Shaastra Maps: Enabling Conceptual Exploration of Indic Shaastra Texts

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Abstract

Indic shaastra texts employ a rigorous, structured style of discourse that adheres to well-laid out conventions of Nyaaya and Mimaamsa. As a result, unlike modern scientific treatises which use free form natural language for their discourse, Indic shaastra texts are more amenable to mechanized navigation and interpretation. Such a facility also simplifies their study by novice readers via creating custom dynamic views on demand for rapid drill-down and assimilation.

This paper contributes a conceptual network representation of Indic shaastra texts called *Shaastra Map* along with a graph query scheme called *ShaastricQL*[1] that together provide these benefits. At its core, ShaastraMap is an overlay directed graph of sentences and sections of one or more Shaastra texts linked via relations widely employed by shaastra authors and experts such as *tantrayuktis* and *padaartha sambandhas*. This representation directly mimics shaastric discourse structure and hence makes the author's intent more explicit to reduce learning barrier. Moreover, ShaastriQL offers primitives to help generate the following custom views of a shaastra text:

- Glossary: Show all the technical terms used in the text along with their definitions, illustrative examples and explanations ·
- Category Hierarchy: Given a conceptual category, show its recursive hierarchy of attributes and sub-categories. ·
- Discourse by topic: Given a topic, show its complete analysis in the text to a given level of detail. ·
- Summary: Show a high-level summary of the text with an incremental drill-down view of details.

We have built a web-based ShaastraMap editor that lets users (i) mark up a shaastra text to describe its structural layout upto individual sentences, (ii) tag the sections and their inter-relationships using well-formed 7-layer shaastric categories based on Nyaaya and Mimaamsa principles of text interpretation, and (iii) explore the text via the above custom views. This paper outlines these capabilities and our experience in the context of mapping four diverse shaastra texts.

1 Introduction

India's traditional scientific knowledge is articulated in numerous shaastra texts in a wide variety of disciplines, e.g., Ayurveda, Jyotisha, Vaastu, Yoga, Aesthetics, Dharma and Artha shaastras to name a few. There is untapped knowledge in the shaastras which can potentially address several prevailing issues in the world. There are areas in modern disciplines which can be augmented with shaastric insights. For these reasons, there is growing curiosity among the younger generation to explore Indic shaastras. Moreover, encoding knowledge for machine processing is

[1] *We recommend pronouncing ShaastriQL as Shaastric-quel.*

Proceedings of the Computational Sanskrit and Digital Humanities, 18^{th} *World Sanskrit Conference 2023*, pages 174–187

crucial for leveraging Indic knowledge for contemporary uses at scale. Some examples of useful applications include an automated tool for Ayurvedic diagnostics assistance, Vaastu compliance checking, and symptom-based herbal remedies. However, due to their highly technical nature and unfamiliar style of discourse for modern seekers, Indic shaastra texts require special training to navigate, grasp and utilize.

1.1 Challenges in exploring Shaastra Texts

There are a number of issues that a novice seeker faces in studying shaastra texts in their current format. The exposition style looks too detailed for first reading as key points often get interspersed with detailed commentaries and nuanced arguments. The definitions of terms and examples of concepts seem hard to locate in flat text. The long compounds and sandhis are difficult to parse and cross-references of concepts drawn from other shaastras are hard to find. The novice cannot benefit from shared community experience from prior readers and more often than not, deep experts of shaastras are hard to obtain.

1.2 Approach to a Solution

An insight into how to make Indic texts more accessible to modern seekers can come from understanding how a traditional scholar digests them, uses cross-references and presents them to his/her students. We explore this further in Section 3. To effectively leverage Indic scientific knowledge for contemporary uses, we need to reduce the didactic burden of scholars for training large numbers of students and also encode the knowledge contained in Indic texts for machine-assisted cognition and mining. Both the objectives can be achieved by encoding shaastra text content as a multi-dimensional concept network with a standard schema for navigation.

In this paper, we present a novel way of representing shaastric content that is amenable to drill-down exploration and topic-based consultancy, by using the inherent structuring schemes of shaastras, specifically Tantrayuktis Lele (1981) and Nyaaya-sambandhas Jha (2010). Section 3 gives further details about Tantrayuktis. We have developed a web-based editor for experts to collaboratively overlay a shaastra text and/or its commentary with a concept map representation. It includes a graph-based concept browser that supports drill-down exploration and summary views. We have evaluated the expressive power of Shaastra Map's representation scheme by applying it to diverse, popular shaastra texts including Tarka sangraha, Saankhya kaarika, KaavyaprakaaSa, Kshemakutuhala, AshtaangahRdaya etc.

The rest of the paper is organized as follows. Section 2 discusses prior work in relation to ours. Section 3 gives the organisation of discourse structure used in the shaastras that inspired our solution. Section 4describes our core contributions, namely, shaastra maps, their definition, creation and knowledge representation structures. Section 4.3 illustrates through actual examples from diverse shaastras, the expressive power of our representation - *tarka sangraha*, *Kaavya prakaasha* and *Saankhya kaarikaa*. Section 4.4 introduces a query scheme for conceptual search using a shaastra map, and how several higher-level views can be expressed using it. Section 5 outlines the implementation details and current status of this work. Section 6 outlines lessons learnt from our experience and suggest directions for further work. Section 7 summarizes the paper's contributions and key takeaways.

2 Related Work

The idea of shaastra maps is inspired by the success of mind maps. The value of mind maps to organize and present knowledge has been well-studied Beel et al. (2019). The proliferation of mind mapping tools (both free and commercial) is a testimony to their effectiveness. However, our unique contribution is in devising a standard schema for semantic networking of Indic text content that allows automated navigational queries. Semantic web is a methodology to represent and organize web content to support sophisticated knowledge processing and visualization. The natural language processing community has developed numerous tools Goyal et al. (2012; Hellwig

(2009; Kulkarni (2016) for automatically inferring semantic linkages among multiple sentences in a paragraph Srinivasan and Parthasarathi (2011). Such tools can be leveraged to infer some of the semantic tags identified in this paper, and hence are complementary. Brat Brat (2016) is a text annotation tool that provides a user-interface for concept mapping, but leaves the higher-level annotation and tagging strategy to the user.

A prior position paper Susarla et al. (2017) has made a strong case for concept mapping of Indic shaastras and proposed a representation scheme for exploiting their inner structure for machine processing. Our paper improves on that work in two ways. First, we propose tantrayuktis and padaartha sambandhas as a sounder basis for shaastra mapping due to their comprehensive and nuanced coverage of shaastric discourse concepts. Second, we offer a query mechanism on shaastra maps to support sophisticated knowledge search and navigation.

3 Organization of Shaastraic Discourse

A traditionally trained shaastric scholar eases the understanding of a shaastric discourse for any audience by (i) mapping the content of a shaastra to suit their audience, (ii) focusing on some concepts and glossing over others, (iii) bringing in relevant external references, etc. based on the objective of the study. This is because a shaastra expert uses his/her familiarity to mentally build a concept map of the flat text along with relevant works, and uses it to assist students in imbibing the concepts without getting overwhelmed.

We view a shaastric discourse as consisting of three aspects, viz.,

1. The categories of entities defined as technical terms specific to the shaastra. Shaastra has specific conventions to enumerate, define, categorize and analyze them.

2. The relations between the categories and postulates that aid in well-formed classification, logical evaluation and conclusion of the shaastric theories

3. The discourse involving logical and rational flow of thought based on the reasoning tenets of Nyaaya through topical discussions, cross-referencing and addressing objections and prima facie views leading to conclusive theorization.

