Consistent Word Segmentation, Part-of-Speech Tagging and Dependency Labelling Annotation for Chinese Language

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Abstract

In this paper, we propose a new annotation approach to Chinese word segmentation, part-of-speech (POS) tagging and dependency labelling that aims to overcome the two major issues in traditional morphology-based annotation: Inconsistency and data sparsity. We re-annotate the Penn Chinese Treebank 5.0 (CTB5) and demonstrate the advantages of this approach compared to the original CTB5 annotation through word segmentation, POS tagging and machine translation experiments.

1 Introduction

The definition of “word” is an open problem in Chinese linguistics. In previous studies of Chinese corpus annotation (Duan et al., 2003; Huang et al., 1997; Xia, 2000), the judgement of word-ood of a meaningful string is based on the analysis of morphology: A morpheme in Chinese is defined as the smallest combination of meaning and phonetic sound in Chinese language, which can be classified into two major types: 1). Free morphemes, which can either be words by themselves or form words with other morphemes; and 2). Bound morphemes, which can only form words by attaching to other morphemes.

An issue with word definition using morpheme classification is that, it potentially undermines the consistency of the representation of words. For example, “论” (theory) is a bound morpheme, therefore the string “进化论” (theory of evolution) is treated as a word; on the other hand the string “进化理” (theory of evolution) are treated as two words, despite the fact that the two strings have the same meaning and structure. In another example, “者” (person) is considered as a bound morpheme, therefore “反对自由贸易者” (people who are against free trade) is treated as one word, while the string without the bound morpheme, i.e. “反对自由贸易” (be against free trade), can only be treated as a phrase of three words.

The morphology-based word definition can also make the data sparsity problem worse in corpus annotation. As an evidence, in the Penn Chinese Treebank 5.0 (CTB5) which is an annotated corpus widely used to train Chinese morphological analysis systems, we found that one of the major sources of the out-of-vocabulary (OOV) words is the compounds that end with a monosyllabic bound morpheme. For example, compounds 利税率 (utility rate) and 次品率 (rate of defective product) end with the compound morpheme 率 (rate); 完成度 (degree of completion) and 活跃度 (degree of activity) end with the compound morpheme 度 (degree); 持续性 (sustainability) and 挥发性 (property of volatile) end with the compound morpheme 性 (property). While these compounds are sparse in the corpus, the morphemes which they...
### Table 1. Disyllabic character-level POS patterns.

| POS Pattern | Example |
|-------------|---------|
| pronoun + noun | 我校 (this university) |
| locative + noun | 后门 (back door) |
| locative + verb | 前述 (described above) |
| noun + locative | 室内 (indoor) |
| pronoun + locative | 此外 (besides) |
| adverb + verb | 猝死 (sudden death) |
| noun + noun | 厂房 (factory plant) |
| noun + measure | 车辆 (vehicles) |
| adjective + noun | 佳酿 (wines) |
| adjective + measure | 高层 (high level) |
| verb + verb | 抽取 (extract) |
| verb + particle | 写完 (finish writing) |
| verb + adjective | 打碎 (break) |
| verb + locative | 综上 (accordingly) |
| verb + noun | 辞职 (resign) |
| adjective + adjective | 优雅 (elegant) |
| adverb + adjective | 最新 (latest) |
| determiner + noun | 各界 (all walks of life) |
| determiner + temporal | 昨日 (the next day) |

### Table 2. Some examples of the word and POS annotation in the original CTB5 and our re-annotation.

| CTB5 Example | Re-annotation |
|--------------|---------------|
| 副主席/NN (vice president) | 副/JJ (vice) 主席/NN (president) |
| 透明度/NN (transparency) | 透明/JJ (transparent) 度/SFN (degree) |
| 非生产性/NN (unproductiveness) | 非/JJ (none) 生产/VV (produce) 性/SFN (property) |
| 中央集权式JJ (politically centralized) | 中央/NN (center) 集权/NN (centralization) 式/SFA (type) |

consist of can be frequently observed; this means these OOV words can be observed and learnt by a word segmenter if we split the morphemes as individual words in the annotation.

