AST-3

Rediscovering Nyaya and Other Darsanas in the Context of Present Day Information Technology Needs

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Abstract

The spectacular explosion of the World Wide Web from experimental stage into a global information infrastructure has created a tremendous need for new intelligent systems to connect information seekers with resources offered by the web providers. The IT world is moving into the semantic mode and the semantics (i.e. meaning and understanding) will come largely from knowledge systems. For the Artificial Intelligence (AI) community, this historic development affords an opportunity to design smart computer agents to help people navigate global information Webs, as they harvest knowledge over multi-lingual data sources. Indian philosophical texts –*Darsanas* and *Vedangas*, provide a gold mine of ideas for work in Knowledge Systems. Sanskrit is a highly expressive language that is amenable for computer processing. It has a well structured, descriptive grammar. Panini, probably belonging to the 5th Century BC, gave a comprehensive and scientific theory of language, phonology, morphology and syntax in his treatise on Sanskrit grammar, Ashtadhyayi, which is formulated with very concise and logically consistent set of rules (under 4000 rules) for derivation of correct Sanskrit word forms and sentences. This paper attempts to provide an introduction to a variety of novel concepts available for logic and language studies in Darsana literature in Sanskrit developed over a time span of three millennia. The present paper describes a set of research goals and tasks to bring the jewels from the classical knowledge of India into the main stream of modern human endeavor in Information Technology.

1.1 Introduction: The World Wide Web

In the short span of its existence, the World Wide Web has resulted in a revolution in the way information is transferred between computer applications. We expect the World Wide Web of information to gradually evolve into the World Wide Knowledge Web with smart computer agents helping users to navigate global information Webs, as they harvest relevant knowledge for specific applications. At the moment the main problem with the web is finding just the right amount of relevant information. To use the Web effectively, people need to be able to locate information resources using retrieval methods that meet the following criteria (Mallery, 1995):

- **Complete (Recall):** All relevant resources available in multiple languages are considered.
- **Correct (Precision):** The task of weeding out extraneous resources is minimized by not over generating (*i.e.*, not making mistakes)
- **Current:** The information located needs to be timely, not months or years out of date.
- **Felicitous:** Retrieved resources are at the appropriate level of abstraction or detail and they coherently

match people's information seeking goals or requirements.

- **Transparent:** Use of retrieval tools must be transparent to non-experts who will be using these systems.

1.2 The Semantic Web

In the **Semantic Web** information is given **well-defined meaning**, better enabling computers and people to work in cooperation (Berners-Lee, Hendler and Lassila, 2001). The essential property of the WWW (World Wide Web) is its universality. The power of a hypertext link is that "anything can link to anything". Web technology must not discriminate between commercial and academic information, among cultures, languages, media and so on and has to be decentralized. For the semantic web to function, computers must have access to structured collections of information (knowledge-bases) and sets of rules for logical inferences to enable them to do Artificial Reasoning. This technology is called **Knowledge Representation.** In addition, there must be mechanisms in place for eliminating paradoxes and unanswerable questions. Another basic component of the Semantic Web is the collection of **ontologies**. Two terms may mean the same thing in different databases. The ZIP code of US addresses becomes the PIN code in India. In the semantic web jargon, an ontology is a document that has a taxonomy and a set of inference rules. The taxonomy defines classes of objects and the relations among them. The effectiveness of software agents on the Internet will increase exponentially as the Semantic web is realized. The real power of the Semantic Web will be realized when people create many programs that collect web content from diverse sources, process the information and exchange the results with other programs.

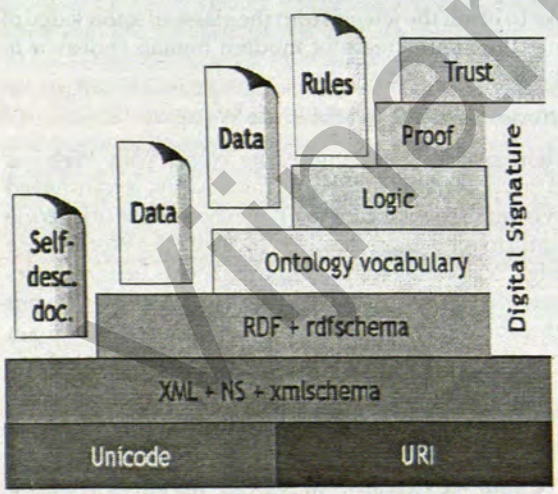


Figure 1: Semantic Web architecture http://www.w3.org/2000/Talks/1206-xml2k-tbl/

2.1 Artificial Intelligence (AI)

AI is the subfield of Computer Science devoted to developing programs that enable computers to display behavior that can (broadly) be characterized as intelligent. Most research in AI is devoted to fairly narrow applications, such as online speech-to-speech translation in limited, well defined task domains. The relations between AI and philosophical logic are part of a larger story.

