Automatic Transformation of the Thai Categorial Grammar Treebank to Dependency Trees

Abstract

A method for deriving an approximately labeled dependency treebank from the Thai Categorial Grammar Treebank has been implemented. The method involves a lexical dictionary for assigning dependency directions to the CG types associated with the grammatical entities in the CG bank, falling back on a generic CG to CDG mapping in case of unknown words. Currently, just a handful of the trees in the Thai CG bank cannot unambiguously be transformed into directed dependency trees. Derived dependency arcs are optionally labeled with a learned classfier, achieving $\approx 75\%$ label accuracy on a sample set. In the process, a number of annotation errors in the CG bank were identified and corrected. Although rather limited in its coverage, excluding e.g. long-distance dependencies, topicalisations and longer sentences, the resulting treebank is believed to be sound in terms structural annotational consistence and a valuable complement to the scarce Thai language resources in existence.

1 Introduction

Syntactic resources play an essential role for the majority of NLP applications, but for Thai language, openly available syntactic resources are few in number: So far, the only reported resources are the CG treebank [Ruangrajitpakorn et al., 2009] and the NAiST dependency bank [Wacharamanotham et al., 2007, Sudprasert, 2008] — others being either unpublished or minuscule in size. These treebanks were approved manually by linguists, and therefore expectedly reliable in terms of accuracy. However, each resource is fairly limited in size. Rather than relying exclusively on labor-intensive manual annotation for further expanding the resources, it would be economically sound to leverage existing efforts and transform an existing treebank in one grammar into the another.

1.1 Categorial grammar

Categorial grammar (CG) is a lexicalised theory in natural language syntax motivated by the principle of constitutionality and organised according to the syntactic elements [Ajdukiewicz, 1935, Steedman, 2000], and forms the theoretical basis for the Thai CG treebank. The resource building effort has been very fruitful, but there remains phenomena of Thai languge, including long-range dependencies and topicalisation [Warotamasikkhadit, 1997], which are unhandled by the instantiation of CG currently in use.

Additionally, although Thai language belongs to a fixed word order typology, Thai spoken language exhibits some flexibility in word order, due to the occasional preference of Thai language users for correspondance in rhyme. As an example, consider the following sentence[1]:

> **อังกฤษ คิดค้น อย่าง หนัก**
> **วัคซีนป้องกันเชื้อไวรัสไข้หวัดนก**
>
> (**Lit**: England/NE invent/V "-ly"/ADVPFX heavy/ADJ avian_flu_vaccine/NP)
>
> "The British are strenuously developing an Avian Flu vaccine."

The adverbial compound formed by **อย่าง หนัก** ("strenuously") conventionally occurs after the direct object, but is in this sentence, it is realised in the pre-direct object position[2] in order for the last syllable of **อย่าง หนัก** to rhyme with the first syllable of **วัคซีน** ("vaccine"). To some degree, this phenomenon from spoken language shines through in written language, especially in the domains of news and recent politics, and is causing a challenge for the employment of CG grammar.

[1] The Thai adverbialising prefix **อย่าง** can be likened to the English "-ly" suffix, which produces an adverbial form from an adjective. Artificial word boundaries has beeen inserted for clarity.

[2] When language users exploit this flexibility in word order to produce aesthetically pleasing sound patterns, it results in a marked form, but the phenomenon is nonetheless productive, and encountered frequently enough to necessitate handling in NLP applications.

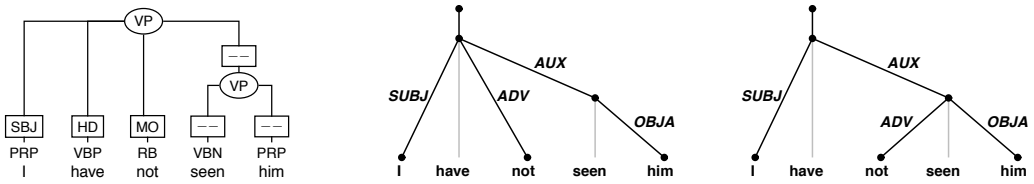


Figure 1: Examplar of ambiguity arising only in dependency representation [Daum et al., 2004]

