Generation of Sanskrit Compounds

Pavankumar Satuluri
University of Hyderabad
pavankumarsatuluri@gmail.com

Amba Kulkarni
University of Hyderabad
apksh@uohyd.ernet.in

Abstract

Sanskrit is rich in compound formation. Pāṇini's grammar has more than 400 rules that deal with the semantic conditions governing the compound formation and the grammatical process involved in the compound formation. In this paper we rewrite the grammar as a combination of phrase structure rules and the regular grammar and list various semantic features as constraints governing the formation of compounds in Sanskrit.

1 Introduction

Compounds play a vital role in any language. They provide a compact way of expressing the thoughts. On the one hand they bring in brevity in the language expressions and on the other hand they make the language rich both at the lexical level as well as at the structural level. For the languages that are rich in compound formation, compound analysis and generation becomes an important and essential component of any Natural Language Processing system.

In Indian grammatical tradition, there is abundant discussion of compounds both at the level of *prakriyā* 'the compound formation involving morphology and phonology', and also at the level of *artha* 'meaning analysis'. The *samarthāhnika* of (Joshi, 1968) gives a detailed account of the discussion involved in the Indian tradition on the semantic compatibility of components and the compositionality of the meaning of a compound from its components. (Pataskar, 1996) has discussed the analysis of the compounds particularly Dvandva (co-ordinative) related sūtrās with their case endings. (Mahavir, 1986) describes the process of generating a compound from its paraphrase (*vigrahavākya*). *Siddhāntakaumudī*(Bhaṭṭojidīkṣitaḥ, 2001) provides the details of various stages involved in the compound processing. And the book worth mentioning is *Pāṇinīyavyākaraṇodāharaṇakośaḥ* (Grimal et al., 1995) which contains the complete derivation of all the compounds that have appeared in the Sanskrit grammar books, along with the details of sūtras used at various stages. The semantic classification of compounds given by Pāṇini is not only restricted to Sanskrit language per say, but is universal. For example, the Cambridge grammar of the English Language (Huddleston and Pullum, 2002) uses this classification to describe compounds in English. Compounds are always binary with an exception of conjunctive and some exo-centric (*Bahuvrīhi*) compounds. Individual components of the compounds can themselves be compounds, thus allowing a recursion in the formation of compounds. For understanding such compounds the underlying constituency structure is important. (Gillon, 2009) proposes an extended phrase structure syntax to represent the underlying constituent structure of the compounds.

The computational analysis of Sanskrit compounds has been described in (Kumar and Kulkarni, 2013; Kumar et al., 2010; Kulkarni and Kumar, 2011). While this system uses Pāṇini's rules for identification of the type and analysis of exceptional compounds, the frequent compound type identification and analysis is done using the statistical properties of the corpus. (Goyal and Huet, 2013) describe various morphological phenomena involved in the generation and analysis of *avyayībhāva* compounds making their analysis more-or-less

complete.

In this paper we describe the process of compound formation, as described in the Pāṇinian tradition, and present it as a phrase structure grammar. All the sūtras from Pāṇini's Aṣṭādhyāyī that deal with the compound formation are studied. They are classified into two sets: the ones which designate a technical term to the input string or a part thereof, and the others which transform the input string into another. The first type of sūtras, in Pāṇinian tradition are termed as *sañjñā* sūtras while the others are termed as *vidhi* sūtras.

In the second section, we describe the compound formation process as described in the tradition. In the third section, we describe this process as a phrase structure grammar with the sūtras designating technical terms expressed as context free rules and the vidhi sūtras as regular expressions. In the fourth section, we brief about the various semantic information needed by the compound formation rules, and finally we classify this semantic information adapting the ontological classification system suggested by (Nair et al., 2013).

2 Compound Formation: Some observations

The formation of a compound involves various changes at morpho-phonological level such as deletion of the case suffixes, sandhi operation, change of accent etc. We illustrate below various operations involved in compound formation.

1. In the formation of *rājapuruṣaḥ* (king's servant), for example, the case suffix of the first component (*rājan* 'king') has disappeared and the 'n' at the end of the stem 'rājan' has also been deleted.