2.2 Knowledge Systems

Knowledge systems include knowledge servers; multi-use ontology, knowledge bases and other knowledge system modules. Knowledge Representation and Reasoning is a vibrant and exciting field of human endeavor, and a key driver of innovation in computer science. KR includes: knowledge modeling and management, reasoning techniques for incomplete & uncertain knowledge, implementation of KR systems in software engineering, in robotics and intelligent agents and for the Semantic Web. KR is concerned with designing and using systems and structures for storing knowledge – hypotheses, theories, facts and rules about some subject in a manner amenable to computers. A body of formally represented knowledge is based on a conceptualization - an abstract view of the world that we wish to represent. In order to manipulate this knowledge we must specify how the abstract conceptualization is represented as a concrete data structure. Conceptualization is the collection of objects, concepts and other entities that are assumed to exist in some area of interest and the relationships that hold among them. Choosing a conceptualization is the first stage of knowledge representation. Ontology is an explicit specification of a conceptualization. Some of the technology outputs of this R&D could be

1. Knowledge Sharing (representation, sharing and reuse) Technologies
   - Knowledge Representation
   - Semantic Web Technologies
   - Large-Scale Repositories of Reusable Knowledge (Language Technologies)
2. Computer Mediated Learning
   - Concept Mapping
   - Problem-based learning
   - Learning of languages such as Sanskrit
3. Human Resource Development (HRD) in Knowledge Engineering

2.3 Knowledge Engineering

Human knowledge is represented, stored and communicated as information by one or several natural languages like English and Sanskrit. This is a well known and well-structured procedure. If the communication from a speaker to a hearer via spoken utterances is modeled by an appropriate computer system, this system needs:

- A theory of language
- A description of language data – the lexicon, the morphology, the syntax, the semantics, the pragmatics and the representation of the context.
- A precise description sufficient for computation Languages can be analyzed by software programs called parsers. Semantics can be conveniently provided by Logic. Natural language, logical languages (such as Propositional and Predicate calculi and the *Navya-Nyaya* language of Nyaya Darsana) and programming languages (such as C++, Prolog, and JAVA) represent three different types of semantic systems as in Fig.1 Logic is a tool of representation and a tool of reasoning. A logical language, L, consisting of a set of sentences and a consequence relation on L and is determined by a signature Ó and a grammar G.

Level I: (Language surface) ? Level II: (Semantic

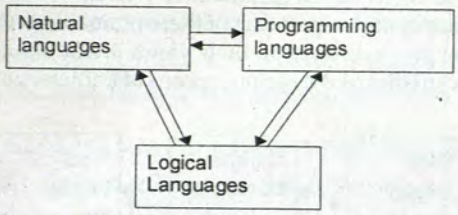


Fig. 2 Three different types of semantic systems

2.4 A sentence and its meaning

The grammarians of Sanskrit have theories about the nature of sentences (vakya) and disputed with Naiyayikas (logicians) who held different (some times even opposite views). A systematic attempt has been made to analyze speech utterances in terms of sentences (vakya), words (pada), stems and suffixes, morphemes and phonemes (varna). Among six Vedangas, two namely Vyakarana (grammar) and Nirukta (etymology) directly deal with language and Chandas (metrics) deals with prosody. The following is a sample of the multiple sources of knowledge available in Sanskrit:

The Mimamsa view: Among darsanas (philosophical systems), Purva Mimamsa is called Vakya sastra or the science of sentence interpretation. Mimamsakas gave a semantic definition of the sentence evolving the concepts of mutual expectancy (akanksha), consistency (yogyata) and contiguity (asatti) as factors necessary for the existence of a sentence. Mimamsakas (Bhattas and Prabhakaras) have different views.

