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The development and evaluation of an automatic clitic generator for Pashto language

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Clitics are unstressed and unaccented words or particles that are phonetically dependent on adjacent words, accented in nature. They are available in many languages around the world including the Pashto language, which is spoken in Pakistan and Afghanistan. The native Pashto speakers use clitics extensively in their everyday conversation and writings. There are two basic types of clitics in Pashto called: Second Position (2P) clitics and Endoclitics. 2P clitics fall into three different categories: Proclitics, Enclitics (Modal) and Adverbial. Proclitics and enclitics are further grouped into context-free and context-dependent clitics. Endoclitics among all the clitics are the most challenging type of clitics, as their generation faces many restrictions. Clitics play a vital role in text generation systems. In general, these systems must be understandable, coherent, and accurate. In addition to this, Pashto Language is a low resource language lacking corpus, parser, tagger, and semantic analyzer. It also lacks syntactic-morphology interaction. Furthermore, there is no automatic clitic generation tool. These challenges make the generation of Pashto cliticised sentences a more challenging task. To overcome these challenges, the linguistic behavior of Pashto clitics is studied and formalized into rules to support the automatic generation of cliticised text in this paper. In particular, it used nine different clitic generation procedures and produced 80 clitic generation rules. The proposed clitic generation system is developed in Python, which generates cliticised sentences from the semantic representation of the sentences. To evaluate the efficiency of the developed system, a corpus of 256 syntactically annotated sentences was developed and used. It used syntactic pattern matching rules for the identification and generation of clitics at the sentence level. The sentences produced were checked against the correct responses to declare them correct or incorrect. The proposed system successfully developed both types of clitics with an overall accuracy of 89.72%. In particular, it produced Proclitics and Enclitics with an accuracy of 91.75%. However, its efficiency for modal clitics (87.95%) reduced the overall efficiency of 2P clitics to 89.85%. The precision of the endoclitic system developed was 89.47%.

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Introduction

Natural Language Processing (NLP) is a subfield of Artificial Intelligence (AI), which deals with the tasks of automated understanding and generation of human languages by computers (Chowdhary, 2020). The task of Natural Language Understanding (NLU) focuses on the integration and use of different aspects of a language such as phonology, morphology, syntax and semantics, to enable the computer to understand and process texts written in a natural language. The Natural Language Generation (NLG) part converts information in different representations such as graphs, logical representations, and databases, which are computer-understandable and processable, into texts that sound like human language (Dušek et al., 2020). The automatic generation of a natural text remains a challenging task as the generated text must be at least coherent, accurate, and understandable. This research takes the challenge of automatic generation of clitics in Pashto texts, as native Pashto speakers use them extensively in their everyday conversation and writing.

Numerous NLG systems have been developed and applied to solve practical problems. Recent advances in NLG methods include question generation using reinforcement learning (Chung et al., 2024), text generation from given data using neural planning (Puduppully, 2022), application of recurrent convolutional neural networks for text generation (Ji et al., 2023) and automatic text generation using deep learning algorithms (Du et al., 2023). Clitics generation is another well-known application of NLG systems.

Clitics are an essential part of the Pashto language, and its native speakers use them extensively in their daily discourse. A text without clitics is perceived by native speakers as artificial, verbose, and boring. A clitic is a bounded morpheme that has the syntactic characteristic of a word. However, it shows evidence of being phonologically bound to another word called the “host” of the clitic. A clitic cannot bear accent or stress and, therefore, leans on its host (Shafiei and Kazemi, 2020). Pashto clitics have been considered to follow Noun Phrase (NP) reduction process, also called Weak Anaphoric Reduction Process (WARP) (Tegey, 1996). This linguistic phenomenon is unique to Pashto language. In WARP, a clitic moves from left to right as the noun or noun phrase before it is removed. This movement obeys the syntactic rules of the Pashto language. In Pashto, clitics can occur at various positions in sentences, except at the beginning of a sentence. Most Pashto clitics occur at the Second Position (2P) of the clause, that is, in the second position to the right of a clause (Babrakzai, 2007).

Pashto NLG applications require the ability to insert correct clitics in the final form of an input text. This task is incumbent to an automatic clitic generation, which is defined as the process of incorporating clitics into a computer generated natural language text. Similarly, the placement of clitics within Pashto sentences is determined by the interaction between phonology and syntax (Tegey, 1996), which makes it difficult to fully account for clitics at a single linguistic level. Therefore, the design of a Pashto clitic generation system is needed to overcome the quasi-absence of language resources and tools. The basic aim of this research work was to develop algorithms for the generation of clitics of the Pashto language. Based on the above statement, the following objectives were used for this study:

1. To study the contexts of occurrences of clitics in Pashto and other natural languages.
2. To design Pashto clitics generation rules.
3. To evaluate the accuracy of Pashto clitics generation rules.

The rest of this paper is organized as follows. Section “Background and literature review” provides background information

for this research, which focuses on several topics that provide the foundation for this study and an overview of clitics in different languages. It also explores relevant literature. Section “Clitics in Pashto” presents the detailed description of the clitics in Pashto. Section “The development of cliticization rules” describes the development of cliticization rules designed, in this work, for the generation of Pashto clitics. It also explores a manually designed corpus used for the evaluation of proposed work. Section “The proposed Pashto clitic generator” presents the proposed rule-based Pashto clitics generator for 2p clitics as well as Endoclitics. Section “Implementation and evaluation” provides the implementation of the proposed system and its evaluation for the corpus considered in this work. This paper provides the conclusion and future directions of this work in Section “Conclusion and future work”.

Background and literature review

This section describes clitics and their role from different aspects of linguistics and presents a brief survey of clitics in different languages across the world. The motivation and objectives of this work are also presented.

Background. The word ‘clitic’ is derived from a classical Greek word which means “inclined; to lean” (Aronoff and Fudeman, 2011). A clitic is a word that cannot have a primary word stress and thus leans on an adjacent word, called the clitic host, which bears the stress. From the developmental and evolutionary perspective of a language, clitics are linguistic elements that are in the developing stages of grammaticalisation. The grammaticalisation process converts non-functional words such as adjectives and verbs into pronouns and auxiliary verbs (Spencer and Luís, 2012). In later stages, these converted words lose their accent and thus become clitics.

Clitics can be divided into three main types on the basis of their positions towards the host. These types are called enclitic, proclitic, and endoclitic. An enclitic is placed at the end of its host, while a proclitic is placed at the beginning of its host. Pashto language has a third type of clitic called endoclitic, which is attached inside its host. (Halpern, 2017) proposed a different classification of clitics by distinguishing simple clitics, special clitics, and bounded words. A simple clitic is a phonologically weak function word such as a preposition, an auxiliary verb, a definite marker, among others, which is phonologically weak. Therefore, it must phonologically adjoin a full (accented) adjacent word. (Spencer and Luís, 2012). A special clitic is defined as “an unaccented bounded form” that “acts as a variant of a stressed free form with the same cognitive meaning and with a similar phonological makeup.” 2p clitics fall into the category of special clitics (Spencer and Luís, 2012). Bounded words are unaccented words, and they always need a host to attach to. An example given by Halpern (2017) is the English possessive “s”. Spencer and Luis (2012) summarized that “Halpern (2017) typology reveals that the distinction between simple clitics, special clitics and bounded words is largely based on two distinguishing features, namely: the syntactic distribution of clitics and the relationship between the clitic form and its full form.”

There are two most widely used but different views about clitics. The first perspective, supported by Tegey (1996), suggests that phonological and syntactic rules interact with each other to generate clitics. The second perspective, which is based on generative grammar, advocates that generative grammar can be adopted to analyze sentences with clitics without considering the interaction between syntactic and phonological rules (Kaisse, 1981).

