State-of-the-Art Vietnamese Word Segmentation

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Abstract—Word segmentation is the first step of any tasks in Vietnamese language processing. This paper reviews state-of-the-art approaches and systems for word segmentation in Vietnamese. To have an overview of all stages from building corpora to developing toolkits, we discuss building the corpus stage, approaches applied to solve the word segmentation and existing toolkits to segment words in Vietnamese sentences. In addition, this study shows clearly the motivations on building corpus and implementing machine learning techniques to improve the accuracy for Vietnamese word segmentation. According to our observation, this study also reports a few of achievements and limitations in existing Vietnamese word segmentation systems.

Index Terms—Vietnamese word segmentation; text modelling; Vietnamese corpus

I. INTRODUCTION

Lexical analysis, syntactic analysis, semantic analysis, disclosure analysis and pragmatic analysis are five main steps in natural language processing [1], [2]. While morphology is a basic task in lexical analysis of English, word segmentation is considered a basic task in lexical analysis of Vietnamese and other East Asian languages processing. This task is to determine borders between words in a sentence. In other words, it is segmenting a list of tokens into a list of words such that words are meaningful.

Word segmentation is the primary step in prior to other natural language processing tasks i.e., term extraction and linguistic analysis (as shown in Figure 1). It identifies the basic meaningful units in input texts which will be processed in the next steps of several applications. For named entity recognition [3], word segmentation chunks sentences in input documents into sequences of words before they are further classified in to named entity classes. For Vietnamese language, words and candidate terms can be extracted from Vietnamese copora (such as books, novels, news, and so on) by using a word segmentation tool. Conformed features and context of these words and terms are used to identify named entity tags, topic of documents, or function words. For linguistic analysis, several linguistic features from dictionaries can be used either to annotating POS tags or to identifying the answer sentences. Moreover, language models can be trained by using machine learning approaches and be used in tagging systems, like the named entity recognition system of Tran et al. [3].

Many studies focus on word segmentation for Asian languages, such as: Chinese, Japanese, Burmese (Myanmar) and Thai [4], [5], [6], [7]. Approaches for word segmentation task are variety, from lexicon-based to machine learning-based methods. Recently, machine learning-based methods are used widely to solve this issue, such as: Support Vector Machine or Conditional Random Fields [8], [9]. In general, Chinese is a language which has the most studies on the word segmentation issue. However, there is a lack of survey of word segmentation studies on Asian languages and Vietnamese as well. This paper aims reviewing state-of-the-art word segmentation approaches and systems applying for Vietnamese. This study will be a foundation for studies on Vietnamese word segmentation and other following Vietnamese tasks as well, such as part-of-speech tagger, chunker, or parser systems.

Figure 1. Word segmentation tasks (blue) in the Vietnamese natural language processing system.

There are several studies about the Vietnamese word segmentation task over the last decade. Dinh et al. started this task with Weighted Finite State Transducer (WFST) approach and Neural Network approach [10]. In addition, machine learning approaches are studied and widely applied to natural language processing and word segmentation as well. In fact, several studies used support vector machines (SVM) and conditional random fields (CRF) for the word segmentation task [8], [9]. Based on annotated corpora and token-based features, studies used machine learning approaches to build word segmentation systems with accuracy about 94%-97%.

According to our observation, we found that is lacks of complete review approaches, datasets and toolkits which we recently used in Vietnamese word segmentation. A all sided
review of word segmentation will help next studies on Vietnamese natural language processing tasks have an up-to-date guideline and choose the most suitable solution for the task. The remaining part of the paper is organized as follows. Section II discusses building corpus in Vietnamese, containing linguistic issues and the building progress. Section III briefly mentions methods to model sentences and text in machine learning systems. Next, learning models and approaches for labeling and segmenting sequence data will be presented in Section IV. Section V mainly addresses two existing toolkits, vnTokenizer and JvnSegmenter, for Vietnamese word segmentation. Several experiments based on mentioned approaches and toolkits are described in Section VI. Finally, conclusions and future works are given in Section VII.

II. CORPUS

A. Language Definition

Vietnamese, like many languages in continental East Asia, is an isolating language and one branch of Mon-Khmer language group. The most basic linguistic unit in Vietnamese is morpheme, similar with syllable or token in English and “hình vĩ” (phoneme) or “tiếng” (syllable) in Vietnamese. According to the structured rule of its, Vietnamese can have about 20,000 different syllables (tokens). However, there are about 8,000 syllables used the Vietnamese dictionaries. There are three methods to identify morphemes in Vietnamese text [11].