The conventions available in the shaastras for describing these aspects can be broadly identified as follows:

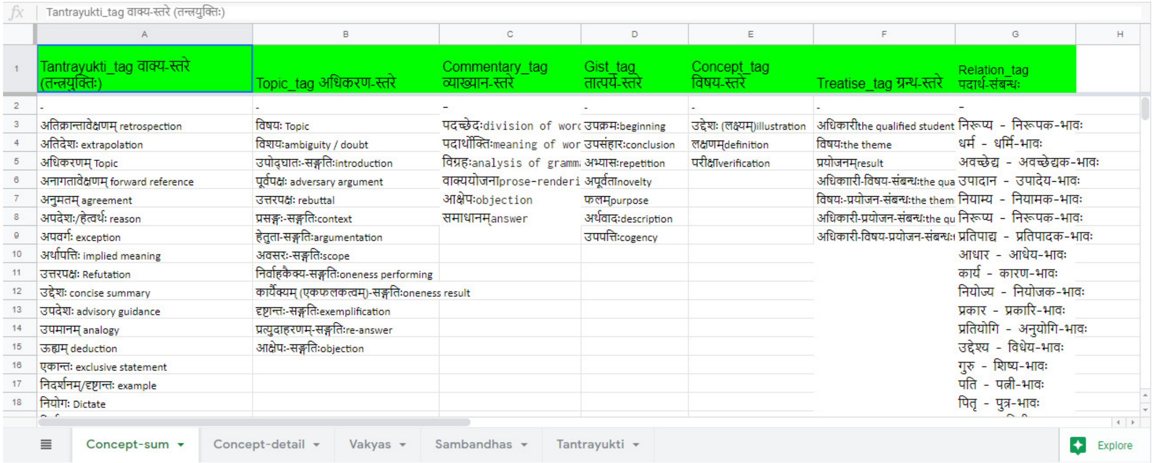
Tantrayuktis – Between 32-43 tantrayuktis are used in celebrated Shaastra texts. Tantrayukti denotes a category of sentence or inter-sentence relationships that denotes their role in a coherent logical discourse. The following elementary and standard structures are found in most shaastra texts.

- UddeSa, LakshaNa, pariikShaa and nirNaya - enumeration, definition, examination of definition and conclusion – the basic navigation structures.
- adhikaraNa, sangati and taatparya-lingas – topicalization, logical succession of discussion and pointers to arrive at conclusions. Each of these have subcomponents that are applied in the discourse as relevant to the context. For instance, adhikaraNa comprises of vishaya, viSaya, poorvapaksha, uttarapaksha, nirNaya – topic, doubt, prima facie view, proponent's view, conclusion. They, in turn use other elements such as hypothesis (pratijnaa), hetu (reason), udAharaNa (illustration), tarka (proof by contradiction), means of proof (perception, inference etc), previous / forward reference, extension of application etc.

Different shaastras employ different subsets of these constructs in their discourse as needed. We find that tantrayuktis cover a superset of these structures, and hence are useful to adopt for the purpose of creating shaastra maps.

Nyaaya-sambandhas – Relations between the categories and concepts that form part of shaastra discourse, e.g., lakshya-lakshaNa-bhaava (defined-definition), dharma-dharmi-bhaava (property-holder), saamaanya-viSesha-bhaava (class-type), avayava-avayavi-bhaava (whole-part) and so on.

Figure 1 enumerates 7 dimensions of concept categorizations used in shaastric discourse with values in each dimension. Our study of these dimensions revealed that many of the categories under Topic, commentary, gist, concept and treatise dimensions are covered under tantrayukti. Hence we believe that tantrayuktis can be used to adequately characterize a shaastra's sections and their linkages. However, capturing inter-concept relations requires, in addition, the padaartha sambandhas listed in the last column of the figure.



	A	B	C	D	E	F	G	H
1	Tantrayukti_tag वाक्य-स्तरे (तन्त्रयुक्तिः)	Topic_tag अधिकरण-स्तरे	Commentary_tag व्याख्यान-स्तरे	Gist_tag तात्पर्य-स्तरे	Concept_tag विषय-स्तरे	Treatise_tag ग्रन्थ-स्तरे	Relation_tag पदार्थ-संबन्धः	
2	-	-	-	-	-	-	-	
3	अतिक्रान्तावेक्षणम् retrospection	विषयः Topic	पदच्छेदःdivision of worc	उपक्रमःbeginning	उद्देशः (लक्ष्यम्)illustration	अधिकारीthe qualified student	निरूप्य - निरूपक-भावः	
4	अतिदेशः extrapolation	विशयःambiguity / doubt	पदार्थोक्तिःmeaning of wor	उपसंहारःconclusion	लक्षणम्definition	विषयःthe theme	धर्म - धर्मि-भावः	
5	अधिकरणम् Topic	उपोद्घातः-सङ्गतिःintroduction	विग्रहःanalysis of gramm	अभ्यासःrepetition	परीक्षाverification	प्रयोजनम्result	अवच्छेद्य - अवच्छेद्यक-भावः	
6	अनागतावेक्षणम् forward reference	पूर्वपक्षः adversary argument	वाक्ययोजनाprose-renderi	अपूर्वताnovelty		अधिकारी-विषय-संबन्धःthe qua	उपादान - उपादेय-भावः	
7	अनुमतम् agreement	उत्तरपक्षः rebuttal	आक्षेपःobjection	फलम्purpose		विषयः-प्रयोजन-संबन्धःthe them	नियाम्य - नियामक-भावः	
8	अपदेशः/हेत्वर्थः reason	प्रसङ्गः-सङ्गतिःcontext	समाधानम्answer	अर्थवादःdescription		अधिकारी-प्रयोजन-संबन्धःthe qu	निरूप्य - निरूपक-भावः	
9	अपवर्गः exception	हेतुता-सङ्गतिःargumentation		उपपत्तिःcogency		अधिकारी-विषय-प्रयोजन-संबन्धःt	प्रतिपाद्य - प्रतिपादक-भावः	
10	अर्थापत्तिः implied meaning	अवसरः-सङ्गतिःscope					आधार - आधेय-भावः	
11	उत्तरपक्षः Refutation	निर्वाहकैक्य-सङ्गतिःoneness performing					कार्य - कारण-भावः	
12	उद्देशः concise summary	कार्यैक्यम् (एकफलकत्वम्)-सङ्गतिःoneness result					नियोज्य - नियोजक-भावः	
13	उपदेशः advisory guidance	दृष्टान्तः-सङ्गतिःexemplification					प्रकार - प्रकारि-भावः	
14	उपमानम् analogy	प्रत्युदाहरणम्-सङ्गतिःre-answer					प्रतियोगि - अनुयोगि-भावः	
15	ऊह्यम् deduction	आक्षेपः-सङ्गतिःobjection					उद्देश्य - विधेय-भावः	
16	एकान्तः exclusive statement						गुरु - शिष्य-भावः	
17	निदर्शनम्/दृष्टान्तः example						पति - पत्नी-भावः	
18	नियोगः Dictate						पितृ - पुत्र-भावः	

Figure 1: Conceptual structures used in Shaastra texts

4 Shaastra Maps

Based on the understanding of shaastric structures in Section 3, we have designed a conceptual network representation of shaastra texts. We describe that in this section.

We define a *Shaastra Map* (hereafter referred to as *SMap*) as a directed graph representation of the content of one or more Indic scientific treatises or shaastra texts. An SMap captures the physical sectional hierarchy, conceptual category hierarchies, logical network of sentences, arguments etc. that constitute a coherent discourse. While discourse analysis in general is a well-developed field with its own knowledge representation conventions, we have designed SMap to specifically encode the common methods and schemas employed in Indic shaastric treatises (e.g., Ayurveda, Artha shaastra, Natya shaastra and Jyotisha, etc.). An SMap makes explicit a shaastra's inherent conceptual network that is normally implicitly understood and mentally navigated by a well-versed traditional shaastra expert. Its purpose is twofold: 1) to simplify the navigation of shaastra texts by novices by giving them access to expert-level insights, 2) to enable machine-navigation, search and mining of Indic shaastra texts at scale. Figure 2 shows the full SMap of tarka sangraha text. The nodes with high fanout indicate clustering of the discourse around a few concepts and branches and long chains indicate their elaboration.