2. Consider the compound *rāmālayaḥ* formed from *rāmasya ālayaḥ* (Ram's abode). Here, in addition to the deletion of case suffix, there is also a sandhi formation *rāma + ālaya = rāmālayaḥ*.

3. In case of co-ordinative compounds such as *rāmakṛṣṇau* (Rama and Krishna) formed from the phrase *rāmaḥ ca kṛṣṇah ca*, in addition to the deletion of the case suffix of the first word, the resulting number (*vacanam*) of the compound is changed to dual.

4. Another interesting phenomenon we come across is the change of the gender. For example consider a phrase *pācikā bhāryā yasya saḥ* (a man whose wife is a cook). The compound form of this phrasal expression is *pācikābhāryaḥ* where the word *bhāryā* which was in feminine is changed to a masculine form *bhārya* since the compound now refers to a male person and *bhārya* is the head of the compound.

5. Then there are certain exceptional cases where there is no elision of the case suffix of the first component as in *yudhiṣṭiraḥ*. Here the locative case suffix of 'yudh' is retained in the compound as well.

6. In some cases, after the compound formation, the compound looses its ability to undergo inflections, and it behaves like an indeclinable. For example *kṛṣṇasya samīpam* (near Kṛṣṇa) is compounded as *upakṛṣṇam* and is in neuter gender and is an indeclinable. One can not use *upakṛṣṇa* as a stem and add certain other case markers to it. Hence, for example, *upakṛṣṇāya* is not possible.

7. During the compound formation, the accents on the components also change. For example a phrase '*rāmaḥ eva īśvaraḥ yasya saḥ (The one for whom Ram is the God) → rāmeśvaraḥ*' as Bahuvrīhiḥ (exo-centric) will have the same accent as that of *rāma*, while a phrase '*rāmasya īśvaraḥ (God of Ram) → rāmeśvaraḥ*' as a Tatpuruṣaḥ (endo-centric) will have a high pitch at the end, though the resulting phonological form the compound is same in both the cases.

8. Finally, deciding the order of components is also important. Change in the order may change the meaning of a compound. For example *mṛttikāghaṭaḥ* (clay-pot) means a pot made of clay while *ghaṭamṛttikā* (pot-clay) means the clay for pot.

Thus the process of compound formation involves various steps such as deletion of case

marker, deciding the order of the components, sandhi operation between the components, deciding the number and gender of the compound thus formed, and finally deciding the accent mark. Pāṇini has given rules for each of these steps. These rules are scattered at various places in the Aṣṭādhyāyī. A part of the first two chapters set conditions for forming the compounds, and a part of the fifth and sixth chapters provide rules for various transformations that take place in the string during the compound formation. We give below a step by step procedure followed by the tradition for deriving a compound from its paraphrase.

3 Compound Formation : Pāṇinian Procedure

Compounds being an important part of the language, Pāṇini deals with them very thoroughly handling the exceptional cases in great detail. Out of around 4000 sūtrās in Aṣṭādhyāyī a little more than 400 sūtrās deal with the compound formation. These rules are scattered at various places in the Aṣṭādhyāyī. We describe below the compound formation process followed by the Pāṇinian tradition.

1. 'Conceptual input' (*Alaukika vigraha*)
   The governing sūtra for compound formation is *samarthaḥ padavidhiḥ* (P2.1.1) which puts a semantic condition on compound formation. A compound is formed only if the meanings of the components are compatible. The compound formation is purely under the dictum of the desire of a speaker (*vaktṛvivakṣādhīnam*). Of course, only if the language and hence the grammar allows such formation, a speaker can form a compound. In other words, there should be some rule in the grammar, which guarantees the formation of a compound with given components and meanings. So for example, assume that a speaker wants to express the concept 'a person who is a servant of a king'. Then he has three basic conceptual elements viz. a person, a king and the servant-master relation between them. The sūtra *ṣaṣṭhī* (P2.2.8) sanctions the formation of a compound if one of the word is in genitive. In order to form a compound, now the paraphrase is expressed as