- Morpheme is the smallest meaningful unit of Vietnamese.
- Morpheme is the basic unit of Vietnamese.
- Morpheme is the smallest meaningful unit and is not used independently in the syntax factor.

In computational linguistics, morpheme is the basic unit of languages as Leonard Bloomfield mentioned for English [12]. In our research for Vietnamese, we consider the morpheme as syllable, called “tiếng” in Vietnamese (as Nguyen’s definition [13]).

The next concept in linguistics is word which has fully grammar and meaning function in sentences. For Vietnamese, word is a single morpheme or a group of morphemes, which are fixed and have full meaning [13]. According to Nguyen, Vietnamese words are able classified into two types, (1) 1-syllable words with fully meaning and (2) n-syllables words whereas these group of tokens are fixed. Vietnamese syllable is not fully meaningful. However, it is also explained in the meaning and structure characteristics. For example, the token “kỳ” in “quốc kỳ” whereas “quốc” means national, “kỳ” means flag. Therefore, “quốc kỳ” means national flag.

Consider dictionary used for evaluating the corpus, extracting features for models, and evaluating the systems, there are many Vietnamese dictionaries, however we recommend the Vietnamese dictionary of Hoang Phe, so called Hoang Phe Dictionary. This dictionary has been built by a group of linguistic scientists at the Linguistic Institute, Vietnam. It was firstly published in 1988, reprinted and extended in 2000, 2005 and 2010. The dictionary currently has 45,757 word items with 15,901 Sino-Vietnamese word items (accounting for 34.75%) [14].

B. Name Entity Issue

In Vietnamese, not all of meaningful proper names are in the dictionary. Identifying proper names in input text are also important issue in word segmentation. This issue is sometimes included into unknown word issue to be solved. In addition, named entity recognition has to classify it into several types such as person, location, organization, time, money, number, and so on.

Proper name identification can be solved by characteristics. For example, systems use beginning characters of proper names which are uppercase characters. Moreover, a list of proper names is also used to identify names in the text. In particular, a list of 2000 personal names extracted from VietnamGiaPha, and a list of 707 names of locations in Vietnam extracted from vi.wikipedia.org are used in the study of Nguyen et al. for Vietnamese word segmentation [8].

C. Building Corpus

In general, building corpus is carried out through four stages: (1) choose target of corpus and source of raw data; (2) building a guideline based on linguistics knowledge for annotation; (3) annotating or tagging corpus based on rule set in the guideline; and (4) reviewing corpus to check the consistency issue.

Encoding word segmentation corpus using B-I-O tagset can be applied, where B, I, and O denoted begin of word, inside of word, and others, respectively. For example, the sentence “Megabit trên giây là đơn vị đo tốc độ truyền dữ liệu.” (“Megabit per second is a unit to measure the network traffic.” in English) with the word boundary result “Megabit trên giây là đơn vị do tốc độ truyền dữ liệu.” is encoded as “Megabit/B trên/B giây/B là/B đơn/B vị/I do/I tốc/B độ/B truyền/B dữ/I liệu/I /O”.

Annotation guidelines can be applied to ensure that annotated corpus has less errors because the manual annotation is applied. Even though there are guidelines for annotating, the available output corpora are still inconsistent. For example, for the Vietnamese Treebank corpus of the VLSI[1] project, Nguyen et al. listed out several Vietnamese word segmentation inconsistencies in the corpus based on POS information and n-gram sequences [15].

Currently, there are at least three available word segmentation corpus used in Vietnamese word segmentation studies and systems. Firstly, Dinh et al. built the CADASA corpus from CADASA’s books [16]. Secondly, Nguyen et al. built vnQTAG corpus from general news articles [8]. More recently, Ngo
et al. introduced the EVBCorpus corpus, which is collected from four sources, news articles, books, law documents, and novels. As a part of EVBCorpus, EVBNews, was annotated common tags in NLP, such as word segmentation, chunker, and named entity [17]. All of these corpora are collected from news articles or book stories, and they are manually annotated the word boundary tags (as shown in Table I).

III. TEXT MODELLING AND FEATURES

To understand natural language and analyze documents and text, computers need to represent natural languages as linguistics models. These models can be generated by using machine learning methods (as show in Figure 2).

