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Design and Development of Part of Speech Tagger for Ge'ez Language Using Hybrid Approach

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Abstract:
Part of Speech tagging is the process of assigning part of speech or other lexical class markers to each word in a sentence or literature. It is the first step to understanding a natural language. Most other tasks and applications heavily depend on it. As to the best of the researcher's knowledge, Ge'ez is the language which does not have developed POS tagger so far. Therefore, this work proposes a hybrid approach, Trigram N tag tagger combined with human written rule, Regular expression and morphological pattern analysis-based tagger, for Ge'ez part of speech tagger.
Ge'ez literatures on syntax, morphology and grammar are reviewed to understand nature of the language and also to identify possible tag sets. Since there was no readymade standard corpus for Ge'ez language, as a result, 26 broad tag sets were identified and 15,154 words from around 1,305 sentences collected from one genre i.e., Holy bible. Then, those words were manually tagged by Ge'ez language professionals for training and testing purpose. Several techniques have been suggested to tag words automatically with their POS tags. Among these, the hybrid of TnT with human annotated rule, regex and morphological pattern analysis of Ge'ez language is assumed to perform better than the TnT taggers taken alone. Different experiments are conducted for the three types of taggers namely the TnT tagger, TnT with Regex tagger and Hybrid tagger. Therefore, 77.87%, 82.23% and 94.32% performances are obtained for TnT tagger, TnT with Regex tagger and Hybrid taggers respectively. Therefore, it is possible to conclude that the hybrid tagger performs better than the TnT tagger and TnT with Regex tagger used individually.

Keywords*: Ge'ez, POS tagger, NLP, TnT, Hybrid POS tagger*

1. Introduction

Language is one of the fundamental features of human behavior and it constitutes a crucial component of our lives. In its written form, it serves as a means of recording information and knowledge on a long term-basis and transmitting what it records from one generation to the next. In its spoken form, it serves as a means of coordinating our day-to-day life with others[1].

According to Noam Chomsky [2], a language is a set (finite or infinite) of sentences, each finite in length and constructed out of a finite set of elements. Language is an aspect of human behavior. In written form, it is a long-term record of knowledge from one generation to the next while in spoken form it is a means of communication. Language is the key aspect of human intelligence and can be categorized as natural and Artificial language. Natural language is an ordinary language that has evolved as the normal means of communication among people. Examples: English, Ge'ez, Amharic, Afaan-Oromo and Tigrigna.

Natural language processing (NLP) is a field of computer science, artificial intelligence, and computational linguistics concerned with the interactions between computers and human (natural) languages. As such, NLP is related to the area of human–computer interaction. Many challenges in NLP involve: natural language understanding, enabling computers to derive meaning from human or natural language input; and others involve generation is a theoretically motivated range of computational techniques for analyzing and representing naturally occurring texts at one or more levels of linguistic analysis for the purpose of achieving human-like language processing for a range of tasks or applications in a computer[3]. Additionally, NLP is the means for accomplishing different types of tasks and/or applications. Such tasks include part of speech (POS) tagging, named entity recognition (NER), information retrieval (IR), speech recognition, machine translation, question answering etc.[3].

POS tagging is the process of assigning part of speech like noun, verb, preposition, pronoun, adverb, adjective or other lexical class markers to each word in a sentence or literature.POS tagging is the first step to understanding a natural language. Most other tasks and applications heavily depend on it[4].The significance of POS (also known as word classes, morphological classes, or lexical tags) for language processing is that it gives large amount of information about a word and its neighbor. POS tagging is considered as one of the basic necessary tools. The accuracy of many NLP applications depends on the accuracy of POS tagger [5]. POS tagging can be used in text to speech (TTS), IR, shallow parsing, information extraction (IE), linguistic research for corpora[6]and also as an intermediate step for higher level NLP tasks such as parsing, semantic analysis, machine translation, and many more [6]. POS tagging, thus, is a necessary application for advanced NLP applications in Ge'ez or any other languages.

Much of the research in natural language processing has been dedicated to resource rich languages like English, French and other major European and Asian languages. African languages have, however, received far too little attention. In fact, most are being spoken by less and less people. Nowadays Part of Speech tagger is developed for different languages and it remains an intensive research area for other different languages. Among the languages with POS tagger developed are Tigrigna[7], [8], Amharic [4], Kafi-Noonoo [9], Arabic [10], Afaan-Oromo[11], etc. As to the best of the researcher's knowledge, Ge'ez is then a language which does not have POS tagger developed so far.

