# CTAP for Chinese: A linguistic Complexity Feature Automatic Calculation Platform

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#### Abstract

The construct of linguistic complexity has been widely used in the research of language learning. Several text analysis tools have been made to automatically analyze linguistic complexity. However, the indexes supported by several existing Chinese text analysis tools are limited and varied due to different research purposes. CTAP is an open-source toolkit for linguistic complexity measurement extraction, which serves all research purposes. Although it was originally developed for English, the Unstructured Information Management (UIMA) framework it used allows the integration of other languages. In this study, we integrated the Chinese component into CTAP, describing the index sets it incorporated and comparing it with three linguistic complexity tools for Chinese. The index set includes 4 levels of 196 linguistic complexity indexes: character level, word level, sentence level, and discourse level. So far, CTAP has implemented automatic calculation of complexity characteristics for four languages, aiming to help linguists without NLP background do their research on language complexity.

Keywords: linguistic complexity analyzer, Chinese, text analysis

## 1. Introduction

Linguistic complexity is a multifaceted construct used in a wide range of contexts (Bult and Housen, 2014), manifested in the variety and complexity of production units or grammatical structures (Wolfe-Quintero et al., 1998). It has been used in various studies, such as second language proficiency and development assessment (Crossley and McNamara, 2014; Bult and Housen, 2014; Kyle, 2016), readability assessment (Vajjala and Meurers, 2012; Feng et al., 2010; Chen and Meurers, 2018), and first language academic writing (Crossley et al., 2011; Weiss and Meurers, 2019). A large number of complexity indexes have been proposed in the above research tasks. However, a common and crucial question these studies have to answer is to what extent the complexity indexes that have existed are valid, which would directly bear upon the validity of the research results. The best way to solve this problem is to compare the proposed indexes with a large number of texts of varying difficulty (Lu, 2010), which requires reliable computational tools that can automatically calculate linguistic complexity index values.

Most of the linguistic complexity work has focused on English (Okinina et al., 2020), so many computational tools can automatically analyze English texts, such as Coh-Metrix, D-Level Analyzer, L2 Syntactic Complexity Analyzer, CTAP, and so on. However, the scope of complexity research has been broadened towards the Chinese in recent years. There are several automated text complexity analysis tools for Chinese, such as the Chinese Readability Index Explorer (CRIE) (Sung et al., 2016), Chinese Coh-Metrix, and Chi-Editor (Jin et al., 2018). Among the complexity indexes provided by these tools, some are different due to their different research purposes, which will be pointed out in Section 2. However, they use different technologies that ultimately lead to different values even for the same indexes. In addition, these tools did not provide corpus management functions or support users in downloading analysis reports locally as text files.

For the above reasons, we integrated Chinese components into the Common Text Analysis Platform (CTAP) (Chen and Meurers, 2016) to support the analysis of Chinese texts. CTAP is a language complexity feature extraction platform for English. The unstructured information management framework it uses makes it extendable, facilitating the addition of new language components. More importantly, it is open-source. So far, the platform has supported the analysis of the complexity indexes for four languages: English, German, Italian and Chinese. The effectiveness and plausibility of textual indexes vary between languages due to their linguistic peculiarities (Sung et al., 2016), so we only transferred 40 linguistic complexity indexes provided for English, German and Italian by integrating a Chinese text processing tool and added 150 indexes for

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Chinese. The Chinese component of CTAP provides a more comprehensive set of indexes than the other existing computational tools for Chinese texts, with support of extractions for 196 linguistic complexity measures, among which average dependency distance, maximum dependency distance, average syntax tree height, and the maximum syntax tree height we implemented are not only applicable to Chinese but also English to measure text complexity.

In this article, we describe the Chinese component of CTAP. The rest of the paper is organized as follows: Section 2 illustrates Chinese complexity research and Chinese automated textual-analysis tools existing. Section 3 introduces the functions of CTAP and NLP tools used in the Chinese component and lists the Chinese complexity indexes it supports. Section 4 describes different characteristics by comparing CTAP and other linguistic complexity measurement tools for Chinese. Finally, the last section concludes the paper and discusses the scope for future work.

#### 2. Related Work

In recent years, with the continuous advancement of information technology, natural language processing, computational linguistics, and second language acquisition, other related disciplines have continued to developed continuously. Researchers are paying more and more attention to the field of text complexity. The study of English complexity started earlier and has produced many research achievements. However, in recent years, the scope of complexity research has been broadened towards Chinese. Taking the field of L2 learning as an example, the research includes investigating the syntactic complexity of the learner's L2 production (Wu, 2016a), the longitudinal development of L2 linguistic complexity (Wu, 2016b), the relationship between complexity and L2 writing quality (Wu, 2018), the effects of learning tasks on the complexity of the learner's L2 production (Wu and Hu, 2021)and comparison of the complexity features in different genres in writing by second language learners (Wu, 2019). In addition, complexity has been used to assess text readability. A Chinese complexity index system with 165 specific complexity indexes was constructed, including four levels of Chinese characters, vocabulary, syntax, and text to assess Chinese textbooks' readability (Wu, 2020). 85 complexity indexes were used to make a refined readability assessment of second language teaching materials (Zhu, 2020). The analysis and calculation of so many indexes must rely on the help of computers, but this is a challenge for researchers without technical background. Therefore, it is necessary to develop an automatic extraction tool for text complexity indexes. To the best of our knowledge, there are several computational systems for automatic linguistic complexity analysis of Chinese texts. For example, CRIE was designed to analyze text complexity and readability. It

