A SCHEME FOR KNOWLEDGE REPRESENTATION IN SAMSKRITAM

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ABSTRACT

Various techniques are employed in Knowledge-Based-Systems to represent Knowledge of different kinds. In this paper, an overview of the scheme of classification of things in the shastraic literature is explored to provide an alternative means of knowledge representation, especially, the context-related one. A suggestion for a possible Lexical structure, Knowledge-Base and Analysis is contained herein. Ontological, Metaphysical (Logical) and Grammatical categorisation of entities with Philosophical aspects are dealt as found in the Shastras.

Lexicon suggested here is based on the famous 'Amara kosa', with fields to cover various syntactic, semantic and contextual aspects. The Knowledge-Base suggested is a Compendium of all Sutras pertaining to various branches of Oriental Learning. The Analysis part is suggested to be in the form of modules/packages for various applications corresponding to the steps involved in the 'human understanding' process, which is also covered here. In short, an attempt is made to present the issues implicit in realising Samskritam as a medium for Knowledge Representation, in Computer-based AI applications.

INTRODUCTION

Modern Knowledge-Based-Systems employ Rules in if-then-else form etc. (Predicate Logic), Semantic Networks and Conceptual Dependency method to represent 'World Knowledge' in Computers. Hudli and Viswanathan [25] have shown the correspondence of these three methods to the **'Shabda-bodha'** concept in the three branches of Shastraic (Samskritam) literature, viz. Nyaya, Vyakarana and Mimamsa. The self-inference generating characteristic of Sanskrit grammar has been brought forth by Rick Briggs [18]. The adequacy of a few well-defined primitive processes as sub-routines/modules/ packages is illustrated in [21]. Thus, for a variety of applications like NLP (Natural Language Processing), MT (Machine Translation), CAL (Computer-Aided Learning) and Expert Systems, the Shastraic concepts could be adopted.

This poses the problem of how knowledge is to be represented in Computer systems. To solve this problem, an appropriate model of knowledge and a set of tools to implement this are required. For modelling of knowledge, epistemological building blocks are needed. Among the tools required for implementation, several forms of knowledge structures can be created presently.

Shastraic literature in Sanskrit contains exhaustive treatment of the various aspects of knowledge, per se, and attempts to systematise its study. Knowledge elements for word, sentence and discourse levels are enumerated, defined, examined and established as building blocks for technical literature.

Panini's Ashtadhyayi deals with word-level aspects like rules for formation of valid word-forms, description of their structure and rules for their usage. This covers simple, compound and concatenated word-formation of various types, parts of speech like nouns, verbs, attributives, relational functors, governance clauses etc. scriptural and literary language, parameters like origin of sound, internal and external effort, phonetic classification, accents etc. at substrate and affix levels for all words. The substrate could be nominal stem or base for nouns and verbal roots for verbs. Affixes include prefixes (like upasarga for verbs, taddhitas for nouns etc.) and suffixes (like sup for nouns, 'thing' etc. for verbs and so on). The process of derivation of valid word-forms becomes thus clearly defined.

The Nyaya shatra deals with Ontological classification of things and proceeds to enumerate, define and verify their essential and typical characteristics. Instruments and objects of knowledge are dealt with in detail. The process of 'human understanding' is described and theories of valid knowledge, error, word-meaning relations, cognition, validity/fallibility etc. are postulated. The linguistic, psychological, ontological, logical and philosophical issues are elaborated besides covering the inference in great detail. Aspects of sentence-hood with necessary criteria like proximity, expectancy and compatibility are evolved and sentential import extraction explained. Thus, this shastra could be thought of as dealing at sentence-level processes.

The Mimamsa Shastra is primarily meant to devise methods for interpretation of Vedic texts, including Upanishads, and does so mainly at discourse level. Here, criteria for determination of discourse import, coherence, conflict resolution, priorities and relative strengths of various instruments of knowledge etc. are described. Theories of the process of cohering of word-meanings at sentence level are a hallmark of this shastra, which has applications in all other shastras as well. Contextual aspects are dealt with in good detail and methodologies evolved by generalisation, to cater to different kinds of conflicting statements in a discourse.