Ge'ez is the classical language of Ethiopia within the Semitic language family. It is grouped under north Ethiopian Semitic along with Təgrä and Təgrinya[12]. Ge'ez or Ethiopic was the spoken language until the end of the Axum Empire in the ninth century [13]. Today this language is used only for religious writings and liturgical services in the Ethiopian Orthodox Tewahido Church, Eritrean Orthodox Tewahido Church, Ethiopian Catholic Church and the Beta IsraelJewish community.

2. Motivation

Ge'ez is the language of many Ethiopian literatures and manuscripts. Several ancient manuscripts, arts, scriptures, heritages, historical, ethical and religious chronicles thatcan be used as a primary source of knowledge are found in Ge'ez language [14]. The ancient philosophy, tradition, history, knowledge etc. of Ethiopia was being written in Ge'ez and also there are different books which are written by this language. These resources can be used as source of philosophy, creativity, knowledge and civilization both to Ethiopia and the rest of the world. To use, keep these resources, and transfer these identities to the next generation, the citizens must understand semantically and syntactically wayof these written books/documents. If they didn't know the idea in the documents, they will not give any attention for these heritages. If someone who is proposed to conduct a research on issues related to the classical custom, history, politics, tradition, and religion of Ethiopia, he/she have to explore the works handed down from the previous generations to the current generation. So, he/she must investigate these literatures. In addition to this, as the language is the ancestor of other modern Ethio-Semitic languages like Tigrinya and Amharic [13], professionals of these languages should also know the linguistic nature of Ge'ez language to earnestly understand and investigate the nature of these modern ones. To use these resources, one must know the language itself or else these literatures have to be translated into either of the currently spoken languages manually, which may take a long time. To solve this problem studying the nature of the language computationally and finally releasing the resources out with the help of Information Technology (IT) to be used by everyone of this era is a critical assignment that deserves research. As the result, it is worth conducting research as to develop apart of speech tagger for Ge'ez to contribute to the complete usage of the language by the generation [15].

3. Statement of the Problem

There are POS taggers that have been developed for international languages like English[16], Arabic[10], Hebrew[17], etc and Ethiopian languages like Amharic[4], Afaan-Oromo[11], Kafi-Noonoo[9], Tigrigna[7] etc. In general, rule based approach, probabilistic or stochastic approach and hybrid approaches which is the combination of stochastic tagging techniques such as hidden Markov models (HMMs) and rule based tagging techniques are used to develop POS tagger for various languages. However, the way they are applied depends on the characteristics of languages. As a result, these POS taggers cannot be applied directly for Ge'ez language. On the other hand, to our best knowledge there is no research conducted on POS tagger development for Ge'ez language which becoming a barrier for research and development works on higher level NLP applications. Hence, the absence of POS tagger system limits researches concerning the NLP of Ge'ez language such as parsing (syntactic and semantic), machine translation, sentence grammar checker, spell checker, speech synthesis etc. as it is used as a pre-processing component for the aforementioned NLP applications. Hence, conducting research on developing an automatic POS tagger for Ge'ez language worth paramount significance.

4. Objectives

4.1.General Objective

The general objective of this research work is to develop POS tagger for Ge'ez language.

4.2.Specific Objectives

So as to achieve the above general objective, the research accomplishes the following specific objectives:

- Review techniques for POS tagging.
- Study the structure of Ge'ez language sentence
- Review, analyze and study the basic word category and tag set for Ge'ez language
- Annotate the given word to its equivalent word class
- Prepare corpus for training and testing the system
- Designandmodel a POS tagger for Ge'ez language
- Develop a Ge'ez POS tagger prototype
- Test the system performance

5. Methods

5.1. Literature Review

Literature review has a vital role for identifying the component of part of speech tagger, comparison of the approaches, detail understanding of problems, finding gaps, identifying methodologies, etc. In addition, in order to understand the problem books, articles, journals and other publications will be reviewed.

5.2. Data Source

So far, there is no readymade tag set for Ge'ez language that can be used in this thesis work. Hence, we are to construct a new corpus and discussions will make with the language experts in order to set tag sets for this language.