4.1 Anatomy of an SMap

An SMap comprises a set of text segment objects and a set of relation objects. Each *text segment* in an SMap is either an individual sentence (vaakya), verse (shloka), chapter (adhikarana) or entire book (grantha). A *relation* (sambandha) is a labelled directed edge between two segments that captures one of several types of connections identified in Indic shaastraic conventions –

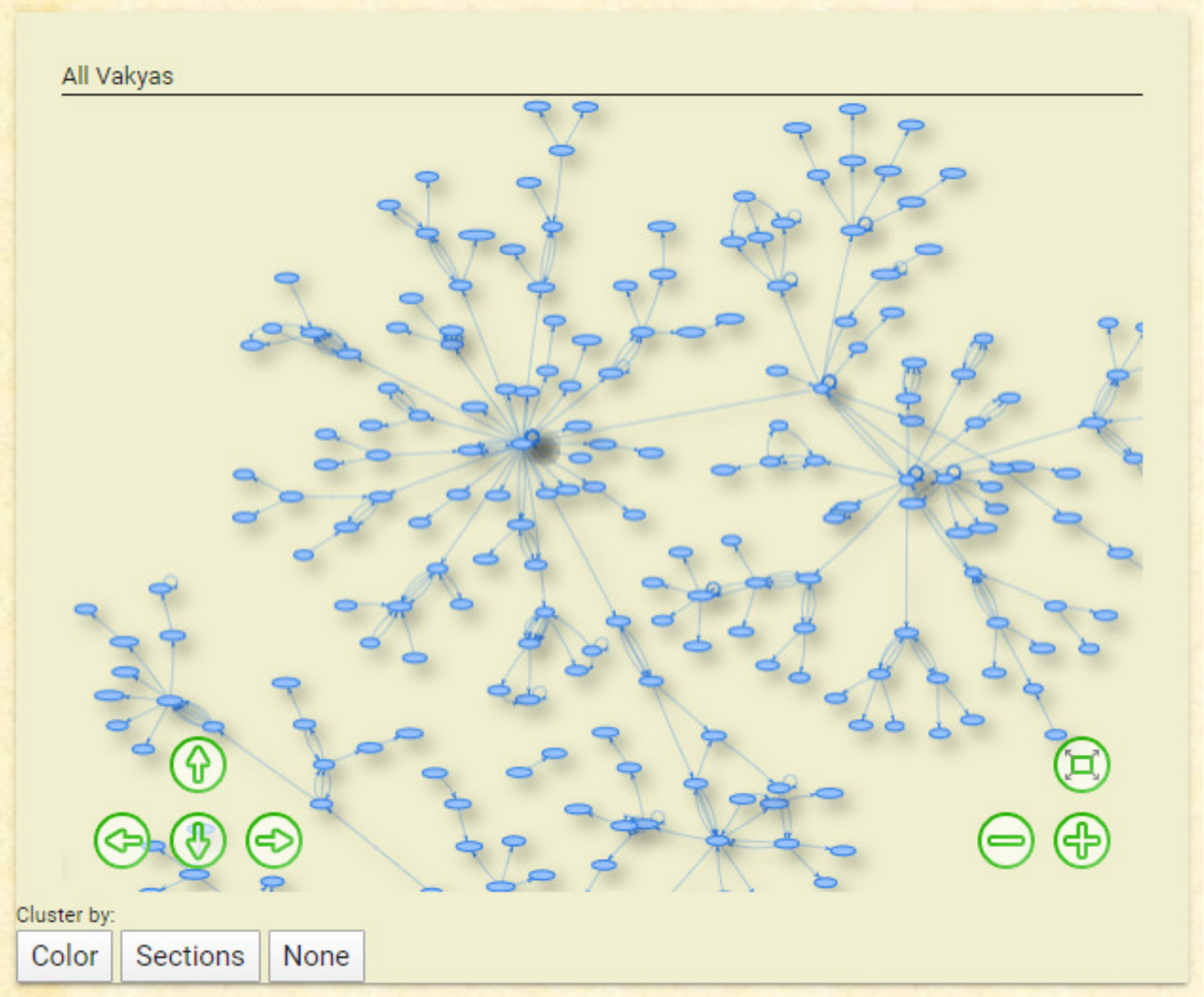


Figure 2: Full SMap graph of Tarka Sangraha text.

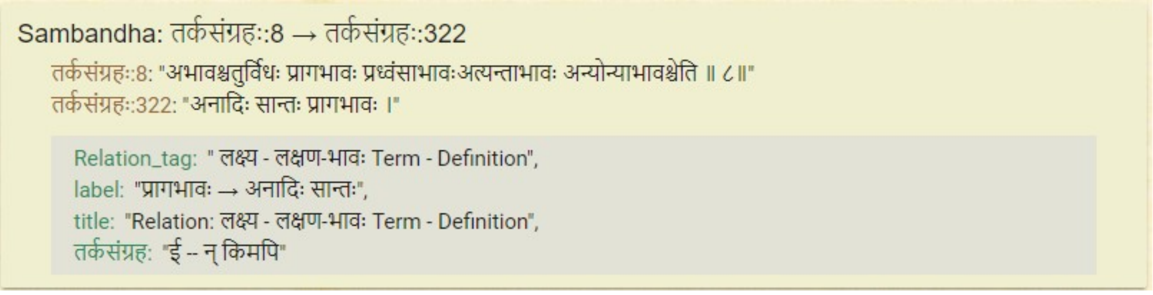
specifically *tantrayuktis* and *nyaaya sambandhas* for the purpose of this paper. We plan to include 6 other types of relations in the future. An SMap relation object is a quintuple:

- [Source segment, source anchor phrase*, relation tag (key=value), target anchor phrase*, target segment]

The scope of our SMap work is to encapsulate information at the level of sentence and above, and not intra-sentence linguistic analysis which is the subject matter of *shaabda-bodha*. There is a large body of existing work devoted to language-level syntactic and semantic analysis within a sentence that can be incorporated into an SMap framework, but is outside the scope of this paper. Since an SMap doesn't tag individual words / phrases as first-class entities below the sentence level, we use anchor phrases in relations to identify technical terms or concept / topic names employed in a shaastra. This reduces the tedium of shaastra mapping process while enabling concept-based search.

Tantrayukti_tags can be used to tag both text segments and relations of an SMap, while Nyaaya padaartha sambandhas, also called Relation_tags are used only to tag relations. In case of segments, tantrayukti tag indicates the type of exposition used in a vaakya or adhikarana, such as term-defining, exemplifying, rebuttal, forward / backward reference, enumerating, concluding, elaborating, commenting etc. Figure 5 shows an 'Uhyam' tantrayukti example in *Kshema kutuhalam* text on culinary science.

Each relation involves an optional anchor phrase of a text segment that conceptually connects it with an anchor phrase in the target segment. Thus, the relations bind together individual sentences into a coherent discourse. For instance, when a sentence uses a technical term defined in another sentence, a relation mentions the term used as the source anchor phrase, sets the relation_tag to *lakshya-lakshana bhaava.* Figure 3 illustrates it with an example from tarka sangraha text.

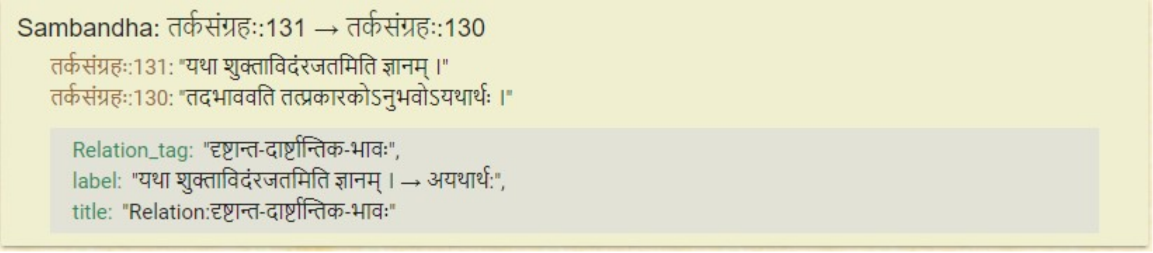


Sambandha: तर्कसंग्रहः:8 → तर्कसंग्रहः:322

तर्कसंग्रहः:8: "अभावश्चतुर्विधः प्रागभावः प्रध्वंसाभावःअत्यन्ताभावः अन्योन्याभावश्चेति ॥ ८॥"
तर्कसंग्रहः:322: "अनादिः सान्तः प्रागभावः ।"

Relation_tag: " लक्ष्य - लक्षण-भावः Term - Definition",
label: "प्रागभावः → अनादिः सान्तः",
title: "Relation: लक्ष्य - लक्षण-भावः Term - Definition",
तर्कसंग्रह: "ई -- न् किमपि"

Figure 3: Capturing term definition and use in tarka sangraha SMap.