   $$rājan + ṅas\ puruṣa + su$$

   where the words *rājan* and *puruṣa* denote the objects 'a king' and 'a person', and the suffix *ṅas* represents the relation between these two elements. This representation called as an *alaukika vigraha* is the starting point of the derivation of a compound. This *alaukika vigraha* now gets a designation *samāsa*. For a *Bahuvrīhi* (exo-centric) compound with a paraphrase

   pītaṃ ambaraṃ yasya saḥ
   Eng: The one whose cloth is yellow

   the *alaukikavigraha* is

   $$pīta + su\ ambara + su$$

   where *su* is the nominative case marker and *pīta* (yellow) and *ambara* (cloth) are the nominative stems. The pronouns *yasya* (whose) and *saḥ* (he) do not appear in the *alaukikavigraha*.

   There are certain pre-positions that are employed when the resulting compound is of the type *avyayībhāva*. E.g. the *alaukikavigraha* of *kṛṣṇasya samīpam* (near Kṛṣṇa) is

   $$kṛṣṇa + ṅas\ upa$$

   The prefix *upa* is used in the sense of near, and is an indeclinable. *Kṛṣṇa* is the nominal stem and *ṅas* is the case marker for genitive singular.

2. Adding special suffixes related to compounds (*samāsānta pratyayas*)
   There are certain suffixes which are added to the compound at the end. These are called *samāsānta pratyaya*s. These are added at the end of the *alaukika vigraha* and are treated as a part of a compound. For example the *sūtra avyayībhāve śaratprabhṛtibhyaḥ* (P5.4.107) adds a *ṭac* suffix if the compound is of type *avyayībhāva* with one of

the word from the list starting with *śarad*. *śarad + ṅas upa → śarad + ṅas upa tac.*

3. Deciding the word order (*upasarjana*)
   The head of a compound more-or-less depends on the type of a compound. The *Tatpuruṣa* (endocentric) compound has second component as the head while the *Avyayībhāva* has the first component as the head. In case of *Bahuvrīhi* (exocentric) it becomes an adjective with the head being the one which is modified and in case of conjunctive compounds, both the words together are heads. In Pāṇini's grammar he labels the component which occupies the first place by the term *upasarjana*. The designator of a word in nominative case in the rule that decides the compound type is the one which gets the designation *upasarjana*.

4. Change of word order (*pūrvanipātaḥ*)
   The result of assigning a label *upasarjana* is termed as *pūrvanipātaḥ*. At this stage, the word with a designation *upasarjana* occupies the first position. For example consider the input

   śarad+ ṅas upa

   The sūtra[1] which sanctions the compound formation consists of two words. The word *avyayam* in the sūtra is in nominative. Hence that word in the *alaukika vigraha* which is an *avyaya* gets a designation *upasarjana*. In the above example *upa* is an avyaya, and therefore *upa* gets a designation *upasarjana*, and it occupies the first place. This changes the order of the input string to

   upa śarad + ṅas.

5. Declaring the string to be a nominal stem (*prātipadikasañjñā*)
   At this point, now the stage is set to generate a new nominal stem (*prātipadikam*) from this expression and thus the whole expression is designated with a label *prātipadikam*[2].

6. Non-deletion of case suffixes (*aluk kārya*)
   There are certain exceptional cases, when the case suffix of the involved words do not get elided[3]. For example,

   yudh + ṅi[4] *sthira + su → yudhi sthira.*

   In all other cases the case suffixes are elided. So at this stage, the conditions of *aluk* are checked. If the conditions are satisfied, then

   - The first word is formed following the word formation rules.
   - The case suffix of the second word is deleted.

   If it is not an exceptional case, then following step is followed.