In this paper, we propose a simple annotation approach for Chinese word segmentation that overcomes the two issues: inconsistency and data sparsity, which are found in the traditional morphology-based annotation approach. We further propose a tagset for part-of-speech tagging and a label set for dependency labelling, which are consistent with our word segmentation strategy and capture more Chinese-specific syntactic structures. We re-annotate the entire CTB5 using this approach, and through word segmentation, POS tagging and machine translation experiments we demonstrate the advantages of our annotation approach compared to the original approach adopted in CTB5.

The remainder of this paper is organized as follows: in section 2 we will describe our proposed annotation approach to word segmentation; in section 3 we will present a POS tagset which is consistent with our word segmentation strategy and a new dependency label set; in section 4 we will demonstrate the effectiveness of our approach compared to the original CTB5 through experiments; we will conclude our work in the last section.

## 2 Word Segmentation Annotation

We categorize the words in CTB5 into three categories: Common words, names, and idioms. For names and idioms, we keep them as individual words since their word boundaries are relatively easy to recognize and the consistency in manual annotation can be achieved with less efforts. We will mainly focus on describing the treatments of common words in this section.
Table 3. Proposed tagset for part-of-speech tagging. The underlined characters in the examples correspond to the tags on the left-most column. The CTB POS are also shown.

The key in our method to define the boundaries of common words is the character-level POS pattern. Character-level POS has been introduced in previous studies (Zhang et al., 2013; Shen et al., 2014) which captures the grammatical roles of Chinese characters inside words; we further develop this idea and use it as a criterion in word definition.

We treat a meaningful disyllabic string as a word if it falls into one of the character-level POS patterns listed in Table 1. The reason we focus on disyllabic patterns instead of other polysyllabic ones is that, based on our observation, meaningful strings with 3 or more syllables (other than names and idioms) are always compounds in Chinese, and therefore can be segmented into a sequence of monosyllabic and disyllabic tokens based on their internal structures. On the other hand, the internal structure in a disyllabic token, though still exists, is more implicit and harder to describe with syntactical relations; we believe that it would increase the difficulties for subsequent tasks, such as dependency parsing, if we further segment these disyllabic strings.

| Tag | Description | Count in CTB5 | Proposed annotation |
|-----|-------------|---------------|---------------------|
| NN  | Noun        | 134,321       | 137,816             |
| PU  | Punctuation | 75,794        | 75,935              |
| VV  | Verb        | 68,789        | 75,033              |
| AD  | Adverb      | 36,122        | 35,922              |
| NR  | Proper Noun | 29,804        | 30,985              |
| P   | Preposition | 17,280        | 17,721              |
| CD  | Cardinal Number | 16,030 | 21,493          |
| M   | Measure Word | 13,686      | 18,091              |
| JJ  | Adjective   | 12,979        | 13,898              |
| DEC | Complementizer | 12,310   | 12,346              |
| DEG | Genitive Marker | 12,145    | 12,145              |
| NT  | Temporal Noun | 9,467      | 4,524               |
| LC  | Locative    | 7,676         | 0                   |
| VA  | Predicative Adjective | 7,630 | 7,518        |
| CC  | Coordinating Conjunction | 7,137 | 7,134         |
| PN  | Pronoun     | 6,536         | 6,646               |
| DT  | Determiner  | 5,901         | 5,970               |
| VC  | Copula      | 5,338         | 5,521               |
| AS  | Aspect Particle | 4,027     | 4,033               |
| VE  | “you3” (“have”) | 2,980     | 2,980               |
| OD  | Ordinal Number | 1,661       | 1,661               |
| MSP | Other Particles | 1,316      | 1,316               |
| ETC | “deng3” (“etc.”) | 1,287      | 0                   |
| CS  | Subordinating Conjunction | 888     | 888                 |
| BA  | Causative Auxiliary | 751       | 756                 |
| DEV | Manner Marker | 621         | 627                 |
| SP  | Sentence-final Particle | 466     | 466                 |
| SB  | Short Passive Auxiliary | 451     | 451                 |
| DER | Resultative Marker | 258       | 258                 |
| LB  | Long Passive Auxiliary | 245      | 245                 |
| FW  | Foreign Word | 33          | 391                 |
| JJ  | Interjection | 12          | 17                  |
| X   | Unknown     | 6            | 6                   |
| SFN*| Nominal Suffix | 0         | 13,212              |
| SFA*| Adjectival Suffix | 0        | 438                 |
| SFV*| Verbal Suffix | 0          | 129                 |

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Following this strategy, a polysyllabic word can be then segmented based on its structure. This is illustrated with examples in Table 2.