Researchers have been studying clitics in different languages around the world. According to Bender (2014), "a clitic is a linguistic element which is syntactically independent but phonologically dependent." A clitic is a word that syntactically functions as a free morpheme but phonetically appears as a bound morpheme. Syntactically free means that the rules of syntax treat the clitic as an independent word. Therefore, clitics functions above the word level. Moreover, clitics are often written as separate words. Phonologically bound means that the clitic is pronounced as if it is affixed to an adjacent word. However, a clitic is not an affix.

Anderson (2011) gave a theoretical framework for the clitic phenomena by examining existing theories and analyzing clitics in different languages. The author studied different languages including Icelandic, Kashmiri, Breton, Surmiran Rumantsch, English, Tagalog, and Pashto. The clitics were studied at phonology, syntax, and phrasal morphology levels. Properties such as agreement, clitic climbing, and clitic doubling are elucidated for pronominal clitics. According to Crystal (2011), "clitic climbing occurs when a clitic moves from its local domain to a higher constituent" while "clitic doubling occurs when a clitic is used despite the existence of an element with the same meaning and function in the same clause". Anderson in his work presented in Anderson (2011) briefly mentioned Pashto endoclitics and classified them as phrasal affixes.

Literature review. Clitics occur in many languages and have been extensively studied by linguists with different orientations. This section illustrates the peculiar properties of clitics in some languages around the world.

Clitics in Indo-European languages. "The Indo-European language family covers most of Europe and spreads, with some breaks, through Iran and Central Asia to South Asia" (Aronoff and Rees-Miller, 2020). Languages such as English, Greek, Spanish, Portuguese, Urdu, and Pashto belong to this family. Example (1) presents a few sentences in English that contain the use of morpheme "s" at various locations.

Example (1):

- (a) What's going on?
- (b) The man is in the big house's room.
- (c) He's teaching Computer Science in the University.

In Example 1(a), the morpheme "s" is used as the contraction of "is", whereas, the morpheme "s" is used to mark possession in Example 1(b). Example 1(c) shows the constituent position of "s" in the sentence.

The status of a morpheme can lead to a debate as it happens for the English possessive marker -s. The debate is on whether the possessive marker is an affix or a clitic. In English language, the possessive marker -s looks very much like an affix which takes an entire noun phrase as its host rather than any individual word in that phrase. Elements of this kind are sometimes called phrasal affixes (Nevis, 1986). Phrase affixes have most of the properties of normal affixes. Each one of them is always attached to another word. They do not fit into any of the established lexical categories for the language. They tend to empress grammatical (specifically inflected) rather than lexical meaning. However, unlike normal affixes, they are "promiscuous" in their attachments meaning that they may attach to words of approximately any category (Nevis, 1986). Lowe (2016) has proposed using the theory of Lexical Sharing in Lexical Functional Grammar to overcome this problem. 2p clitics occur only in a specific position in a sentence: Either after the first word or after the first phrase. Therefore, these clitics are not sensitive to the POS of the preceding word (Spencer and Luis, 2012).

Traditional Spanish grammar considers two classes of pronouns: stressed pronouns (also called strong pronouns) and unstressed pronouns (also called weak pronouns). The latter are the clitics and they are the only type of clitics in Spanish language unlike other languages such as Pashto, which also has auxiliary and modal clitics. Spanish pronominal clitics are phonologically deficient and cannot be coordinated, modified, or emphasized. They can not appear in isolation, and they do appear only before or after a verb depending on different syntactic and morphological factors.

In Spanish, a clitic doubling construction encodes an entity within a clause by attaching a weak pronoun (clitic) to the verb and an independent nominal phrase which is co-referential to this weak pronoun (Belloro, 2007). The Spanish clitic doubling occurs only with direct and indirect objects, and these doubling constructions are grammatically optional. The analysis of clitic doubling in Spanish is problematic as it raises the question whether the clitic or the independent phrase is the argument of the verb. Belloro (2007) suggests that the clitic doubling must depend on the cognitively accessible target-referent sentence. The dialect of Spanish spoken in and around Buenos Aires, Argentina, is known as Rioplatense or River Plate Spanish. Castel (2005) used a microgrammar of River Plate Spanish clitics to address the word-order constraints underlying the combinatory potential of clitics with other clitics and clitics with their governing verbs. Clitics are defined as functor signs that seek arguments (verbs or other clitics) in the forward direction.

Endoclitics are not common as proclitics and enclitics. In addition, their positions differ in different languages. The endoclitics in European Portuguese follow an intermorphemic placement while they follow an intramorphemic placement in Pashto language (Smith, 2013). (Smith, 2013) highlighted that the "intramorphemic placement of clitics is more challenging for linguistic theory, as it could involve a complex interaction of morphology, syntax and phonology, which is impossible to model directly in some (but crucially not all) frameworks."

Urdu language is an Indo-european language and it belongs to the Indo-Aryan language family branch. Butt and King (2008) analyzed Urdu genitive case marker as a clitic and the ezafe construction as either a phrasal affix or clitic in Urdu language. The authors tried to discover the possibilities for the interaction of phonology, morphology, and syntax to determine lexical and affixal properties of clitics as well as their behavior as an independent syntactic unit. The authors used post-lexical prosodic phonology to cover the properties of clitics and ezafe. They concluded that phrasal affixes and clitics should not be distinguished from each other. However, this point of view has been contradicted as Rgveda clitics have been described, which are obtained from the prosodic movement of clitics between the c-structure and p-structure in Lexical Functional Grammar (Lowe, 2016).

Clitics in Semitic languages. Semitic languages belong to the Afro-Asiatic language family. Arabic is the most widely-spoken Northwest Semitic language. It has only proclitics and enclitics and does not have endoclitics like the Pashto language. (Nash and Rouvieret, 2002) studied the distinction between enclitics and proclitics in pronominal clitic constructions in Romance and Semitic languages. Their analysis is based on two underlying assumptions: 1) clitics do not take pre-identified positions in a sentence or phrase but use maximum knowledge of categorial structure for placement; and 2) the placement of a clitic is dependent on inflectional properties of the language.

Amharic language belongs to the South Semitic branch (Kramer, 2012). In Amharic, first-person clitic pronouns proceed with a second-person pronoun. Amharic clitic doubling has been

argued to be either agreement feature or pronoun-like morphemes that associate with the direct object and attach to the nearest verb. Amharic clitics have been found to occur only to the right of the host verb or noun. The clitics attaching to verbs have prepositional properties, whereas, clitics attaching to nouns are mostly interpreted as possessives (Kaech, 2022).

Clitics in Austronesian languages. The Austronesian language family covers a large set of languages. The western Austronesian languages have been identified to exhibit pronominal clitics. According to (Hemmings, 2016), “clitic phenomena is another means often used to distinguish between the Philippine-type and Indonesian-type.” It was suggested that 2p enclitics are “a key feature of Philippine-type languages while proclitic actors are characteristics of Indonesian-type languages (Hemmings, 2016)”.

Tagalog is a western Austronesian language spoken mainly in Philippines. In Tagalog, 2p clitics can occur only in one specific position, that is, immediately after the first accented word of a clause (Spencer and Luís, 2012). However, their occurrence is under some morphological constraints. Monosyllabic pronominals must precede other clitics and non-pronominal clitics must precede disyllabic pronominals. The clitics in Pashto and Tagalog share some similarities in terms of syntax. Discourse clitics combine with sentential clitics (Spencer and Luís, 2012) forming a cluster of clitics in both the languages. (Kaisse, 1981) analyzed clitics in different languages and concluded that, even though, the 2p clitics principle holds for the languages such as Tagalog, there exist languages such as Pashto, in which the position of 2p clitics after an initial is possibly a phrasal constituent.