Thus, the tenets of these three shastras throw sufficient light on matters of interest in AI and as such, a scheme for realising a knowledge representation based on these will now be described.

Three distinct constituents of a knowledge representation scheme could be a Lexicon or Vocabulary/Dictionary, a knowledge base and a set of programs for analysis of the knowledge base. In the present context, these three parts are explained hereafter.

THE LEXICON PART

Noun Representation:

The Lexicon part mainly covers nouns only. The lexicon is suggested to be based on 'Amarakosa', the popular sanskrit vocabulary. Every word or entry could have various fields of information associated with it. The exact format of storage is not dealt with here. It could use an appropriate representation like semantic net or frame etc.

The aspects to be covered are the following: i) Word, ii) Its gender, iii) ending (ajantha, halantha etc.), iv) part of speech, v) nominal stem and affix, vi) derivation (process with

relevant reference to grammar rules), vii) meaning(s) (in sanskrit through synonyms etc., and in english), viii) synonyms' reference, ix) sense of word-meaning(s) with derivation(s), x) contextual information (like sample usage etc.), xi) attributes - application in specific branches of learning etc. i.e., encyclopedic/thesaurus type detail, xii) reference in amara kosha (quarter of the verse where the word appears), xiii) ontological/metaphysical/logical category of the item represented by the word and xiv) any other special characteristics or miscellaneous information (typically accent-related meaning data etc.) in a serial, indexed structure.

A description of the above fields follows.

i) The word field contains index of nouns from the amara kosha (about 15000 words) in a serial list. With usage of this system, other words from lexicons like Medini, Vishwa, Halayudha, Vyjayanthi, Ratna, Yadava etc. could be selectively added with their references, on as required basis. These are stored in indexed form to facilitate quick sorting/search.

The words could be common nouns, proper nouns, pronouns, class/species denoters among nouns, homonyms, indeclinables (or propositions, conjunctions, interjections etc.) and may include compound words as well. Compound words are suggested to be hyphenated at possible constituent word-breaks, to start with. The information about the compounding would be in the relevant field. Nominative case singular form (unless required otherwise) is used for nouns (subanthas) with the nominal stem and sup affix separated by a '+' mark.

ii) The gender field gives the gender(s) in which the word can occur. When more than one gender is applicable, the attendant entries in the other relevant fields like ending are also made. The operators used for such denotation in amara kosha also is indicated in brackets. As an example, to mean 'dust', one of the four sanskrit words renu, dhuli, pamsu or rajas could be used in masculine and feminine, only feminine, only masculine and only neutral genders respectively. So much detail is packed in a half- verse of amara kosha 'renur dvayoh striyam dhulih pamsur naa na dvayoh rajah'. Here, the operators used are dvayoh, striyam, naa and na dvayoh.

Including these would help analyse amara kosha itself with this system, particularly the control characters used to demarcate between words of different genders among synonymous groups, like 'rupa bheda, sahacharya and special, express mention (as above). The efficiency of expression and brevity achievable can then be appreciated. Also, the linganushasana portion of Panini could be referred suitably in this column.

iii) The ending field indicates the end character (vowel or consonant) in order to help in forming various declensions during sentential import analysis etc. The endings are about 30 in number with 13 in vowels and 17 in consonants. These cover all the three genders and their combinations. [13] lists about 224 types of subanthas (nouns) based on endings and gender and in one initial study reported, look-up tables of the modified 'sup' suffixes for all these types are used for quick acquaintance with the scheme.

iv) The part of speech field indicates the category of the word as noun, pronoun, class

name, adjective, relational functor, indeclinable, specific connotational in a particular branch of study etc, e.g, idioms, figuratives, simile, metaphors, epithets, poetic forms etc. 'Visheshya nighna' in amara kosha is an example. Association of technical class names are also included here. For compound words, relevant details of the constituent words and compounding information also is mentioned. An index of the various parts of speech encountered is prepared under the software implementation stage, for the purpose.