is composed of three systems: CRIE, CRIE-CFL (Chi-

nese as a foreign language), and CRIE-DK (Domain Knowledge). Among the three systems, CRIE was used to analyze Chinese texts for native speakers, CRIE-CFL was created to analyze foreign-language reading materials for CFL, and CRIE-DK was invented to assess the knowledge content levels of texts, such as the readability and conceptual difficulty of a web page or e-book (Sung et al., 2016). Chinese Coh-Metrix was created to analyze the cohesion and coherence of Chinese texts. Therefore it focuses on referential cohesion measures (e.g., Local Nouns Overlap), connective measures (e.g., Coordinating Connective), and latent semantic analysis measures for Chinese. It was developed based on Coh-Metrix (Graesser et al., 2011), an online tool for assessing English texts coherence, often used in second language acquisition. Chi-Editor was invented to analyze foreign-language reading text readability, aiming to offer difficulty level of reading material to the international Chinese teacher.

None of the above tools are specifically used to calculate and extract complexity features, so the complexity features they implement are not comprehensive. By adding the Chinese components to CTAP, we aim to provide a complexity index extraction tool with a broader index set than the existing three Chinese complexity analysis tools. CTAP calculated many features about Chinese character components, syntax trees, dependency information, collocation information, and grammar level to make the text complexity assessment more accurate. In addition, CTAP provides corpus management and visualization functions and support to download the calculated index values to the local in the text form , which is convenient for researchers to use in subsequent research. Finally, CTAP allows to aggregate new indexes with its flexible and extendible architecture.

# **3.** CTAP and Its Extension to Chinese

## 3.1. CTAP Architecture

The Common Text Analysis Platform (CTAP) (Chen and Meurers, 2016) is a web-based language complexity index automatic extraction tool. This tool is not limited to specific research tasks, and the unstructured information management framework it uses is very convenient for adding new indexes or other language modules. In this section, we will make a brief introduction to CTAP as well as the NLP tool we use for Chinese text preprocessing.

#### 3.1.1. An Overview of CTAP User Modules

The CTAP system consists of four basic modules: Corpus Manager, Feature Selector, Analysis Generator, and Result Visualizer. Corpus Manager enables users to upload many texts and build multiple corpora. Feature Selector is used to group the selection of the complexity indexes into index sets. Then, users can utilize Analysis Generator to generate analyses. Result Visualizer is a module for visualizing these analysis results. These modules are designed to be user-friendly and powerful, which enable users to focus more on research findings instead of paying too much effort to text preprocessing and annotation procedures. By the way, the system is compatible with Chinese components as it is language-independent.

### 3.1.2. NLP Tools for Text Preprocessing

To annotate Chinese texts with high quality in an automatic way, we decide to choose the Stanford CoreNLP toolkit for annotations. CoreNLP is a widely-use, highperformance, and multi-lingual NLP tool created by the Stanford NLP Group (Manning et al., 2014). It contains a pipeline to produce a set of annotations with high precision given a raw text, which we use for sentence splitting, tokenization, part-of-speech tagging, constituency parsing, and dependency parsing. The annotated text is used to extract indexes later on.

# 3.2. Complexity Indexes for Chinese in CTAP

At present, the Chinese component of CTAP includes 196 linguistic complexity indexes, 40 of which are available for English, German and Italian. These common indexes contain lexical richness (e.g., type-token ratio), lexical variation (e.g., verb variation), lexical density (e.g., noun density), number of syntactic constituents (e.g., verb phrase), and syntactic complexity (e.g., mean length of noun phrases). Because there are large morphological and syntactic differences between the characteristics of Chinese and alphabetic languages (Sung et al., 2016), 150 complexity indexes included the Chinese component of CTAP are unique. The implemented measures are distributed among the following four levels: character level, lexical level, sentence level, and paragraph level.

#### **3.2.1.** Character Level

Character level can be divided into three subcategories: character complexity (10 indexes), character richness (9 indexes), and character sophistication (14 indexes).

Character complexity Chinese characters are composed of components, while components are composed of strokes. The number of components and strokes are valid indexes to measure character complexity. Wang and Peng (1999) proposed that there is a significant stroke number effect in the processing of Chinese characters (Wang and Peng, 1999). The more strokes, the slower the processing speed. For this reason, we developed two types of indexes: one is stroke-countbased (e.g., the average number of character strokes) and the other is component-count-based (e.g., the average number of Chinese character components). Besides, we divided Chinese characters into three categories according to the number of strokes: Low-strokecount characters, Intermediate-stroke-count characters, and High-stroke-count characters. Low-stroke-count character contains 1 to 8 strokes, Intermediate-strokecount character contains 9 to 16 strokes and Highstroke-count character contains more than 16 strokes (Wu, 2020). Information about strokes is from the Chinese Proficiency Test Application Form Word (2006), which is developed by the Ministry of Education and State Language Commission and contains 5,500 characters. Information about components is from Network of the Chinese characters research team <sup>1</sup>, which includes 4,033 characters.

Character richness Character richness refers to the degree of variation of Chinese characters used in a text. There are many ways to calculate the richness of Chinese characters. The most widely used indicator is the Type-Token Ratio (TTR), which is the ratio of the type of Chinese characters in the text to the total number of characters in the text (Templin, 1957). The higher the value of TTR, the more abundant Chinese characters are used. However, the validity of the TTR indicator will be affected by the length of the text. Therefore, we added Log TTR, Root TTR, Uber TTR, and Corrected TTR to measure the character richness of a text. Besides, characters that appear only once in a text are seen as one of the signs that distinguish a text from other texts and can reflect on character richness (Islam et al., 2012). Thus, we also use the number of characters that appear only once and the proportion of characters that appear only once to measure character richness.