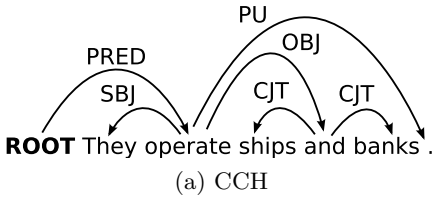
1.2 Dependency representation

In recent years, dependency representation has seen a dramatic increase in interest, likely due to a number of appealing properties of the representation. In comparison to phrase structure grammar, dependency structures provide a relatively direct encoding of predicate-argument structure, which is relevant to subsequent analyses [Nivre, 2005]. Dependency representation is arguably better suited for languages with flexible word order. Additionally, having no non-terminal nodes, dependency structures are often perceived as leaving room for less ambiguity as well as being more computationally managable.

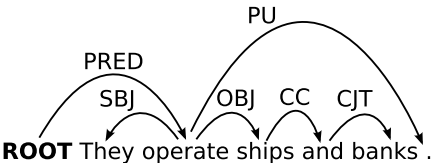
Certainly, dependency representation has drawbacks of its own in terms of ambiguity, some of which are specific to dependency representation. In particular, Figure 1 shows a construction with an unambiguous constituent structure, which in dependency space is ambiguous with respect to the attachment of the adverb [Daum et al., 2004].

Furthermore, dependency structure allows for a number of ways to represent coordinated phrases, some having the *coordinating conjunction as head* (CCH) of the coordinate structure, and a special dependency label *CJT* that does not describe the grammatical function of the conjuncts (Figure 2a). Another option is having the *coordinating conjunction as dependent* (CCD) of one of the conjuncts, thus allowing one conjunct to occur with a dependency label expliciting its grammatical function (Figure 2b). McDonald and Nivre [2007] offer a thorough review of these and other candidate analyses in use. Unfortunately, none of the conceivable representations are unproblematic from a linguistic perspective [Daum et al., 2004], or offer the same transparency as the coordination rules of CCG do [Boonkwan, 2009].

Nonetheless, given the availability of generally applicable, trainable dependency parsers, and reports of beneficial applications of dependency analysis in tasks such as word-alignmeent [Ma et al., 2008] and reordering [Chang et al., 2009] for statistical machine translation, a dependency treebank of good quality is a highly desirable resource.



(a) CCH



(b) CCD

Figure 2: Two possible analyses of a coordination [Kübler et al., 2009]

1.3 Outline

The rest of the paper is organised as follows. In Section 2 we briefly review other works dealing with similar transformations, before presenting the approach taken in this work in Section 3. Section 4 describes the experimental setting and results, which are discussed in Section 5. Finally, Section 6 concludes the paper.

2 Related work

In preperation for the CoNLL-X shared task on dependency parsing [Buchholz and Marsi, 2006], a number dependency trees were derived from a number of constituency-based phrase structure treebanks, most of which has grammatical function (e.g. "subject" and "object") as part of the annotation. The conversion process for such treebanks would involve a *head table* with rules of the form

- "the head child of a VP/clause is the child with the HD/predicator/hd/Head function" and
- "[the dependency label] for a token is the function of the biggest constituent of which this token is the lexical head".

The case of the Thai CG bank is different, as it does not directly contain any grammatical functions. On the other hand, identifying head tokens is relatively straight-forward when augmenting the

CG annotation with dependency directions [Ruangrajitpakorn and Supnithi, 2010].

Chanev et al. [2006] faced a similar situation in their transformation of the BulTreeBank to dependency representation. Heads were first identified from explicitly stated rules in a head table. Lacking explicit grammatical functions in the source treebank, they explored a heuristic rule-based approach for the labeling with a *dependency table,* containing rules based on parent constituents. Although good results are achieved, they report of errors like mistaken subjects and objects.

3 Methodology

The situation with the Thai CG bank is a little different. Together with a set of combinatory grammer rules, the CG type tags and bracketing present in the treebank unambigously specify the constituent structure of the treebank sentences. When the CG type tags are augmented with dependency directions, a dependency tree can be derived with relative ease from the CG-based constituents. Grammatical functions, however, are not immediately evident from the CG trees.

We first describe a relatively straight-forward method for deriving the dependency trees, and next consider the more daunting task of assigning functional labels to the dependency arcs. Figure 3 shows a schematical overview of the proprosed method.