Clitics in Udi Language. The Udi language belongs to the Northeast Caucasian language family. Like Pashto, the Udi language also has endoclitics. In Udi, the verb carries tens-mood-aspect as a suffix. The verb roots (stems) are classified as simple or complex. Simple stems are monomorphemic. Person markers and some other grammatical morphemes can be inserted in a verbal root (Luís and Spencer, 2005). These person markers and morphemes are considered endoclitics with the following properties (Ganenkov et al., 2011). They:

1. attach to constituent, which bears the main focus in a sentence.
2. appear inside the monomorphemic verb stem.
3. break the lexical integrity principle. The internal structure is affected by the syntax and the position of clitic.

The review of existing work conducted in this work concludes that current studies focus on issues such as incorporating clitics into existing generative grammars, differentiating clitics and affixes, and theorising the interaction of different linguistics components such as phonology, syntax, morphology, and prosodic structures with respect to clitics. In general, clitics are found to be phonologically bound and follow syntactic rules of distribution similar to words.

Clitics and NLP. The basic steps in any NLP system are tokenization, morphological analysis or generation, POS tagging, and syntactic parsing. Tokenization splits a sequence of language symbols into a list of tokens that includes lexical words. Morphological analysis splits a lexical word into a sequence of morphemes. POS tagging labels each token with its grammatical class. Syntactic parsing analyzes the grammatical structure of sentences.

For possible clusters of clitics (including four proclitics before the stem while three enclitics after the stem), (Alotaiby et al., 2010) evaluated the impact of including an Arabic clitic tokenizer

during the tokenization of a large Arabic corpus containing 600 million words. The authors found that by adding the clitic tokeniser, the lexicon size at the end of the tokenization process was reduced by 24.54%. (Attia, 2007) implemented a clitic guesser for the Arabic language in their Arabic tokenizer. European NLP systems have also been adopted to process Arabic clitics (Grefenstette et al., 2005).

Clitics have been studied for morphological processing. Indonesian cliticized words have been analyzed at the morphological level by (Larasati, 2012). Such a morphological study has been carried out for English language to decide that the English Possessive “s” is a clitic or it behaves like an affix (Lowe, 2016). (Pineda and Meza, 2005) have developed computational models for parsing and generation of clitics in Spanish language. (Goldstein and Haug, 2016) worked on the generation of Greek clitics, and for this reason they added multiple context-free grammars to c-structure. They performed various experiments and obtained good response. Pronominal clitic parsing for French has been implemented in the multilingual Fips parser. The parser is capable of differentiating between pronominal chains and the absorption of arguments in reflexive reciprocal clitics when these clitics agree with the syntactic subject (Wehrli, 2017). (Groß, 2014) used catena-based dependency morphology to analyze clitics, which is an extension of the catena-based dependency syntax. They used morph catena and hyphenation to analyze the process of cliticization.

The non-existence of automated methods for clitics’ generation in Pashto language motivated us to design clitics’ generation rules and, then, implement them as clitics’ generator using Python language. The main objective is to help develop, ultimately, an NLP application.

Clitics in Pashto

In linguistics literature, clitics are described as morphemes that are neither independent words nor morphological affixes. Syntactically and phonologically, clitics follow the host word to which they are attached. They are grouped into two (2) generic types called 2p clitics and endoclitics, where the former is further subgrouped as proclitics, enclitic (Modal) and adverbial clitics. Proclitics are prefixed to host postpositions, whereas, enclitics are suffixed to host pronoun, noun, or a prepositional phrase. Proclitics are also called oblique pronominal clitics, which are also called directional verbal clitics when they occur with the verbs only. Examples of such verbs are *leel* “to send”, *khyel* “to show”, and *bakhel* “to forgive”. Endoclitics are inserted into the root or stem of the host by splitting the root or stem into semantically deficient parts. Table 1 presents the complete list of Pashto clitics.

In general, Pashto clitics occurs in the 2p of a clause or sentence (Babrukzai, 2007). They may also occur in other different positions in sentences except at the beginning of a sentence. According to (Tegey, 1996), “2P clitics appear after the first stress-bearing phrasal constituent in the Pashto clause”. The phrasal host must contain at least one primary accent (Dost, 2005). On the other hand, an endoclitic is inserted inside a word by splitting the word into two separate non-adjacent and semantically vacuous parts. Endoclitics may not be considered morphological inflections as their semantics are not related to the host word in most cases (Din, 2013). (Bögel, 2010) analyzed that endoclitics are subject to prosodic and syntactic constraints. Logically, a clitic is placed after the first item that carries lexical stress in a sentence. Syntactically, endoclitics appear after aspect-caused stressed constituents. Morphologically, endoclitics violate the principle of lexical integrity, which states that syntactic operations may not

Table 1 Clitics in Pashto language. Enc and Pro represent Enclitic and Proclitic in given order.

Number	English	Case						Type
		Direct		Possessive		Oblique		
1 sg	I, my, me	می	mi:	Enc	—	—	ر	Pro
2 sg	you, your	دی	di:	Enc	—	—	—	—
3 sg	he/she, his/her him/her	ی	i:	Enc	—	—	در	Pro
1 plu	we, our, us	ام	m	Enc	مو	mo:	ور	Pro Pronominal
2 plu	you-all, your, you	ام	m	Enc	مو	mo:	ر	Pro
3 plu	they, their, them	ی	i:	Enc	—	—	در	Pro
—	will	به	bə	Enc	—	—	ور	o:r
—	must, should, let	دی	di:	Enc	—	—	—	—
—	indeed, but	خو	xo:	—	—	—	—	—
—	then, so	نو	no:	—	—	—	—	Adverbial
—	—	و	o:	Enc	—	—	—	Perfective
—	not	نه	nə	—	—	—	—	Negative

Table 2 The distribution of sentences of the developed corpus in different types of clitics.

Types of clitics	No of sentences
Pronominals (Proclitics and Enclitics)	97
Modal	83
Endoclitics	76
Total	256

interfere with the morphology of words (Azizud Din et al., 2012); (Kopris and Davis, 2005).

The development of cliticization rules

This section first introduces the structure of the corpus developed during this work. It then summarizes the clitics replacement options for different parts of speech along with syntactic structures, which provide basis for the generation of cliticization rules. It also enlists procedures for developing different types of cliticization rules.

Corpus design. This work developed a medium-sized corpus due to the nonexistence of such a corpus for the Pashto language. This corpus is carefully, but manually, designed from the existing work presented in Rashteen (1994); Tegey (1996); Wardak (1990). It consists of 256 sentences, which are selected from a large set of literature. Table 2 provides the distribution of these sentences based on different types of clitics. The sentences selected for cliticization in this work are morpho-syntactically annotated manually as the proposed system requires input in this format. This annotated form considered the morpho-syntactic information such as direct object, subject, strong pronouns and their cases, number, and gender. The sentences in corpus are declarative and they are all encoded using a Prolog like predicate syntax.

Table 3 illustrates example annotated sentences of different types of clitics from the developed corpus.

Developing cliticization rules. This section presents nine (9) different procedures that are used to design clitic generation rules, which are divided into five groups called: context-free clitics, context-dependent clitics, adverbial clitics, modal clitics and endoclitics, as shown in Fig. 1. Clitic generation task can be defined as the process of inserting a clitic into a sentence in place of a strong pronoun. The placement of clitic in a sentence is determined by the syntactic properties of different parts of a sentence such as verb and subject (Azizud Din et al., 2012). Based on the above mentioned design procedures, a set of eighty (80) different rules are developed for clitics' generation in this work. These rules are enlisted as in the supplementary file from serial number 0–79. Clitics placements along with the cliticization procedure(s) for different types of clitics are presented in Section “Context-free replacement rules” to “Generating endoclitics” while the design procedures are enlisted in Table 13.