Character sophistication The sophistication of Chinese characters is affected by the frequency of Chinese characters in daily life. The higher the frequency of Chinese characters, the easier it is to recognize them. The character sophistication indexes are calculated by referring to the Chinese character frequency tables, which are the Chinese Gigaword character frequency table, L2 Chinese Textbooks character frequency table, and Contemporary Chinese Corpus character frequency table. The Chinese Gigaword Corpus<sup>2</sup> is is a comprehensive archive of newswire text data that has been acquired from Chinese news sources. The L2 Chinese Textbooks Corpus contains many textbooks, which can reflect the usage of each character in educational settings. The Contemporary Chinese Corpus is a large-scale balanced corpus, which contains about 20 million characters. There are two types of indexes in the character sophistication category: Logarithmic Character Frequency (Type) and Logarithmic Character Frequency (Token).

In the field of Chinese second language teaching and acquisition, the difficulty level of Chinese characters stipulated in the Chinese Proficiency Grading Standards for International Chinese Language Education (referred to as the Grade Standard later) are important factors to measure the difficulty of Chinese characters. The higher the level of Chinese characters specified in the Grade Standard, the more difficult it is.

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https://learnm.org
2https://catalog.ldc.upenn.edu/
LDC2011T13
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#### 3.2.2. Lexical Level

The lexical level mainly involves five subcategories: lexical richness (9 indexes), lexical variation (9 indexes), lexical density (28 indexes), lexical sophistication (26 indexes), and basic count of words (9 indexes).

**Lexical richness** The lexical richness indexes refer to the degree of repetition of words used in a text which regardless of the part of speech. The fewer words that are repeated in a text, the richer the words used. Same as the character richness, the lexical richness indexes include: TTR, Log TTR, Root TTR, Corrected TTR, Uber TTR, number of words appearing only once, and proportion of words appearing only once.

Lexical variation The lexical variation indexes reflect the degree of variety of five content word types: nouns, verbs, adjectives, adverbs, and all content words. Content words play an important role in conveying the information of the article. Research shows that people would spend more time processing sentences with more content words (Carpenter and Just, 1983). These indexes calculate the ratio of the number of the five content word types to the number of all content word tokens. The content words contain nouns, verbs, adjectives, adverbs, numerals, measure words, pronouns, distinguish words, interjections, and onomatopoeic words (Huang and Liao, 2011). Verbs often serve as the core component of sentences, so we gave it the special attention that not only the ratio with the number of all content word tokens is considered. but also the ratio with the number of verb tokens.

Lexical density The lexical density indexes refer to the density of every part of speech. In Chinese, all words are divided into content words and function words. Content words are used to convey information and express meaning, while function words are used to organize the structure of the text and express logical relationships. The more content words in the text, the greater the vocabulary density and the greater the amount of information conveyed (Johansson, 2008). Existing studies have also found that function words have a great contribution to the prediction of text difficulty (Sung et al., 2015; Wang, 2005; Wang, 2017; Zuo and Zhu, 2014). Therefore, we add the density indexes of various content words and function words to CTAP. The function words contain prepositions, conjunctions, auxiliary words, and sentence-final particles (Huang and Liao, 2011). The lexical density indexes calculate the ratio of the number of different parts of speech to the number of word tokens.

**Lexical sophistication** Lexical sophistication can be measured by word frequency. Many studies have indicated that word frequency is related to word response time, with participants responding faster to words that appear more often (Forster and Chambers, 1973; Whaley, 1978). The lexical sophistication indexes are calculated separately for all words, lexical words, and func-

tional words, and each of them is based on the Chinese Gigaword, L2 Chinese Textbooks Corpus, and Contemporary Chinese Corpus. In addition, it introduces the vocabulary level information in the Grade Standard, which calculates the difficulty of vocabulary by mean value and variance of grade, as well as the proportion of simple words (1-3) and difficult words (7-9).

**Word length** The last subcategory is word length. There is an inverse relationship between lexical length and lexical frequency. The longer the word, the lower the frequency used in the text (Deng and Feng, 2013). Based on the above analysis, we can draw a conclusion that the longer the word, the more difficult it is for people to understand it. Thus, we calculated the number of single-character words, two-character words, three-character words, and four and more characters words.

#### 3.2.3. Sentence Level

The sentence level mainly involves the analysis of three aspects of the sentence in texts: sentence length (8 indexes), sentence constituent complexity (18 indexes), and syntactic structure complexity (28 indexes).

**Sentence length** The sentence length indexes include the mean sentence length in characters and words, its standard deviation, and the longest sentence length. Generally, the longer the sentence, the greater the amount of information and the more difficult it is to understand the sentence.

**Sentence constituent complexity** Sentence constituent complexity indexes include the number of every syntactic constituent, its mean length, and diversity. The sentence constituents mainly include noun phrases, verb phrases, prepositional phrases, coordinate phrases, adjectival modifiers, and sentences. The denser the syntactic structure, the higher the cognitive burden on readers. Existing studies have found that the number of noun phrases, verb phrases, and adjective phrases in a sentence is related to the grade of Chinese textbooks for elementary and middle schools (Sun, 2015; Jiang, 2018). Thus, we developed the number of every sentence constituent, its mean length, and diversity to measure sentence constituent complexity.