3 Part-of-Speech and Dependency Label Set

To perform POS tagging re-annotation on CTB5 together with our proposed word segmentation approach, we use a POS tagset which is derived from the one used in the original CTB5 annotation. We show the tagset in Table 3 with comparison of number of occurrences of each tag in the original CTB5 and the re-annotated version, respectively. The tagset introduces several changes: First, we eliminate the use of the “LC” tag for locative words. This tag is assigned to all words that indicate locations and directions, such as 上 (up), 下 (down), 左 (left), 右 (right), 内 (inside), 外 (outside) etc.. We instead tag these words based on their real syntactic roles in sentences, such as “NN” (noun), “AD” (adverb) or “VV” (verb). Second, we add three new tags into the tagset for suffixes: “SFN” (nominal suffix), “SFA” (adjectival suffix), and “SFV” (verbal suffix). These tags are given to monosyllabic tokens appearing at the end of compounds, which are the bound morphemes in the traditional view. Based on our observation, these tokens have the ability to determine the syntactic role of the entire compound. For example, any compound that end with a nominal suffix “度” (degree) always act as nouns in a sentence. It should be noted that because of this characteristic of suffixes, we can tag the children of suffixes in compounds based on their meaning but not their syntactic roles. We show some examples in Table 2 to illustrate our POS tagging strategy for compounds.

In Table 4 we present a dependency label set developed based on the Stanford Dependencies (De Marneffe et al., 2006) and its Chinese version (Chang et al., 2009), which defines 45 dependency relations for Chinese sentences. This label set is also closely related to the Universal Dependency1 with many of their labels compatible with each other. We explain the major characteristics of our label set in the following subsection.

3.1 Chinese Specific Labels

**dislocated** The label “dislocated” is originally defined in the universal dependencies for languages such as Japanese to describe the syntactic relation of words in a topic-comment structure, but is not defined for Chinese. However, in Chinese it is frequent to see the topic-comment structure in a sentence, for example:

1. 這/this 本/-measure- 書/book 他/he 買/buy 的/-particle- (This book, he bought it)

In this sentence, 這本书 (this book) is the topic and 他买的 (he bought) is the comment. One common view of the syntactic structure of this sentence is that, 他 (he) is the subject of the predicate 他 (buy), and 书 (book) is the direct object. This treatment sees a topic-comment structure as having an OSV (object-subject-verb) word order, which is acceptable; it however has some problems in certain cases, for example:

2. 這/this 本/-measure- 書/book 他/he 買/buy 的/-particle- 昨天/yesterday 不見/disappear 了/-particle- (This book that he bought disappeared yesterday)

In this sentence, 书 (book) is still the direct object of 买 (buy), while it is also the subject of 不见 (disappear). Because of the nature of the dependency grammar we adopted, for such a structure we would have to choose one relation for 书 (book), either “nsubj” or “dobj”, and discard the other relation which would cause a loss of the syntactic information encoded in the parse tree.

Moreover, the OSV word order cannot explain all topic-comment structure such as the following example:

3. 這/this 場/-measure- 火/fire 幸虧/fortunately 消防/ﬁreﬁghting 隊/team 來/come 得/-particle- 早/early (This fire, fortunately the firefighters came in time)