Sambandha: तर्कसंग्रहः:131 → तर्कसंग्रहः:130

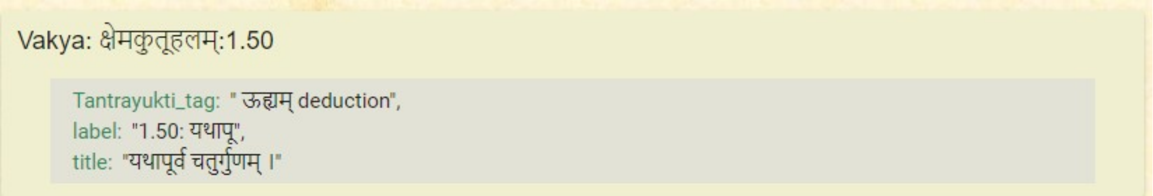
तर्कसंग्रहः:131: "यथा शुक्ताविदंरजतमिति ज्ञानम् ।"
तर्कसंग्रहः:130: "तदभाववति तत्प्रकारकोऽनुभवोऽयथार्थः ।"

Relation_tag: "दृष्टान्त-दार्ष्टान्तिक-भावः",
label: "यथा शुक्ताविदंरजतमिति ज्ञानम् । → अयथार्थः",
title: "Relation:दृष्टान्त-दार्ष्टान्तिक-भावः"

Figure 4: Capturing a concept and its example in tarka sangraha SMap.

4.2 Creating an SMap

SMap creation from a raw shaastra text is currently a manual process since it involves proficiency in identifying deep shaastraic concepts. However, we have defined the structure and schema of



Vakya: क्षेमकुतूहलम्:1.50

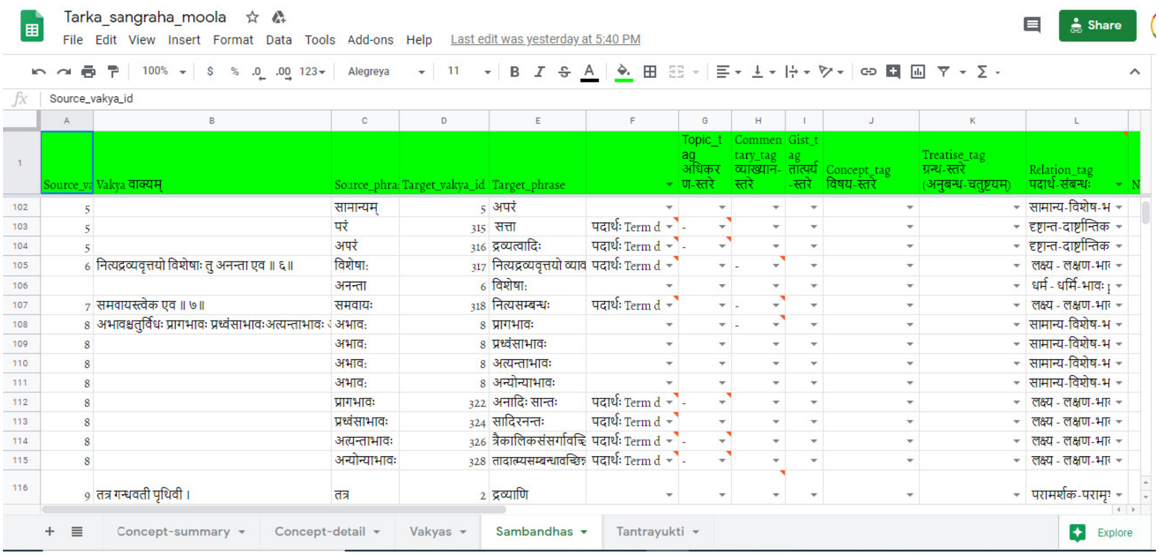
Tantrayukti_tag: " ऊह्यम् deduction",
label: "1.50: यथापू",
title: "यथापूर्वं चतुर्गुणम् ।"

Figure 5: Tantrayukti tag for a vaakya in Kshema kutuhalam text.

SMaps and developed software tools for visualization and editing of SMaps as well as a powerful query mechanism to perform knowledge queries on SMap content. Transforming one or more shaastra texts into an SMap involves the following manual steps:

- Markup the text to identify the various structural entities - chapters, sections, verses, sentences - with unique IDs so they can be explicitly tagged and referred in relations.
- Tag the entities with SMap-defined entity attributes and their values.
- Create inter-entity relations with SMAP-defined relation types.

We provide a facility to export and edit an SMap in a spreadsheet containing a vaakya sheet and sambandha sheet for tagging purpose. We have built a web-based SMap UI editor that includes a text editor for markup, structural viewer and an SMap explorer that enables specific canned views of shaastra texts described in Section 4.4.