Syntactic structure complexity The syntactic structure complexity is mainly analyzed from the following four aspects: the parse tree depth, the dependency distance, the grammar, and the collocation. The height of the parse tree can effectively reflect the complexity of the syntax. It has been proven that the higher the parse tree, the more complex the sentence (Sun, 2015; Jiang, 2018; Wu and Hu, 2021). We counted the distribution of syntax trees height in the Chinese Treebank 8.0 and took 80% of the distribution (that is 14) as the boundary value. Based on this, we measure the syntactic complexity by using mean parse tree depth, its standard deviation, the height of the highest parse tree, the number of sentences whose parse tree height is greater than 14, and their proportion. In addition, dependence distance can reflect the cognitive difficulty of sentences (Liu, 2007). Dependence distance refers to the linear distance between words with syntactic relations. The research results of cognitive linguistics show that in syntactic processing, the linear distance between two syntactically related words affects the storage and integration of working memory. As the linear distance between two words becomes longer, the cognitive cost also increases (Gibson and others, 2000). Therefore, indexes about dependence distance include: the average and the maximum number of words before the head verb, mean dependence distance, and maximum dependence distance. Grammar level is also an important factor affecting text comprehension for Chinese second language learners. Indexes about grammar include the average of grammatical levels, the proportion of grammar at each level, and the RTTR of grammar at each level. Hu (2021) proposed collocation-based features of syntactic complexity.

#### 3.2.4. Paragraph Level

The paragraph level mainly involves two subcategories: basic count of paragraphs (5 indexes) and cohesive complexity (23 indexes).

**Basic count of paragraphs** The basic count of paragraphs indexes include the number of paragraphs, mean paragraph length, and the longest paragraph length.

**Cohesive complexity** The cohesion was divided into lexical cohesion, reference and logical cohesion (Cai, 2020), which we use to analyze cohesive complexity. Lexical cohesion mainly refers to the pattern of lexical repetition and cohesion in discourse, which includes local cohesion and global cohesion. Local cohesion refers to the lexical repetition between close-distance clauses, while global cohesion refers to the lexical repetition between far-apart sentences (Hoey, 1991).

The lexical cohesion is calculated separately for all words, content words, nouns, and verbs, including cohesion between adjacent sentences and cohesion among all sentences in a text. The reference contains the proportion of the first person pronouns, the second person pronouns, the third person pronouns, interrogative pronouns, and demonstrative pronouns. The logical cohesion includes the proportion of coordinating connectives, alternative connectives, progressive connectives, condition connectives, hypothetical connectives, causal connectives, purposive connectives, and concessive connectives.

# 4. Comparing Linguistic Complexity Analysis Tools for Chinese

In the following we compare four linguistic complexity analysis tools for Chinese: CRIE, Chinese Coh-Metrix, Chi-Editor and CTAP, describing the main differences among them. These differences are analyzed from the following dimensions: First, we compare index sets in the different tools. Secondly, we present different functions of the four tools. Then we describe the interpretation of results calculated by the tools and their source code availability and we discuss the tools' extendibility and the transparency of the intermediate analysis steps at last. Table 1 presents an overview of the comparison.

#### 4.1. Linguistic Complexity Indexes

Because the research aims of the four tools are different, the index sets they provide are also different. CRIE focuses on the complexity of native language texts, second language texts, and texts in specific domains, so it provides 36 indexes, including 29 general indexes and 7 indexes that are only applicable to the complexity of second language texts. Chinese Coh-Metrix focuses on the cohesion of the text, so among the 50 indexes it provides, 31 indexes are used to measure the cohesion of the article. Chi-Editor aims to grade the reading materials provided by Chinese international teachers, so it will give the level of second language reading materials, but only 6 indicators are analyzed. However, CTAP is not limited to specific research goals, so it provides more generic and comprehensive index sets, including 196 indexes. Since Chi-Editor provides fewer features, it is not discussed in this part of the comparison.

Only 13 complexity indexes are present in all three tools, including character complexity (e.g., low-stroke-count characters), lexical richness (e.g., type-token ratio), POS density index (e.g., pronoun), basic count of sentences (e.g., mean sentence length in tokens) and cohesive complexity index (e.g., personal pronouns per token). The vast majority of measures are different. we will analyze the differences in these indexes from four aspects: character level, lexical level, sentence level, and paragraph level. Table 2 gives a detailed comparison of the indexes provided by these tools.

#### 4.1.1. Character Level

For character complexity, CRIE and Chinese Coh-Metrix provide indexes related to the number of strokes while CTAP uses the number of components and number of characters that appear only once in addition to the number of strokes. For character richness, CTAP offers more fine-grained character richness indexes than CRIE, such as Root TTR, and Uber TTR. For character sophistication, CTAP is the only tool that uses reference corpora to measure character sophistication.