7. Elision of suffix (*subluk*)
   When a *prātipadika* label is attached to a string, as a result the case suffixes of both the stems are deleted(*subluk*). For example

   rājan+ṅas puruṣa+su → rājan puruṣa

8. Transformation of the first component:
   The first component undergoes certain transformations, in the presence of the second component. For example, *pāda* changes to *pada* if it is followed by *āti*

   pāda + āti → pada + āti

9. Transformation of the second component:
   The second component also undergoes certain changes in the presence of the first component. For example, *sthira* changes to *ṣṭhira* in the presence of *yudhi*.

   yudhi + sthira → yudhi ṣṭhira

10. Padakārya:
    Each of the components thus transformed obligatorily certain operations which are independent of the context. For example in the case of *rājan* 'n' gets deleted.[5]

[1] *avyayam-vibhakti-samīpa-samṛddhi-vyṛddhyarthābhāvātyyāsamprati-śabdaprādurbhāva-paścādyathānupūrvya-yaugapadya-sādṛśya-sampatti-sākalyānta-vacaneśu* (P2.1.6)

[2] *kṛttaddhitasamāsāśca* (P1.2.46)

[3] *aluguttarapade* (P6.3.1)

[4] *haladantatsaptamyāḥ sañjñāyām* (P6.3.9)

[5] *nalopaḥ prāipadikāntasya* (P8.2.7)

11. Joining of the words (sandhikārya)
    The two components thus transformed, now are joined together undergoing a sandhi operation. For example

    $$rāma\ ālaya \rightarrow rāmālaya$$

12. Deciding the gender of a derived nominal stem (*liṅganirdhāraṇam*)
    Such a stem is now all set to undergo word formation rules. But before that, this stem should get the proper gender. Gender of a nominal lexicon is the property of the lexical item[6]. An *avyayībhāvaḥ* compound is always in neuter gender[7]. While in the case of *tatpuruṣaḥ* (endocentric) and *dvandva* (co-ordinative) compounds[8] the gender of the compound is same as the second component. In the case of *Bahuvrīhiḥ*(exo-centric), the gender is same as that of the word it modifies.

13. Word Formation
    The final step is the word formation.

4 Sanskrit Compound Generator

The rules pertaining to the compound formation are primarily of two types. The first type of rules designate a label to the string. These rules are called *sañjñā sūtra*s. These rules create an environment or trigger certain rules when they are activated. The other rules are of type *vidhi* 'an action or a process'. These actions transform the input string. The first type of rules are implemented as a context free grammar, while all the rules related to the process which transform the input string are represented as a regular grammar. These *vidhi sūtra*s are further of three types.

1. Right context:
   $W_1\ W_2 \rightarrow W_3\ W_2$
   i.e. W_1 changes to W_3 in the context of W_2.

2. Left context:
   $W_1\ W_2 \rightarrow W_1\ W_3$
   i.e. W_2 changes to W_3 in the context of W_1.

3. Extended right context:
   $W_1\ W_2 \rightarrow W_1\ W_2\ W_3$
   i.e. In the context of W_1 and W_2, W_3 is appended to the input string.

Here is an example for each of them.

1. *pādasya padājyātigopahateṣu* (P6.3.52)
   The first component *pāda* is changed to *pada* if the second component is either of *āji*, *āti*, *upahata*, or *ga*.

   $$pāda\ /\ āji\ |āti\ |ga\ |upahata \rightarrow \text{pada}.$$

2. *jyotirāyuṣaḥ stomaḥ* (P8.3.83)
   The second word *stoma* changes into *ṣṭoma*, if the first word is either *jyotis* or *āyus*.

   $$stoma \rightarrow ṣṭoma\ /\ jyotis\ |āyus$$

3. *antarbahirbhyām ca lomaḥ* (P5.4.117)
   This sūtra states a condition for adding a special suffix at the end of a compound. If the second component is *loman* and the first component is either *antar* or *bahir*, then a suffix *ap* is added to the compound.

   $$antar\ |bahir\ loman \rightarrow antar\ |bahir\ loman\ ap$$

In the above three patterns, the words W_1 and W_2 represent either some phonological pattern such as a string ending in a vowel, or may stand for a particular word such as *pāda* or may represent a list of words such as *śaratprabhṛti*[9].