fx Source_vakya_id

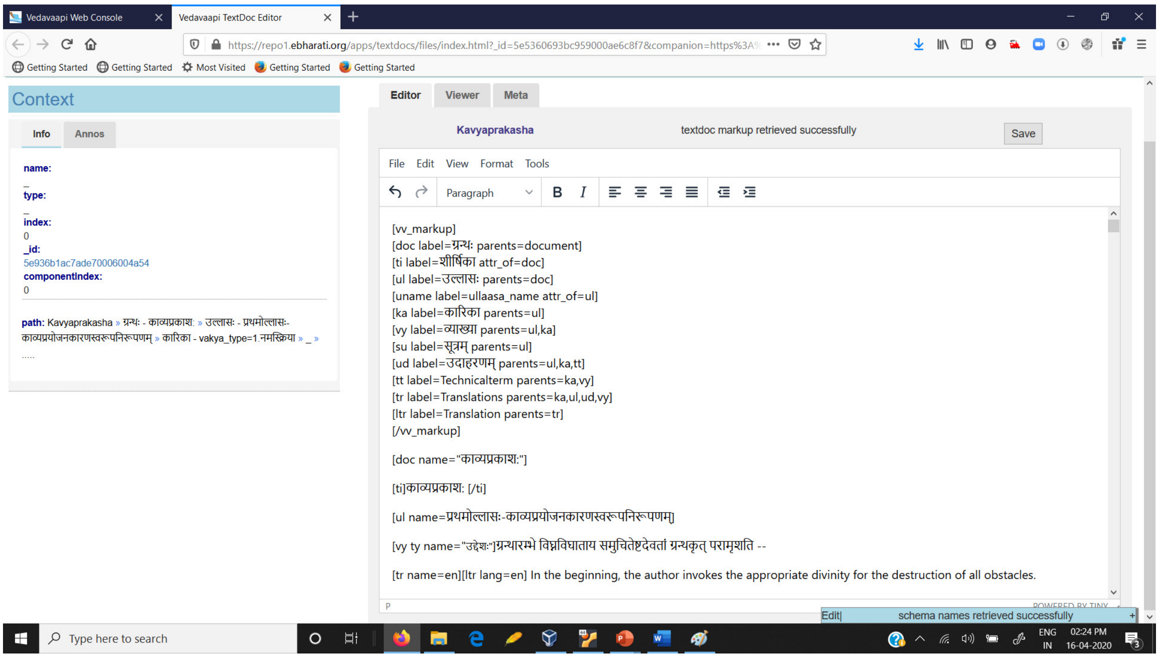
	A	B	C	D	E	F	G	H	I	J	K	L	
1	Source_va	Vakya वाक्यम्	Source_phra	Target_vakya_id	Target_phrase		Topic_tag अधिकरण-स्तरे	Commentary_tag व्याख्यान-स्तरे	Gist_tag तात्पर्य-स्तरे	Concept_tag विषय-स्तरे	Treatise_tag ग्रन्थ-स्तरे (अनुबन्ध-चतुष्टयम्)	Relation_tag पदार्थ-संबन्धः	N
102	5		सामान्यम्	5	अपरं							सामान्य-विशेष-भ	
103	5		परं	315	सत्ता	पदार्थः Term d	-					दृष्टान्त-दार्ष्टान्तिक	
104	5		अपरं	316	द्रव्यत्वादिः	पदार्थः Term d	-					दृष्टान्त-दार्ष्टान्तिक	
105	6	नित्यद्रव्यवृत्तयो विशेषाः तु अनन्ता एव ॥ ६॥	विशेषाः	317	नित्यद्रव्यवृत्तयो व्याव	पदार्थः Term d		-				लक्ष्य - लक्षण-भा	
106			अनन्ता	6	विशेषाः							धर्म - धर्मि-भावः	
107	7	समवायस्त्वेक एव ॥ ७॥	समवायः	318	नित्यसम्बन्धः	पदार्थः Term d		-				लक्ष्य - लक्षण-भा	
108	8	अभावश्चतुर्विधः प्रागभावः प्रध्वंसाभावःअत्यन्ताभावः	अभावः	8	प्रागभावः			-				सामान्य-विशेष-भ	
109	8		अभावः	8	प्रध्वंसाभावः							सामान्य-विशेष-भ	
110	8		अभावः	8	अत्यन्ताभावः							सामान्य-विशेष-भ	
111	8		अभावः	8	अन्योन्याभावः							सामान्य-विशेष-भ	
112	8		प्रागभावः	322	अनादिः सान्तः	पदार्थः Term d	-					लक्ष्य - लक्षण-भा	
113	8		प्रध्वंसाभावः	324	सादिरनन्तः	पदार्थः Term d						लक्ष्य - लक्षण-भा	
114	8		अत्यन्ताभावः	326	त्रैकालिकसंसर्गावच्छि	पदार्थः Term d	-					लक्ष्य - लक्षण-भा	
115	8		अन्योन्याभावः	328	तादात्म्यसम्बन्धावच्छिन्न	पदार्थः Term d	-					लक्ष्य - लक्षण-भा	
116	9	तत्र गन्धवती पृथिवी ।	तत्र	2	द्रव्याणि							परामर्शक-परामृ	

Figure 6: SMap spreadsheet of Tarka Sangraha for editing relations.

Markup of a Shaastra Text

The first step to creating a shaastra map is to identify the meaningful units of a treatise, the smallest being a vaakya. To facilitate this, we have devised a simple markup scheme that enables a shaastra text's unique structural hierarchy to be expressed without too much verbosity unlike XML. It allows a shaastra text's verses to be resplit into sentences, which is essential for tagging. We are open to replacing this markup with other more standardized / sophisticated markup schemes if found suitable.

Figure 7 shows the markup created in SMap structural editor for *KaavyaprakaaSa* a seminal saahitya-shaastra text by Mammata. Figure 8 illustrates how the resultant structure is visualized using the SMap structure viewer:



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index:
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componentIndex:
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path: Kavyaprakasha » ग्रन्थः - काव्यप्रकाशः » उल्लासः - प्रथमोल्लासः-काव्यप्रयोजनकारणस्वरूपनिरूपणम् » कारिका - vakya_type=1.नमस्क्रिया » _ »
.....

textdoc markup retrieved successfully

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[ul label=उल्लासः parents=doc]
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[doc name="काव्यप्रकाशः"]

[ti]काव्यप्रकाशः [/ti]

[ul name=प्रथमोल्लासः-काव्यप्रयोजनकारणस्वरूपनिरूपणम्]

[vy ty name="उद्देशः"]ग्रन्थारम्भे विघ्नविघाताय समुचितेष्टदेवतां ग्रन्थकृत् परामृशति --

[tr name=en][ltr lang=en] In the beginning, the author invokes the appropriate divinity for the destruction of all obstacles.
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P

POWERED BY TINY

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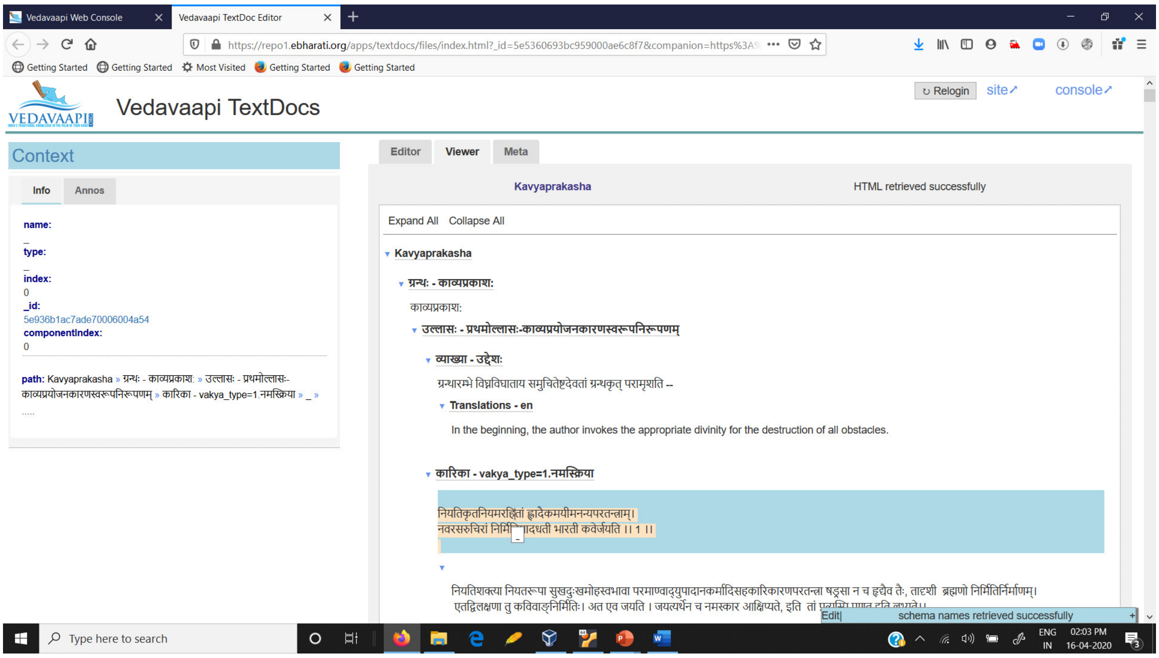
Figure 7: Specifying a shaastra text’s structural hierarchy via custom markup.



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componentIndex:
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path: Kavyaprakasha » ग्रन्थः - काव्यप्रकाशः » उल्लासः - प्रथमोल्लासः-काव्यप्रयोजनकारणस्वरूपनिरूपणम् » कारिका - vakya_type=1.नमस्क्रिया » _ »
.....

HTML retrieved successfully

▾ Kavyaprakasha

▾ ग्रन्थः - काव्यप्रकाशः

काव्यप्रकाशः

▾ उल्लासः - प्रथमोल्लासः-काव्यप्रयोजनकारणस्वरूपनिरूपणम्

▾ व्याख्या - उद्देशः

ग्रन्थारम्भे विघ्नविघाताय समुचितेष्टदेवतां ग्रन्थकृत् परामृशति --

▾ Translations - en

In the beginning, the author invokes the appropriate divinity for the destruction of all obstacles.