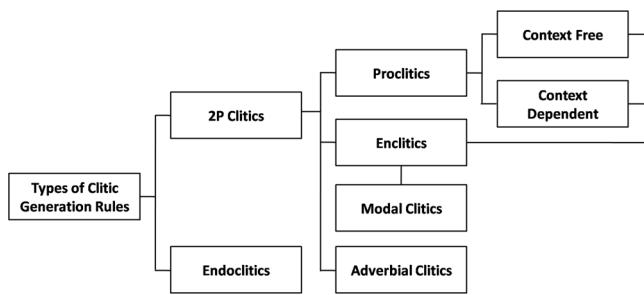
Context-free replacement rules. A context-free replacement rule is applied when a strong pronoun has to be replaced by a 2p clitic. It is called “context-free” as it requires no syntactic constraints along with the grammatical features of strong pronouns. These grammatical features are person (first, second, or third), gender (feminine or masculine) and number (singular or plural). Table 4 provides the relationship, used by the context free replacement rule, between strong pronouns and 2p clitics. The **Context-free Procedure** for the development of context free replacement rules is numbered as Procedure/Rule 1 and it is presented in first row of Table 13.

Context-dependent replacement rules. Table 5 shows the replacement rules used for the generation of syntactically constrained context sensitive clitics. The application of these rules

Table 3 Example annotated sentences of the developed Pashto Corpus.

Clitics	Examples of Manually Annotated Sentences
Pronominal Clitics	sen{txt("زه خپله خور بیا م"), output("خور می بیا م"), dob("خور", "زه", "خپله", "بیا", "م", "fem"), vb("بیا", "زه", "خپله", "p1,sng,present)}
Modal Clitics	sen{txt("زه به بشار ته حم"), output("زه به بشار ته حم"), noun("بشار", "زه"), postp("تھ", "حم"), vb("حم", "present")}
Endoclitics	sen{txt("ما پوبن کو"), output("پوبن می کو"), sp("ما"), adj("کو", "پوبن"), vb("کو", "aux"), postp("کو")}

The short terms used in the annotation of sentences include txt = raw sentence; output = target cliticised sentence; sp = strong pronoun; dob = direct object; fem = feminine; vb = verb; pl = plural; sng = singular; present = present tense; postp = post-position; and adj = adjective;

**Fig. 1** The types of clitics' generation rules.

is based on matching the syntactic constraints specified in rules with those syntactic features marked in the annotated sentence (Din et al., 2013). The pronoun is transformed into either a pronominal clitic or an oblique pronominal clitic, when all the conditions given in Conditions column of Table 5 are satisfied. If a condition cannot be met for a given pronoun, then, the default clitic is generated as shown in Table 5 by an absence of conditions.

Context dependent clitics generation is achieved using four different procedures. These procedures are termed as Procedure-2/Rule-2, Procedure-3/Rule-3, Procedure-4/Rule-4, Procedure-5/Rule-5 and they are provided in Table 13 from row 2 to 5 in given order. Procedure-5 is used for the generation of oblique pronominal clitics.

Generating Adverbial clitics. The adverbial clitics in Pashto are خو [kho] and نو [no]. Clitics خو [kho] can be added at the beginning of a sentence, where as نو [no] can be added at the end of a sentence. These clitics are different from other clitics as they do not substitute strong pronouns but are, instead, used as focus elements. The use of these adverbial clitics alters the focus of a sentence. Procedure-6/Rule 6 is used to add "kho" and "no" clitics to a sentence and it is given in sixth row of Table 13.

Generating Modal clitics. The modal clitic ټ [bə] can be inserted into a sentence to mark the obligation and future tense, respectively. These clitics cannot be substituted for a strong pronoun as they are functionally different from pronominal clitics and oblique pronominal clitics. This clitic can be added after the subject or the prepositional phrase of a sentence in present tense. However, it cannot be added in the context of past perfect of irregular verbs. To insert modal "bə" clitic in a sentence, Procedure-7/Rule-7 is used, which inserts "bə" after subject or prepositional phrase if the sentence is in present tense. The logic of Procedure-7 is given in row 7 of Table 13.

Generating Endoclitics. Endoclitic generation rules are treated separately as they are based on the morphological splitting of words. Recall that an endoclitic is a clitic that is attached inside its host. The rules of endoclitic generation are based primarily on the identification and presence of infinitives in sentences (Din et al., 2013). In Pashto language, there are five types of infinitives: (i) infinitives of ل, (ii) infinitives of ول, (iii) infinitives of يدل, (iv) infinitives of کول and (v) infinitives of کیدل.

Infinitive ل has two types. The first type consists of a single word, which cannot be divided into two morphemes, while the second type consists of two separable words. In the bi-morphemic infinitives, often the first morpheme is meaningless. Examples of infinitives having one and two morphemes are shown in Table 6. The last column of the table shows the division of the two word infinitives into separate parts as well as the insertion of a clitic in the middle.

According to the syntactic conventions of Pashto, when the infinitives end with

آل

and occur with a clitic, the perfective marker ټ is placed at the beginning next to the clitic first. Examples of application of this rule are shown in Table 7.

Infinitives ending with ول are divided into two types. In the first type, the part of the word that is attached to the final syllable ول is semanticless and cannot occur in an isolated form. An example of such a word is ګرخول, in which the first part is

ګرخ

, and has no semantic sense. In the second type of words, the first part has special meaning and can have grammatical role of an adjective or a noun. Examples of these two types of words are shown in Table 8.

The words ending with يدل do not allow endoclitic embedding. These infinitives have two types. In the first type, the first part of the word has no meaning. An example of such a word is ګرخیدل. In the second type, the first part is meaningful (adjectives and nouns). Examples of such words include ځنګیدل and توریدل. Table 9 shows a few more examples of such infinitival words.

Infinitives ending with the word کول ("to do") have also two types. The first type of infinitive needs an object, while the second type does not need any object. Examples of کول are shown in Table 10.

The clitic placement differs with the aspect. In past imperfective form, the clitic moves to the end of the word, while in past perfective form, the clitic is embedded inside the word.

Table 4 Context-free replacement rules for substituting strong pronouns with 2P clitics.

Person	Gender	Strong Pronoun → 2P Clitic	
First Person	Singular	Feminine	
(own) خپله		✓	xplə → me:
(my) زما	✓	✓	zm → me:
(my own) ما خپلی	✓	✓	m xpli: → me:
(I own) زه خپل	✓		zəpl → me:
(I own) زه خپله		✓	zəplə → me:
(yours) ستا	✓	✓	st → de:
(I own) ما خپل	✓	✓	m xpl → me:
(we) موږ	✓	✓	mo:ng → m
(we own) موږ خپل	✓		mo:ng xpl
(we own) موږ خپله		✓	mo:ng xplə
(we own) موږ خپل	✓	✓	mo:ng xpl
Second Person	Singular	Feminine	
(you own) تا خپله		✓	t xplə → de:
(you own) ته خپل	✓		təpl → de:
(you own) ته خپله		✓	təplə → de:
(you own) تاسو خپل	✓		tso: xpl → m
Third Person	Singular	Feminine	
(him) د هنہ	✓		dəə → e:
(it) دا	✓	✓	d → e:
Combined pronominals	Singular	Feminine	
(we him) موږ دهنه	✓		mo:ng dəə → m e:
(he I) هنہ ما	✓		ə → me: e:
(you mine) تا زما	✓		t zm → de: me:
(he yours) هنہ ستا	✓		əəst → de: e:
Oblique pronominals	Singular	Feminine	
(upon you) پ تا	✓	✓	pət → dr
(from you) تا نه	✓	✓	t nə → drnə
(upon me) پ ما	✓	✓	pəm → r
(to him) د	✓		d tə → o:rtə

Table 11 shows examples of the placement of clitic in the past imperfect and past perfect tenses.

Infinitives ending with the word کول (“to be”) are divided into two types. In the first type, an object is required, while in the second type, no object is required. Examples of such words are shown in Table 12.