3.1 Terminology

For any given CG type t, we use thethe *arity* (admittedly a bit sloppily) to denote the ordered list of arguments expected by a type. The arity of the type `s\np/ws/np` is thus `/np`, `/ws` and `\np` — that is,

- a noun phrase from the right, followed by
- a subordinate clause beginning with the Thai word ว่า ("that", subordinate clause marker), and
- another noun phrase from the left.

Complementary, we define the *yield* of t as the set of possible CG types which may result from functional application of a CG rule. The transitive verb type `s\np/np`, for example, yields

- `s\np` and
- `s`

after receiving a `np` to the right, and another `np` to the left, respectively. This is simply the basic combinatory CCG rules:

$$\begin{array}{llll} \text{X/Y} & \text{Y} & \Rightarrow & \text{X} \\ \text{Y} & \text{X\Y} & \Rightarrow & \text{X} \end{array}$$

Algorithm 1 Pseudo-code for propagating dependency directions to non-terminal nodes.

```
def propagateDirections(node):
  for child in node.children:
    propagateDirections(child)
  if node.hasDependencyDirection:
    return
  for child in node.children:
    if child.yields(node.type):
      node.depDirs = child.depDirs
      break
```

3.2 Dependency directions

The first transformation step, which can rightly be regarded as a necessary preprocessing step before the actual transformation, involves a lexical dictionary for assigning dependency directions to the CG types associated with the grammatical entities in the CG bank, falling back on a generic CG to CDG mapping in case of unknown words.

Note that only terminal nodes will have assigned dependency directions assigned by this procedure. Dependency directions are propagated to non-terminal nodes in a bottom-up fashion by the procedure `propagateDirections` (Algorithm 1). In identifying which child to adopt dependency directions from, the parent node type is checked against the yield of each child node.

3.3 Head finding

Dependency arcs are assigned by a procedure that implements the CDG dependency derivation rules introduced by Ruangrajitpakorn and Supnithi [2010] (motivated by Collins, 1999). Let $c : d$ signify a CDG type c and a dependency structure d, and the notion $h(\mathrm{d}_1) \rightarrow h(\mathrm{d}_2)$ represent a dependency arc between the head of d_1 and the head of d_2 (with $h(\mathrm{d}_1)$ governing $h(\mathrm{d}_2)$) . Then the derivation rules are:

$$\begin{array}{llll} \text{X/<Y:d}_1 & \text{Y:d}_2 & \Rightarrow & h(\mathrm{d}_1) \leftarrow h(\mathrm{d}_2) \\ \text{X/>Y:d}_1 & \text{Y:d}_2 & \Rightarrow & h(\mathrm{d}_1) \rightarrow h(\mathrm{d}_2) \\ \text{Y:d}_1 & \text{X\<Y:d}_2 & \Rightarrow & h(\mathrm{d}_1) \leftarrow h(\mathrm{d}_2) \\ \text{Y:d}_1 & \text{X\>Y:d}_2 & \Rightarrow & h(\mathrm{d}_1) \rightarrow h(\mathrm{d}_2) \end{array}$$

In addition to the standard combinatory rules for forward and backward functional application above, the Thai CG bank makes use of a CCG-style *serialisation* rule to handle e.g. serial verb constructions, which are used in Thai (and Chinese) to express serial or consecutive events. As Boonkwan [2009], we take the notion of a *serial verb construction* to mean a series of verbs or verb phrases without explicit connectives marked with (or understood to have) the same grammatical categories, and sharing at least one common argument, typically a subject.