5.3. Tools

In order to achieve the research objectives, a relevant tools and methods or approaches will be used. To develop the system, selection of python as a programming language demand for implementation extend from the possibility to combine the execution of other related components.

5.4. Evaluation

To evaluate the performance of the system, the prototype of the system was developed and tested with samples tagged sentences. The performance of the system is measured against the manually prepared corpus.

6. Related Work

This section reviews earlier POS-tagging works conducted in Semitic languages which are categorized under the same language branch as the Ge'ez language and other Ethiopian and international languages which are not Semitic language families.

6.1. Semitic Languages

Yemane Keleta and Yamamoto Kazuhide[7] presents part of speech tagging research for Tigrinya from the newly constructed Nagaoka Tigrinya Corpus. The raw text was extracted from a newspaper published in Eritrea in the Tigrinya language. The POS tagged corpus contains 72,080 tokens and 73 tag set. Subsequently, a supervised learning approach based on conditional random fields (CRFs) and support vector machines (SVMs) was applied, trained over contextual features of words and POS tags, morphological patterns, and affixes. For a reduced tag set of 20 tags, an overall accuracy of 90.89% was obtained on a stratified 10-fold cross validation. Enriching contextual features with morphological and affix features improved performance up to 41.01 percentage point, which is significant.

Teklay Gebregzabiher [8]introduced a hybrid approach POS tagger for Tigrigna language. In this work the author used a combination of HMM, which is widely used under stochastic approach and adapting Brill transformation-error driven learning approach to drive machine learned rules for designing the rube based tagger component. The author has collected a total of 26,000 words from Tigrigna news broadcasting agencies and annotate manually with their corresponding word class. In addition to this, the author has identified 36 tag sets for the entire tagging process. Among the total word, 75% (20,000) words used for training purpose while the remaining 25% (6000) words used for testing purpose. Generally, this study finds tag of a word in two main steps. The first step is performed by the HMM tagger. The HMM tagger first annotates the given raw text and provides a level of confidence (threshold value) for each tag sequences. In the second step, the confidence level of each tag sequence compared with the minimum confidence level that is set by the author using the output analyzer module. In order to test the accuracy of the proposed method, the author conducted different experiment for the three types of taggers namely HMM tagger, rule based tagger and hybrid tagger. As a result, the author has got an accuracy of 89.13% for HMM, 91.8% for rule based and 95.88% for hybrid tagger.

Binyam Gebrekidan [4] developed POS tagger for Amharic language. The author designed a POS tagger state-of-the-art machine learning algorithms for Amharic language. The author uses annotated data available for their experiments which is WIC corpus (≈207k) tokens. In order to increase the performance of the tagger the author uses the following three methods: First, the POS tagged corpus (WIC) has been cleaned up to minimize the preexisting tagging errors and inconsistencies. Second, the vowel patterns and the roots, which are characteristics of Semitic languages, have been used to serve as important elements of the feature set. Third, state-of-the-art of machine learning algorithms have been used and parameter tuning has been done whenever necessary and as much as possible. Finally, the accuracies have crossed above the 90% limit.

Hadni Meryeme*etal* [10]Proposes POS Tagging technique for Arabic language using hybrid approach. The developed tagger employed an approach that combines rule-based method with HMMs based on the Arabic sentence structure. The proposed technique uses different contextual information of the words with a variety of the features which are helpful to predict the various POS classes. To evaluate its accuracy, the proposed method has been trained and tested with two corpora: The Holy Quran corpus and Kalimat corpus for discretized Classical Arabic language. Parts of it were used to train and to test the tagger. The experiment results demonstrate the efficiency of the method for Arabic POS Tagging. In fact, the obtained accuracies rates are 97.6%, 96.8% and 94.4% for respectively their Hybrid Tagger, HMM Tagger and for the Rule-Based Tagger with Holy Quran corpus. And for Kalimat corpus they obtained 94.60%, 97.40% and 98% respectively for rule-based tagger, HMM tagger and their hybrid tagger. In fact, the accuracy was slightly increased with the increasing of the number of words in the training corpus. However, their tagger cannot handle for unknown

words or tagging accuracy of unknown words ware very low. Additionally, their tagger cannot handle in extraction of multi-word terms.