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1 http://universaldependencies.org/
| Label    | Description               | Example Phrase                                                                 | Example Dependency   |
|----------|---------------------------|-------------------------------------------------------------------------------|----------------------|
| acomp    | adjectival complement     | 鞋是全新的 (the shoes are brand new)                                        | acomp(是 are, 全新 brand new) |
| advmod   | adverbal modifier         | 他看上去很疲倦 (he looks very tired)                                       | advmod(疲倦 tired, 非常 very) |
| amod     | adjectival modifier       | 漂亮的首飾 (cute accessory)                                                  | amod(首飾 accessory, 漂亮 cute) |
| appos    | appositional modifier     | 總統奧巴馬 (president Obama)                                                  | appos(奧巴馬 Obama, 總統 president) |
| asp      | aspect marker             | 他給了我一本書 (he gave me a book)                                         | asp(給 gave, 了 -aspect-) |
| attr     | attributive modifier      | 他是一位醫生 (he is a doctor)                                                | attr(是 is, 醫生 doctor) |
| aux      | auxiliary verb            | 必須解決 (must solve)                                                        | aux(解決 solve, 必須 must) |
| auxpass  | passive auxiliary         | 他被刺殺了 (he was assassinated)                                             | auxpass(刺殺 assassinated, 被 -auxiliary-) |
| auxcaus  | causative auxiliary       | 把問題解決 (solve the problem)                                               | auxcaus(解決 solve, 把 -auxiliary-) |
| cc       | coordinating conjunction  | 聰明又可愛 (smart and cute)                                                  | cc(聰明 smart, 又 and) |
| ccomp    | closed clausal complement | 他說他喜歡游泳 (He said that he likes swimming)                             | ccomp(說 said, 喜歡 likes) |
| conj     | conjunct                  | 聰明又可愛 (smart and cute)                                                  | conj(聰明 smart, 可愛 cute) |
| csubj    | clausal subject           | 能夠代表祖國參賽是他的夢想 (being able to play in the game for his country is his dream) | csubj(是 is, 參賽 play) |
| csubjpass| clausal passive subject   | 他在考試中作弊被老師發現了 (that he cheated during the exam is found out by the teacher) | csubjpass(發現 find out, 作弊 cheat) |
| dep      | undefined dependency      | 添加一個日程安排時間星期二地點 3 樓 (add an event, time Tuesday, location 3rd floor) | dep(時間, 添加) |
| det      | determiner                | 那本書 (that book)                                                           | det(本 -measure-, 那 that) |
| discourse| discoursal modifier       | 唉, 終於到星期五了 (oh, thank God it’s Friday)                              | discourse(到 is, 唉 oh) |
| dislocated| dislocated modifier       | 書是他買的 (book he bought) 這場火幸虧消防隊來得早. (this fire, fortunately the firefighters came in time) | dislocated(書 book, 本 buy) |
| dobj     | direct object             | 買了一本書 (bought a book)                                                   | dobj(買 bought, 書 book) |
| foreign  | foreign compound          | 職棒大聯盟 (Major League Baseball)                                            | foreign(Major, League) |
| foreign  | foreign compound          | 職棒大聯盟 (Major League Baseball)                                            | foreign(Major, Baseball) |
| iobj     | indirect object           | 他給了我一本書 (he gave me a book)                                          | iobj(給 gave, 我 me) |
| list     | list relation             | 添加一個日程安排時間星期二地點 3 樓 (add an event, time Tuesday, location 3rd floor) | list(時間 time, 地點 location) |
| mark     | clause marker             | 他把信件給我之後就走了 (he left after he gave me the letter)               | mark(給 give, 之後 after) |
| mes      | measure relation          | 一本書 (a book)                                                              | mes(書 book, 本 -measure-) |
| ncomp            | nominal complement | 坐在椅子上 (sit on a chair) | ncomp(椅子 chair, 上 -complementizer-) |
|------------------|--------------------|---------------------------|---------------------------------------|
| neg              | negation modifier  | 不擅長 (be not good at)   | neg(擅長 be good at, 不 not)          |
| nn               | noun compound modifier | 原油期貨價格 (oil futures price) | nn(價格 price, 原油 oil) nn(價格 price, 期貨 futures) |
| npadvmod         | noun phrase adverbial modifier | 大約十米左右寬 (about 10 m wide) | npadvmod(寬 wide, 米 m) |
| nsubj            | nominal subject    | 他給了我一本書 (he gave me a book) | nsubj(給 gave, 他 he) |
| nsubjpass        | passive nominal subject | 他被刺殺了 (he was assassinated) | nsubjpass(刺殺 assassinated, 他 he) |
| num              | numeric modifier   | 一本書 (a book)           | num(本 -measure-, 一 a) |
| p                | punctuation        | 梨、橘子和香蕉 (pears, oranges, bananas) | p(梨 pears, 、 ) |
| pcomp            | prepositional complement | 由於路上人太多, 我遲到了 (because it was so crowded, I was late) | pcomp(由於 because, 太多 so crowded) |
| pobj             | prepositional object | 他坐在椅子上 (he sits on a chair) | pobj(在 on, 椅子 chair) |
| ps               | associative marker | 這是我的家 (this is my home) | ps(我 me, 的 ’s) |
| poss             | possessive modifier | 這是我的家 (this is my home) | poss(家 home, 我 me) |
| prep             | prepositional modifier | 他坐在椅子上 (he sits on a chair) | prep(坐 sits, 在 on) |
| prt              | phrasal verb particle relation | 他們打起來了 (they started a fight)  | prt(打 fight, 起來 -auxiliary-) prt(整理 summarize, 成 become) |
| rcmodrel         | relative clause complementizer | 他回來的時候 (by the time he came back) | rcmodrel(回來 come back, 的 -complementizer-) |
| rcmod            | relative clause modifier | 這本是他買的書 (this is the book he bought) | rcmod(書 book, 買 buy) |
| suff             | suffix relation    | 科技界 (sci-tech industry)  | suff(界 industry, 科技 sci-tech) |
| tmod             | temporal modifier  | 他回來的時候天已經亮了 (it was bright outside by the time he came back) | tmod(亮 bright, 時候 time) |
| topic            | topic marker       | 這本書是他買的 (this is the book he bought) | topic(書 book, 是 is) |
| vmod             | verb modifier      | 他打開門發現屋裏有人 (he opened the door and found out there is somebody inside) | vmod(發現 found out, 打開 open) |
| xcomp            | open clausal complement | 他不喜歡打網球 (he doesn’t like to play tennis) | xcomp(喜歡 like, 打 play) |

