<tr>
<td>RP</td>
<td>Right</td>
<td>RP R T NP</td>
</tr>
<tr>
<td>PP</td>
<td>Left</td>
<td>PP E VP SBAR AP QP</td>
</tr>
<tr>
<td>QP</td>
<td>Left</td>
<td>QP M</td>
</tr>
<tr>
<td>XP</td>
<td>Left</td>
<td>XP X</td>
</tr>
<tr>
<td>YP</td>
<td>Left</td>
<td>YP Y</td>
</tr>
<tr>
<td>MDP</td>
<td>Left</td>
<td>MDP T I A P R X</td>
</tr>
<tr>
<td>WHNP</td>
<td>Left</td>
<td>WHNP Np Nc Nu Np N P</td>
</tr>
<tr>
<td>WHAP</td>
<td>Left</td>
<td>WHAP A N V P X</td>
</tr>
<tr>
<td>WHRP</td>
<td>Left</td>
<td>WHRP P E T X</td>
</tr>
<tr>
<td>WHPP</td>
<td>Left</td>
<td>WHPP E P X</td>
</tr>
<tr>
<td>WHXP</td>
<td>Left</td>
<td>XP X</td>
</tr>
</tbody>
</table>

for Vietnamese in greater detail.

We are currently experimenting the extraction of a French LTAG from a French treebank (Abellé et al., 2003). We also plan to compare quantitatively syntactic structures of French and Vietnamese. We believe that a quantitative comparison of the two grammars may reveal interesting relations between them since, due to historical reason, by being in contact with the French language, Vietnamese was enriched not only in vocabulary but also in syntax by the calque of French grammar.

Acknowledgement

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