There are two common modeling methods for basic NLP tasks, including n-gram model and bag-of-words model. The n-gram model is widely used in natural language processing while the bag-of-words model is a simplified representation used in natural language processing and information retrieval [18], [19]. According to the bag-of-words model, the representative vector of sentences in the document does not preserve the order of the words in the original sentences. It represents the word using term frequency collected from the document rather than the order of words or the structure of sentences in the document. The bag-of-words model is commonly used in methods of document classification, where the frequency of occurrence of each word is used as an attribute feature for training a classifier. In contrast, an n-gram is a contiguous sequence of \( n \) items from a given sequence of text. An n-gram model is a type of probabilistic language model for predicting the next item in a given sequence in form of a Markov model. To address word segmentation issue, the n-gram model is usually used for approaches because it considers the order of tokens in the original sentences. The sequence is also kept the original order as input and output sentences.

IV. BUILDING MODEL METHODS

There are several studies for Vietnamese Word Segmentation during last decade. For instance, Dinh et al. started the word segmentation task for Vietnamese with Neural Network and Weighted Finite State Transducer (WFST) [10]. Nguyen et al. continued with machine learning approaches, Conditional Random Fields and Support Vector Machine [8]. Most of statistical approaches are based on the architecture as shown in Figure 2. According to the architecture, recent studies and systems focus on either improving or modifying difference learning models to get the highest accuracy. Features used in word segmentation systems are syllable, dictionary, and entity name. The detail of all widely used techniques applied are collected and described in following subsections.

A. Maximum Matching

Maximum matching (MM) is one of the most popular fundamental and structural segmentation algorithms for word segmentation [20]. This method is also considered as the Longest Matching (LM) in several research [10], [4]. It is used for identifying word boundary in languages like Chinese, Vietnamese and Thai. This method is a greedy algorithm, which simply chooses longest words based on the dictionary. Segmentation may start from either end of the line without any difference in segmentation results. If the dictionary is sufficient [20], the expected segmentation accuracy is over 90%, so it is a major advantage of maximum matching. However, it does not solve the problem of ambiguous words and unknown words that do not exist in the dictionary.

There are two types of the maximum matching approach: forward MM (FMM) and backward MM (BMM). FMM starts from the beginning token of the sentence while BMM starts from the end. If the sentence has word boundary ambiguities, the output of FMM and BMM will be different. When applying FMM and BMM, there are two types of common errors due to two ambiguities: overlapping ambiguities and combination ambiguity. Overlapping ambiguities occur when the text AB has both word A, B and AB, which are in the dictionary while the text ABC has word AB and BC, which are in the dictionary. For example, "cụ già đi nhanh quá" (there two meanings: "the old man goes very fast" or "the old man died suddenly") is a case of the overlapping ambiguity while "tốc độ truyền thông tin" is a case of the combination ambiguity.

As shown in Figure 2, the method simplification ambiguities, maximum matching is the first step to get features for the modelling stage in machine learning systems, like Conditional Random Fields or Support Vector Machines.

B. Hidden Markov Model (HMM)

In Markov chain model is represented as a chain of tokens which are observations, and word taggers are represented as predicted labels. Many researchers applied Hidden Markov model to solve Vietnamese word segmentation such as in [9], [21] and so on.

N-gram language modeling applied to estimate probabilities for each word segmentation solution [22]. The result of this method depends on corpora and is based maximal matching strategy. So, they do not solve missing word issue. Let \( P(s) \)
is a product of probabilities of words created from sentence $s$ (1) with length $m$:

$$s = w_1 \ldots w_m$$  (1)

Each conditional probability of word is based on the last $n$-1 words (n-gram) in the sentence $s$. It is estimated by Markov chain model for word $w_i$ from position $i-n+1$ to $i-1$ with probability (2)

$$P(w_i | w_i^{i-n+1})$$  (2)

We have equation (3)

$$P(s) = \prod_{i=1}^{m} P(w_i | w_i^{i-1}) \approx \prod_{i=1}^{m} P(w_i | w_i^{i-n+1})$$  (3)

C. Maximum Entropy (ME)

Maximum Entropy theory is applied to solve Vietnamese word segmentation [16, 23, 24]. Some researchers do not want the limit in Markov chain model. So, they use the context around of the word needed to be segmented. Let $h$ is a context, $w$ is a list of words and $t$ is a list of taggers, Le [16, 23] used

$$P(t_1 \ldots t_n | w_1 \ldots w_n) \approx \prod_{i=1}^{n} P(t_i | h_i)$$  (4)

$P(s)$ is also a product of probabilities of words created from sentence $s$ (1). Each conditional probability of word is based on context $h$ of the last $n$ word in the sentence $s$.