There are some sūtras which use an extra information other than the input string. This information falls under four broad categories:

- The morphological analysis of a word,
- The semantic category of a word involving ontology,
- The meaning of a word, and
- The relation between two components.

For the compound generator, we used a semantically rich lexicon where the words are classified following the extended ontology of Nyāya-Vaiśeṣika and are also marked for the relations among them. We describe these features in the next section. The grammar used for compound generation is produced in Table 2 and the lexer in Table 1.

[6] *prātipadikārtha liṅga-parimāṇavacana-mātre prathamā* (P2.3.46)
[7] *avyāyībhāvaśca* (P2.4.18)
[8] *paravalliṅgam dvandvatatpuruṣayoḥ* (P2.4.26)
[9] list of words starting from śarad

padam:	subantam	
|	tiṅantam	(not expanded further)
;		
subantam:	stem sup	{Word_generation(stem,sup)}
;		
stem:	$stem_{NT}$	
|	$stem_T$	
;		
$stem_{NT}$:	kṛt	(not expanded further)
|	taddhitaḥ	(not expanded further)
|	samāsaḥ	{ if not_aluk($stem_1$,sup_1,$stem_2$,sup_2){ sup-deletion($stem_1$,sup_1)(**subluk**) } sup-deletion($stem_2$,sup_2)(**subluk**) decide_order($stem_1$,$stem_2$) (**upasarjana**) change_order($stem_1$,$stem_2$) (**pūrvanipāta**) transform($stem_1$,$stem_2$) (**pūrvapadakārya**) transform($stem_2$,$stem_1$) (**uttarapadakārya**) process_stem($stem_1$)(**padakārya**) process_stem($stem_2$)(**padakārya**) sandhi($stem_1$,$stem_2$)(**sandhikārya**) decide_gender($stem_1$,$stem_2$,samāsa_type) (**liṅganirdhāraṇam**) decide_number($stem_1$,$stem_2$,samāsa_type) (**vacananirdhāraṇam**) }
;		
samāsa:	alaukikavigrahaḥ	{add_samāsānta_pratyaya ($stem_1$, sup_1, $stem_2$, sup_2)}
;		
alaukikavigrahaḥ:	stem '+' sup stem '+' sup	
|	avyaya stem '+' sup	
|	stem '+' sup avyaya	
;		

Table 2: Grammar for Compound Generation

sup:	su|au |jas
|	am |auṭ |śas
|	tā |bhyām |bhis
|	ṅe |bhyām |bhyas
|	ṅasi |bhyām |bhyas
|	ṅas |os |ām
|	ṅi |os |sup
;	
avyaya	su
|	upa
|	prati
;	
$stem_T$	[a-zA-Z]+
;	

Table 1: Lexer for Compound Generator

5 Lexical Semantics

Some rules for compound generation required ontological information, while some rules expected certain semantic relations between the components. The Nyāya-Vaiśeṣika school of philosophy in Indian tradition has dealt with the ontological classification of the real objects which is accepted to all the branches in Indian knowledge system. All the words in the Amarakośa were classified following and extending this scheme further by Nair (Nair, 2011). To this classification, she also added various other properties, called as *upādhi*s, a word may have other than its ontological status. For example, to be an eatable, or to be drinkable are the special properties which can not be classified under the ontology without violating the essential property of a tree viz. the single inheritance[10]. We examined all the semantic conditions found in all the sūtras related to compound generation. Some ontological categories (*jāti*s as well as *upādhi*s) which are used by Pāṇini were missing in the tables developed by Nair, since these were basically prepared using the lexicon from Amarakośa. We added these missing categories to the table of ontological classification (Figure 1) and the missing properties to the table of upādhis (Figure 2). The lexicon enriched with the ontological and special properties belonging to the upādhi chart is used for the compound generation. In addition to the ontological category of a word and the special properties of it such as *upādhis*, the knowledge-Net of Amarakośa also contains the relations words may have with others such as part-whole relation. The compound formation rules use the following relations:

- part-whole relation (*avayava-avayavī bhāvaḥ*)
- resemblance for comparison (*upamāna-upameya*)
- contradictory / opposition (*vipratiṣiddha*)