The clitic may divide the constituents of a compound verb only when it is in perfective aspect to preserve the meaning of the sentence. Endoclitic generation is performed using two procedures: Procedure-8/Rules-8 and Procedure-9/Rule-9. The logic for these procedures is presented correspondingly in row 8 and 9 of Table 13.

The proposed Pashto clitic generator

The rules developed in previous section (Section “Developing cliticization rules”) are used for developing Pashto clitic generator in this section. An overview of different parts of Pashto clitic generator is shown in Fig. 2. It takes a non-clitic morpho-syntactically annotated sentence or a sequence of such sentences as input and, therefore, the clitic generation is considered as a post-

generation process. The proposed system produces a Pashto cliticised sentence based on two algorithms: one for 2p Clitics generation (Algorithm 1) while the other for endoclitics (Algorithm 2), as a result. Both algorithms require a set of resources such as a list of clitics, a list of pronouns, syllabification dictionary, and a set of clitics’ generation rules, in order to generate cliticised sentences of one of the two categories.

Figure 3 illustrates the cliticization process of the proposed generator with the help of an example of 2p Clitics. On the left-side of figure is an example of a Pashto sentence that is going to the process of cliticization. This input sentence is a non-clitic sentence. As mentioned earlier, the words in the input sentence need to be annotated with morpho-syntactic information. The sentence is, therefore, shown in morpho-syntactic form. The next step finds a matching cliticization rule against the structure of the sentence. The next stage produces the 2p cliticised form of the sentence. Since the given sentence belongs to 2p Clitics, it has no infinitives and, thus, the 2p Cliticised form is produced as an output of the developed parser instead of its equivalent sentence with Endoclitics.

Table 5 Context-dependent replacement rules to substitute pronouns with Pronominal clitics.

Person	Gender	Conditions	Pronoun → Pronominal Clitic
First Person	Singular	Feminine	
(own) خپله	✓	✓	dob(fem), vb(p1, plu, present) xplə → m
(own) خپله	✓	✓	dob(fem), vb(p2, sng, present) xplə → de:
(own) خپله	✓	✓	- xplə → me:
(I own) زه خپل	✓	-	- zəxpl → me:
(I own) زه خپل	-	✓	- zəxplə → me:
(I) ما	✓	✓	postp(پسیته سر) m → r
(I) ما	✓	✓	prep(پ) m → rbnde
(I) ما	✓	✓	adj(), vb(aux) m → me:
(I) ما	✓	✓	adv(), vb(aux) m → me:
(own) خپل	✓	✓	dob(mas), vb(p1,sng, present) Xpl → me:
(own) خپل	✓	✓	sub(p1), dob(mas) Xpl → me:
(own) خپل	✓	✓	dob(mas), vb(p2, plu, present) Xpl → m
(own) خپل	✓	✓	dob(mas), vb(p1, plu, present) Xpl → m
Second Person	Singular	Feminine	
(you) تا	✓	✓	postp(ت) t → drnə
(you) تا	✓	✓	postp(ت) t → Dr
(you) تا	✓	✓	prep(t → drbnde
(you) تا	✓	✓	- t → de:
(it) د	✓	✓	vb(past) D → e:
(it) د	✓	✓	vb(aux) D → e:
(you) تاسو	✓	✓	vb(plu, past) t so: → m
Third Person	Singular	Feminine	
(of his) په هغه	✓		postp(باندی), pəə → e:
(of her) په هغی		✓	postp(باندی) pəəi: → o:r
(of her) په هغی		✓	No pəəi: → e:
(of his) د هغه	✓		dəə → e:
(of his) د هغه	✓		(نه ار سره ار باندی) postp(نه) dəə → o:r
(their) د هغوری	✓	✓	(نه ار سره ار باندی) postp(نه) d əo: → o:r
(their) د هغوری	✓	✓	d əo: → e:
(of her) د هغی	-	✓	(نه ار سره ار باندی) postp(نه) d əi: → o:r
(of her) د هغی	-	✓	- d əi: → e:
(their) په هغوری	✓		postp(باندی) pəəo: → o:r
(their) په هغوری	✓		No pəəo: → e:
(he) هغه	✓		No əə → e:
(he) هغه	✓		(نه ار سره ار باندی) postp(نه) əə → o:r
(they) هغوری	✓	✓	(سره باندی) postp(سره) əo: → o:r
(they) هغوری	✓	✓	No əo: → e:
(her) هغی		✓	(باندی سره نه) postp(باندی سره نه) əi: → o:r
(her) هغی		✓	- əi: → e:

Algorithm 1 is developed that automatically generates clitic sentences that fall into 2p clitics. It takes the morpho-syntactically annotated form of an input sentence “s” that is assumed to have a strong pronoun. The algorithm explores the rules’ set one by one until it is completely exhausted. It selects a rule with a strong pronoun similar to the one in input ‘s’. The algorithm checks the morpho-syntactic constraints of the sentence against the rule, and it is used if all constraints are satisfied. In case of failure, the

algorithm moves to next rule. When an applicable rule is found, the strong pronoun is removed from the sentence and a clitic suggested by the rule is introduced at a position specified by the rule. In case, there is no matching rule in the rules’ set, the algorithm produces the input sentence as an output.

This work uses strict morpho-syntactic constraints. Therefore, the proposed clitic generator is unable to use more than one rule against a sentence. In response, the current solution is fully

Table 6 Generation rules for ل.

One word infinitives			Two words infinitives			
			Words	Division	Endoclitic	
وهل	o:əl	to beat	پوري وتل	پوري o:tl	وتنل + پوري	
تل	tll	to take	پري وتن	پري وتنل	وتنل + پري	
پال	pəll	to keep	بوتلل	بو bo:tll	تلل + بو	
خورل	xo:tł	to eat	پريپنودل	pri:go:dl	پري + پنودل	
موندل	mo:ndl	to find out	پرا نيستل	pro ni:stl	نيستل + پرا	
ژرل	ʒtł	to cry	خملاستل	tsmlɔ stl	لا ستل + خم	

Two types of infinitives for ل and Endoclitic generation.

Table 7 Rules for single word infinitives.

	Infinitive		Clitic	Endoclitic	ن	Endoclitic
و خبیل / و خکل	tskl / tʃsl / tsł	to drink (vt)	می	خبیل + می + و	خبیل + نه + و	
و چلول	ʃlo:l	to run (vt)	می	چلول + می + و	چلول + نه + و	
و روزل	ro:zl	to emphasize (vt)	می	روزل + می + و	روزل + نه + و	
و خورل	xo:tł	to eat(vt)	ام	خورل + ام + و	خورل + نه + و	
و کتل	Ktl	to look (vt)	دی	کتل + دی + و	کتل + نه + و	
ولوستل	lo:stl	to read (vt)	دی	لوستل + دی + و	لوستل + نه + و	
ولیدل	li:dl	to see (vt)	می	لیدل + می + و	لیدل + نه + و	
ولیکل	li:kl	to write (vt)	ی	لیکل + ی + و	لیکل + نه + و	
وبخیل	bi:o:l	to forgive (vt)	ی	بخیل + ی + و	بخیل + نه + و	
و خوبیتل	xo:stl	to want (vt)	ی	خوبیتل + ی + و	خوبیتل + نه + و	
و زانگل	əro:stl	to swing (vt)	می	زانگل + می + و	زانگل + نه + و	
و ریبل	e:bl r	to reap	می	ریبل + می + و	ریبل + نه + و	
و زغمل	zəml	to endure	می	زغمل + می + و	زغمل + نه + و	
و رتل	tł r	to reprimand	دی	رتل + دی + و	رتل + نه + و	
و داغل	dəgl	to mark	دی	داغل + دی + و	داغل + نه + و	
و ختل	tʂł	to lick	دی	ختل + دی + و	ختل + نه + و	
و خندل	tʂndł	to shake	ی	خندل + ی + و	خندل + نه + و	
و خیرل	tsi:rl	to tear, to rend	ی	خیرل + ی + و	خیرل + نه + و	
و سپارل	spɔrl	to endure	ی	سپارل + ی + و	سپارل + نه + و	

Table 8 Generation rules for ول.