Table 4. Proposed dependency label set.
Unlike in the other two examples, the topic here, 這場火 (this fire), is not the direct object of the verb in the comment, 幸虧消防隊來得早 (fortunately the firefighters came in time).

To overcome these difficulties, we employ a different view which treats the topic-comment structure as having double subjects in a SSV word order. We define the first subject, 這本書 (this book) in example 2, as the head in a “dislocated” relation, and the subject-verb phrase, 他买的 (he bought) in example 2, as the modifier. The head in this dislocated relation can then form a “nsubj” (nominal subject) relation with the main predicate of the sentence, 不见 (disappear). Similarly, in example 3, the topic and the comment still form a dislocated relation even though the topic is not a direct object of the verb in the comment.

prt and prep We define the “prt” relation in two ways:

i. A relation between a verb and a particle. For example, 想像 (imagine) is the head in a “prt” relation of 所 (particle) in the sentence 這是他們所不能想像的 (this is what they can’t imagine).

ii. A relation between a verb and its succeeding complement. For example, 打掃 (clean) is the head in a “prt” relation of 完 (finish) in the sentence 房間打掃完了 (the room has been cleaned).

We use the “prt” relation in the second case to capture the predicate-complement structure in Chinese. The verb 完 (finish) in the second example above functions to complement the meaning of the main verb, 打掃 (clean), and the sentence is still grammatical when the complement verb is removed: 房間打掃了 (the room is cleaned).

The complement verb sometimes also functions as a coverb in a serial verb construction, which takes its own direct object. For example:

4. 把/-auxiliary- 數據/data 綜理/summarize 成/become 報告/report (summarize the data into a report)

Here the two verbs 綜理 (summarize) and 成(become) form a “prt” relation, while they are the heads of 數據 (data) and 報告 (report) in the “dobj” relation.

A difficulty with labeling “prt” is that, it can be easily confused with the “prep” (prepositional modifier) relation. For example, one can argue that 成 (become) is a preposition instead of a verb and should be tagged as IN, so that the relation between 整理 (summarize) and 成 (become) would be “prep”. To overcome this ambiguity, we apply a simple test: If the phrase headed by the word with a VV vs. IN ambiguity can be moved to a position before the main verb, then this word is a preposition and a prepositional modifier of the main verb; otherwise it is a verb. Here since the phrase “成 報告” (into report) cannot be moved to the position before 整理 (summarize), it should in fact be a verb phrase, not a prepositional phrase.

suff We define the suffix relation in a compound which has a “stem-suffix” structure. The suffix word with a POS tag SFN, SFA, or SFV is the root of the subtree formed by the words in the compound. It has one and only one child in this subtree, which is the head of the “stem”, and the dependency relation between them is labelled as “suff”.

