Free Word Order in Sanskrit and Well-nestedness

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Abstract

The common wisdom about Sanskrit is that it is free word order language. This word order poses challenges such as handling non-projectivity in parsing. The earlier works on the word order of Sanskrit have shown that there are syntactic structures in Sanskrit which cannot be covered under even the non-planarity. In this paper, we study these structures further to investigate if they can fall under well-nestedness or not. A small manually tagged corpus of the verses of Śrīmad-Bhagavad-Gītā (BhG) was considered for this study. It was noticed that there are as many well-nested trees as there are ill-nested ones. From the linguistic point of view, we could get a list of relations that are involved in the planarity violations. All these relations had one thing in common—that they have unilateral expectancy. It was this loose binding, as against the mutual expectancy with certain other relations, that allowed them to cross the phrasal boundaries.

1 Introduction

Sanskrit is inflectionally rich and it rarely uses position to encode any syntactic or semantic relation between words. This enables Sanskrit to move the words freely in a sentence. Within Indian tradition, the word order was regarded as free, provided the proximity (*sannidhi*) is not violated. The Indian theorists found the sentences with different arrangements of words to be equivalent in meaning, with an exception of subject-predicate (*uddeśya-vidheya*). The difficulty in understanding the verses due to deviation from the 'default' word order, however, had been realised. The commentators commenting on the verses have followed this 'default' word order known as the *anvaya* of a verse (*śloka*)[1]. But this default word order is not followed strictly either by the commentators or by the authors while composing prose. When the Sanskrit texts started being translated into fixed word order European languages, the free word order of Sanskrit had been noted. The westerners tried to propose a framework for the Sanskrit word order. However, these studies also lead to only a preferential, or frequent arrangement, and not 'the' arrangement. The deviations were considered to be the exceptions. Even while discussing the syntax, much emphasis had been laid on the concord and government rather than order.

Though Sanskrit allows free movement of words, and there are preferential word orders, certainly not all permutations of the words are allowed. So the attention of the researchers then was drawn to the restrictions on word order rather than possible word orders. The first systematic account of the word order in Sanskrit was by Staal (1967). He introduced a concept of 'wild tree' which allows the movement of the items within a phrase freely. In this model, any two items from different phrases cannot interleave or the words in one phrase cannot leave their place and move to the domain of other phrases.

This model was formalised and empirically tested by Gillon on a corpus of approximately thousand Classical Sanskrit prose sentences. Half of the sentences of this corpus was from a single text,[2] and the other half was selected at random from the sentences found in Apte (1925). His empirical observations confirm the model suggested by Staal

[1] *ādau kartṛpadam vācyam dvidīyādipadam tataḥ |*
ktvātumunlyap ca madhye tu kuryād ante kriyāpadam ||
viśeṣaṇam puraskṛtya viśeṣyam tadanantaram |
kartṛkarmakriyāyuktam etad anvayalakṣaṇam ||
(Samāsacakra karikās 4, 10)
(English: Starting with *kartṛ*, followed by other words, placing the non-finite verb forms such as *ktvā*, *tumun*, *lyap* in between, place the main verb at the end. Starting with adjectives, targeting the headword, in the order of kartṛ-karma-kriya gives an *anvaya* (natural order of words).)

[2] Prose commentary by Dharmakīrti on the *Pramāṇavārttika*.

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with an exception of movement of genitives and adjectives across the clause boundaries.

Aralikatti (1991) studies the modern Sanskrit texts and conversations from the point of view of the flexibility in word order. He found that the modern writings and the conversations follow the default word order. Scharf et al. (2015) presents the preliminary observations with regards to the comparison of the word order in prose and verse which confirm more flexibility in verses than in prose.

In order to develop a computational parser for Sanskrit, these theoretical insights are very much useful. Kulkarni et al. (2015) studied and carried out an empirical study of the verses in Srimad-Bhagavad-Gītā(BhG). The aim of this study was to gain insights regarding the flexibility in the word order to build a computational model of grammatical sentences in Sanskrit. They could fit a weakly non-projective (or planar) model for the Sanskrit sentences, barring a few cases. One important observation was that the number of cases of violation of planarity condition in verse was higher than the number of exceptions studied by Gillon in prose. Another observation was with respect to the relations involved in the planarity violation. It was observed that in addition to the two relations viz. the adjective (*viśeṣaṇa*) and the genitive, pointed out by Gillon, a few other relations such as vocative, negation etc. also violated the planarity of the graph. But these relations were not as frequent as the genitive and adjective. At the same time, the behaviour of these relations was the same irrespective of whether the text is a prose or a verse.