6.2. Non-Semitic languages

Eric Brill [16]developeda simple rule-based tagger for English language with very few rules performs on par with stochastic taggers. The author ran two experiments where all words were known by the system. First, the Brown Corpus was divided into a training corpus of about one million words, a patch corpus of about 65,000 words and a test corpus of about 65,000 words. When tested on the test corpus, with lexical information derived solely from the training corpus, the error rate was 5%. Next, the same patches were used, but lexical information was gathered from the entire Brown Corpus. This reduced the error rate to 4.1%. Finally, the same experiment was run with lexical information gathered solely from the test corpus. This resulted in a 3.5% error rate. Note that the patches used in the two experiments with no unknown words were not the optimal patches for these tests, since they were derived from a corpus that contained unknown words. Zelalem Mekuria and Yaregal Assabie [9] developed POS tagger for Kafi-Noonoo using a hybrid approach. For training and testing purpose, 354 untagged Kafi-noonoo sentences are collected from two genres and annotated using an incremental corpus preparation approach. And 34 POS tags are identified for tagging purpose. After assigning word class information on each word within the sentences, both HMM and rule-based taggers are trained on 90% of the tagged sentences to generate probabilities i.e. lexical and transitional probability for the statistical component of the hybrid tagger and set of transformation rules for the rule-based component of the hybrid tagger. Based on these probabilities and transformation rules, the hybrid tagger assigns the most suitable word class information for the given untagged Kafi-noonoo texts. The performance of the prototypes i.e. HMM, rule-based and hybrid taggers ware tested using different experiments. As a result, HMM and rule-based tagger with unigram initial state tagger shows 77.19% and 61.88% accuracy respectively whereas, the hybrid tagger improves the accuracy to 80.47%. Even though there is no one way of choosing the size of training/testing set, this thesis applies heuristics such as 10% testing and 90% training corpus. But,doing so can bias the classification results and the results may not be generalizable.

Getachew Mamo and Million Meshesha [11] presents part-of-speech tagger for Afaan-Oromo using HMM approach. For training and testing purpose, the authors collected 159 sentences (with a total of 1621 words) from different sources to make the corpus balanced and they used 17 tag set. In the tagging process, the tagger assigns word classes to a given Afaan-Oromo text with two main phases. In the first phase, the tagger trains on the training data in order to compute and store both lexical and transitional probability of training data. In the second phase, the tagger accepts untagged Afaan-Oromo text and tokenized into words. Then, the tagger assigns the correct POS tag for each token. This is achieved by using unigram and bigram model of the Viterbi algorithm by taking the stored information during the first phase. The authors have tested the performance of the tagger using tenfold cross validation mechanism. As a result, they have got 87.58% and 91.97% accuracy for unigram and bigram model respectively.

From the related work, we have seen research done for both Semitic and non-Semitic language families thatwere conducted by different approaches such as hybrid approaches for Tigrigna[8], Arabic[10],Kafi-Noonoo[9], probabilistic approach for Afaan-Oromo[11],Amharic[4], Tigrigna[7] and rule based approach for English[16].For our best knowledge, there is no research attempt on Ge'ez POS tagger. As a result, the purpose of our proposed research is to fill in this research gap.

7. Scope and Limitations

The aim of this study is to develop POS tagger for Ge'ez words based on the corpus into their appropriate category. The corpus that we develop for this thesis work is domain specific corpus, a text corpus that will collect from a single domain, in this case the holy bible domain only. During the development of the corpus, the tagset use will have meant to give information of words about their word class category but not about the issues like gender, number, tense etc.Moreover, there are limited NLP researches done for Ge'ez language and hence there have been difficulties of using previous works as a reference. However, the text of the corpus will be written language words. Thus, this work is subject to the following scope and limitation:

- The tagset provide only word class information
- The corpus will be prepared from one genre that is holy bible.

8. System Design

POS tagging involves many difficult problems, such as insufficient amounts of training data, inherent POS ambiguities, and most seriously, many types of unknown words which are pervasive in any application and cause major tagging failures in many cases.

Several approaches have been proposed to annotate words automatically with their POS tags. Among these, the hybrid of TnT and rule-based approach is assumed to perform better than the TnT and rule-based taggers when they are taken alone. For this thesis, a hybrid approach, which is a combination of TnT, human annotated rule, and morphological pattern analyzer tagger is designed for Ge'ez language. The hybrid tagger of Ge'ez consists of three main components these are initial state (TnT tagger), output analyzer and rule-based tagger and morphological analyzer-based tagger. The overall architecture of the system including the connection between the components and the algorithm are shown in Figure 1 and Figure 2 respectively.