▾ कारिका - vakya_type=1.नमस्क्रिया

नियतिकृतनियमरहितां ह्लादैकमयीमनन्यपरतन्त्राम्।
नवरसरुचिरां निर्मितिमादधती भारती कवेर्जयति ।। 1 ।।

▾

नियतिशक्त्या नियतरूपा सुखदुःखमोहस्वभावा परमाण्वाद्युपादानकर्मादिसहकारिकारणपरतन्त्रा षड्रसा न च हृद्यैव तैः, तादृशी ब्रह्मणो निर्मितिर्निर्माणम्।
एतद्विलक्षणा तु कविवाङ्निर्मितिः। अत एव जयति । जयत्यर्थेन च नमस्कार आक्षिप्यते, इति तां प्रत्यस्मि प्रणत इति लभ्यते।।

Edit| schema names retrieved successfully

Figure 8: SMap Structure viewer

4.3 Shaastra Mapping Examples

In this section, we illustrate the SMap tagging process via examples from four shaastra texts that employ diverse discourse styles, tantrayuktis and relations. Our objective is to evaluate how well the diversity of exposition is covered by the SMap tag set.

4.3.1 Tarka sangraha

Tarka sangraha text is an elementary text on Navya Nyaaya that is widely studied by junior students. It describes ontological categories and sub-categories extensively.

Identifying type of the sentence according to tantrayukti

- Example 1: ‘अभावश्चतुर्विधः प्रागभावः प्रध्वंसाभावःअत्यन्ताभावः अन्योन्याभावश्चेति'(Vk id_8): this sentence is tagged as ‘उद्देशः’ because it is concise summary for further elaboration.

- Example 2: ‘असाधारणं कारणं करणम्' (Vk id_137): this sentence is tagged as ‘पदार्थः’ because it is a definition of a term.

- Example 3: ‘यथा शुक्ताविदंरजतमिति ज्ञानम्' (Vk id_131): this sentence is tagged as निदर्शनम्/दृष्टान्तः’ because it states an example of a false knowledge.

- Example 4: चक्षुः संयुक्ते घटे रूपस्य समवायात्' (Vk id_158): this sentence is tagged as व्याख्यानम् because it explains why samyukta-samavaaya is the relation to perceive colour of the pot.

Relating the source and the target phrase

- Example1: सामान्य-विशेष-भावः (Type-subtype) In Tarkasamgraha Experience is classified into four. The relation between Experience and its types is सामान्य-विशेष-भावः (Type-subtype). From the sentence यथार्थनुभवश्चतुर्विधः(Vk id_133) the phrase यथार्थनुभवः is targeting प्रत्यक्षानुमित्युपमितिशाब्दभेदात् (Vk id_134) with the relation tag सामान्य-विशेष-भावः (Type-subtype).

- Example 2: लक्ष्य - लक्षण-भावः Term - Definition In Tarkasamgraha Perceptive cognition is defined in the sentence इन्द्रियार्थसंनिकर्षजन्यं ज्ञानं प्रत्यक्षम्(Vk id_149), here the phrase प्रत्यक्षम् is targeting इन्द्रियार्थसंनिकर्षजन्यं ज्ञानं with the relation tag लक्ष्य - लक्षण-भावः Term - Definition.

- Example 3: दृष्टान्त-दार्ष्टान्तिक-भावः In Tarkasamgraha Pruthivi is defined as one of the types of Dravya. And further it is divided into three. Each type of Pruthivi has an example. In this sentence पुनस्त्रिविधा शरीरेन्द्रियविषयभेदात्(Vk id_13) शरीर, इन्द्रिय, विषय are stated as three types. So, each phrase is targeting अस्मदादीनाम्(Vk id_14), गन्धग्राहकं घ्राणम्(Vk id_15) andमृत्पाषाणादिः(Vk id_17) respectively with दृष्टान्त-दार्ष्टान्तिक-भावः relation tag.

- Example 4: धर्म - धर्मि-भावः property - holder In Tarkasamgraha Rupam (colour) is divided into seven and each is an attribute to different objects. In particular Pruthivi is attributed with all the types of colours. In the sentence तत्र पृथिव्यां सप्तविधम् (Vk id_63) the source phrase पृथिव्यां is targeting सप्तविधम् with the धर्म - धर्मि-भावः property - holder relation tag.

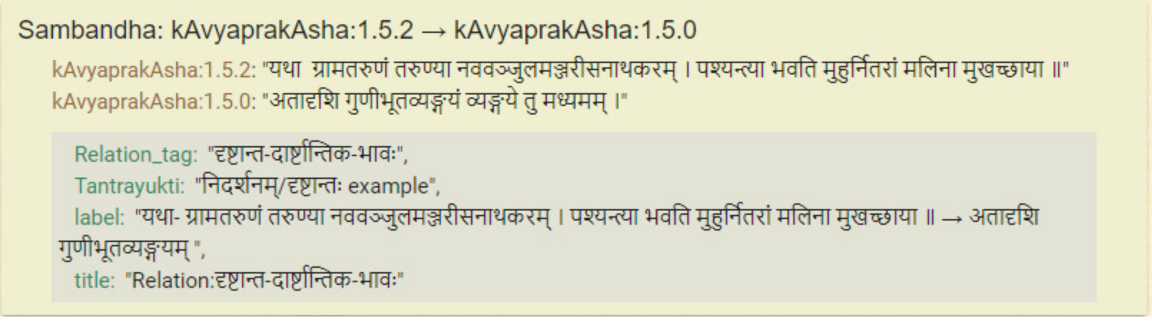
4.3.2 Kaavyaprakaasha

kaavya prakaasha is a seminal text on Indic theory of poetics - saahitya shaastra - this is compulsory for Master’s students in Sanskrit throughout India. Unlike tarka sangraha, this text is more descriptive with lot of examples of concepts and their commentary. Figure 9 shows an example of concept-example relation in this text as shown in its SMap viewer.

Identifying type of the sentence according to tantrayukti

- Example 1:इति हेतुस्तदुद्भवे (Vk id_1.2.8)’ this sentence is tagged as ‘उद्देशः’ because it is concise summary for further elaboration.

- Example 2: तददोषौ शब्दार्थौ सगुणावनलङ्कृती पुनः क्वापि।(Vk id_1.3.2)’ this sentence is tagged as ‘पदार्थः’ because it is a definition for a term.



Sambandha: kAvyaprakAsha:1.5.2 → kAvyaprakAsha:1.5.0

kAvyaprakAsha:1.5.2: "यथा ग्रामतरुणं तरुण्या नववञ्जुलमञ्जरीसनाथकरम् । पश्यन्त्या भवति मुहुर्नितरां मलिना मुखच्छाया ॥"
kAvyaprakAsha:1.5.0: "अतादृशि गुणीभूतव्यङ्ग्यं व्यङ्ग्ये तु मध्यमम् ।"

Relation_tag: "दृष्टान्त-दार्ष्टान्तिक-भावः",
Tantrayukti: "निदर्शनम्/दृष्टान्तः example",
label: "यथा- ग्रामतरुणं तरुण्या नववञ्जुलमञ्जरीसनाथकरम् । पश्यन्त्या भवति मुहुर्नितरां मलिना मुखच्छाया ॥ → अतादृशि गुणीभूतव्यङ्ग्यम् ",
title: "Relation:दृष्टान्त-दार्ष्टान्तिक-भावः"

Figure 9: Concept-example relation in Kavyaprakaasha text.

- Example 3: काव्यं कर्तुं विचारयितुं च ये जानन्ति तदुपदेशेन करणे योजने च पौनःपुन्येन प्रवृत्तिरिति |(Vk id_1.2.7) ‘ this sentence is tagged as व्याख्यानम् because it explains why samyukta-samavaya is the relation to perceive colour of the pot.