These relations which do not conform to the planar graphs had a special status. A peep into the Indian theories of verbal cognition revealed that these exceptions correspond to the cases where the words have unilateral expectancy (*utthāpya ākāṅkṣā*). Such grammatically accepted sentences were studied further in order to build a proper computational model for parsing them. In this paper, we test whether the exceptions to the planar graphs fall under the category of well-nested graphs or not.

The organisation of the rest of the paper is as follows. In the next section, we describe various parameters to classify the syntactic structures mathematically. In the third section we discuss two major concepts—the concept of expectancy (*ākāṅkṣā*) and the concept of proximity (*sannidhi*)—from Indian theories of verbal cognition (*śābdabodha*) that are useful from the point of view of dependency. In the fourth section, we describe the empirical experiments we carried out to classify the cases of proximity violation. We show that the violations do occur both in the well-nested as well as ill-nested graphs and that the non-planarity is mainly due to the adjectival and genitive relations with a few cases of other non-*kāraka* relations such as negation, vocative, conjunction, etc. Finally we conclude that the *utthita* and *utthāpya ākāṅkṣā* provide a better classification for the non-planar graphs rather than well-nested and ill-nested classification.

2 Dependency Structures

In this section we present the formal definition of various mathematical structures associated with the dependency. The dependency parse of a sentence is expressed in the form of a tree structure. This tree is a Directed Acyclic Graph with one root node, and all other nodes connected to at least one other node in the tree by a direct edge.

2.1 Projectivity Principle

The principle of projectivity imposes certain constraints on the dependency tree which bans certain dependency structures.

> A sentence is projective if and only if we can draw a dependency tree whose every node can be projected by a vertical line onto its word form in the surface string without crossing another projection or a dependency edge.

Thus, if A depends directly on B and some other element C intervenes between them (in linear order of string), then C depends directly on A or on B or on some other intervening element. Thus the projectivity requires the node to dominate a continuous substring of the sentence and bans on discontinuous constituents. The intuitive 'wild tree' notion of Staal comes very close to this projectivity principle. Dependency grammars that allow only projective structures are closely related to the context-free grammars (Gaifman, 1965), and hence can be parsed in cubic time (Eisner, 1996).

It was noticed that there are certain constructions in natural languages that do not fit in with the dependency tree satisfying the projectivity principle. Hence the constraint was further relaxed, so as to allow some non-projectivity. Figure 1 shows one dependency graph exhibiting non-projectivity.

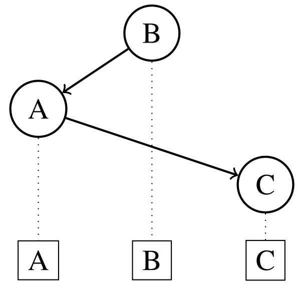

Figure 1: Non Projective Graph

2.2 Weak Non-projectivity (Planarity)

A dependency tree is weakly non-projective if there is no crossing among the relation edges when plotted on one side of the sentence (either above or below). This is also a planar graph. The planar graph in computational linguistics is the same as the one from the computer science with one modification that all the edges are drawn on the same side (either above or below) of a sentence. Thus a dependency graph is planar, if it does not contain nodes i, j, k, l such that $i < j < k < l$ and $edge(i, k)$ and $edge(j, l)$.

For example, Figure 1 shows the crossing of a dependency relation with the projection. But the same dependency relations when drawn with words arranged in a linear order and the edges drawn above the sentence, the crossing disappears (See Figure 2).

Figure 2: Planar dependency graph for (1)

2.3 Well-nestedness

The well-nested constraint imposes restrictions on the positioning of the disjoint sub-trees. Two trees are called disjoint if neither of their roots dominates the other. Two subtrees T_1 and T_2 interleave, iff there are nodes l_1, r_1 of T_1 and l_2, r_2 of T_2, such that $l_1 < l_2 < r_1 < r_2$. A dependency graph is well-nested, iff no two of its disjoint subtrees interleave. If the two trees that interleave are not disjoint, that is if the root of one tree governs the root of the other tree, then the interleaving of edges in such trees is allowed. Dependency trees which have overlapping edges across disjoint subtrees are considered as ill-nested.