Words are of four types as yaugika (denotational = derived), rudha (connotational = convention), yogarudha (denotational and connotational) and yaugika rudha (denotationally connotational), depending on the process of derivation of the relation between the word and the object they denote. This classification also is mentioned here.

v) The nominal stem and affix field aids the process of semantic extraction by splitting words into substrate and affix parts. An index of various prefixes and suffixes applicable for nouns and verbs is to be prepared under the programming stage. Annexure -I lists the common affixes. (e.g.nominal bases get 'sup' suffixes and 'taddhita' prefixes etc. while verbs get 'upasarga' prefixes and 'thing' suffixes etc. normally).

vi) The derivation field indicates the formation of the word, e.g., the word 'Rama' is derived as 'ramayati iti Ramah', where 'ram' is the root, meaning, 'to please'. Here, references to roots/affixes and rules of grammar involved in obtaining the form are indicated. However, the entire 'ashtadhyayi' would be needed to be codified for completely describing the derivation. This aspect is addressed in the 'knowledge base' stage.

vii) The meaning field provides the meanings of words in the forms of a) description (for certain proper nouns etc.), b) explanation (in terms of categories etc.), c) specification of the context where the word could occur, d) sample usage or e) with synonyms. Compound word meanings are given by decomposition of the compound word giving constituent word meaning and compounding meaning. These meanings are indexed for various situations of simple and compound words including base, affix, case, karaka, compounding, accent, context and derivation dependent changes in word senses in the programming part. The essential characteristic and typical characteristics of the various ontological categories are also included. To improve the utility and aid better interaction, this field could be both in sanskrit and english.

A lot of research work is involved in optimising the representation of information in this field. The scheme should be a mix of production rules, semantic and conceptual nets and frames for the different parts. [19] provides many useful hints on using naive theories of human understanding for this purpose.

viii) The synonyms field gives cross reference in the lexicon to synonymous words. The serial number is used for the purpose. This helps in analysing the grouping of synonymous words in amara kosha and the control operators like "ending with 'thu' and beginning with 'atha' denote separate groups of words" mentioned in the metalanguage of amara kosha.

ix) The sense of word meanings field indicates the class of the word among yaugika,

rudha etc. This field is useful in applying the various techniques of semantic extraction based on criteria evolved particularly in Mimamsa. Conflict resolution is mainly by assigning weightages to the various senses of word meanings together with priority/ relative strength of the different senses.

Apart from these derivational aspects of word meanings, there are different levels of word senses like primary and secondary denotation, Implication, Suggestion, figurative and idiomatic usages, poetic fancies, metaphors, personifications, ellipses, allomorphism etc. which really pose a great challenge to ingenuity to generalise to any reasonable degree of success. Yet, this is a very interesting and richly rewarding study as learning of human cognitive processes qualitatively improves.

Annexure - II illustrates the numerous forms of word meanings specially implication and suggestion etc. as used in sanskrit classical literature.

x) The contextual information field generalises the various parts of speech which go with the word in question and illustrates typical usage patterns. This would help homing on to a probable context quickly. The famous example of the word 'saindhava', which could mean both a horse of the sindhu region or common salt depending upon when it is requisitioned (while eating or in a warfield) typifies the form of information to be contained here.

The ontological/metaphysical/philosophical categories are used to describe the context. Difference among various schools of thought is maintained distinctly to study the respective viewpoints from a common knowledge-based system.

xi) The attributes field lists certain technical categories or labels of words used in shastraic context. Terms like generator, generated, referent, referred, attribute, substrate, cause, effect, supporter, supported, operator, operated etc. which denote relations embodied in objects and their adjectives are covered here. Further, certain relations expecting connectives like the word father (of whom?), requiring mention of another related object are included. While determining sentential import, one of the criteria applied is expectancy of words. Since sentential import is made up of individual word senses filling up their meanings into a coherent form, listing of possible attributes of a word (denoting the various functions the word could perform in the sentence) would help in this process. Panini's gana patha classification also is relevant in this field. Certain syntactic usages in technical literature also could be indicated. These apply mostly to adjectives. As before, an index of all possible classifications has to be prepared.