#### 4.1.2. Lexical Level

For lexical richness, CRIE only uses 4 indexes to measure lexical richness included the number of tokens, type-token ratio, the total number of content words, and the total number of negation words. Chinese Coh-Metrix use 7 indexes, including type-token ratio, content words type-token ratio, the measure of textual lexical diversity (MTLD), the number of tokens, the number of word types, the number of content words types, and the number of content words tokens. Apart from the two indexes, CTAP offers various variants of TTR. Chinese Coh-Metrix provides the measure of textual lexical diversity (MTLD) and content word type-token

		CTAP	CRIE	Chinese coh-metrix	Chi-editor
No. of indexes		196	36	50	6
-	Corpus manager	yes	no	no	no
Function	index selector	yes	yes	yes	no
	Result visualizer	yes	yes	no	no
Source code availability		open source	proprietary	proprietary	proprietary
Extendibility		extendible	not extendible	not extendible	not extendible
Transparency of Results		no	no	no	yes

Table 1: Comparison of CTAP, CRIE, Chinese coh-metrix, and Chi-editor

ratio. Among these features, CTAP does not provide indexes about content words, negative word count, and MTLD, but it provides various variants of TTR to reduce the impact of text length.

For lexical variation, CTAP is the only tool offering lexical variation indexes.

For lexical density, CTAP analyzed the density of 9 types of content words and 4 types of function words, while CRIE only analyzed the density of three parts of speech, and Chinese Coh-Metrix analyzed the density of seven parts of speech.

For lexical sophistication, the three tools introduce different reference corpora. Since CTAP is not limited to specific research goals, it employs two native corpora: the Chinese Gigaword and Contemporary Chinese Corpus. In addition, it also introduces L2 Chinese Textbooks Corpus to serve Chinese international teachers. CRIE uses the list of 8000 Chinese words published by the Steering Committee for the Test of Proficiency-Huayu (SC-TOP) (Chang, 2012) to measure the lexical sophistication of learners' reading materials. Chinese Coh-Metrix uses Children corpus to measure children reading materials' lexical sophistication.

For word length, the three tools calculate the number of two-character and three-character words. Based on this, the Chinese Coh-Metrix also calculates the number of words with four or more characters. CTAP calculates the number of words with four or more characters and the number of single-character words.

#### 4.1.3. Sentence Level

For sentence length, CTAP not only calculates the average sentence length and the longest sentence length but also calculates the standard deviation of the sentence length to analyze the distribution of sentence length. CRIE only calculated the average sentence length and the longest sentence length.

For sentence constituent complexity, CTAP pays more attention to the number of various phrases (e.g., noun phrases), their mean length and density, while CRIE only supports the calculation of the number of sentences and idioms and the density of noun phrases, idioms, and simple sentences.

For syntactic structure complexity, in particular, CTAP is the only tool that introduces syntax trees, dependency, grammar, as well as collocation information to measure the complexity of syntax.

#### 4.1.4. Paragraph Level

For the basic count of paragraphs, CTAP provides 5 indexes about the number and length of paragraphs, while CRIE only provides the number of paragraphs and the mean number of sentences per paragraph.

For cohesive complexity, only 3 indexes of cohesive complexity have been implemented in CRIE. CTAP offers many indexes about reference, connection, and word overlap to measure cohesive complexity. Chinese Coh-Metrix apart from these indexes also uses sentence syntax similarity, minimal edit distance, and LSA.

#### 4.2. Function

#### 4.2.1. Corpus Manager

During the texts upload process, Coh-Metrix and Chi-Editor only support uploading one text at a time through the web page. CRIE provides two ways for users to upload texts: one is to upload a text directly on the web page, and the other is to upload multiple texts at a time in packages, but it should be noted that the size of the packages must not exceed 15M. CTAP provides corpus management functions, supporting uploading, storage, and management of multi-text corpus so that researchers can analyze the same batch of texts from different perspectives.

#### 4.2.2. Feature Selector

In the feature selection process, since the main purpose of Chi-Editor is to provide international Chinese teachers with the level of difficulty in reading text, it does not support feature selection but gives six default index values as a reference after text analysis. Both Chinese Coh-Metrix and CRIE allow users to select indexes. However, the Chinese Coh-Metrix only supports selecting indexes in one dimension (e.g. coherence) at a time. CRIE allows users to select multi-dimensional indexes but does not support saving the selected index set. CTAP supports the construction of index sets, users can customize multiple index sets according to different research purposes and content. In addition, each index has a detailed explanation and source, which is convenient for users to choose.

#### 4.2.3. Result Visualizer

The four tools have different ways of presenting analyze results. The Chi-Editor and Chinese Coh-Metrix directly display indexes values on the web page, while the analysis report provided by CRIE is presented in a visual form, including the complexity index values and the corresponding level. CTAP displays the complexity index values of the text or corpus input by the user and does not compare these values with the preset reference values. This supports researchers to use their corpus and indexes flexibly to achieve different research purposes. In addition, CTAP not only supports downloading the analysis results directly to the local but also supports basic drawing operations to visualize the results, so as to better serve the user's next analysis.

#### 4.3. Interpretation of Results

CRIE provides a reference standard for users. It tells the users whether the index values contained in the article are higher or lower than the index values of different levels of articles in the reference corpus. In other words, it can tell the users difficulty level of the input article based on every single index.

Chi-Editor uses "The Graded Chinese Syllables, Characters and Words for the Application of Teaching Chinese to the Speakers of Other Languages" (Liu, 2010) and "International Curriculum for Chinese Language Education" (CLEC, 2008)as the grading reference standards, and generates text difficulty values through algorithms and provides directly difficulty level of the text. Chinese Coh-Metrix and CTAP only provide the value of each index but do not provide specific readability estimates based on reference corpora or external reference data. It purposefully reports only numerical index values, aiming to give users the greatest degree of freedom, allowing users to compare with any corpus that is suitable for research purposes.