Algorithm for Hybrid Tagger

1. Read the text to be tagged
2. Shuffle the input text
3. Segment and tokenize the sentence
4. Prepare unique words Dictionary
5. Prepare common prefixes Dictionary
6. Get trained TnT and Regex tagger
7. Tag the test corpus by using TnT and Regex
8. Compare with gold tag
9. While testing! = gold tag
   9.1. Apply the word with the given rule if the word contains wuetu
   9.2. Analyze morphological patterns of the word and tag accordingly
10. End of hybrid tagger

Figure 1: Hybrid Tagger Algorithm

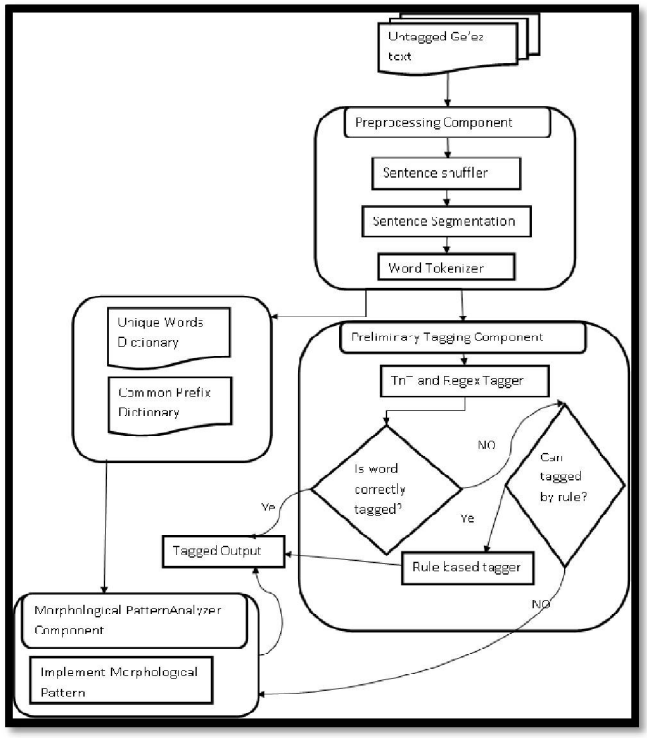

Figure 2: Hybrid Tagger Architecture

9. Experiment and Results

Several experiments with different training set on three POS tagger have been conducted for Ge'ez POS tagger. The entire corpus shuffled and divided into two main sets: training set and testing set. The training set covers 90% of the entire corpus. The remaining 10% of the corpus is used for testing purpose.

9.1. Test Result of TnT Tagger

We use NLTK tool for implementing the experiment of Ge'ez TnT tagger by a little bit modification. Ten different experiments are conducted on the TnT tagger using different portions of the training set to see the excellence of the training set based on the observation that can be made on the learning curve. We started training the system using the 10% of the training set. After the tagger is trained, its performance is measured on the testing set. Having got a low performance of the tagger trained on the 10% of the training set, we kept on adding the training data by 10% until they got a desired performance of the tagger. Table 6.1 shows the different experiments conducted using different portions of the training set with the corresponding performance of the tagger.

Training set	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Performance (%)	50.65	58.51	62.78	66.08	69.08	70.44	72.57	74.08	75.187	77.87
Difference	50.65	7.86	4.27	3.3	3	1.36	2.13	1.51	1.107	2.683