Figure 3 is well-nested, because the edges $1 \rightarrow 3$ and $2 \rightarrow 5$, of the two disjoint trees $1 \rightarrow 3 \rightarrow 4$ and $2 \rightarrow 5$, interleave, but the node 1 of the first tree governs the node 2 of the second tree.

In Figure 4, the edges $3 \rightarrow 5$ and $2 \rightarrow 4$ interleave, and neither 2 nor 3 is governed by the other. Hence this is an ill-nested tree.

In Figure 5, the edges $1 \rightarrow 3$ and $2 \rightarrow 5$ interleave, and again neither 1 nor 2 govern the other. Hence this is also an ill-nested graph.

All projective trees are weakly non-projectives and all weakly non-projective trees are well-nested by definition.

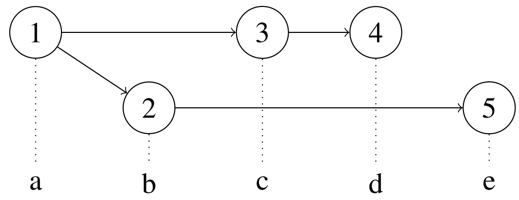

Figure 3: Well-nested graph

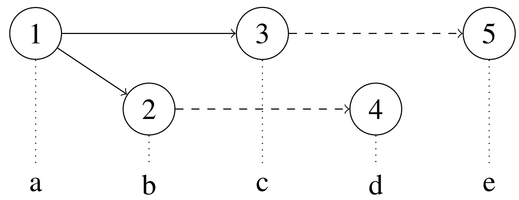

Figure 4: Ill-nested graph

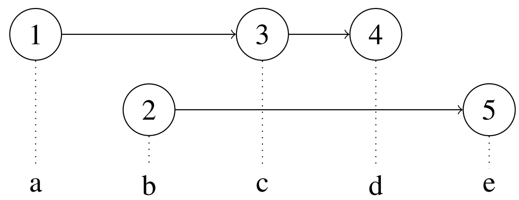

Figure 5: Ill-nested graph

In the next section, we look at some linguistic concepts that are useful for understanding the potency of various dependency relations in the interleaving.

3 Indian Theories

According to the exegesists (*mīmāṃsakas*) a sentence is defined as

> *arthaikatvāt ekam vākyam*
> *sākāṁkṣam cet vibhāge syāt | MS 2.1.46*

(A sentence is an integral unit conveying a single purpose, and when it is split into two parts, some words in one part would have an expectancy for

some other words in the other part.)
This implies that each word in a sentence either satisfies an expectancy of or has an expectancy for some other word in a sentence. That is every word in a sentence should be connected with at least one other word in it. Let us represent the words in a sentence by the nodes, and the expectancies between words by edges joining the nodes. Two nodes connected by an edge do not have the same status. One of them has an expectancy and the other one satisfies the expectancy. Hence we use directed edges to mark this asymmetry.

3.1 Expectancy and Proximity

Indian grammatical texts discuss two kinds of expectancies—*utthita* and *utthāpya*. The expectancies which are mutual, direct and natural are termed *niyata/utthita ākāṅkṣā* (restricted or risen expectancy) (Kunjunni Raja, 1963). The expectancy between a verb and the words denoting kārakas or between relational words falls under this category. In a Sanskrit sentence '*dvāram pidhehi*' (close the door), the verb 'close' has an expanctancy of a *karma* (object) which is fulfilled by the word '*dvāram*' (the door). Inversely, a verb is expected with the word 'door' mentioning what to do with the door. Expectancies of *kāraka* relations are mutual. In contrast to mutual expectancy, the expectancy that is unilateral is called *aniyata* or *utthāpya ākāṅkṣā* (unrestricted or to be raised). This is aroused only if necessary. So it is potential. For example, in a phrase such as 'white cow', the expectancy of 'white' for a noun is natural, but the expectancy of 'cow' to have an adjective is potential. It gets aroused only in the presence of an adjective such as 'white'. Even a noun in apposition may arouse an expectancy. Similarly, a noun in genitive arouses an expectancy of another noun. And this expectancy is uni-directional and not mutual.