A knowledge base of pair of words with such relations is being developed to handle the cases of compounds that require the components to be in one of the above relations. For example, the words *śīta* and *uṣṇa* denote opposite properties, and hence by *vipratiṣiddham cānadhikaraṇavāci (P2.4.13)* rule, they are meaning-wise compatible to form a compound word. Similarly the words *ghana* and *śyāma* undergo compound formation by the rule *upamānāni sāmānyavacanaiḥ (P2.1.55)*. Finally there are certain cases where the semantic condition involved does not refer to the meaning of a word, but to a general context, or to a situation. For example, a condition that the compound thus formed will be a name of the person (*sañjñā*), or a condition that the objects denoted by the two components are in total contact with each other during the complete duration (*atyantasaṃyoga*), and so on. For generation of compounds involving such knowledge, we seek the information from the user through an user interface.

6 Conclusion

We have tested this generator on around 200 examples and they produced the correct results. Appendix - gives the results of four different type of compounds. The testing of exceptional compounds is on. This study provides a model for building similar generator for compounds in modern Indian Languages.

[10]The Nyāya texts describe six conditions for a property to be a class property termed as *jātibādhaka*s

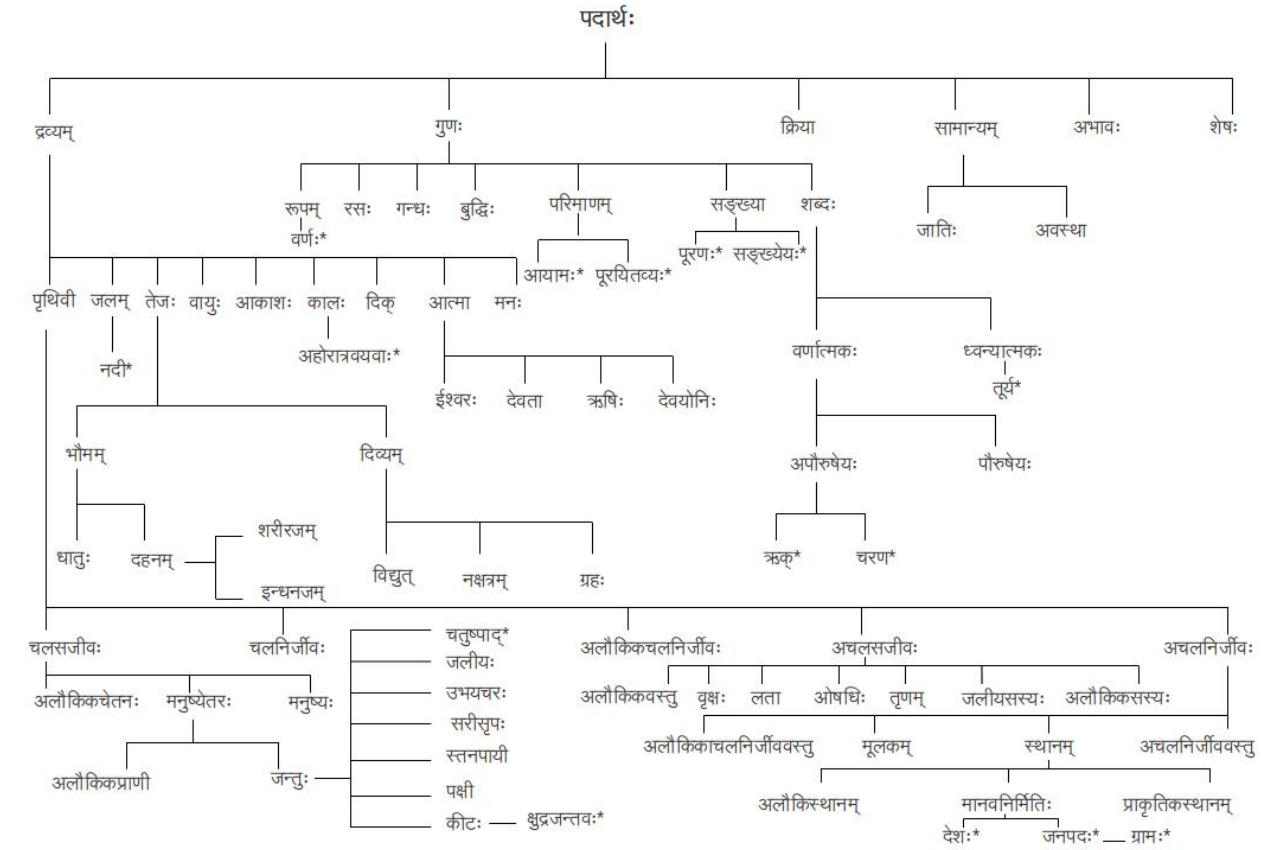

Figure 1: Ontological classification

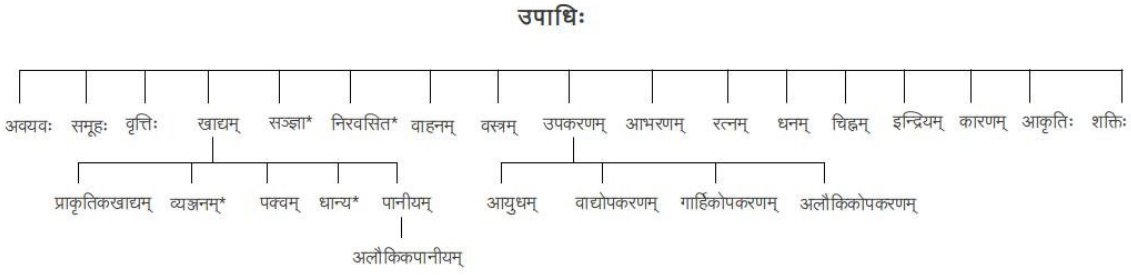

Figure 2: Other properties

A Tatpuruṣaḥ

Input *rājan + ṅas puruṣa + su* 2.2.8