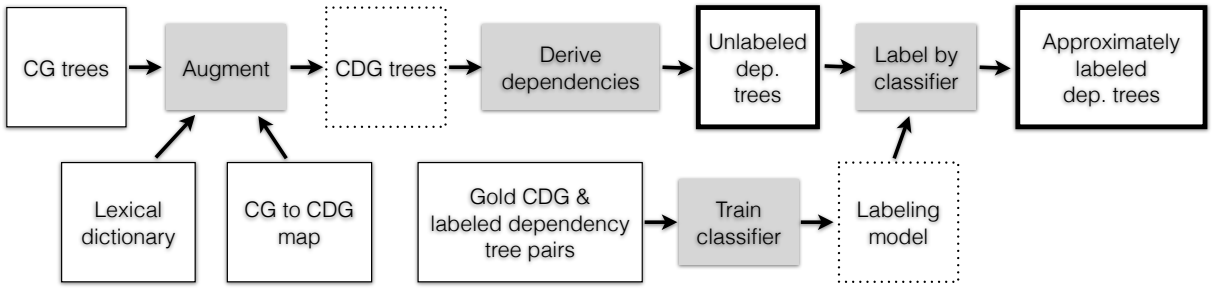


Figure 3: Transformation overview

As an example, the verbs **ตรวจ** ("examine") and **พบ** ("find") occur serially in the following sentence[3] from the CG bank, indicating a resultative course of events [Thepkanjana and Uehara, 2009]:

นักวิชาการ ตรวจ พบ ไวรัส โคโรน่า ใน ชะมด

(**Lit**: scientist/N examine/V find/V virus/N corona/N in/PP otter-civet/N)

"The scientist examined the otter-civet and found coronavirus."

We introduce a generalised derivation rule for serial constructions which simply designates the head of the first dependency structure as governing the head of the following dependency structure:

$$\text{X:d}_1 \;\; \text{X:d}_2 \quad \Rightarrow \quad h(\text{d}_1) \rightarrow h(\text{d}_2)$$

The rule is generalised in the sense that it handles *serial noun constructions* as well as serial verb constructions.

Further CCG-style combinatory rules, such as functional composition and type raising, are not currently in use in the Thai CG bank, and therefore not handled by the transformation.

An outline of the head finding procedure is given as Algorithm 2. Intuitively, the algorithm proceeds by, for each node in turn, beginning at the terminal nodes, identifying sibling nodes which satisfy the arity of the of the node CG type. For each sibling node satisfying an argument, the dependency derivation rule is applied and the sibling is removed.

It is worth noting that while both terminal and non-terminal nodes are involved in this process, we are only interested in assigning dependency arcs to terminal nodes, as non-terminals are absent in the all-terminal dependency structure. This is ensured by an implementation detail of the procedure `registerHead` (omitted from Algorithm 2), in which non-terminal nodes act as proxies for their terminal heads.

[3] Articifial word boundaries inserted for clarity.

Algorithm 2 Pseudo-code for the head-finding procedure.

```
def assignHeads(node):
  for c in node.nonterminalChildren:
    assignHeads(c)
  for c in node.terminalChildren:
    assignHeads(c)
  for arg in node.type.arguments:
    if arg.side == 'right':
      sibl = node.rightSiblings.first
    else
      sibl = node.leftSiblings.last
    break unless arg.matches(sibl)
    if arg.side == 'right':
      if arg.dependencyDir == '>':
        registerHead(sibl, node)
      else: # <
        registerHead(node, sibl)
      node.rightSiblings.shift
    else: # left
      if arg.dependencyDir == '>':
        registerHead(node, sibl)
      else: # <
        registerHead(sibl, node)
      node.leftSiblings.pop
```

3.4 Dependency labeling

Although the CDG-augmentation of the CG treebank implies a dependency structure for each sentence, there are no immediate clues available about the specific grammatical functions of dependency arcs. Obviously, there are some clear-cut cases: When a token with CDG type $((\mathtt{s}\backslash <\mathtt{np})\backslash >(\mathtt{s}\backslash <\mathtt{np}))\backslash <\mathtt{num}$ modifies a token with CDG type `num`, it must be an application of a *quantifier* (with dependency type "quan"), as exemplified in Figure 4.

Other cases are less obvious. Even when taking dependency direction and argument position into consideration, there are still cases with several possible dependency types, as shown in Figure 5.

While for many practical purposes an unlabeled dependency structure is sufficient, having proper dependency labels is nonetheless desirable. In lack of an exact transformation, the approach explored in this work relies instead on training a classifier to predict the correct dependency label given local