#### 4.4. Source Code Availability

Among the existing linguistic complexity analysis tools for Chinese, only CTAP is open-source. CRIE, Chinese Coh-Metrix, and Chi-Editor only provide a web-based graphical interface for users to use online. CTAP not only provides a free and open online version but also provides open-source code to encourage relevant researchers to add new indexes or new languages to jointly promote the development of language complexity research. The Chinese component of CTAP is available opensource at https://github.com/blcuicall/ multilingual-ctap. The toolkit is freely available at https://ctap.litmind.ink.

#### 4.5. Extendibility

Among the three Chinese Textual-analysis tools, Chinese Coh-Metrix, CRIE, and Chi-Editor only support the analysis of Chinese text. CTAP is developed for multilingual collaborative research and can be extended to other languages. At the same time, the various parts of the CTAP framework are independent of each other, facilitating index updates and integration of new languages.

#### 4.6. Transparency of Results

Word segmentation and part-of-speech tagging are the basis of all index calculations. It is important for researchers to see the specific results of word segmentation and part-of-speech tagging. Among the four text complexity analysis tools, only Chi-Editor gives the specific results of word segmentation.

#### 5. Conclusion and Future Work

With the deepening of language complexity research, more and more indexes have been proposed. How to extract, calculate and verify the effectiveness of these indexes on a large scale has become an important issue. In this paper, we have integrated the Chinese component which supports broad index extraction into CTAP. So far, CTAP supports the extraction of 196 indexes to analyze Chinese texts. Among the 196 indexes, indexes related to syntax trees (e.g., mean parse tree depth index)and dependency structures (e.g., mean dependency distance)can be used for English. In addition, we used component information with Chinese character characteristics to measure the complexity of Chinese characters (e.g., the average number of character Strokes). At the same time, we have made a comprehensive comparison between CTAP and the three existing language complexity analysis tools for Chinese. CTAP not only supports comprehensive language complexity index extraction but also allows adding new complexity indexes and language components.

In the future, we will incorporate semantic indexes and add more indexes with Chinese characteristics, such as grammatical structure, etc. We will present the segmentation and pos tagging results of Stanford CoreNLP on the platform and allow users to check them manually. Then CTAP will automatically calculate the feature values with the proofread results to ensure the accuracy of the feature values and the transparency of the results. We hope that more languages can be integrated into CTAP through cooperation to promote the development of language complexity research.

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#### 8. Appendix

Linguistic complexity	CTAP	CRIE	Coh-
measure	0	onu	metrix
Character Richness			
Type Token Ratio (TTR)	+	_	_
Number of Tokens	+	+	
Number of Types	+	-	
Type Token Ratio (Log	+		
TTR)	т	-	_
Type Token Ratio (Root TTR)	+	-	-
Type Token Ratio (Uber)	+	-	-
Type Token Ratio (Cor-	+	-	-
rected TTR)			
Number of Characters	+	-	-
that Appear Only Once			
The Proportion of Char-	+	-	-
acters that Appear Only			
Once			
Character Complexity			
Average Number of	+	+	+
Character Strokes			
Average Number of	+	-	-
Character Type Strokes			
Low-Stroke-Count	+	+	+
Characters			
Low-Stroke-Proportion	+	-	-
Characters			
Intermediate-Stroke-	+	+	+
Count Characters			
Intermediate-Stroke-	+	-	-
Proportion Characters			
High-Stroke-Count	+	+	+
Characters			
High-Stroke-Proportion	+	-	-
Characters			
Average Number of Chi-	+	-	-
nese Character Compo-			
nents (Based on Charac-			
ter Type)			
Average Number of Chi-	+		
nese Character Compo-			
nents (Based on Charac-			
ter Token)			
Character Sophistication			
Gigaword Logarithmic	+		
Character Frequency	-	-	-
(Type)			
Gigaword Logarithmic	+		
	+	-	-
Character Frequency (Token)			

Linguistic complexity measure	СТАР	CRIE	Coh- metrix	Linguistic complexity measure
Corpus of L2 Chinese	+	-	-	Number of Content
Textbooks Logarithmic				Words Types
Character Frequency				Number of Content
(Type)				Words Tokens
Corpus of L2 Chinese	+	-	-	Total Number of Content
Textbook Logarithmic				Words
Character Frequencys				Number of Words that
(Token)				Appear Only Once
Contemporary Chinese	+	-	-	The Proportion of Words
Corpus Logarithmic				that Appear Only Once
Character Frequency				Total Number of Nega-
(Type)				tion Words
Contemporary Chinese	+	-	-	Lexical Variation Feature
Corpus Logarithmic				Noun
Character Frequency				Squared Verb Variation 1
(Token)				Corrected Verb Variation
Average of Character	+	_	-	
Levels (Token)				Verb
SD Character Levels	+	-	-	Adverb
(Token)				Adjective
Average of Character	+	-	-	Verb Variation 1
Levels (Type)				
SD Character Levels	+	-	_	Modifier
(Type)				Lexical
The Proportion of the	+	_	_	POS Density Feature
Difficult Characters (To-	'			Noun
ken)				Interjection
The Proportion of the	+			Adjective
Difficult Characters		_	-	Punctuation
(Type)				Ordinal Number ofber
The Proportion of the	+			Functional Words
Simple Characters (To-	Т		_	Lexical Words
ken)				Cardinal Number ofber
The Proportion of the	+	_		Adverb
Simple Characters		_	-	Preposition
_				Pronoun
(Type) Lexical Richness				Verb
		1		Conjunction
Type Token Ratio (Uber)	+	-	-	Number oferal
Type Token Ratio (Cor-	+	-	-	Measure word
rected TTR)				Localizer
Type Token Ratio (TTR)	+	+	+	Auxiliary Words
Type Token Ratio (Root	+	-	-	Sentence-final particle
TTR)				Bei-construction
Type Token Ratio (Log	+	-	-	Onomatopoeia
TTR)				Ba-construction
Content Words Type To-	-	-	+	Average Number of POS
ken Ratio				tags per sentence
Measure of Textual Lex-	-	-	+	Dummy Verb
ical Diversity (MTLD)				Modal Verb
Number of Tokens	+	+	+	Personal Pronoun
Number of Word Types	+	-	+	
				Interrogative Pronoun