Words with first part are meaningless	Endoclitic Generation	Two words infinitives having first part are meaningful				
		Words	Division	Word + clitic	Endoclitic Generation	
تینتول	tʃtɔ:l	و تینتول می + و	سینتول	سین + ول	سینتول + می	کرل + می + سین
غورخول	xo:rdzɔ:l	و غورخول می + و	مورول	می + ول	می + مورول	کرل + می + مور
گرخول	grdzo:l	و گرخول دی + و	چکول	چک + ول	دی + چکول	کرل + دی + چک
خندول	xndo:l	و خندول دی + و	ما تول	مات + ول	دی + ماتول	کرل + دی + مات
ژرول	ʒtɔ:l	و ژرول ی + و				
زغول	zɪlo:l	و زغول ی + و				

deterministic. The user interface of the proposed 2p clitics' generator is shown in Fig. 4.

Algorithm 1. Second Position Clitics Generator for Pashto Language.

```

Require: A syntactically annotated sentence s
Ensure: Producing a cliticised sentence or the actual sentence
//Initializations
RulesTable = Get and Assign all 2P Clitic
Generation Rules;
1: while (The RulesTable is not completely exhausted) do
2:   Select a Rule (Rule (i));
3:   if (Rule (i).StrongPronoun is in statement s) then
4:     if (s satisfies all syntactic constraints in Rule (i)) then
5:       Remove Rule (i).StrongPronoun from s;
6:       Insert Rule (i).Critic at position specified by Rule
(i).Position in s;
7:       Return;
8:     else
9:       Continue;
10:    end if
11:   else
12:     Continue;
13:   end if
14: end while

```

Table 9 Types of words ending in يدل.

Type-1	Type-2		
تېتېدل	tṣti:dl	سپنېدل	spi:ni:dl
غورخېدل	gō:rdzi:dl	مرېدل	mṛē:dl
خندېدل	xnd e:dl	جنګېدل	dʒngi:dl
گرخېدل	gr dži:dl	ماتېدل	m̥te:dl
ژرېدل	ʒrē:dl	ځغېدل	dž̥li:dl

Table 10 Types of words ending in کیدل.

Type-1	Type-2		
کول پخلا	pxl̥ ko:l	کول کر	kr ko:l
کول پری	pre: ko:l	کول زیاتې	zi:ptəj ko:l
کول پوری	po:re: ko:l	کول وابنه	o:ɒsə ko:l
کول پورتہ	po:rtə ko:l	کول ظلم	zlm ko:l

Table 11 Clitic occurrence with Type-1.

Words with clitics at the end (past imperfective)	Endoclitic generation (past perfective)
مې + کول پخلا	pxl̥ ko:l me: + پخلا
مې + کول پری	pre: ko:l me: + پری
دې + کول پوری	po:ri:ko:l de: + پوری
دې + کول خانسته	xpəjstə ko:l de: + خانسته
ې + کول پورتہ	po:rtə ko:l e: + پورتہ
ې + کولم خانسته	xpəjstə ko:lm e: + خانسته

Algorithm 2 presents the pseudocode for generating endoclitics. It works identically to the 2p Clitics generation system presented in algorithm 1 except that it searches for Informative verb (iv) in the input sentence. If an iv is found in the input sentence, then, it is split into two syllables: A and B. If the input sentence has already a clitic (clt), then, the clt is removed from the sentence and inserted between A and B. Otherwise, if the sentence has a strong pronoun, then, the clitic (clt) specified by the rule is inserted between the two syllables A and B, and the strong pronoun is removed from the sentence. For the purpose of finding the syllabification of infinitive verbs, the generator uses only a single dictionary of infinitive verbs that specifies the syllables of verbs and infinitive verbs. A portion of this syllabification dictionary is shown in Fig. 5. The user interface for the proposed Endoclitic generator is provided in Fig. 6.

Algorithm 2. Endo-Clitics' Generation for Pashto Language.

```

Require: A syntactically annotated sentence s
Ensure: Producing a cliticised sentence or the actual sentence
//Initializations
RulesTable = Get and Assign all relevant Rules;
1: while (The RulesTable is not completely exhausted) do
2:   Select a Rule (Rule (i));
3:   if (Rule (i).StrongPronoun is in statement s) then
4:     if (s contains infinitive verb (iv)) then
5:       Split iv into two syllables A and B having A as a single
syllable from syllabification dictionary (given in Fig. 5);
6:       if (s has a clitic (clt)) then
7:         Remove clt from s;
8:         Replace iv in s with A + clt + B;
9:         Return;
10:        else
11:          Remove Rule (i).StrongPronoun from s;
12:          Replace it in s with A + Rule (i).clt + B;
13:          Return;
14:        end if
15:      else
16:        Continue;
17:      end if
18:    else
19:      Continue;
20:    end if
21: end while

```

Implementation and evaluation

This section explores the implementation platform of the proposed clitics' generation system and the corpus used for its evaluation. It defines the measure used for the evaluation purposes and then discusses the evaluation results.

The implementation. Python language is used for the implementation of the proposed clitic generator in this work. It is used for its high-level syntax that allows one to manipulate strings and help develop rapid prototypes. It comes with a large set of libraries for text processing tasks such as POS tagging and syntactic parsing.

Table 12 Infinitives ending with the word خو.

Type-1	Type-2
کید ل پخا	pxlɒ ki:d 1
کید ل پری	pre: ki:d 1
کید ل پوری	po:re: ki:d 1
کید ل پورته	po:rtə ki:d 1
کید ل کر	kr ki:d 1
کید ل زیاتی	zi:vtej ki:d 1
کید ل وابهه	o:vəhə ki:d 1
کید ل ظلم	zlm ki:d 1

The Corpus used. This work evaluated the efficiency of the proposed algorithms by using a manually developed medium sized corpus of 256 sentences for Pashto language in this work. The design and structure of this corpus are provided in “Corpus Design”.

Evaluation metric. This work used a single metric called: accuracy to find out the efficiency of the proposed algorithm against different types of clitics. This work calculated the accuracy in percent(%). Accuracy is calculated with the help of Equation (1).

$$\text{Accuracy} = (\text{No. of correct sentences} / \text{total no. of sentences}) \times 100 \quad (1)$$

Evaluation and results. During the evaluation, all the 256 Pashto sentences in the selected corpus, in the annotated form presented in Table 3 except the output part, were fed to the Python-based clitic generator through the user interfaces given in Figs. 4 and 6

Table 13 Summary of 9 rules' generating procedures for two generic types of clitics: second position clitics (7 Procedures) and Endoclitics (2 Procedures).