Another concept from the Indian grammar viz. *sannidhi* (proximity) puts certain constraints on the word order. It states that the words that are related to each other should not be intervened by other words.

The proximity, along with the expectancy was further studied by Kulkarni et al. (2015). They carried out an empirical evaluation of a manually annotated corpus to understand the nature of this ban on crossing of dependency relations. They found that one of the relations involved in the crossing of edges was corresponding to the unilateral expectancy. A few cases were also found where both the relations involved had mutual expectancies.

In this paper, we study these cases where the planarity constraint is violated and investigate if these cases of violations are well-nested or not.

4 Dependency Graphs and Planarity

Sanskrit is inflectionally rich. So the common wisdom is that we can move around the words in any order. For example, the following sentence with three words,

(1) *śvetaḥ aśvaḥ dhāvati*
White horse runs

can have 3! (=6) permutations. But among these the following permutation, for example,

(2) *aśvaḥ dhāvati śvetaḥ.*
A_horse runs white.

is non-projective (See Figure 6).

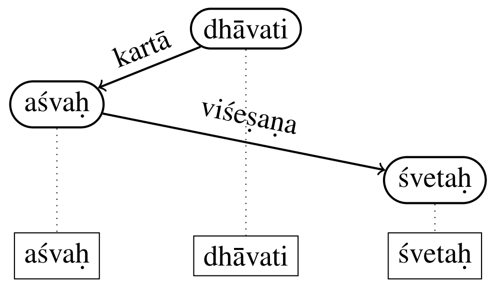

Figure 6: Non Planar Graph

However if the relation edges are plotted above the sentence, we notice that it produces a planar graph (See Figure 7).

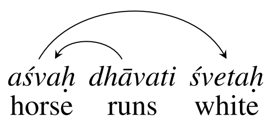

Figure 7: Planar dependency graph for (2)

But every non-projective graph may not produce a planar graph. For example, consider sentence (3).

(3) *Rāmaḥ* *dugdham* *pītvā*
Rama{nom.} milk{acc.} drink{abs.}
śālām *gacchati.*
school{acc.} go{3p.sg.}.

Rama goes to school after drinking milk.

This sentence has 5 words. But not all the 5! (=120) combinations are meaningful. The following sentence obtained by permuting the words in the above sentence is not meaningful.

(4) **Rāmaḥ* *śālām* *dugdham*
Rama{nom.} school{acc.} milk{acc.}
gacchati *pītvā.*
go{3p.sg.} drink{abs.}.

*Rama to school milk goes drinking.

It not only violates the projectivity principle, but even the graph is non-planar as there are crossings (See Figure 8). And this sentence is grammatically ill-formed.

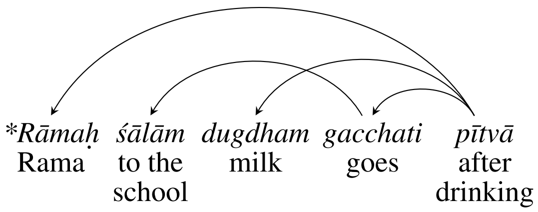

Figure 8: Planar dependency graph for (4)

On the other hand, the sentence (5) below has a non-planar graph and the sentence is grammatically well-formed.

(5) *eṣaḥ vāk-viṣaya-bhūtaḥ saḥ te vīraḥ.*
This speech-topic-become he your hero.

This is the hero who has become the topic of your speech.

In this sentence, the demonstrative adjective '*saḥ*' modifying a predicate noun '*vīraḥ*', intervenes between its predicate '*bhūtaḥ*' and the agent (*kartā*) of the 'speech' (*vāk*) viz. '*te*', as shown in Figure 9.

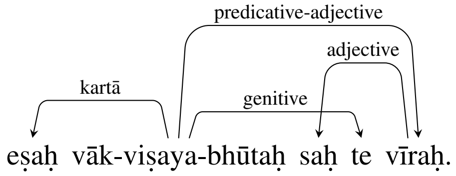

Figure 9: Planar dependency graph for (5)

Below is a part of a verse from Śrīmad-Bhagavad-Gītā (BhG) that exhibites similar phenomenon.

cañcalam hi manaḥ kṛṣṇa
pramāthi balavat dṛḍham |
tasya aham nigraham manye
vāyoḥ iva suduṣkaram || BhG 6.34

(English: For, O Krishna, the mind is unsteady, turbulent, strong and obstinate, I consider its control to be as difficult as of the wind.)