The motivation of employing the “suff” label is to relieve the data sparseness problem of word forms in annotated corpora. Compounds, especially those with a “stem-suffix” structure, is a major source of new words in Chinese language. These compounds, however, often share a set of suffix words which has a limited amount of instances. We think it is more effective for a parser to learn from features with word forms by treating the suffix words as the heads of compounds.

4 Evaluation

4.1 Re-annotated Corpus

We re-annotated the entire CTB5 with our proposed word segmentation and POS tagging annotation strategies. We further re-annotated 3,000 sentences which are randomly sampled from the training set of CTB5 using our proposed dependency label set. This re-annotated set is compared with the same sentences with the original annotation in a machines translation experiment in section 4.3.
Table 5. Statistics of the original CTB5 and our re-annotated version.

(a) Word Segmentation Results

| Corpus            | P    | R    | F    |
|-------------------|------|------|------|
| Original          | 97.21| 97.36| 97.28|
| Re-annotated      | 97.97| 97.56| 97.76|
| Re-annotated-partial | 97.68| 97.63| 97.65|

(b) Joint Segmentation and POS Tagging Results

| Corpus            | P    | R    | F    |
|-------------------|------|------|------|
| Original          | 93.42| 93.56| 93.49|
| Re-annotated      | 94.55| 94.16| 94.35|

Table 6. Experimental results for morphological analysis on CTB5.

To evaluate the consistency of our annotation, 4 trained annotators were divided into two equal groups to perform 2-way annotation on a small subset (first 100 sentences in files 301-325), and each pair of annotators were assigned with 50 sentences. The inter-annotator agreement is 99.10% for segmentation, 98.37% for POS tagging, and 95.62% for dependency labeling.

Table 5 shows some of the statistics of the original and the re-annotated CTB5. We split CTB5 in the same data division as in previous studies (Jiang et al., 2008a; Jiang et al., 2008b; Kruengkrai et al., 2009; Zhang and Clark, 2010; Sun, 2011). The training, development and test set have 18,089, 350 and 348 sentences, respectively. Compared to the original CTB5, the re-annotated training set has a lower percentage of unknown words and unknown word-POS pairs found in the corresponding test set. This is consistent with our observation that compounds with internal structures are one of the major sources of OOV words.

4.2 Morphological Analysis Experiments

We compared the performance of a state-of-the-art joint word segmentation and part-of-speech tagging system (Kruengkrai et al., 2009) on the original and our re-annotated CTB5. We used the position-character (POC) tagset and the baseline feature set described in (Shen et al., 2014).

We trained all models using the averaged perceptron (Collins, 2002), which is an efficient and stable online learning algorithm. The models applied on all test sets are those that result in the best performance on the dev sets. To learn the characteristics of unknown words, we built the system’s lexicon using only the words in the training data that appear at least 2 times.

We use precision, recall and the F-score to measure the performance of the systems. Precision (P) is defined as the percentage of output tokens that are consistent with the gold standard test data, and recall (R) is the percentage of tokens in the gold standard test data that are recognized in the output. The balanced F-score (F) is defined as $\frac{2 \cdot P \cdot R}{P + R}$.

We compared the performance of the morphological analyzer on the original and the re-annotated CTB5. The results of the word segmentation experiment and the joint experiment of segmentation and POS tagging are shown in Table 6(a) and Table 6(b), respectively. Each row in these tables shows the performance of the same system trained on the corresponding corpus.

For “Re-annotated-partial” in Table 6(a), we applied a different setting in order to directly compare the annotation consistency and data sparsity between the two corpora: We used the training set from the re-annotated corpus to train the system but the test set from the original corpus in the evaluation. To make the evaluation meaningful, we added an extra criterion when calculating the precision and the
Table 7. Experimental results for Chinese-Japanese machine translation on ASPEC corpus using Moses system.

| System          | BLEU-4 |
|-----------------|--------|
| Character       | 31.60  |
| Original        | 31.46  |
| Re-annotated    | 32.08  |

Table 8. Experimental results for Chinese-Japanese machine translation on ASPEC corpus using KyotoEBMT system.

| System         | BLEU-4 |
|----------------|--------|
| Original       | 32.00  |
| Re-annotated   | 32.97  |

recall: If the outmost boundaries of a sequence (two or more) of output tokens are consistent with a token in the test set, we consider that the output correctly identifies this token in the test set.

