Generation of Sanskrit Compounds

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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 samarthāhnikā 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). Siddhāntakaumudi (Bhaṭṭojidikṣitah, 2001) provides the details of various stages involved in the compound processing. And the book worth mentioning is Pāṇiniyavyākaranodāharaṇakośaḥ (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
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 saṁjñā 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 briefly 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 rāmakṛṣṇaḥ (Rama and Krishna) formed from the phrase rāmaḥ ca kṛṣṇaḥ 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 bhārya 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 yuddhiṣṭiraḥ. Here the locative case suffix of ‘yudh’ is retained in the compound as well.

6. In some cases, after the compound formation, the compound loses its ability to undergo inflections, and it behaves like an indeclinable. For example kṛṣṇasya samipam (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 Bahuvrīḥ (exo-centric) will have the same accent as that of rāma, while a phrase ‘rāmasya īśvaraḥ (God of Ram) → rāmeśvaraḥ’ as a Tatpurusā (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 mṛttikāghataḥ (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 Āṣṭādhyāyī. 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 Āṣṭādhyāyī a little more than 400 sūtrās deal with the compound formation. These rules are scattered at various places in the Āṣṭādhyāyī. We describe below the compound formation process followed by the Pāṇinian tradition.

1. ‘Conceptual input’ (Alaukika vigraha)

The governing sūtra for compound formation is samarthah 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 (vaktr.vivaks.¯ adh¯ ınam). 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 sasṭhī (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

\[\text{rājan} + \text{nas puruṣa} + \text{su}\]

where the words rājan and puruṣa denote the objects ‘a king’ and ‘a person’, and the suffix nas 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

\[\text{pīta} + \text{su ambara} + \text{su}\]

Eng: The one whose cloth is yellow

the alaukikavigraha is

\[\text{pīta} + \text{su ambara} + \text{su}\]

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

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

\[kṛṣṇa + \text{nas upa}\]

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

2. Adding special suffixes related to compounds (samāśanta pratyayā)

There are certain suffixes which are added to the compound at the end. These are called samāśanta pratyayās. These are added at the end of the alaukika vigraha and are treated as a part of a compound. For example the sūtra avyayībhāve saratprabhṛtibhyāḥ (P5.4.107) adds a tāc suffix if the compound is of type avyayībhāva with one of
the word from the list starting with ‘sarad.
’sarad + ūnas upa → sarad + ūnas upa tac.

3. Deciding the word order (upasarmāna)
The head of a compound more-or-less depends on the type of a compound. The Tatpurusa (endocentric) compound has second component as the head while the Avyayabhava has the first component as the head. In case of Bahuvrahi (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 upasarmāna. The designator of a word in nominative case in the rule that decides the compound type is the one which gets the designation upasarmāna.

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

śarad+ūnas upa

The sūtra1 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 upasarmāna. In the above example upa is an avyaya, and therefore upa gets a designation upasarmāna, and it occupies the first place. This changes the order of the input string to

upa śarad + ūnas.

5. Declaring the string to be a nominal stem (prātipadikasāmāṇijña)
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 prātipadikam2.

6. Non-deletion of case suffixes (aluk kārya)
There are certain exceptional cases, when the case suffix of the involved words do not get elided3. For example,

yuddhi + ūni4 sthira + su → yuddhi 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+ūnas 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 ōti

pāda + ōti → pada + ōti

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 s.t.hira in the presence of yuddhi.

yuddhi + sthira → yuddhi s.t.hira

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

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1 avyayam-vidhakti-samipya-samyadhi-vyrdhgyarthāvāyāyāsamanprati-subdapiṇdurbhāva-paścādyabādhyāyabhyaya-sādṛṣṭya-sāmpatti-sākalānta-vacaneśa (P2.1.6)
2 kṛttaddhitasamāsāśca (P1.2.46)
3 aluguttaradāpe (P6.3.1)
4 haladantatsaptamyāh saṁjñiāyam (P6.3.9)
5 nālopaḥ prātipadikāntasya (P8.2.7)
11. Joining of the words (sandhikārya)
   The two components thus transformed, now are joined together undergoing a sandhi operation. For example
   \[ \text{rāma álaya } \rightarrow \text{ rāmá álaya} \]