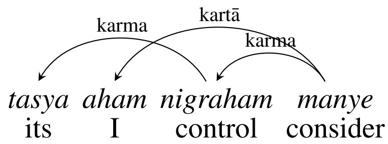

Figure 10: Analysis of BhG 6.34

In the second line of this verse the main verb is '*manye*' (consider) whose *kartā* is '*aham*' (I). The *karma* of the verbal noun '*nigraham*' (control) is the pronominal '*tasya*' (its), which refers to '*manaḥ*' (mind) in the first part of the verse. Thus the word sequence '*tasya aham nigraham manye*' produces two crossing edges involving the relations of *kartā* and *karma*.

Let us see one more example. This is 18th śloka of 10th chapter.

vistareṇa ātmano yogaṁ
vibhūtiṁ ca janārdana |
bhūyaḥ kathaya tṛptiḥ hi
śṛṇvato nāsti me'mṛtam || BhG 10.18

(English: O Janardan, tell me again elaborately your own yoga and manifestations. For, I'm not satisfied when I listen to your immortal words.)

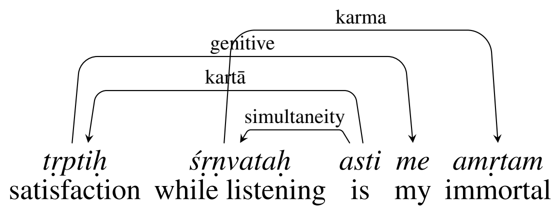

Figure 11: Analysis of BhG 10.18

In this verse, again we look at the second part of the second line in the verse. The *kartā* of the main verb '*asti*' (is) is '*tṛptiḥ*' (satisfaction), the *karma* of '*śṛṇvataḥ*' (while listening) is '*amṛtam*' (immortal), and there is a genitive relation between '*me*' (my) and '*tṛptiḥ*' (satisfaction). We see two crossings, one between the *kartā* and *karma*, and the other between genitive and *karma*.

There is an important difference between the crossing in Figures 9, 10 and 11 though all of them are grammatically sound. In Figure 9 the relations involved in crossings are genitive and adjective. In Figure 10 the relations are *kartā* and *karma*, which are the arguments of the verb, called *kāraka* relations in Sanskrit grammar. So in one sentence, there is a crossing between two *kāraka* relations. In another, the crossing is between non-*kāraka* relations. As we have seen earlier, the *kāraka* relations have mutual expectancies, while the non-*kāraka* relations such as genitive and adjective have unilateral expectancy. And in Figure 11, we see both types of crossings. Further we notice that while the graphs of Figure 9 and Figure 10 are well-nested, the graph of Figure 11 is ill-nested.

Now we describe the empirical observations of the dependency trees of BhG with special reference to the crossings involved and the well-nestedness.

4.1 Experiment

Sanskrit is a low resource language from the point of view of computational resources. For this experiment, we needed treebanks. A treebank developed under SHMT[3] consists of simple prose sentences, which hardly shows any crossings. There are some efforts to develop treebanks following the Universal Dependency (UD) (Hellwig et al., 2020). Since we aim at using the Pāṇinian grammar, the UD treebanks were not useful for our experiment. Therefore we decided to base our experiments on the same treebank that was used by Kulkarni et al. (2015). This treebank consists of verses from Śrīmad-Bhagavad-Gītā. It has 700 verses. Some verses were made up of more than one sentence while in some cases more than one verse formed one sentence. We followed the mīmāṁsaka's definition of a sentence given in section 3.

There were several ślokas which consisted of more than one sentence with an ellipsis of one or more word. For the evaluation purpose, we considered only complete sentences. So all the sentences with ellipsis of the verbs were not considered. For example, the first part of the verse BhG 1.15

pāñcajanyam hṛṣīkeśaḥ
deva-dattam dhanañjayaḥ |

consists of two sentences,

[3]A project funded by Meity for the Development of Computational Tools and Sanskrit-Hindi Machine Translation.