xii) Reference in amara kosha gives the source of the word meaning as indicated and is useful for citation during query. This is more an editorial requirement than technical, but would provide a correlation between dictionary and original (verse) form of amara kosha. Also, the lexicon module could be independently used in learning/teaching applications better with such a feature.

xiii) Information about the classification of the word separately is useful in analysis of sentential import from the point of view of various schools/systems of thought. Also, the study of the tenets of various branches of learning from the 'sutras' (aphorisms) on a

comparative basis would be easier.

xiv) The special characteristics/miscellaneous field allows for future expansions, accommodates details/remarks/comments not fiting into any other field and takes any additional information about the word like vedic usage etc. Thus, a scheme for dealing with nouns is described.

Verb representation

As far as the verbs are concerned, a database using Panini's dhatu patha has to be created. Here, parameters like gana (bhvadi etc.), type of usage (parasmai/atmane pada etc), ending consonant ('ith'), accent of the 'ith', tenses/moods (lakaras), prefixes (upasarga), suffixes like 'thing' for lakaras, vikarana for the gana, and others like 'nich' etc., meanings of roots, various affixes (prefixes and suffixes), accents, changes in meanings and formations due to upasargas, change of voice from active/passive etc, control characters like 'it' denoting whether the root activity requires an object or not, vedic forms etc. are to be similarly coded. The verbs are about 2000 in number and their classification into related groups also facilitates the organisation of data about them. 'Shabda Ratnavali' is a work which is handy in such classification of both nouns and verbs.

Apart from these, analysis of concatenation/compounding of words in sanskrit needs a lot of research and in-depth study to arrive at a suitable means of representation in a Computer. Karakas are another class of concepts to be properly represented to aid sentential import analysis. Annexure - I lists 51 types of compounding and 48 types of concatenations prevalent. Initially, hyphenation, empirical methods of calibration/ pruning with examples etc. are to be resorted to.

THE KNOWLEDGE BASE PART

The second requirement is for an exhaustive knowledge base. This could typically consist of the sutras of all the branches of learning in shastraic literature. There are three levels of learning identified, viz. Experience (consciousness), Knowledge (pure Science) and Skill (applied science). Accordingly, shastras dealing with these are called para vidya, apara vidya and kala. Para vidyas or brahma vidyas deal with meditation and self-realisation on the basis of upanishad portion of vedas (scriptural texts). These are elaborated in Brahma Sutras of sage Vyasa.

Among the apara vidyas are 14 branches of study consisting of 4 Vedas (rg, yajur, sama and atharva), their 6 auxiliaries - shiksha (phonetics), vyakarana (grammar), chandas (prosody), nirukta (epistemology), jyautisha (astronomy) and kalpa (ritualistic directory), nyaya (logic), mimamsa (vedic text interpretation), epics/mythology and codes of moral rectitude.

The applied sciences are the various arts and crafts, fine arts, classical literature, medicine, engineering, technology, sculpture, architecture, aesthetics, biology, botany, zoology, gemology, geology, metallurgy, aeronautics, meteorology, genetics etc. numbering 64 and are called as kala.

Of these, the ones relevant for knowledge-based systems applications are the apara

vidyas directly and hence, their tenets need to be represented in an exhaustive knowledge base for analytical purposes. A compendium all sutras called 'sakala shastra sutra kosha' would have to be prepared. These tenets are either in aphorisms (a sort of terse, pithy sentence) form or as verses. Their analysis is what is to be attempted through an expert system for such a research. Here, the lexicon assists semantic extraction.

These sutras of individual branches of study are to be coded in a uniform manner, tabulated suitably with fields/columns giving necessary details in a form compatible with computer operation as well as the lexicon described. This portion is quite laborious as the subject is vast. Here, another area of fundamental research, also advantageous to undertake through sanskrit, i.e., Speech-to-text conversion, would amply complement the present research. Also, the total (1 to 1) correspondence between spoken and written Sanskrit could be harnessed gainfully, helping the codification of the extant knowledge base through recitation/recording. In the same vein, Image processing research also could help by automatic character recognition and generation from written inputs, including manuscripts.