Table 1: TnT Tagger Performance

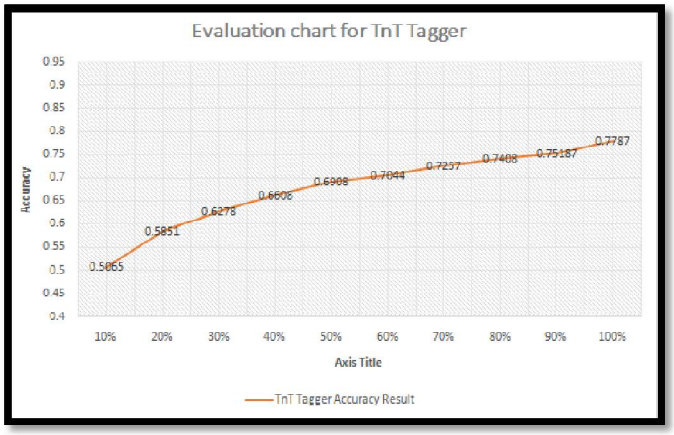

Figure 3: TnT Tagger Performance Curve

The TnT tagger in Figure 2, shows 77.87 % accuracy when all of the training data is used (100%). However, this result indicated the worst performance of an annotating Ge'ez corpora. This can be explained by two reasons. The first one is as TnT is a statistical tagger for training purpose it needs large corpus size but we use small corpus size which makes it very difficult for stochastic taggers to create probability distribution to hold transitions between different states. The second reason can be from grammar order in Ge'ez sentences in which free grammar which is no agreement among subject-object-verb order. Due to the aforementioned reasons, for Ge'ez language, TnT tagger score the worst accuracy result comparing with different language using this tagging approach, for example for English using Penn Treebank corpus which contains 50,000 sentences (1.2 million words) scores an accuracy of 96.7 % [23]. In the same manner (additionally) for Amharic language using 1065 news texts (210,000 words) score the overall performance 92% [45].

9.2. Test Result of TnT and Regex Tagger

To test the performance of the TnT and Regex Tagger like that of TnT tagger, ten different experiments are conducted using different portions of the training set. Table 6.2 shows the different experiments conducted using different portions of the training set with the corresponding performance of the TnT with back off of Regex tagger.

The most difficult task of TnT tagger is tagging of unknown words, words do not appear in training phase [23]. Hence, if the baseline TnT algorithm encounters a word in the testing set which did not appear in the training set, it will simply annotate it as "UNK" (unknown). Rather than failing to annotate in this way, the alternate versions of TnT identify a back off tagger. Thus, when the algorithm comes upon an unknown word, it will pass off the tagging task to the back off tagger. Such bakeoffs can be chained together but there is usually no additional improvement in having more than one or two bakeoffs. The most common class of lexeme in the corpus is nouns. TNT and Regex performs better than TnT based tagger. By replace "UNK" to "N" get a little bit accuracy change in the tagger. Figure 6.3, shows the curve shows 82.23 % which is 4.36 % difference comparing with TnT tagger in Figure 6.1.

Training set	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Performance (%)	63.50	68.56	71.42	73.65	75.67	76.77	78.45	79.65	80.04	82.23
Difference	63.50	5.06	2.86	2.23	2.02	1.1	1.68	1.2	0.39	2.19

Table 2: TnT and Regex Tagger Performance

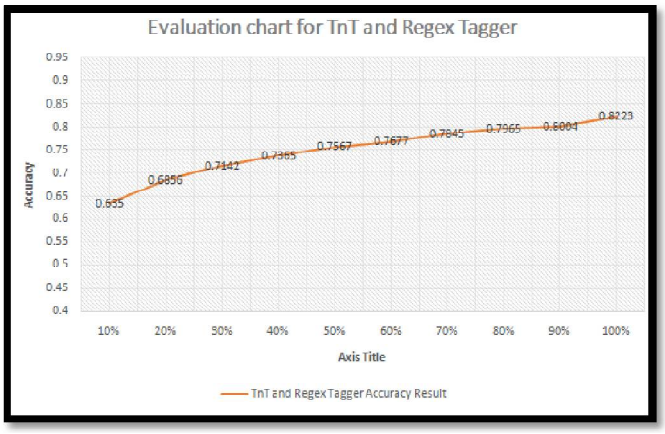

Figure 4: TnT with Regex Tagger Performance Curve

9.3. Test Result of Hybrid Tagger

Hybrid tagger of Ge'ez language is combination of TnT with back off of Regex tagger and contains morphological pattern analysis. In order to tag a given text with the hybrid tagger, first the Regex assigns tags to tokens on the basis of matching patterns. For instance, we might guess that any word contains ten digits of numbers or match numbers with \d is a cardinal number, and is tagged as CR. It follows sequential order, and the first one that matches are applied. The final regular expression (r'.*', 'N'), is a catch-all that tags everything as a noun. The reaming task will be done by TnT tagger. Even though the combined tagger, TnT with back off of Regex tagger is better perform than TnT only, but still the result is acceptable. Consequently, it is important to associate morphological pattern analysis with the tagger which is making hybrid tagger. In addition to TnT with back off of Regex tagger, the hybrid tagger work by guessing unknown word using morphological pattern of the word. In unknown word guessing, the POS tag of an unknown word is predicted using affix of the unknown word, morphological patterns and substrings methods. We use probability method to guess the POS tag of unknown word. Finally, by combing all those techniques we got an acceptable performance result.