D. Conditional Random Fields

To tokenize a Vietnamese word, in HMM or ME, authors only rely on features around a word segment position. Some other features are also affected by adding more special attributes, such as, in case ‘?’ question mark at end of sentence, Part of Speech (POS), and so on. Conditional Random Fields is one of methods that uses additional features to improve the selection strategy [8].

There are several CRF libraries, such as CRF++, CRF-suite [19]. These machine learning toolkits can be used to solve the task by providing an annotated corpus with extracted features. The toolkit will be used to train a model based on the corpus and extract a tagging model. The tagging model will then be used to tag on input text without annotated corpus. In the training and tagging stages, extracting features from the corpus and the input text is necessary for both stages.

E. Support Vector Machines

Support Vector Machines (SVM) is a supervised machine learning method which considers dataset as a set of vectors and tries to classify them into specific classes. Basically, SVM is a binary classifier. however, most classification tasks are multi-class classifiers. When applying SVMs, the method has been extended to classify three or more classes. Particular NLP tasks, like word segmentation and Part-of-speech task, each token/word in documents will be used as a feature vector. For the word segmentation task, each token and its features are considered as a vector for the whole document, and the SVM model will classify this vector into one of the three tags (B-IO).

This technique is applied for Vietnamese word segmentation in several studies [8, 25]. Nguyen et al. applied on a segmented corpus of 8,000 sentences and got the result at 94.05% while Ngo et al. used it with 45,531 segmented sentences and get the result at 97.2%. It is worth to mention that general SVM libraries (such as LIBSVM, LIBLINEAR, SVMlight, Node-SVM, and TreeSVM), YamCha is an opened source SVM library that serves several NLP tasks: POS tagging, Named Entity Recognition, base NP chunking, Text Chunking, Text Classification and event Word Segmentation.

V. TOOLKITS

vnTokenizer and JVnSegmenter are two famous segmentation toolkits for Vietnamese word segmentation. Both two word segmentation toolkits are implemented the word segmentation data process in Figure 2. This section gives more details of these Vietnamese word toolkits.

A. Programming Languages

In general, Java and C++ are the most common language in developing toolkits and systems for natural language processing tasks. For example, GATE[16], OpenNLP[11], Stanford CoreNLP[12] and LingPipe[13] platforms are developed by JAVA while foundation tasks and machine learning toolkits are developed by C++. CRF++, SVMlight[17], and YAMCHA[14]. Recently, Python becomes popular among the NLP community. In fact, many toolkits and platforms have been developed by this language, such as NLTK[15], PyNLPl[16] library for Natural Language Processing.

B. JVnSegmenter

JVnSegmenter[17] is a Java-based Vietnamese Word Segmentation Tool developed by Nguyen and Phan. The segmentation model in this tool was trained on about 8,000 tagged Vietnamese text sentences based on CRF model and the model extracted over 151,000 words from the training corpus. In addition, this is used in building the EnglishVietnamese Translation System[20, 27, 28]. Vietnamese text classification[29] and building Vietnamese corpus[30, 31].

http://jvnsegmenter.sourceforge.net/
C. vnTokenizer

vnTokenizer\textsuperscript{20} is implemented in Java and bundled as Eclipse plug-in, and it has already been integrated into vn-Toolkit, an Eclipse Rich Client application, which is intended to be a general framework integrating tools for processing of Vietnamese text. vnTokenizer plug-in, vnToolKit and related resources, including the lexicon and test corpus are freely available for download. According to our observation, many research cited vnTokenizer\textsuperscript{21} to use word segmentation results for applications as building a large Vietnamese corpus \textsuperscript{22}, building an English-Vietnamese Bilingual Corpus for Machine Translation \textsuperscript{23}, Vietnamese text classification \textsuperscript{24}, \textsuperscript{25}, etc.

VI. EVALUATION AND RESULTS

This research gathers the results of Vietnamese word segmentation of several methods into one table as show in Table II. It is noted that they are not evaluated on a same corpus. The purpose of the result illustration is to provide an overview of the results of current Vietnamese word segmentation systems based on their individual features. All studies mentioned in the table have accuracy around 94-97% based on their provided corpus.