The views of grammarians: Katyayana defined sentences as follows: A sentence is that [cluster of words] which possesses a finite verb [as an element]. "eka tin vakyam". (This rule should be interpreted as a *bahuvrihi* compound rather than rather than as a *tatpurusha* compound (*samasa*). "pacati" alone will not make a sentence but the cluster Devadattahah pacati would qualify). But look at "pasya, mrga dhavati". (Look, the deer runs). This has two verbs. Does this denote one or two sentences? Notion of "eka-vakyata" (single sentenceness) in an utterance received attention. The fundamental problem is to unearth the relation between the linguistic element (sabda) and artha (meaning). Patanjali's definition: Sabda is that which, when articulated, is seen to convey the idea of the referent. For grammarians sabda is not just any sound but a meaning bearing unit. Mandana Misra's sphotasiddhi is the cause that produces the idea of its meaning. Bharthrhari's Sphota theory – Vakya sphota – a complete utterance of the sentence is the unit of language. This is to be related to the pada sphota.

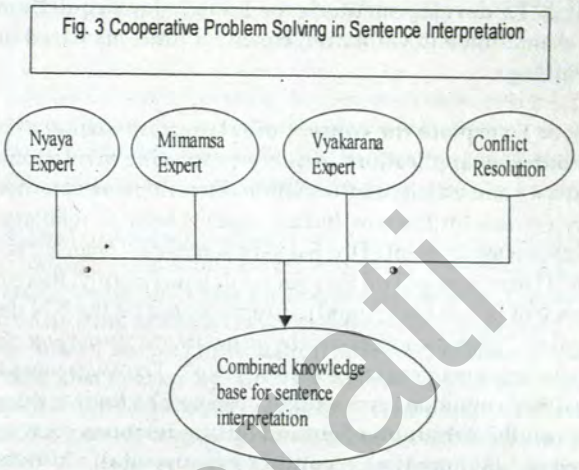
What is a "pada" (word)?

Panini's definition uses a formal criterion sup-tin-antam padam (1.4.14 sutra)

Do words signify universals (jati) or particulars?

Panini is ambiguous, Katyayana and Patanjali hold different views,

Lexical View: Amarasimha in Amarakosa gives a lexical definition of sentence, as a cluster of verbal and non-verbal words.



Nyaya view: Early Naiyayikas agreed that meaning includes jati (universal), vyakti (particular) and configuration (akriti) while later naiyayikas used the notion jati-visista-vyakti. Significative power or import (sakti) of words and polysemy (multiple meanings) of words are recognized. Gautama's definition is that a sentence (vakya) is a sound sequence with inflection (vibhakti). Later Naiyayikas used semantic criteria. They consider, for example, "pacati" as a vakya rather than as a pada as pacati (pac+a) is a compound word denoting the mental effort and physical act involved in cooking. Naiyayikas also did not think that the verbal element is important for constituting a proper sentence. E.g. ghato nilah. Bhutale ghatah. (The pot [is] blue. The pot [is] on ground.) Pramana-vakya denotes acceptable sentences.

Navya Nyaya view: The Navya Nyaya theory is that spoken language is only the language in the primary sense. Written language is language only in a derived sense to the extent that the written symbols remind one of spoken words. Written language is impossible without spoken language and succeeds spoken language logically in time. Theories of Language learning and theories of meaning are closely connected. Language used as a means of communication must ensure that hearer understands what the speaker intends to convey. Language is thus a source of information (though it is second hand!). It is thus the instrumental cause which produces the cognition of sentence meaning. The concept of meaning is defined purely from the point of view of the hearer. The speaker has already the knowledge which he wants to communicate to the hearer. In case of svarthanumana – inference for oneself – he infers with out using any words at all. When he wants to communicate the inference to others, pararthanumana, he uses a sentence with five limbs (panchaavayava nyaya vakya).

4. Some achievable goals and tasks for work in this area

Goal 1: To achieve human-machine communication through two natural languages, Sanskrit being one of them and the other, English or any of the Indian languages. To start with Sanskrit-English, Sanskrit-IL can be individual sub-goals, where IL is any Indian language.

Task 1: To create an unambiguous English vocabulary for Indian logic for use by CS and IT communities

Task 2: To develop methods for knowledge acquisition, representation and validation based on concepts based on Indian logic.

Task 3: To explore the concept of relation (*sambandha*) in the context of applications in query-processing in relational databases and efficient information retrieval from Internet.
Navya-nyaya (or the new Indian logic) is logic of relations. The awareness content of the Sanskrit sentence, "*Bhutale ghato nasti*" (There is no pot on the ground or equivalently, there is absence of pot on the ground), is represented by the NN description: "*ghatatva-visista-abhava ghata-abhava vaisistyam cha sva-avachinna-pratiyogikatva-sambandhena*". The awareness is a qualified cognition representing absence of a known thing "pot" on the substratum "ground" using relations such inherence (samavaya), contact (samyoga), limiter (avacchedaka), location-locatee (aadhara - aadheya), subjunct-adjunct (anuyogi-pratiyogi) etc. It is a challenging task to translate this language into symbolic form and machine generation of NN description.