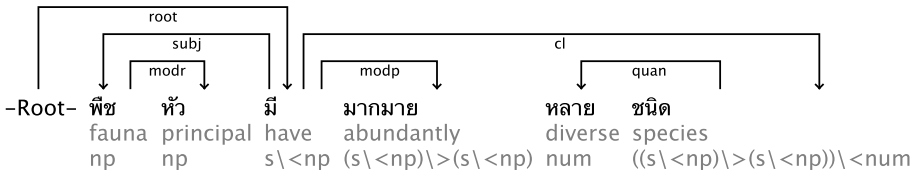
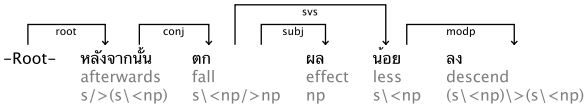
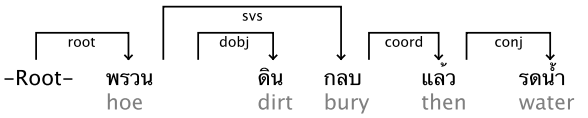


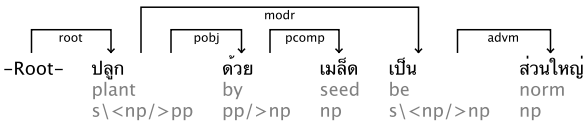
Figure 4: An unmistakekable labeling case: Given the CDG types of **หลาย** ("diverse") and **ชนิด** ("species"), the only dependency label supported by the examined data is "quan" (*quantifier*).



(a) Subject (subj)



(b) Direct object (dobj)



(c) adverbialiser (advm)

Figure 5: Different labeling of left-pointing dependency arcs with $\mathtt{s}\backslash < \mathtt{np}/ > \mathtt{np}$ as head CDG type and `np` as dependent CDG type. See Figure 6 for depency type abbreviations.

features of the tokens involved, as they occur in the dependency structure derived from the CDG tree. Two feature sets are suggested: The basic set comprising head and dependent CDG type, as well as dependency direction ("L" or "R", as seen from the dependent). The other set extends the basic set by including surface forms.

4 Experiments

The Thai CG bank made available for this research contains 1,428 CG trees, comprised of

- 539 verb phrases or subject-omitted phrases ($\mathtt{s}\backslash\mathtt{np}$),
- 363 sentences (`s`),
- 372 noun phrases (`np`) and
- 4 prepositional phrases[4] (`pp`).

[4]As there is no explicit sentence boundary marker in Thai [Satayamas and Kawtrakul, 2004], it is often unclear what constitutes "a sentence". The distribution of tree types reflect the partitioning of token sequences made by the treebank annotators for the purpose of treebanking.

The lexical dictionary used contains possible CDG types for 38.250 word forms, with an average of 2 types listed per word form. For six of the word forms, the dictionary lists several possible dependency directions for a single CG type. These confusable CDG types and the dictionary entries they occur for are listed in Table 1.

An example sentence from the treebank affected by the ambiguous mapping of the adverb **ตอนนี้** ("at present") is [5]:

ตอนนี้ เธอ กำลัง ยุ่ง มาก

(**Lit**: this-moment/ADV she/PRON "-ing"/AUX busy/ADJ very/ADV)

"At this moment she is being very busy."

Examples of the latter two ambiguity classes of the lexical dictionary (Table 1) were not encountered in the treebank — i.e. the affected word forms do not occur with an ambiguous CG type. In dealing with these ambiguous entries in the lexical dictionary, we simply (and naively) choose the first mapping option.

The generic CG to CDG mapping, used in addition to the lexical dictionary as fallback for word forms not found in the lexical dictionary, also exhibits some degree of ambiguity. The seven CG types with multiple possible CDG equivalents are listed in Table 2.

4.1 Dependency labeling

To evaluate the classification-based approach to assigning dependency labels, a sample of 678 labeled dependency edges from the NAiST dependency treebank [Wacharamanotham et al., 2007] was used, along with corresponding CDG trees obtained from a related work (manuscript in preparation). The *basic* and *extended* feature sets desribed in section 3.4 on the preceding page were evaluated with four different classifiers[6] (see Table 3).

[5]The Thai auxillary verb **กำลัง** indicates the present participle, meaning "in the act of", similar to the English suffix, "-ing". Artificial word boundaries has been inserted for clarity.