Clitics category	Procedure no.	Rule design procedure
2p Clitics/ Proclitic/ Context Free	1	if (a strong pronoun of s matches first column of Table 2) then Replace it to its corresponding clitic given in last column; end if
2p Clitics/ Proclitic/ Context Dependent	2	if (a pronoun is found in s AND no syntactic features matches in a rule in Table 3) then Move the word on right of pronoun to its left;Replace pronoun with its corresponding clitic given in last column; end if
2p Clitics/ Proclitic/ Context Dependent	3	if (a pronoun is found in s AND syntactic features matches in a rule in Table 3) then Move the word on the right of pronoun to its left;Replace pronoun with its corresponding clitic given in last column; end if
2p Clitics/ Proclitic/ Context Dependent	4	if (a two pronouns found in the start of the s) then Move the word on the right of these pronouns to their left; Replace pronouns with their corresponding clitic given in last column of Table 3; end if
2p Clitics/ Proclitic/ Context Dependent	5	if (a strong pronoun with a postposition is found in a sentence) then Change the strong position to its equivalent oblique pronominal clitic given in last column of Table 3; end if
2p Clitics/ Adverbial	6	if (a strong pronoun in a sentence with no syntactic constraints found) then Add و [kho] at the start and ه [no] at the end of the sentence; end if
2p Clitics/ Modal	7	if (the sentence is in present tense) then Add clitic کیدل after the subject or prepositional phrase; end if
Endoclitics	8	if (a strong pronoun with infinitive is found in a sentence) then Replace the strong pronoun with its corresponding clitic between syllables A and B obtained from Syllabification Dictionary (given in Fig. 5) Replace infinitive in sentence with A + clitic + B; end if
Endoclitics	9	if (infinitive verb found in a sentence) then Split the infinitive verb into Syllables A and B as per Syllabification Dictionary given in Fig. 5 Replace infinitive in sentence with A + clitic + B; end if

2p clitics are further in four sub-categories: Context Free (1 procedure), Context Dependent (4 procedures), Adverbial (1 procedure) and Modal (1 procedure). S stands for statement.

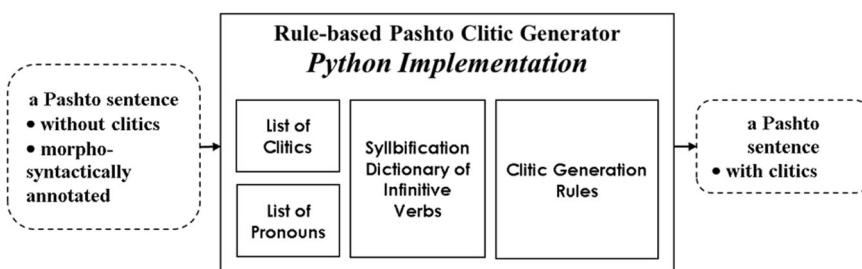


Fig. 2 An overview of the Pashto clitics' generation process.

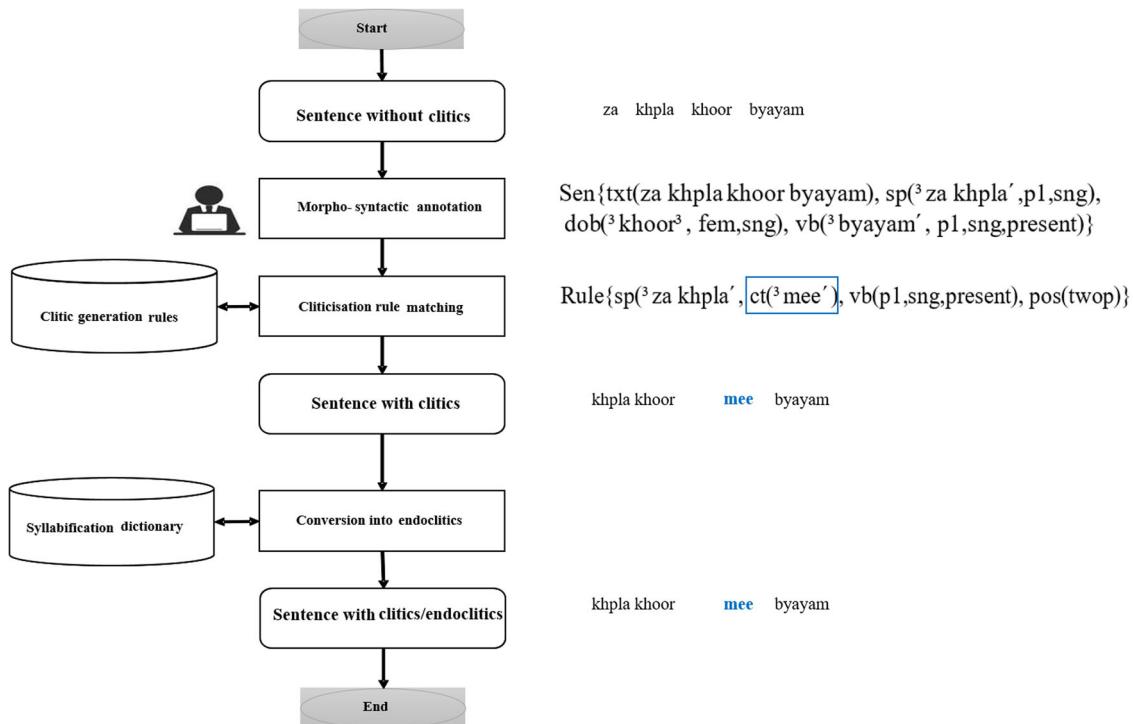


Fig. 3 Control flow of the proposed Pashto clitic generation system.

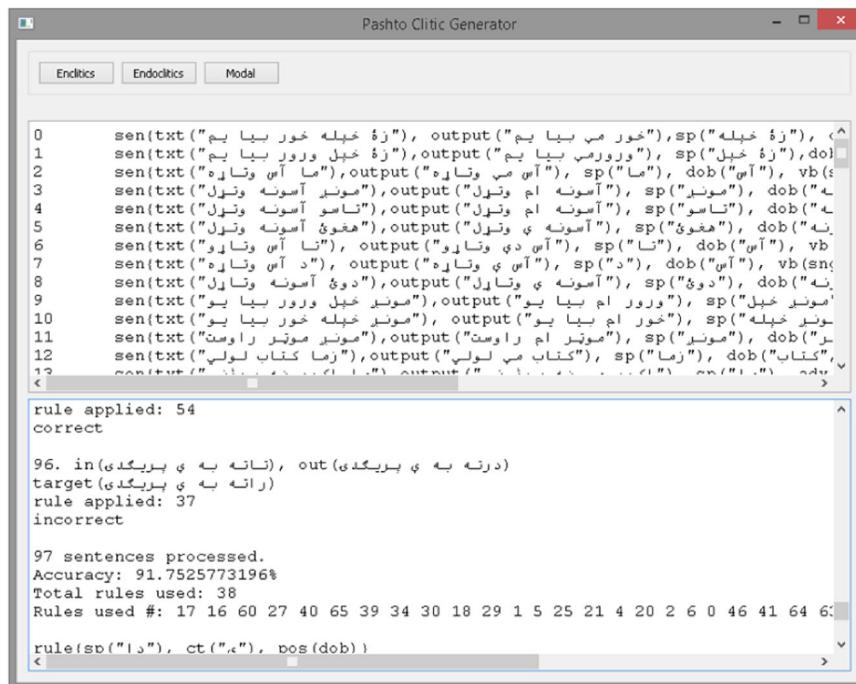


Fig. 4 User interface for input and output of the proposed 2p Clitic generator.

for 2p clitics and endoclitics correspondingly. The output of the clitic generator against each sentence is, then, compared to the output part of corresponding sentence in the Pashto corpus. If both the generated and expected sentences exactly match each other, the sentence generation is recorded as correct, otherwise, incorrect. The developed system generates the generated sentence along with summary of the rules applied and accuracy and produces in the lower half of the user interface given in Figs. 4 and 6.

The summary of results in terms of accuracy for different categories of clitics, 2p Clitics and Endoclitics in groups as well as overall responses for both categories is presented in Table 14. It shows that 73 out of 83 sentences with modal clitics were cliticised correctly, yielding an accuracy of 87.95%. Proclitics and enclitics gave 91.75% accuracy (as it correctly cliticised 89 out of 97 sentences) while the 89.47% accuracy (as it converted 68 out of 76 sentences correctly) was achieved for endoclitics. The corpus included a total of 180 sentences that fall in 2p clitics, in which

162 were correctly cliticised yielding an accuracy of 89.85%. A total of 230 sentences out of 256 in the considered corpus were correctly cliticised giving an overall accuracy of 89.72%.