Relating the source and the target phrase

- Example: सामान्य-विशेष-भावः (Type-subtype) In Kāvyaprakāśa, Avarakāvya-type is classified into two. The relation between avarakāvya and its types is सामान्य-विशेष-भावः (Type-subtype). From the sentence शब्दचित्रं वाच्यचित्रम् अव्यङ्ग्यं त्ववरं स्मृतम् ॥ (Vk id_1.6.0) the phrase अवरं is targeting two subtypes शब्दचित्रं andवाच्यचित्रम् (Vk id_1.6.1) with the relation tag सामान्य-विशेष-भावः(Type-subtype).

4.3.3 Saankhya Karika

Saankhya kaarika has a mix of ontological discourse and philosophical reasoning. It is a widely studied root text on Saankhya system of Indian philosophy.

- Example 1: ‘दृष्टम्-अनुमानम्-आप्तवचनं च(Vk id_4.1a)’ is tagged as ‘उद्देशः’ because it is concise summary of the list of epistemological tools, which will be elaborated later.

- Example 2: महत्-आदि तच्च कार्यं प्रकृति-विरूपं सरूपं च (Vk id_8.2) is tagged to निर्देशः for.this sentence detailed enumeration of Mahat etc fromमहद्-आद्याः प्रकृति-विकृतयः सप्त (Vk id_3.1b) sentence.

- Example 3: एकान्त-अत्यन्ततः-अभावात्(Vk_1.2c) is tagged as अपदेशः/हेत्वर्थः as it is explaining the reason for why one has to enquire into Anumana, rather completely depending upon sensory perception and Vedas.

- Example 4: सत्कार्यम् (Vk id_9.2c) is tagged as निर्णयः type of sentence because it is concluding that the effect / product exists in the cause, after explaining all the valid reasons.

- Example 5: सङ्कल्पकमिन्द्रियं च (VK id_27.1b) is tagged as योगः as it adds one more characteristic of mind as a continuation from the previous statement which defines the ‘’Manas’’

- Example 6: युगपत् चतुष्टयस्य तु वृत्तिः क्रमशश्च तस्य निर्दिष्टा(VK id_30.1) is tagged as अतिक्रान्तावेक्षणम् because it is retrospecting what is said earlier regarding Indriya and Antahkarana. }

4.3.4 Ashtanga Hrdayam

Ashtanga Hrdayam is a popular foundational text of Ayurveda studied by most practitioners. It has highly structured descriptions of herbs and their properties.

Identifying type of the sentence according to tantrayukti

- Example: In Asthanga Hridaya, there is a separate chapter for medicinal data that starts with the vaakya अथौषधवर्गः (Vk id_1), this is tagged as ‘अधिकरणम्’ .

Relating the source and the target phrase

All the following examples are in relation to the sentence, ‘नागरं दीपनं वृष्यं ग्राहि हृद्यं विण्मबन्धनुत् // रुच्यं लघु स्वादुपाकं स्निग्धोष्णं कफवातजित् (Vk id_43)

- Example 1: नागरं is source phrase and अथौषधवर्गः (Vk id_1) is target phrase with विषय - विषयि-भावः relation tag.
- Example 2: नागरं is source phrase and दीपनं, वृष्यं, ग्राहि, हृद्यं, विबन्धनुत्, रुच्यं, कफवातजित् are target phrases with धर्म - धर्मि-भावः relation tag. According to this tag, the karma (action of drug) properties of nagara can be extracted.
- Example 3: नागरं is source phrase and लघु and स्निग्ध are target phrases with गुण-गुणि-भावः relation tag. According to this tag, the guna (physical quality) properties of nagara can be extracted.
- Example 4: नागरं is source phrase and स्वादुपाकं is target phrase with गुण-गुणि-भावः relation tag. According to this tag, the rasa (taste) properties of nagara can be extracted.
- Example 5: नागरं is source phrase and उष्णं is target phrase with गुण-गुणि-भावः relation tag. According to this tag, the virya (potency) property of nagara can be extracted.

Overall, by using धर्म - धर्मि-भावः, गुण-गुणि-भावः, the rasapanchaka (rasa, guna, virya, vipaaka, karma) of a drug or a dravya is easily extracted from Ayurveda texts or lexicons. Note that though uShNa-tvam, svaadu-tvam, laghu-tvam, diipanam etc. are guNas / properties of Naagara, they are visheshas of different saamaanya categories (or classes), namely, viirya, rasa, guna and karma respectively and need to be connected as such to reconstruct the schema of oshadhis from text.

4.4 ShaastriQL: A Shaastric Query Library for Conceptual Search using SMaps

To facilitate an extensible set of services using SMap, we devised a powerful recursive graph query library in Python and Javascript that yields a subset of the given SMap based on the following filtering criteria.

- A starting segment selector: Select the starting text segments for navigation based on their properties,
- A sequence of one or more hop selectors: Navigate from chosen segments to their neighbors based on the attributes of the linking relation as well as of the target segment reached, ·
- Number of hops to traverse (-1 means unlimited hops), and
- Inclusion criteria: Select which segments and relations to include in the resultant subset of SMap, regardless of which were traversed during query processing.

Result_smap = mySMap.filter(start_node_selector, hop_selectors, nhops, inclusion_criteria)

In ShaastriQL, we aim to support functional chaining paradigm similar to JavaScript, i.e., lazy execution of queries, programmatic iteration over their results and feeding them to subsequent operations to generate sophisticated views of a shaastra text. Towards that end, we support the following primitive operations on an SMap:

SMap.filter(start_nodes=[], hop_selectors[], nhops=-1,inclusion_criteria=None): A generic ShaastriQL query that returns a filtered, iterable SMap object to enable functional chaining. Default parameter values are mentioned in the function signature.

SMap.segments(filter=None): Provide the text segment objects of given SMap as an iterable list.

SMap.relations(filter=None): Provide the relation objects of given SMap as an iterable list.

Using these operators, a variety of canned views can be created on an SMap:

SMap.terms(): Provide a glossary of technical terms / concepts defined in the treatise as iterable list. This involves querying for vaakyas with padaartha tantrayukti. To retrieve the terms being defined, hop_selector can be set to retrieve lakshya-lakshana bhaava relations. The source anchor phrase denotes the term. Figure 10 show the Glossary of term definitions generated in SMap viewer for *Vedaanta saara* text.

SMap.properties(dravya): List properties (guNas) of a dravya mentioned in the treatise. This involves search for *dharma-dharmi bhaava* and *guNa-guNi bhaava* relations where the target anchor phrase is the dravya name. Then traverse the guNa-guNi relations recursively to retrieve its property hierarchy.

SMap.examples(concept): Retrieve examples of a concept mentioned in the treatise. This involves retrieving drshTaaanta-daarShTaantika bhaava relations whose target anchor phrase is the concept name, along with their source segment, which is the example sentence.

SMap.type_hierarchy(term): Recursively enumerate the type-subtype hierarchy of a term. This involves starting with the nirdesha vaakya of given term (enumerating tantrayukti).

SMap.table_of_contents(): Show the section hierarchy of the treatise (chapters, sections, subsections etc.). This involves navigating the avayava avayavi relations recursively starting with the adhikaraNa vaakyas.

SMap.summary(N): Create an N-sentence summary of the treatise. This involves starting with vaakyas tagged as adhikaraNa tantrayukti (i.e., head sentences), and retrieving their neighboring vaakyas until the target of N vaakyas is reached.