(a) *pāñcajanyam hṛṣīkeśaḥ (dadhmau)*
Pāñcajanya Hṛṣīkeśa (blew)

(b) *deva-dattam dhanañjayaḥ (dadhmau)*
Devadatta Dhanañjaya (blew)

There are two sentences, and both of them require a verb '*dadhmau*', which is to be borrowed from the next part. Such parts of verses which are devoid of a verb are not considered for the evaluation.

Similarly, in Sanskrit, the copula is absent. The tagging scheme demands the presence of a verb, and therefore, while tagging the verses, the copula is provided. Since in the original verses the copula is absent, we have not considered these verses/part of these verses where such copula is provided manually.

In order to decide whether the dependency graph is well-nested or not, we need to distinguish between the relations that show governance from those that do not show governance. All the relations that have mutual expectancy show governance. Table 1 lists all the relations that have mutual expectancy, and Table 2 shows all the relations that have only unilateral expectancy.

kartā	kartṛsamānādhikaraṇam
karma	karmasamānādhikaraṇam
karaṇam	sampradānam
apādānam	adhikaraṇam

Table 1: Relations with mutual expectancies

sambodhyaḥ	sambandhaḥ
śaṣṭhīsambandhaḥ	viśeṣaṇam
samuccitam	pratiṣedham
samuccayadyotakaḥ	nirdhāraṇam
prayojanam	hetuḥ
samānakālaḥ	pūrvakālaḥ
kriyāviśeṣaṇam	

Table 2: Relations with unilateral expectancies

In Figure 3, the edge $1 \rightarrow 3$, which crosses the edge $2 \rightarrow 5$, should be from Table 1. If either $1 \rightarrow 3$ is not from Table 1, or the two edges belong to two disjoint trees as in Figure 5, then the dependency graph is ill-nested. With the set of relations as described in Tables 1 and 2 we classified the dependency graphs of BhG verses. Table 3 shows the results of this empirical study.

Analysed sentences	1396	100.00%
Weakly non-projective	1153	82.59%
Only Well-nested	49	3.51%
Only Ill-nested	74	5.30%
Both Ill and well nested	120	8.60%

Table 3: Analysis of BhG

5 Discussions

The majority of the sentences (around 83%) have dependency graphs that are weakly non-projective. The remaining 17% graphs did not have planar graphs as they involved crossings of the dependency relations. Several of the sentences had more than one crossing. Some of these crossings show well-nestedness while the others show ill-nestedness. We notice that trees with only well-nested crossings are considerably less than trees with only ill-nested crossings. Further, there are almost double the number of sentences that have both ill-nested as well as well-nested crossings. Any graph, that involves both ill-nested as well as well-nested crossings, essentially is an ill-nested graph. Thus we notice that almost 14% of the sentences have ill-nested graphs. Thus every sixth sentence of the corpus has a non-planar graph, involving crossings between the disjoint graphs, with the majority of them being ill-nested. In order to understand more about these crossings, we looked at the relations involved in them. Table 4 shows the distribution of relations with mutual and unilateral expectancies in crossings.

We noted down the relations involved in crossings, and counted the number of instances of crossings that show well-nestedness or ill-nestedness. As expected, we noticed that, barring a few cases, at least one relation among the two relations involved in crossing has unilateral expectancy. Kulkarni et al. (2015) has discussed various examples of crossing where both the relations are with mutual expectancy.

Relations	Well-nested	Ill-nested
Mutual×Mutual	3	15
Mutual×Unilateral	109	136
Unilateral×Unilateral	82	99

Table 4: Relations involved in crossings

Now we provide one example each of the crossings with unilateral expectancies. The first one corresponds to a well-nested graph involving a crossing between a *kartā* and a *viśeṣaṇam*. This is from the first line of *śloka* 7.2.

jñānam te aham sa-vijñānam
idam vakṣyāmi a-śeṣataḥ |

(Eng: I will tell you this knowledge combined with realisation in detail.)