Coh-

metrix +

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Demonstrative Pronoun

Proper Noun

Linguistic complexity	CTAP	CRIE	Coh- metrix	Linguistic complexity	СТАР	CRIE	Coh- metrix
measure				measure			
Lexical Sophistication Fea Gigaword Logarithmic	ature +	-	-	Contemporary Chinese Corpus Logarithmic	+	-	-
Word Frequency (AW Type)				Word Frequency (AW Token)			
Gigaword Logarithmic	+	_		Contemporary Chinese	+	_	_
Word Frequency (AW				Corpus Logarithmic			
Token)				Word Frequency (LW			
Gigaword Logarithmic	+			Type)			
Word Frequency (LW	- T	-	-	Contemporary Chinese	+		
1 2 3				Corpus Logarithmic	- T	-	-
Type)				Word Frequency (LW			
Gigaword Logarithmic	+	-	-	Token)			
Word Frequency (LW							
Token)				Contemporary Chinese	+	-	-
Gigaword Logarithmic	+	-	-	Corpus Logarithmic			
Word Frequency (FW				Word Frequency (FW			
Type)				Type)			
Gigaword Logarithmic	+	-	-	Contemporary Chinese	+	-	-
Word Frequency (FW				Corpus Logarithmic			
Token)				Word Frequency (FW			
Corpus of L2 Chinese	+	-	-	Token)			
Textbooks Logarithmic				Average of Word Levels	+	-	-
Word Frequency (AW				(Token)			
Type)				SD Word Levels (Token)	+	-	-
Corpus of L2 Chinese	+	-	-	Average of Word Levels	+	-	-
Textbooks Logarithmic				(Type)			
Word Frequency (AW				SD Word Levels (Type)	+	-	-
Token)				The Proportion of the	+	-	-
Corpus of L2 Chinese	+	-	-	Difficult Words (Token)			
Textbooks Logarithmic				The Proportion of the	+	-	-
Word Frequency (LW				Difficult Words (Type)			
Type)				The Proportion of the	+	-	-
Corpus of L2 Chinese	+	-	-	Simple Words (Token)			
Textbooks Logarithmic				The Proportion of the	+	-	-
Word Frequency (LW				Simple Words (Type)			
Token)				Breakthrough Vocabu-	_	+	_
Corpus of L2 Chinese	+	-	-	lary			
Textbooks Logarithmic				Waystage Vocabulary	_	+	_
Word Frequency (FW				Threshold Vocabulary	_	+	_
Type)				Vantage Vocabulary	_	+	
Corpus of L2 Chinese	+	-	_	Effective Operational	-	+	
Textbooks Logarithmic				Proficiency Vocabulary	_		
Word Frequency (FW				Difficult Words			
Token)					-	+	-
Contemporary Chinese	+			Average of Vocabulary	-	+	-
Corpus Logarithmic	+	-	-	Levels			
				Mean Square of Vocabu-	-	+	-
Word Frequency (AW				lary Levels			
Type)				Polysemy	-	-	+
				Age of Acquisition for	-	-	+
				All Words			