The author has proceeded with the preparation of the data manually for such a codification in about 13 different systems of thought, numbering over 20000 sutras, in a particular data structure. The salient details are given below.

1. **Ashtadhyayi** of sage **Panini**, contains well-stuctured grammar rules for sanskrit language consisting of about 4000 sutras in 8 chapters and 32 quarters (the longest sutra having not more than 90 characters!).

2. **Nyaya sutras** of sage **Goutama**, dealing with sensory perception, Inference, Analogy, Verbal Testimony, various aspects of polemics, debate, syllogism, fallacies etc. in all describing 16 entities 'worth knowing about for realising the ultimate', in 528 sutras covered in 5 chapters, 10 Ahnikas, and under 84 major topics, as depicted in Annexure - III.

3. **Vaisheshika sutras** of sage **Kanada**, also dealing with logical aspects, particularly mataphysical and material properties with reasoning, contained in 369 sutras in 10 chapters and 20 Ahnikas.

4. **Mimamsa sutras** of sage **Jaimini**, containing 2617 sutras in 12 chapters, 60 quarters, 907 topics each giving out a maxim/rule for interpretation of Vedic texts, as illustrated subjectwise in Annexure - IV.

5. **Brahma sutras** of sage **Vyasa**, having 545 sutras in 4 chapters, 16 quarters and 156 topics, devising methodology for analysing Upanishadic texts. This is also called as uttara mimamsa and is counted as one branch of study alongwith Mimamsa.

6. **Sankhya sutras** of sage **Kapila**, describing about Nature, its evolutes, theory of cause and effect, metaphysics etc. in 555 sutras spread over 6 chapters.

7. **Yoga sutras** of sage **Patanjali**, dealing with mental states, control of body and mind harmoniously and rigorous means of self- control and realisation, consisting of 195 sutras in 4 quarters of one chapter.

8. **Chandas sutras** of sage **Pingala**, dealing with Prosody, metrics and other aspects of prose and poetry applicable to Vedic as well as classical literature containing 286 sutras in 18 chapters.

9. **Nirukta** of sage **Yaska**, dealing with epistemological, exegetical, phonological, morphological and semantic aspects of Vedic literature with a dictionary of 1773 vedic words, fully derived and explained with examples, giving out criteria for such an analysis, containing 12 chapters, 49 quarters and 3 major Sections, in prose order.

10. **Kalpa sutras**, typically of sage **Apastamba**, divided into 6 portions - i) Paribhasha Sutras being the metalanguage and conventions used in kalpa sutras in 160 sutras in 4 quarters of 1 chapter, ii) Dharma sutras dealing with moral rectitude, conduct and character, physical, spiritual and ritualistic aspects of human behaviour at individual and society levels, contained in 1362 sutras of 2 chapters, 11 sections and 29 sub-sections, iii) Grihya sutras dealing with domestic vedic ritualry, cosisting of 405 sutras, 8 sections and 23 sub-sections, iv) Pithrmedha sutras describing obsequial ritualry comprising 306 sutras in 2 chapters, v) Shulba sutras describing constructional and architectural aspects of sacrificial altars etc. involving Vedic Mathematical principles, contained in about 300 sutras, 6 sections and 21 sub-sections, and vi) Shroutha sutras describing the various sacrifices mentioned in Vedas, contained in over 10000 sutras in 23 chapters and scores of sections and sub-sections.

11. **Shiksha** of **Panini** etc. dealing with phonetics for Vedic intonation and accents, pronunciation and certain special features of Vedic grammar etc, in verse form.

12. **Jyautisha** of sage **Lagadha**, describing astronomical aspects for Vedic rituals and sacrifices, in verse form and

13. **Alankara sutras** of **Vamana** dealing with classical literature contained in 12 chapters and about 300 sutras.