12. Deciding the gender of a derived nominal stem (liṅganirdhāram)
   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. An avayāvibhava compound is always in neuter gender. While in the case of tatpurusah (endocentric) and dvandva (co-ordinative) compounds the gender of the compound is same as the second component. In the case of Bahuvrīhih (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 saṁjñā śūtras. 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 śūtras 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. \[ pādasya padāyātigopahateṣu \] (P6.3.52)
   The first component \[ pāda \] is changed to \[ āji, āti, upahata, or ga. \]
   \[ pāda / āji \mid āti \mid ga \mid upahata \rightarrow pāda. \]

2. \[ jyotirāyusah stomaḥ \] (P8.3.83)
   The second word \[ stoma \] changes into \[ s.toma \], if the first word is either \[ jyotis \] or \[ āyus. \]
   \[ stoma \rightarrow s.toma / jyotis \mid āyus \]

3. \[ antarbahirbhyām ca lomah \] (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.
   \[ antar \mid bahir loman \rightarrow antar \mid bahir loman ap \]
   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 \[ sāratprabhṛti. \]

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.

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\(^{6}\)pratipadikārtha \(\mid\) liṅga-parimāṇavacana-mātre prāhām (P2.3.46)

\(^{7}\)avyāyāvibhava (P2.4.18)

\(^{8}\)paravallingam dvandvatatpurusayoh (P2.4.26)
Table 2: Grammar for Compound Generation
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 upādhis, 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. We examined all the semantic conditions found in all the sūtras related to compound generation. Some ontological categories (jātis as well as upādhis) 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-avayavi bhāvaḥ)
- resemblance for comparison (upamāna-upameya)
- contradictory / opposition (vipratisiddha)

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 sīta and uṣṇa denote opposite properties, and hence by vipratisiddham cānadhikaraṇa vacanai (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 upamānani sāmāṇyavacanaih (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 (saṁjña), or a condition that the objects denoted by the two components are in total contact with each other during the complete duration (atyantasam. yoga), 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.
Figure 1: Ontological classification

Figure 2: Other properties
A Tatpuruṣaḥ

Input rājan + Ṽas puruṣa + su 2.2.8
alaukikavigrahaḥ → rājan + Ṽas puruṣa + su
samāsasaiṇīṇā → rājan + Ṽas puruṣa + su tatpuruṣaḥ
samāśānta pratayāḥ → (Not Applicable)
prātipadikasaṇīṇā → rājan + Ṽas puruṣa + su tatpuruṣaḥ prātipadikasaṇīṇā
aluk → (Not Applicable)
subluk → rājan puruṣa
upasarjanasaṇīṇā → rājan puruṣa
pūrvanipātaḥ → rājan puruṣa
pūrvaṇapadakāryam → rāja puruṣa
uttarapadakāryam → (Not Applicable)
sandhikāryam → rāja puruṣa
liṅganirdhāraṇam → rājapuruṣa
vibhaktikāryam → rājapuruṣa + su → rājapuruṣaḥ

B Avyayībhāvaḥ

Input śarad + Ṽas upa + su 2.1.6
alaukikavigrahaḥ → śarad + Ṽas upa + su
samāsasaiṇīṇā → śarad + Ṽas upa + su avyayībhāvaḥ
samāśānta pratayāḥ → śarad + Ṽas upa + su avyayībhāvaḥ tac
prātipadikasaṇīṇā → śarad + Ṽas upa + su avyayībhāvaḥ prātipadikasaṇīṇā
aluk → (Not Applicable)
subluk → śarad upa
upasarjanasaṇīṇā → śarad upa
pūrvanipātaḥ → upa śarad
pūrvaṇapadakāryam → (Not Applicable)
uttarapadakāryam → (Not Applicable)
sandhikāryam → upa śarada
liṅganirdhāraṇam → upa śarada
vibhaktikāryam → upa śarada + su → upaśaradam

C Bahuvṛīhiḥ

Input pīta + su ambara + su 2.2.24
alaukikavigrahaḥ → pīta + su ambara + su
samāsasaiṇīṇā → pīta + su ambara + su bahuvṛīhiḥ
samāśānta pratayāḥ → (Not Applicable)
prātipadikasaṇīṇā → pīta + su ambara + su bahuvṛīhiḥ prātipadikasaṇīṇā
aluk → (Not Applicable)
subluk → pīta ambara
upasarjanasaṇīṇā → pīta ambara
pūrvanipātaḥ → pīta ambara
pūrvapadakāryam → (Not Applicable)
uttarapadakāryam → (Not Applicable)
sandhikāryam → pīṭāmbara
liṅganirdhāraṇam → pīṭāmbara
vibhaktikāryam → pīṭāmbara + su → pīṭāmbaraḥ
References