Training set	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Performance (%)	87.24	89.46	90.46	91.30	91.97	92.24	92.85	93.40	93.92	94.32
Difference	87.24	2.22	1.00	0.84	0.67	0.28	0.61	0.55	0.52	0.40

Table 3: Hybrid Tagger Performance

10. Application of Results

There are many advantages of developing POS tagger for a specific language. In the first place, it is the basis for developing other higher level applications of NLP such as parsing, information extraction, information retrieval, question answering, text to speech, etc. These applications can be used in different areas of the Ge'ez language. Accordingly, the beneficiaries of this study are:

- Researchers who want to conduct on higher level application of NLP for this language such as spell checker, grammar checker, speech recognition, etc.
- People who want to learn Ge'ez as a second language; it may help them to discover the word categories and grammar construction.
- It can be used as an input for full parser
- It can be used in text-to-speech system to correct the way of pronunciation
- It can be used for surface linguistic analysis

11. Conclusion and Recommendation

11.1. Conclusion

POS tagging is the process of assigning POS like noun, verb, preposition, pronoun, adverb, adjective or other lexical class markers to each word in a sentence or literature. POS tagging is the first step to understanding a natural language. Most other tasks and applications heavily depend on it. POS tagging is considered as one of the basic necessary tools. It is a research area in the field of NLP for different languages. Several techniques have been suggested to tag words automatically with their POS tags. Among these, the hybrid of TnT with human annotated rule, regex and morphological pattern analysis of Ge'ez language is assumed to perform better than the TnT taggers taken alone.

Corpus is an important component in NLP in general and POS in particular. For this thesis, a corpus with a total of 1305 sentences is collected from one genre. For this thesis, 26 POS tags are identified as a tag set for annotating a raw text. The tag set indicates only word class rather than gender, number, tenses etc. The training set consists 90% of the total corpus (around 1175 sentences) and the testing set consists 10% of the corpus (around 130 sentences).

NLTK and Python3.6.2 are used in the implementation and experiment of the Ge'ez POS tagger. Hence, different experiments are conducted for the three types of taggers namely the TnT tagger, TnT with Regex tagger and Hybrid tagger. Therefore, 77.87%, 82.23% and 94.32% performances are obtained for TnT tagger, TnT with Regex tagger and Hybrid taggers respectively. Therefore, it is possible to conclude that the hybrid tagger performs better than the TnT tagger and TnT with Regex tagger used individually.

11.2. Recommendation

There are lots of research areas in NLP that can be done for local languages. The same thing holds true for Ge'ez language. Therefore, to assist researchers, it will be of great paramount if a standard corpus for Ge'ez language is developed that will be available for NLP researchers in Ge'ez language. Among these, POS tagging is a useful form of linguistic analysis. It serves as pre-processing component for many higher levels NLP applications such as spelling checker, grammar checker, question answering, etc. Therefore, the researchers in the area of NLP application can use the design of our model or the implemented system as input or as a preprocessing component within their research.

Finally, this research work suggests the following key points as a future work:

- Preparation of a balanced corpus that contains texts which represent different genres like theological and hymn books such as Synaxarium (the book of the saints of the Ethiopian Orthodox Church), deeds of the martyrs etc. and other books beyond religious scriptures such as fictions, textbook etc.

- Comparative study of three different approaches (CRF, SVM classifiers based and ANN based taggers for Ge'ez Language with more training and testing data)
- Extending this work by training in large corpus and using large tag sets that can identify gender, number, tense etc. with different feature set
- Comparison of two hybrid approaches: the hybrid of ANN and TnT tagger and the hybrid of TnT and CRF for Ge'ez language
- Morphological pattern analysis component of hybrid approach that proposed for Ge'ez POS tagger is based on unknown word guessing mechanism. Therefore, in order to further improve the tagging results, this approach can be extended to use the full feature of Ge'ez morphological analyzer.

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