THE PROGRAMMING PART

The analysis utilising the lexicon and knowledge base described is treated in this section. Obviously, this is the trickiest part as the process of human understanding called as 'vyutpatti' (or 'shakti graha') in shastras is a complex one involving various types and levels of inputs (many of them being dynamically updated by conscious beings) as summarised in 'Muktavali': 'Shakti graha results from a combination of grammar, analogy, lexicon, verbal testimony, conversation, extrapolation, explanation/commentary, proximity of known words etc.' Also, human learning process is almost continuous throughout life and hence, to mimic it even modestly on a machine is quite a task.

Modelling of knowledge at various levels as contained in the shastraic tenets are to be tried out through generalisation as far as practicable. Inference mechanisms, rule chaining, priority allocation, metalanguage and control character/operator concepts, various test procedures and criteria established for selection of word senses in nyaya and mimamsa schools need thorough study. The various indices hitherto mentioned are to be prepared by defining essential characteristic and typical features with general contexts for their usage or weightage if choice is involved.

For this purpose, the contents of each shastra, devoid of the technical details, are to be abstracted as a skeleton of merely the procedure/approach/methodology employed in analysis concerned there. Annexures - I to IV give the overview of the macro level of vyakarana, sahitya (classic literature), nyaya and mimamsa branches. These are to be followed up by similar trees for every entry/node in the macro level chart. Such graphical depictions clarify many a hidden aspects besides helping better interaction among researchers in Computer and traditional learning fields.

The next stage of analysis is to formulate small work packages involving specific program segment generation, e.g, for every type of compound word formation (among the 51 types), general procedure involved in decomposition and criteria to expect a particular type in a particular context/situation could be envisaged as a module. Integrating such modules/packages is the final objective. This involves large number of experts but has the advantage of being parallely carried out and spread out geographically as well, provided proper co-ordination to avoid duplicative efforts is ensured.

Guidance in this regard, though to a limited extent, is available from works like [1], [2], [3] etc. The first reference contains an excellent exposition of many classical systems of thought under well-devised categories, about 125 in number, in 3 major sections dealing with Instruments of knowledge, Objects of knowledge and objective/goal, summarising the diverse opinions about them in lucid verse style, greatly facilitating a comparative study of all schools of thought on any specific subject. This latter aspect is most relevant for computer modelling and representation.

But, these require good mastery in sanskrit to follow the theme behind the classification and analysis. Also, the greatest incentive for going ahead with such an endeavour is that the benefits accruing are in practically any field of daily life and philosophy alike, as the language sanskrit has but one form irrespective of application areas. Also, the treasure inherited from a glorious lineage of mighty masters of intellectual enquiry should spur all to willingly toil and succeed.

APPLICATIONS

As described earlier, the applications of a knowledge-based system modelling knowledge as defined in shastras has practically infinite scope, as at all the three levels of knowledge, all the literature could be analysed and studied to gain expertise in the respective fields. Besides, teaching/learning process would be greatly helped by this scheme. Moreover, a good opportunity would have been provided to the coming generations in assimilating and appreciating the merit of one of the oldest civilisations of the world.

IMPLEMENTATION ISSUES

As far as realising this goal is concerned, the author is unable to suggest any concrete steps, as this is a mere idea of an individual and the distinction between idea on the one hand and a feasible project on the other is well recognised. So, an opportunity would have to be created for the competent persons to get the necessary things done. In conclusion, it may be mentioned that it would be in the fitness of things if India takes a leading part in such an important field of research and prides in its rich heritage.

ACKNOWLEDGEMENTS

I am indebted to H.H. Shri Paramananda Bharati Swamiji for initiating me into the field of trying to interface the Sanskrit technical literature and AI-related Computer methods. I have also had the good fortune of being able to count on the support of many a great admirers of Sanskrit in various walks of Life.

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List of Annexures (in Sanskrit) Can be found in the paper Sakala-Sastra-Sutra-Kosa.

1. Overview of Sanskrit Grammar.

2. Overview of Sanskrit Classical Literature.

3. Overview of Nyaya Shastra.

4. Overview of Mimamsa Shastra.