The output generated by the 2p Clitics generator and Endoclitic generator given in Fig. 4 and Fig. 6 correspondingly gave a summarized insight. However, the rules used against different cases are not totally visible. Table 15 is produced to

provide this missing including total number of sentences processed, the number of rules used to process these sentences and the list of rules used in each case. It shows that Proclitics and Enclitics fired 38 rules while cliticizing the 97 sentences. The number of rules increased to 56 when 83 sentences were processed for modal clitics. However, 47 different rules were used to process 76 sentences for Endoclitics.

1	وتل#پوري	21	داغل#و
2	پري#وتل	22	ختل#و
3	بو#تتل	23	خندل#و
4	پري#پسول	24	خيرل#و
5	پر#نيستل	25	سپارل#و
6	خ#لاستل	26	تبستول#و
7	بخشل#و	27	غورخ ول#و
8	چلول#و	28	گرخ ول#و
9	روزل#و	29	خندول#و
10	خورل#و	30	ژدول#و
11	كتل#و	31	زغل ول#و
12	لوستل#و	32	سپين#کيرل
13	ليدل#و	33	مير#کيرل
14	ليکل#و	34	جک#کرل
15	بخشل#و	35	مات#کيرل
16	غوبستل#و	36	کيرل#پخلا
17	زانکل#و	37	کيرل#پري
18	ريبل#و	38	کيرل#پوري
19	زغم#و	39	کيرل#خاسئسته
20	رتل#و	40	کيرل#پورته

Fig. 5 The syllabification dictionary (partial) for Pashto language.

Conclusion and future work

Conclusion. The study explored the linguistic rules of Pashto clitics and then formalized them for automatic clitic generation. It was learned that very little computational work has been done on various aspects of the Pashto language. Several important tools that are considered helpful in processing the Pashto language are yet to be developed. The most important tools required for processing Pashto general text are a POS tagger and a syntactic parser. Pashto morphology, ambiguity and syntax are some other important areas, which must be researched in detail.

This work proposed a Pashto language clitic generator and implemented it using Python language. The system takes syntactically annotated sentences as input and applies appropriate rules, from the large set of rules developed in this work, for converting strong pronouns into clitics. Besides pronominal, oblique pronominal, modal and adverbial clitics, the developed system successfully demonstrated the generation of endoclitics. It achieved an overall accuracy of 89.72% on a test corpus of 256 sentences developed and used in this work. Individually, it cliticised proclitics and enclitics with an accuracy of 91.75%, modal clitics with an accuracy of 87.95%, and endoclitics with an accuracy of 89.47%. One of the strengths of the proposed clitic generator is post-processing nature making it capable of introducing clitics in the text generated by any method/technique. It, therefore, makes the text generation systems independent of clitic generation. The clitic generation based on post-processing effectively decouples text generation and clitic generation tasks, and thus simplifying the text generator architecture.

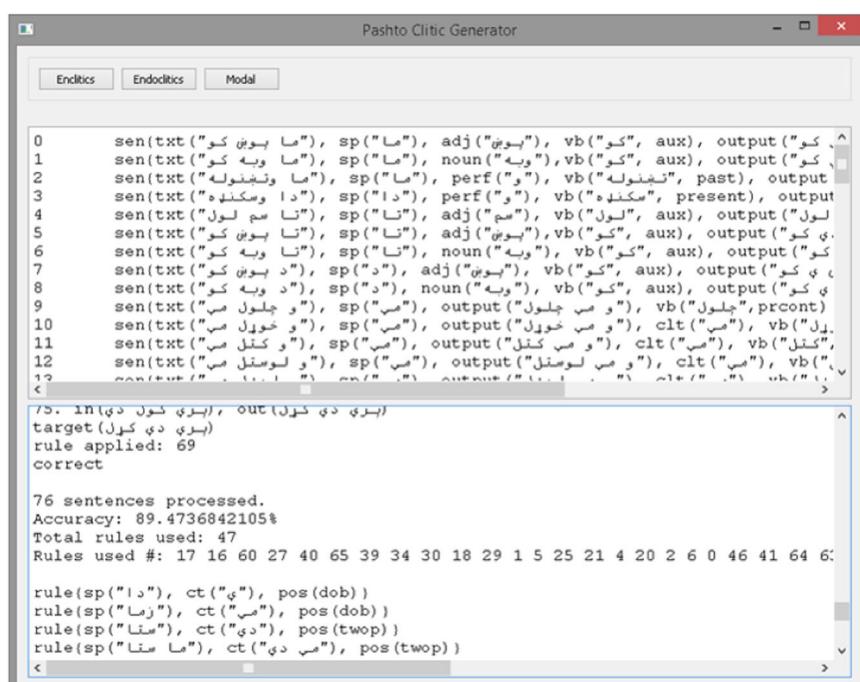


Fig. 6 User interface for the input and output of the proposed Endoclitic generator.

Table 14 Category-wise, group-wise and overall accuracy of the proposed Pashto language Clitics' generator.

Serial No.	Clitics category/group	Sentences (number)	Correctly cliticised (number)	Incorrectly cliticised (number)	Accuracy (%)
1	Modal	83	73	10	87.95
2	Proclitics and Enclitics	97	89	8	91.75
3	Endoclitics	76	68	8	89.47
4	2p Total (Serial 1 and 2)	180	162	18	89.85
5	Overall Total (Serial 1, 2 and 3)	256	230	26	89.72

Table 15 Summary of the output of the critics' rule generation system for different types of Clitics.

Clitics type	Sentences processed (Number)	Accuracy (%)	Rules used (Number)	List of rules
Proclitics and Enclitics	97	91.75	38	17, 16, 60, 27, 40, 65, 39, 34, 30, 18, 29, 1, 5, 25, 21, 4, 20, 2, 6, 0, 46, 41, 64, 63, 53, 54, 37, 66, 32, 33, 56, 58, 57, 35, 55, 38, 51 and 59
Modal Clitics	83	87.95	56	17, 16, 60, 27, 40, 65, 39, 34, 30, 18, 29, 1, 5, 25, 21, 4, 20, 2, 6, 0, 46, 41, 64, 63, 53, 54, 37, 66, 32, 33, 56, 58, 57, 35, 55, 38, 51, 59, 3, 12, 9, 8, 14, 13, 15, 7, 10, 73, 67, 70, 69, 74, 75, 71, 72 and 68
Endoclitics	76	89.47	47	17, 16, 60, 27, 40, 65, 39, 34, 30, 18, 29, 1, 5, 25, 21, 4, 20, 2, 6, 0, 46, 41, 64, 63, 53, 54, 37, 66, 32, 33, 56, 58, 57, 35, 55, 38, 51, 59, 3, 12, 9, 8, 14, 13, 15, 7 and 10

Future work. To enhance the performance of the proposed system, there is a strong need to develop resources for the Pashto language that will be identified in the future. These future directions include the:

1. development of a Pashto morphological analyzer.
2. design of a Pashto syntactic parser.
3. increase in size of Pashto annotated corpus.

Data availability

The list of rules, the corpus, and the output of the clitic generator are provided as supplementary files.

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Author contributions

Aziz Ud Din developed the corpus, cliticization rules, and clitic generation system, performed experiments, prepared initial tables and figures. Ihsan Rabbi developed the cliticization rules, performed experiments, prepared the initial draft, improved figures and tables, and approved the final draft. Umar Farooq developed the rules generation procedures and algorithms, evaluated the proposed system, analyzed the results, and prepared the final draft. Jawad Khan performed experiments, analyzed the results, and approved the final draft. Younhyun Jung designed the experiments, prepared the initial draft, and approved the final draft.

Competing interests

The authors declare no competing interests.

Ethical approval

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Informed Consent

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Additional information

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