This study also evaluates the Vietnamese word segmentation based on existing toolkits using the same annotated Vietnamese word segmentation corpus. There are two available toolkits to evaluate and to segment. To be neutral to both toolkits, we use the EVBNews Vietnamese corpus, a part of EVBCorpus, to evaluate Vietnamese word segmentation. The EVBNews corpus contains over 45,000 segmented Vietnamese sentences extracted from 1,000 general news articles (as shown in Table III) \textsuperscript{17}. We used the same training set which has 1000 files and 45,531 sentences. vnTokenizer outputs 831,455 Vietnamese words and 1,206,475 tokens. JVnSegmentor outputs 840,387 words and 1,201,683. We correct tags (BIO), and compare to previous outputs, we have rate from vnTokenizer is 95.6% and from JVnsegmenter is 93.4%. The result of both vnTokenizer and JVnSegmenter testing on the EVBNews Vietnamese Corpus are provided in Table IV.

VII. CONCLUSIONS AND FUTURE WORKS

This study reviewed state-of-the-art approaches and systems of Vietnamese word segmentation. The review pointed out common features and methods used in Vietnamese word segmentation studies. This study also had an evaluation of the existing Vietnamese word segmentation toolkits based on a same corpus to show advantages and disadvantages as to shed some lights on system enhancement.

There are several challenges on supervised learning approaches in future work. The first challenge is to acquire very large Vietnamese corpus and to use them in building a classifier, which could further improve accuracy. In addition, applying linguistics knowledge on word context to extract useful features also enhances prediction performance. The second challenge is design and development of big data warehouse and analytic framework for Vietnamese documents, which corresponds to the rapid and continuous growth of gigantic volume of articles and/or documents from Web 2.0 applications, such as, Facebook, Twitter, and so on. It should be addressed that there are many kinds of Vietnamese documents, for example, Han - Nom documents and old and modern Vietnamese documents that are essential and still needs further analysis. According to our study, there is no a powerful Vietnamese language processing used for processing Vietnamese big data as well as understanding such language. The final challenge relates to building a system, which is able to incrementally learn new corpora and interactively process feedback. In particular, it is feasible to build an advance NLP system for Vietnamese based on Hadoop platform to improve system performance and to address existing limitations.

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\textsuperscript{20}http://mim.hus.vnu.edu.vn/phuonglh/softwares/vnTokenizer

\textsuperscript{21}https://scholar.google.com/
Table II
EVBNEWS VIETNAMESE CORPUS

| Method       | Features                                           | Corpus                                         | Result   | Result          |
|--------------|----------------------------------------------------|------------------------------------------------|----------|-----------------|
| NN with WFST | Dictionary, proper name                            | 305 newspaper articles, 7,800 sentences        | 98.36%   | Dinh et al. [10] |
|              | Morphological analyzer                             |                                                 |          |                 |
| ME           | Syllable, dictionary, proper name, misc, Vietnamese Syllable | CADASA, 24,240 sentences                       | 94.44%   | Dien Dinh and Thuy Vu [16] |
| ME           | Syllable, dictionary, proper name, misc, Vietnamese Syllable | 4,800 sentences, 113, 000 syllables 22         | 93.70%   | Le et al. [23]  |
| SVMs         | Syllable, BMM, FMM, proper name, misc, foreign     | 1000 newspaper articles, 45,531 sentences      | 97.2%    | Ngo et al. [36] |
| SVMs         | Syllable, dictionary, proper name, misc, Vietnamese Syllable | 305 newspaper articles, 150 novel sentences 8,000 sentences 23 | 94.05%   | Nguyen et al. [8] |
| CRFs         | Syllable, dictionary, proper name, misc, Vietnamese Syllable | 305 newspaper articles, 150 novel articles 8,000 sentences | 95%      | Nguyen et al. [8] |

Table III
EVBNEWS VIETNAMESE CORPUS

| Statistics         | vnTokenizer | JVnSegmenter |
|--------------------|-------------|--------------|
| Number of Files    | 1,000       | 1,000        |
| Number of Sentences | 45,531     | 45,531       |
| Number of Words    | 832,441     | 832,441      |
| Number of Tokens   | 832,441     | 832,441      |

Table IV
VIETNAMESE WORD SEGMENTATION RESULT OF VNTOKENIZER AND JVNSEMENTER

| vnTokenizer | JVnSegmenter |
|-------------|--------------|
| Number of Files | 1,000 | 1,000 |
| Number of Sentences | 45,531 | 45,531 |
| Number of Words | 832,441 | 832,441 |
| Number of Tokens | 832,441 | 832,441 |
| Correct Tags   | 1,153,198   | 1,122,752   |
| Rate           | 95.6%       | 93.4%       |

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