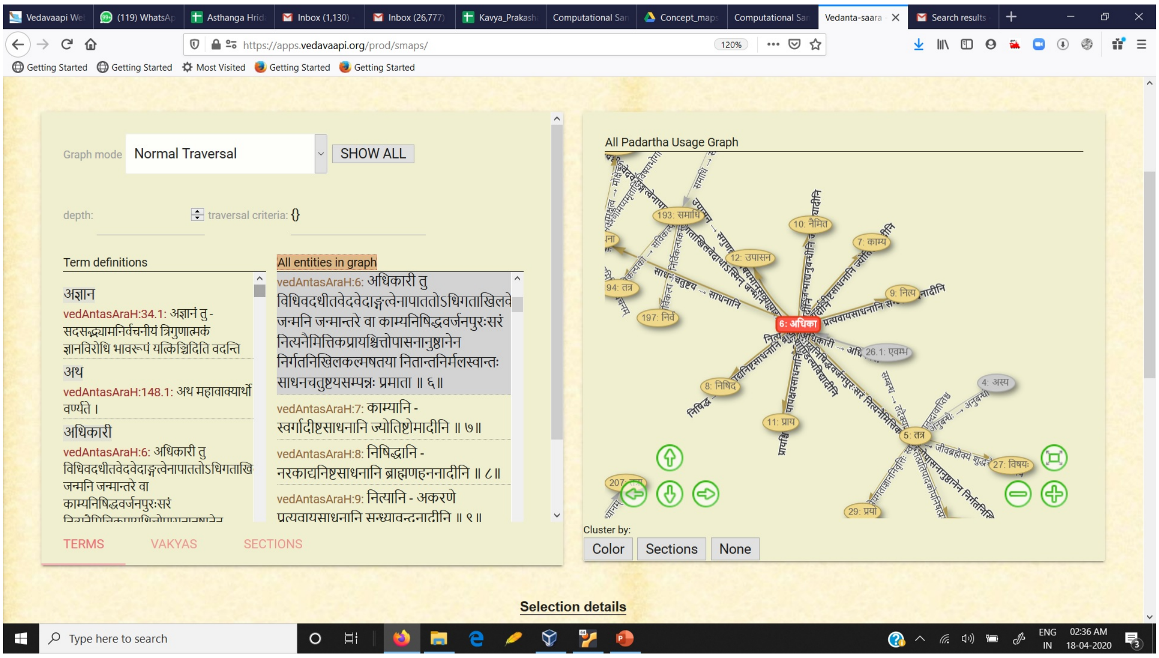
SMap.discourse(concept): Retrieve the entire hierarchy of sentences on given topic and its analysis, in depth-first or breadth-first order.

SMap.sahadharmis(dravya): Retrieve dravyas with similar properties to given dravya. This involves the following steps:

- First, we retrieve saamaanya-vishesha siblings of given dravya. To do this, we first retrieve saamaanya-vishesha relations whose target phrase is dravya name and source phrase denotes its class name, followed by segments reachable from the class name by one hop via saamaanya-vishesha relation.
- Then we retrieve all the dharmas / guNas of given dravya via SMap.properties(dravya).
- Finally, we select those siblings of dravya whose guNa set maximally overlaps its guNa set.

5 Implementation Status

We have implemented Shaastra maps as an application on a scalable annotated object store based on MongoDB JSON object database Susarla and Challa (2019). All entities and relations are stored as objects in the object store, and the ShaastriQL graph traversal API is built on MongoDB's query language. We have implemented a web-based SMap editor (Figure 8 provides a screenshot) and an SMap navigation tool (Figure 10 shows a screenshot). We are in the process of integrating SMap network editing UI (for segment and relation tagging) into the SMap editor. Since ShaastraMap functionality has humans in the loop and does not interpret the language of the text directly, its paradigm is applicable not only to shaastra texts but contemporary applications where plain text needs to be converted into knowledge maps for mining. How well the shaastraic paradigms of SMap ecosystem apply to contemporary text mining is an open question worth exploring.



Graph mode Normal Traversal SHOW ALL

depth: traversal criteria: {}

Term definitions

अज्ञान

vedAntasAraH:34.1: अज्ञानं तु - सदसद्भ्यामनिर्वचनीयं त्रिगुणात्मकं ज्ञानविरोधि भावरूपं यत्किञ्चिदिति वदन्ति

अथ

vedAntasAraH:148.1: अथ महावाक्यार्थो वर्ण्यते ।

अधिकारी

vedAntasAraH:6: अधिकारी तु विधिवदधीतवेदवेदाङ्गत्वेनापाततोऽधिगताखि जन्मनि जन्मान्तरे वा काम्यनिषिद्धवर्जनपुरःसरं

All entities in graph

vedAntasAraH:6: अधिकारी तु विधिवदधीतवेदवेदाङ्गत्वेनापाततोऽधिगताखिलवे जन्मनि जन्मान्तरे वा काम्यनिषिद्धवर्जनपुरःसरं नित्यनैमित्तिकप्रायश्चित्तोपासनानुष्ठानेन निर्गतनिखिलकल्मषतया नितान्तनिर्मलस्वान्तः साधनचतुष्टयसम्पन्नः प्रमाता ॥ ६॥

vedAntasAraH:7: काम्यानि - स्वर्गादीष्टसाधनानि ज्योतिष्टोमादीनि ॥ ७॥

vedAntasAraH:8: निषिद्धानि - नरकाद्यनिष्टसाधनानि ब्राह्मणहननादीनि ॥ ८॥

vedAntasAraH:9: नित्यानि - अकरणे प्रत्यवायसाधनानि सन्ध्यावन्दनादीनि ॥ ९॥

TERMS VAKYAS SECTIONS

Figure 10: Glossary browsing of *Vedaanta-saara* text in SMap viewer.

ShaastriQL is currently available as a Python API library, and is in use to support the SMap application. We are building a Javascript version and hope to enrich it into a domain-specific functional language with a JavaScript substrate to enable powerful E-reader UI tools for Sanskrit texts.

We have created SMaps of substantial portions of a dozen Sanskrit treatises so far, with a combined size of more than 4000 sentences and 7000 relations. We have designed and delivered a training and certification course on shaastra mapping[2] to 160 Sanskrit scholars across India, and have initiated projects to map 6 major Sanskrit works including Patanjali Mahabhashyam, Yogasutra with Vyaasa bhaashya, Shukraniiti, Artha shaastra, Ashtaanga Hrdayam and a few introductory Jyotisha and Vaastu texts. All the SMap templates and the tools created so far are publicly available at `https://apps.vedavaapi.org/smaps`. For further queries, please contact info@vedavaapi.org.

6 Lessons Learnt and Future Directions

Our experience with Shaastra mapping is that it requires more than academic understanding of Nyaaya and mimaamsa texts. It requires the ability to apply their principles to identify Shaastric knowledge structures in other disciplines. As a result, initial training of traditional scholars to identify Tantrayuktis and sambandhas accurately has been quite tedious and intellectually challenging and forced us to gain nuanced understanding of their semantics. However, we now managed to train more than 160 scholars and have a dozen manually tagged SMaps. A possible avenue of research would be to combine training data with machine-learning for human-assisted annotation of Shaastra map categories in texts. This will greatly accelerate Indic knowledge mining for contemporary utility.

A second avenue is to explore enriching ShaastriQL into a full-blown knowledge processing language and compare its expressive power to prevailing knowledge representation and query paradigms such as Semantic Wikipedia. How well can SMap representation and ShaastriQL support mining of contemporary non-shaastra texts?

[2] https://mitvedicsciences.edu.in/announce/shaastric-modeling/

A third avenue is to explore the synergy of Shaastra mapping with sentence-level and word-level linguistic analysis tools to create an end-to-end knowledge transformation pipeline. Can knowing the tantrayukti of a sentence help resolve the ambiguities that cause hurdles for shaabda-bodha? For instance, can we build custom sentence parsers to automatically extract ontologies from Indic texts based on tantrayukti hints like "enumeration, term-defining sentence" etc.? A fourth avenue is to explore how Mimaamsa nyaayas can be used for effective knowledge mining and robotic intelligence. A fifth avenue is to take knowledge mining towards building deployable Indic models to enrich contemporary knowledge with shaastric insights.

7 Conclusion

In this paper, we presented ShaastraMaps, a knowledge representation and query scheme based on Indic shaastraic paradigm for easy assimilation and machine-processing of Indic scientific texts. While extensive work happened in language processing of Sanskrit at or below sentence level, this paper hints at the feasibility of exploiting Indic knowledge science constructs to enable higher-order meaning processing of Indic knowledge treatises at scale. To exploit this opportunity requires Sanskrit / shaastra scholars and computing professionals to work across boundaries towards application-oriented study of shaastras.

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