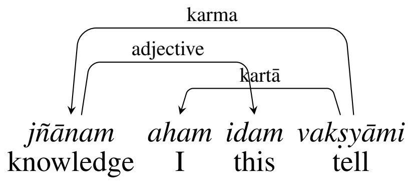

Figure 12: Analysis of BhG 7.2

In this tree, the two edges labelled adjective and *kartā* belong to two disjoint trees, and the head node '*vakṣyāmi*' of the *kartā* relation governs the head node '*jñānam*' of the adjectival relation. Hence this is a well-nested tree with a crossing between a relation of *kartā* having mutual expectancy with a relation of adjective having unilateral expectancy.

Now we present another example. This is 21st *śloka* from the same 7th chapter.

yaḥ yaḥ yāṁ yāṁ tanuṁ bhaktaḥ
śraddhayā arcitum icchati |

(Eng: Whichever form any devotee wants to worship.)

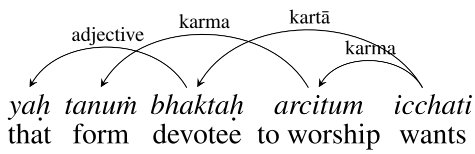

Figure 13: Analysis of BhG 7.21

In this dependency graph, we notice that there is a crossing between *karma* and an adjective, and neither of the heads governs the other, giving rise to an ill-nested graph. This graph also shows another crossing between a *kartā* and a *karma* relation, which corresponds to the well-nested graph.

Now we present two examples, where both the relations have unilateral expectancy. The first one is a well-nested graph which corresponds to the 4th *śloka* of 18th chapter.

niścayaṁ śruṇu me tatra
tyāge bharatasattama |

(Eng: O the most excellent among the descendants of Bharata, hear from me the firm conclusion regarding the abandonment.)

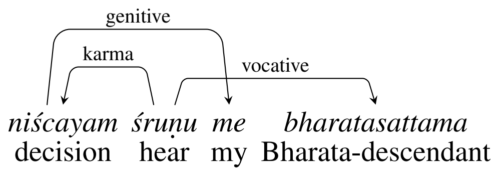

Figure 14: Analysis of BhG 18.4

In this graph, there is a crossing of two unilateral relations viz. genitive and vocative. The graph is well-nested, as the head of the genitive is governed by the head of the vocative relation.

The example of an ill-nested graph involving two unilateral relations is the first *śloka* of the 9th chapter.

idam tu te guhyatamam
pravakṣyāmi anasūyave |
jñānam vijñānasahitam
yat jñātvā mokṣyaseaśubhāt || BhG 9.1

(Eng: I shall now reveal to you the non-envious, the greatest secret, the knowledge combined with realisation, having known which you shall be free from evil.)

We show the partial graph with crossing relations.

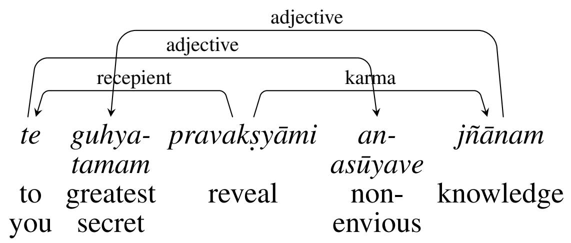

Figure 15: Analysis of BhG 9.1

In this graph, we see three crossings. The first one between the recipient and the adjective, the second one between the *karma* and the adjective, and the third one between the two adjectives. The first two crossings correspond to the well-nested graph. But the third one corresponds to the ill-nested one.

Finally, among the unilateral relations that contribute to either well-nested or ill-nested graphs, adjective, vocative, genitive and negation are prominent, followed by conjunction. Among the relations having mutual expectancy, *kartā*, *karma* and *adhikaraṇaṁ* are more prominent.

6 Conclusion

Sanskrit, as the common wisdom goes, is a free word order language. The Calder mobile model of Staal which conjunctures the free movement of the words within a phrase was found to be partially correct. Gillon through empirical study pointed out that there are certain cases of violation of this model. Later Kulkarni et al, again through the empirical study showed that the cases of violations of planarity correspond to the relations exhibiting unilateral expectancy. In this paper, we showed that there are as many cases of well-nested crossings as ill-nested ones. Thus not all syntactic structures of Sanskrit can be covered under the well-nested trees. A majority of non-planar graphs are ill-nested. In most of the cases, unilateral relations are involved in the violation of planarity as well as well-nestedness.

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