alaukikavigrahaḥ → rājan + ṅas puruṣa + su
samāsasañjñā → rājan + ṅas puruṣa + su tatpuruṣaḥ
samāsānta pratyayāḥ → (Not Applicable)
prātipadikasañjñā → rājan + ṅas puruṣa + su tatpuruṣaḥ prātipadikasañjñā
aluk → (Not Applicable)
subluk → rājan puruṣa
upasarjanasañjñā → rājan puruṣa
pūrvanipātaḥ → rājan puruṣa
pūrvapadakāryam → rāja puruṣa
uttarapadakāryam → (Not Applicable)
sandhikāryam → rāja puruṣa
liṅganirdhāraṇam → rājapuruṣa
vibhaktikāryam → rājapuruṣa + su → rājapuruṣaḥ

B Avyayībhāvaḥ

Input *śarad + ṅas upa + su* 2.1.6
alaukikavigrahaḥ → śarad + ṅas upa + su
samāsasañjñā → śarad + ṅas upa + su avyayībhāvaḥ
samāsānta pratyayāḥ → śarad + ṅas upa + su avyayībhāvaḥ tac
prātipadikasañjñā → śarad + ṅas upa + su avyayībhāvaḥ prātipadikasañjñā
aluk → (Not Applicable)
subluk → śarad upa
upasarjanasañjñā → śarad upa
pūrvanipātaḥ → upa śarad
pūrvapadakāryam → (Not Applicable)
uttarapadakāryam → (Not Applicable)
sandhikāryam → upa śarada
liṅganirdhāraṇam → upa śarada
vibhaktikāryam → upa śarada + su → upaśaradam

C Bahuvrīhiḥ

Input *pīta + su ambara + su* 2.2.24
alaukikavigrahaḥ → pīta + su ambara + su
samāsasañjñā → pīta + su ambara + su bahuvrīhiḥ
samāsānta pratyayāḥ → (Not Applicable)
prātipadikasañjñā → pīta + su ambara + su bahuvrīhiḥ prātipadikasañjñā
aluk → (Not Applicable)
subluk → pīta ambara
upasarjanasañjñā → pīta ambara
pūrvanipātaḥ → pīta ambara
pūrvapadakāryam → (Not Applicable)
uttarapadakāryam → (Not Applicable)
sandhikāryam → pītāmbara
liṅganirdhāraṇam → pītāmbara
vibhaktikāryam → pītāmbara + su → pītāmbaraḥ

References

Bhaṭṭojidīkṣitaḥ. 2001. *vaiyākaraṇasiddhantakaumudī*. Motilal Banarsidass, New Delhi.