Task 4: To develop a methodology of semantic analysis of ordinary *(laukika)* Sanskrit sentences using multiple knowledge sources - lexicon (kosha), grammar (vyakarana), logic (nyaya) and exegesis (mimamsa)
An important subtask is to develop a machine usable knowledge base with rules from these diverse systems analyzing a common list of sentences. This task is a cooperative sentence analysis task. Some questions are: Is the process parallel or hierarchical? Is there use of pragmatics in classical Sanskrit studies? Is "common sense reasoning" part of logical understanding?

Task 5: To develop systems for knowledge acquisition and text summarization based on discourse analysis
This conversational game metaphor of discourse analysis is appropriate for analyzing the *vada* and *katha* tradition in *tarka sastra* (the art of debate, often considered along with Nyaya, the science of logic) particularly when *jalpa* and *vitanda* are used in debate.) Many debates in Upanishads and Buddhist literature (see Appendix 2) provide a wonderful database for discourse analysis.

Task 6: To develop systems for Coherent and Query Specific summary extraction from multiple documents
Present day search engines use key-word based search. Mimamsa suggests the following approach for gain knowledge regarding the *prameya*, the topic of interest and summary: Definite knowledge (*tattva*) established by means of six elements.

- Introduction (*upakrama*) and Conclusion (*upasamhara*) taken together (and checking consistency between them)
- Repetition (*abhyaasa*), uniqueness (*apurvata*), purpose (*phala*), topicality (*arthavada*) and additional proof (*upapatti*).

Can this provide a better way to search the web for more accurate information retrieval?

Task 7: Formulation of the process for four types of cognition
The task here is to obtain veridical knowledge (prama) from the four instruments (pramanas). Determination of relative importance and sequencing of these pramanas is the first step. Philosophers differed in their views about the number and characteristics of the various means of knowledge (pramâas).

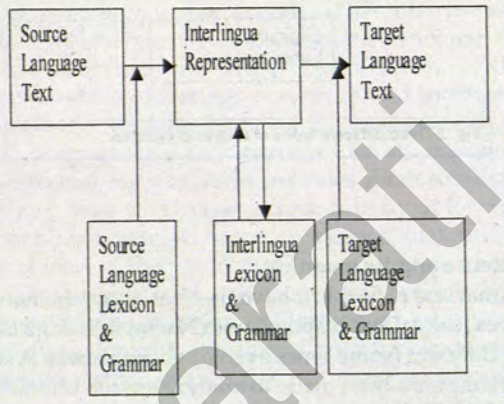


Fig. 4 Schematic of Proposed Human Machine Communication Model

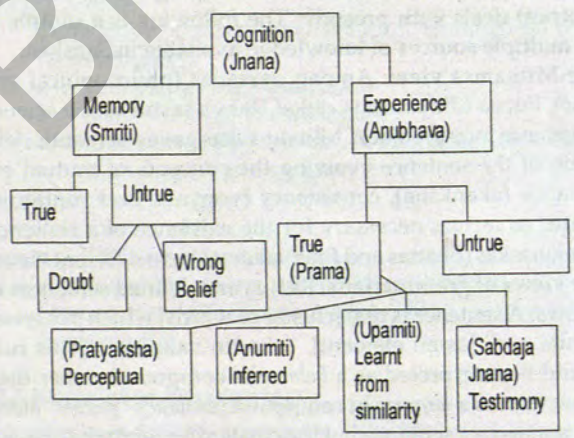


Fig. 5 Nyaya View of Cognition

The most widely accepted pramâ?a was perception. Inference and verbal testimony (such as an utterance by a competent speaker or a statement from the Vedas) were also considered important. Some schools added analogy (upamana) and other special kinds of inference (e.g. arthapatti and anupalabdhi). Because of their differing ontologies, schools also disagreed about the objects of knowledge (prameya). Nyâya held that these were self, body, sense organs, mind, rebirth, pain and freedom (mok?a). Sâkhya linked the objects of cognition to the sense organs: the eye has colour as its object, the ear has sound, the tongue taste, and so on; inference has as its objects things beyond sensory perception, such as consciousness, the undifferentiated material stuff of the universe, and causal relations.

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