The results show that, the morphological analyzer can obtain higher accuracies in both word segmentation (0.48 points absolute in F-score) and joint (0.86 points absolute in F-score) experiments. Furthermore, in the word segmentation experiment “Re-annotated-partial” where we mapped the output of the system which is trained using the re-annotated training data to the original CTB5 test set, the accuracy is significantly higher than that of the “Original”, which demonstrates the better consistency in our re-annotation corpus.

### 4.3 Machine Translation Experiments

To show that a morphological analysis system and a dependency parsing system can both benefit from our re-annotation, we conducted two sets of Chinese-to-Japanese machine translation experiments where a morphological analyzer and a dependency parser are used respectively.

The parallel corpus we used is the Chinese-Japanese part of the Asian Scientific Paper Excerpt Corpus (ASPEC), containing 672k sentence pairs. We used 2,090 and 2,107 additional sentence pairs for tuning and testing, respectively.

In the first set of experiments, we segmented the Japanese sentences using JUMAN (Kurohashi et al., 1994), and the Chinese sentences using the same morphological analyzer described in the last subsection. For decoding, we used the state-of-the-art phrase based statistical machine translation toolkit Moses (Koehn et al., 2007) with default options. We trained the 5-gram language models on the target side of the parallel corpora using the SRILM toolkit with interpolated Kneser-Ney discounting. Tuning was performed by minimum error rate training (MERT) (Och, 2003), and it was re-run for every experiment.

In the second set of experiments, we used the same morphological analyzers to segment and tag the POS of Japanese and Chinese sentences as in the first set. We further parsed the dependency structures of the Japanese sentences using KNP (Kawahara and Kurohashi, 2006), a lexicalized probabilistic dependency parser, and for the Chinese sentences we used a second-order graph-based parser proposed in (Shen et al., 2012). For decoding, we used the tree-to-tree example-based machine translation framework KyotoEBMT with default options.

We report results on the test set using BLEU-4 score, which was evaluated using the multi-bleu.perl script in Moses based on Juman segmentations. The significance test was performed using the bootstrap resampling method proposed by Koehn (2004).

In Table 7 we compare the performance of three Moses models: In “Character” we used a simple segmentation strategy for the Chinese sentences where we treated each character as a token; in “Original” and “Re-annotated” we segmented the Chinese sentences using the corresponding models described in

\[ p < 0.05 \text{ in McNemar’s test.} \]

\[ \text{http://lotus.kuee.kyoto-u.ac.jp/ASPEC/} \]

\[ \text{http://www.speech.sri.com/projects/srilm} \]

\[ \text{http://nlp.ist.i.kyoto-u.ac.jp/EN/index.php?KyotoEBMT} \]
the last subsection. The results show, with the underlying machine translation system being the same, the segmenter trained with the original CTB5 failed to support the system to outperform the simple character-based segmentation, while on the other hand the system using the segmenter trained with our re-annotated CTB5 significantly outperformed both “Character” and “Original”.

In Table 8 we show the result of the experiment with KyotoEBMT, a tree-to-tree machine translation system which requires unlabeled dependency annotation in the model training. 3,000 sentences with original and re-annotated dependency labels were used for training the parsers in “original” and “re-annotated” settings, respectively. The result shows that, the model “Re-annotated” which used the training set with the proposed annotation, it significantly outperformed the baseline model “Original” by 0.97 point in BLEU-4 score.

5 Conclusion

We have proposed a new annotation approach for Chinese word segmentation, part-of-speech tagging, and dependency labelling. By re-annotating the CTB5 and conducting word segmentation, POS tagging and machine translation experiments, we have demonstrated that this approach has the advantages in achieving higher annotation consistency as well as less data sparsity, compared to the original annotation of CTB5. We couldn’t show the comparison in dependency parsing experiments as we currently have only 3,000 annotated sentences; this experiment will be included in our future work.

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