[6]Experiments with the learners were done using leave-one-out cross-validation, with the exception of LibSVM, which was run using the standard K-fold cross-validation of the easy.py script [Chang and Lin,

Word form(s)	CG type	Possible CDG equivalents	Interpretation
น่า	(s\np)/(s\np)	(s\ < np)/ > (s\ < np) (s\ < np)/ < (s\ < np)	Adverb "please" Auxiallary verb "should"
ตอนนั้น ("at that time") ตอนนี้ ("at present") ขณะนั้น ("at that moment") ขณะนี้ ("this moment")	s/s	s/ > s s/ < s	Conjunction Adverb of time
กับ	np\ < np/ > np	np\ > np/ > np np\ < np/ > np	Preposition "with" Conjunction "and"

Table 1: Entries in the lexical dictionary which are ambiguous with respect to dependency direction

CG type	Possible CDG equivalents
np\np/np	np\ > np/ > np np\ < np/ > np
s/s	s/ > s s/ < s
s\s	s\ > s s\ < s
(s\np)/(s\np)	(s\ < np)/ > (s\ < np) (s\ < np)/ < (s\ < np)
s/(s\np)	s/ > (s\ < np) s/ < (s\ < np)
s\(s\np)	s\ < (s\ < np) s\ > (s\ < np)
s/(s\np)/np	s/ > (s\np)/ > np s/ < (s\np)/ > np

Table 2: Cases of CD to CDG mappings which are ambigous with respect to dependency direction

Classifier	Basic feats	+forms
RandomForest-Weka	61.8%	69.5%
LibSVM	**62.8%**	**74.2%**
NearestNeighbors	60.9%	68.0%
NaiveBayes	60.2%	60.2%

Table 3: Accuracy of different classifiers in recovering the correct dependency labels

5 Discussion

The process of transforming CDG-augmented CG trees to (unlabeled) dependency trees was (not surprisingly) successful. In this work, the issue of ambiguous CDG types affects only a very small number of trees, but remains an issue to be aware of.

Dependency labels were not reliably recoverable by looking only at CDG types and dependency direction. However, by including head and dependent token surface forms as features for the classifier, a substantial reduction in error rate — from 0.372 to 0.258 ($\approx 31\%$) — was gained. It seems hopeful that even better recovery of dependency labels can be obtained with this approach once more training material (in the form of sentences with both CDG and labeled dependency analyses) become available.

Rather than the approximated classfier-based approach to labeling, one could consider settling for an exact but partial labeling by only assigning those dependency labels which unambigously arise from tuples of head and dependent CDG types. However, the dependency labels obtainable with absolute certainty in this way are often of the less interesting kind — e.g. "conj" for a s\ < np governed by a s/ > (s\ < np) — while the more useful labels remain ambiguous.

6 Conclusion and future work

In the process, a considerable amount of syntactical and annotational errors in the Thai CG bank were identified and corrected. The authors are of the belief that this work has not only provided a means for continual expansion of resources for Thai natural language processing, but also helped improve the quality the existing CG resource.

As a related work (manuscript in preparation) progresses, more CDG trees for labeled NAiST dependency trees will become available. With this extra training material, the learned classifier used for labeling in this work should become more reliable. Further improvement might also be achiev-

2001].

Complements *subject* (subj) • *clausal subject* (csubj) • *direct object* (dobj) • *indirect object* (iobj) • *prepositional object* (pobj) • *prepositional complement* (pcomp) • *subject or object predicative* (pred) • *clausal predicative* (cpred) • *conjunction* (conj) • *subordinating conjunction* (sconj) • *nominaliser* (nom) • *adverbialiser* (advm)

Adjuncts *parenthetical modifier* (modp) • *restrictive modifier* (modr) • *tense modifier* (modt) • *mood modifier* (modm) • *aspect modifier* (moda) • *locative modifier* (modl) • *parenthetical apposition* (appa) • *restrictive apposition* (appr) • *relative clause modification* (rel) • *determiner* (det) • *quantifier* (quan) • *classifier* (cl) • *coordination* (coord) • *negation* (neg) • *punctuation* (punc) • *double preposition* (dprep) • *parallel serial verb* (svp) • *sequence serial verb* (svs)

Figure 6: Dependency types from the annotation guidelines [Sudprasert, 2008] for the NAiST dependency treebank.

able from an expanded feature set, including for example the argument position (in addition to side) and one or two generations of grandparent nodes.

Further development of the Thai CDG formalism is also expected, in particular for the analysis of sentence-like noun phrases. This will likely need special handling in the dependency representation as well. Currently, the NAiST annotation guidelines do not specify a label for this phenomenon.

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