Concreteness for Con-

tent Words

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Linguistic complexity	СТАР	CRIE	Coh-	Linguistic complexity	СТАР	CRIE	Coh
measure		CKIL	metrix	measure		CKIL	metri
Content Word Frequency	-	_	+	Mean Number of Verb	+	_	-
Word Frequency	-		+	Phrase Per Simple			
Minimum Word Fre-	_		+	Clause			
quency per Sentence	_	_	Т	Mean Number of Coor-	+		
Average Logarithmic	_		_	dinate Phrase Per Simple	Ţ	_	
Frequency of Domain	-	+	-	Clause			
Content Words					_		
				Modifiers per Noun Phrase	-	+	
Word Length	1						
Number of Single Char-	+	-	-	Verb Phrases per Sen-	+	-	
acter Words				tence			
Proportion of Single	+	-	-	Mean Number of Prepo-	+	-	
Character Words				sitional Phrases Per Sim-			
Number of Two Charac-	+	+	+	ple Clause			
ters Words				Simple Sentence Ratio	-	+	
Number of Three Char-	+	+	+	Idioms per Sentence	-	+	
acters Words				Sentence Length Feature			
Proportion of Two Char-	+	-	-	Average Sentence	+	-	
acters Words				Length Based on Char-			
Proportion of Three	+	-	-	acters			
Characters Words				Mean Sentence Length	+	+	
Number of Words that	+	_	+	in Tokens			
Contains Four Charac-				SD Sentence Length	+	-	
ters and More				(Based on Word Token)			
Proportion of Words that	+			SD Sentence Length	+		
Contains Four Charac-	- T	-	-	(Based on Character	Т	-	
ters and More				Token)			
				,			
Average Word Length	+	-	-	SD Sentence Length	+	-	
Syntactic Constituents Con	1	Feature		(Based on Character			
Noun Phrase	+	-	-	Type)			
Prepositional Phrase	+	-	-	SD Sentence Length	+	-	
Coordinate Phrases	+	-	-	(Baesd on Word Type)			
Verb Phrase	+	-	-	Number of Longest Sen-	+	-	
Adjectival Modifier	+	-	-	tence Length (Based on			
Sentences	+	+	-	Character Token)			
Idioms	-	+	-	Number of Longest Sen-	+	+	
Mean Length of Noun	+	_	-	tence Length (Based on			
Phrase (token)				Word Token)			
Mean Length of Preposi-	+	-	-	Syntactic Complexity Feat	ture		
tional Phrase				Sentences with Complex	-	+	
Mean Length of Verb	+	-	-	Semantic Categories			
Phrase (token)				Mean Parse Tree Depth	+	-	
Prepositional Phrases	+	_		Feature			
per Sentence		-	-	SD of Parse Tree Depth	+	-	
1				The Height of the High-	+	_	
Noun Phrases per Sen-	+	+	-	est Parse Tree			
tence				Number of Sentences	+	_	
Coordinations per Sen-	+	-	-	Whose Parse Tree	- T	-	
tence							
Number of Simple	+	-	-	Height Is Greater Than			
Clause Per Sentence				14			
Mean Number of Noun	+	-	-				
Phrase Per Simple							
Clause	1						

Linguistic complexity measure	СТАР	CRIE	Coh- metrix	Linguistic complexity measure	СТАР	CRIE	Coh- metrix
Proportion of Sentences Whose Parse Tree	+	-	-	Mean Number of Sen- tences per Paragraph	-	+	-
Height Is Greater Than 14				Mean Paragraph Length (Based on Character To-	+	-	-
Average Number ofber of Words Before the	+	-	-	ken)			
Head Verb				Mean Paragraph Length (Based on Word Token)	+	-	-
Maximum Number of- ber of Words Before the Head verb	+	-	-	Longest Paragraph Length (Based on Char- acter Token)	+	-	-
Mean Dependency Dis-	+	-	-	Longest Paragraph	+	-	-
tance Maximum Dependency	+	-	-	Length (Based on Word Token)			
Distance				Cohesive Complexity Feat	ure	1	1
Average of Grammatical Levels	+	-	-	Personal Pronouns per Token	+	+	+
SD Grammatical Levels The Proportion of the	+++	-	-	1st Person Pronouns per Token	+	-	+
First-level Grammar The Proportion of the	+			2nd Person Pronouns per Token	+	-	+
Second-level Grammar				3rd Person Pronouns per	+	-	+
The Proportion of the Third-level Grammar	+	-	-	TokenInterrogativePronouns	+	-	+
The Proportion of the Fourth-level Grammar	+	-	-	per Token Demonstrative Pronouns	+	-	+
The Proportion of the Fifth-level Grammar	+	-	-	per Token Coordinating Connce-	+	_	+
The Proportion of the Sixth-level Grammar	+	-	-	tives per Token Follow Conncetives per	+		+
First-level Grammar	+	-	-	Token		-	
(RTTR) Second-level Grammar	+	-	-	Alternative Conncetives per Token	+	-	+
(RTTR) Third-level Grammar	+	-	-	Progressive Conncetives per Token	+	-	+
(RTTR) Fourth-level Grammar	+			Condition Conncetives per Token	+	-	+
(RTTR)				Hypothetical Connce-	+	-	+
(RTTR)	+	-	-	tives per Token Causal Conncetives per	+	-	+
Sixth-level Grammar (RTTR)	+	-	-	TokenPurposiveConncetives	+	-	+
Total Grammar RTTR	+	-	-	per Token			
Total Collocation RTTR	+	-	-	Concessive Conncetives	+	-	+
Unique Collocation	+	-	-	per Token			
RTTR				Positive Conjunctions	-	+	-
UniqueCollocation Ra- tio	+	-	-	Negative ConjunctionsLocal Lexical Words	-+	+	- +
LowfreqCollocation Ra-	+	-	-	Overlap Local Nouns Overlap	+	-	+
Basic Count of Paragraphs	3	I		Local Verbs Overlap	+	_	+
The Number of Para-	,   +	+	-	Local Words Overlap	+	-	- -
graphs				Global Lexical Words Overlap	+	-	+

Linguistic complexity measure	СТАР	CRIE	Coh- metrix
Global Nouns Overlap	+	-	+
Global Verbs Overlap	+	-	+
Global Words Overlap	+	-	-
Sentence Syntax Sim-	-	-	+
ilarity (Adjacent Sen-			
tences)			
Sentence Syntax Sim-	-	-	+
ilarity (across Para-			
graphs)			
Minimal Edit Distance	-	-	+
(Part of Speech) (Adja-			
cent Sentences)			
Minimal Edit Distance	-	-	+
(Part of Speech) (Across			
Paragraphs)			
Minimal Edit Distance	-	-	+
(All words) (Adjacent			
Sentences)			
Minimal Edit Distance	-	-	+
(All words) (Across			
Paragraphs)			
Local LSA	-	-	+
Global LSA	-	-	+
LSA Given/New	-	-	+
LSA Verb Overlap	-	-	+