Brendan S. Gillon. 2009. Tagging classical sanskrit compounds. In Amba Kulkarni and Gérard Huet, editors, *Sanskrit Computational Linguistics 3*, pages 98–105. Springer-Verlag LNAI 5406.

Pawan Goyal and Gérard Huet. 2013. Completeness analysis of a Sanskrit reader. In *Proceedings, 5th International Symposium on Sanskrit Computational Linguistics*. D. K. Printworld(P) Ltd.

F. Grimal, V. Venkataraja Sarma, and S. Lakshminarasimham. 1995. *Pāṇinīyavyākaraṇodāharaṇakośaḥ*. Prentice-Hall of India, New Delhi.

Rodney Huddleston and Geofrey K. Pullum. 2002. *The Cambridge Grammar of the English Language*. Cambridge University Press.

S. D. Joshi and J. A. F. Roodbergen. 1999. On kāraka, vibhakti and samāsa. *Annals of the Bhandarkar Oriental Research Institute*, 80(1-4):95–112.

S. D. Joshi. 1968. *Patañjali's Vyākaraṇa - Mahābhāṣya Samarthāhnika (P. 2.1.1)*. Centre of Advanced Study in Sanskrit, University of Poona, Poona.

Kauṇḍabhaṭṭaḥ. 2005. *Vaiyākaraṇabhūṣaṇasāraḥ*. Chaukamba Sanskrit Pratisthan.

Amba Kulkarni and Anil Kumar. 2011. Statistical constituency parser for Sanskrit compounds. In *Proceedings of ICON 2011*. Macmillan Advanced Research Series, Macmillan Publishers India Ltd.

Anil Kumar and Amba Kulkarni. 2013. Clues from Aṣṭādhyāyī for compound type. In Malhar Kulkarni and Chaitali Dangarikar, editors, *Recent Researches in Sanskrit Computational Linguistics Fifth International Symposium Proceedings*, pages 62–83. D. K Printworld (P) Ltd, New Delhi.

Anil Kumar, Vipul Mittal, and Amba Kulkarni. 2010. Sanskrit compound processor. In G N Jha, editor, *Proceedings of the 4th International Sanskrit Computational Linguistics Symposium*. Springer-Verlag LNAI 6465.

Mahavir. 1986. Treatment of samāsa in pāṇini. *Annals of the Bhandarkar Oriental Research Institute*, 67(1-4):147–158.

M. Srimannarayana Murti. 1974. *Sanskrit Compounds. A Philosophical Study*. The Chowkamba Sanskrit series Office, Varanasi, India.

Sivaja S. Nair, Shrinivasa Varakhedi, and V. Sheeba. 2013. Extended nyāya-vaiśeṣika ontology as applied to amarakośa knowledgenet. In Malhar Kulkarni and Chaitali Dangarikar, editors, *Recent Researches in Sanskrit Computational Linguistics Fifth International Symposium Proceedings*, pages 223–242. D. K Printworld (P) Ltd, New Delhi.

Sivaja S. Nair. 2011. *The Knowledge Structure in Amarakośa*. University of Hyderabad.

Bhagyalata Pataskar. 1996. Some observations about the compound structure of aṣṭādhyāyī. *Annals of the Bhandarkar Oriental Research Institute*, 77(1-4):121–131.

K. V. Ramakrishnamacharya. 2010. *Bhūṣaṇasāratattvaprakāśikā*. Rashtriya Sanskrit Vidyapeetam, Tirupati.