
An Indian logic-based argument representation formalism for knowledge-sharing¹

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Abstract

Knowledge-sharing is the fundamental aspect of learning from ancient days. By exchanging questions and answers in a debate fashion, knowledge is explored. Argumentation can be thought of as a knowledge-sharing mechanism where construction of arguments and counter-arguments towards reaching mutually agreed upon conclusions is modelled after the rational discussion of knowledge-sharing. The procedural approach of generation and exchange of arguments is with the intention of reaching a definite conclusion at the end of discussion irrespective of the winning or losing of the individual arguments. A procedural argumentation system for knowledge-sharing, similar to the one discussed above will be of immense use only when the representational facts of world knowledge are well captured and represented as identical with the representation of natural intelligence. Indian Philosophy suggests various rules for classifying and representing the world knowledge to enhance the procedure of argumentation in reaching new inferences. This paper discusses a new mathematical model that caters to the special requirements of classification and hypothetical argumentative reasoning (tarka) of Indian philosophy. The main focus is the emphasis given to the existence of relations between concepts and foundation of invariable connection between concepts/relations of the arguments that is indicated by the philosophy. The extracted knowledge from the arguments exchanged is captured using 'Indianised logics', an Indian Logic based argument representation formalism. The arguments are deeply analysed for the presence of conceptual and relational conflicts. This is achieved by referring to the presence and/or absence of invariable concomitance, so that, the decision of justifying the represented invalid knowledge with or without proof shall be made clear in knowledge-sharing through rational discussion.

Keywords: Mathematical model, Knowledge representation, Procedural argumentation, Logic, Indian philosophy, Knowledge-sharing and Argument.

1 Introduction

Knowledge-sharing deals with the transfer of world knowledge from one person to another by following specific patterns of inferences using reasoning procedures. A number of philosophies have defined frameworks for efficient learning through knowledge-sharing by discussions [19, 20]. Applying argumentative procedures for learning involves drawing conclusions by repeated submission of questions and answers, thereby exploring the subject of discussion [33]. Argumentation can be defined as reasoning in the presence of imperfect information by constructing and weighing up arguments. It is an approach for inconsistency

¹This work is an extended version of the paper titled 'A Mathematical Model for Argument Procedures based on Indian Philosophy', *Proc. of International Conf. on Artificial Intelligence & Applications (AIA'06) as part of 24th IASTED International Multi-conference on Applied Informatics (AI'06)*, Innsbruck, Austria, February 13–16, 2006.

management in which conflict is explored rather than eradicated [10]. Procedural argumentation tries to resolve knowledge inconsistencies by analysing arguments and providing suitable counter-arguments. In spite of exploring the argument conflicts, procedural argumentation also tries to eradicate the explored conflicts by constructing counter-arguments from the Indian philosophical viewpoint. Indian philosophy states a number of reasoning techniques and refutation mechanisms which aid this process of learning by knowledge-sharing through argument procedures [36, 39]. The methodology of reasoning adopted from Indian philosophy tries to infer from arguments and counter-arguments by highlighting the flaws or holes in pre-stated propositions based on inconsistencies with respect to the ontological commitments.

To serve the purpose of knowledge-sharing and to support the sharing and reuse of formally represented knowledge, a common vocabulary and a terminological ontology which describes the world knowledge concepts are essential. The common vocabulary is at a lower instance level which is also abstract in its very nature. The terminological ontology is at a higher level, which is partially domain-related [18]. In this context, Nyaya Sastra, the famous Indian school of Philosophy, has laid great stress on categorisation of world knowledge into a classification framework [1, 36]. Though the philosophical emphasis of Nyaya Sastra strengthens the ontology's classification scheme, efficient storage and retrieval of classified world knowledge is highly dependent on the representation formalism, a major issue in building the ontology [23]. Description logics (DL) have been used to represent ontology in many systems [12]. However, the definition of ontological entities provided by standard DL does not tackle the special requirements dictated by Nyaya Sastra's classification framework [2]. Modification of basic reasoning services of standard DL by Aghila [2] created scope for definition of more descriptive concept elements based on Indian philosophy. But the extended DL [3] was only an attempt to model the Nyaya Sastra's classification framework. Representation of procedural arguments which serves as the carrier of argument knowledge require a more enhanced argument representation formalism to suit the procedural form of argumentation, which results in efficient knowledge-sharing [36, 39].

The basis of our work is the idealisation of methodology of procedural argumentation for knowledge-sharing which is adapted from two Indian perspectives: Nyaya Sastra, the Indian logic system and Nannool, the famous treatise on Tamil grammar. Nyaya states the syllogistic method of argument formation. Several methods of Nyaya refutation are found to be identical with Nannool, which also describes additional refutation strategies [7, 13, 28]. To model the advanced reasoning and refutation mechanisms of Indian philosophy, we propose 'Indianised logics', a more suitable knowledge representation for expressing world knowledge through procedural arguments. Here, we consider every argument as a collective representation of concept and relation elements. By analysing the concept and relational elements of submitted arguments and invariable concomitance relation inherently present as a special property attached to the elements of arguments, holes or flaws present in the arguments which will aid in the construction of effective counter-arguments as refutations to the submitted arguments shall be identified.

2 Ontology in Knowledge-sharing

World knowledge used for reasoning is mostly uncertain in nature. To overcome this uncertainty, a methodology based on formal specifications of shared resources, reusable components and standard services are needed. Specifications of shared vocabulary play an

important role in such a methodology. Most knowledge-based systems operate and communicate using statements in a formal knowledge representation with the domain-oriented knowledge as an input when dealing with negotiation and information exchange. Ontology is a formal mechanism of representing the world knowledge, out of which effective and easy reasoning is possible while knowledge-sharing [17]. A specification of a representational vocabulary for a shared domain of discourse with definitions of classes, relations, functions and other objects is called an ontology [18].

Ontological commitments are agreements that define a clear boundary of how to *view* the ontology [11]. This means that the specification format is independent of the internal representation such that the ontological commitments are defined only at the knowledge level. In the context of multiple entities participating in knowledge-sharing, a common ontology can serve as a knowledge-level specification of the ontological commitments of a set of participating entities that are involved in discussion. A common ontology defines the vocabulary with which queries and assertions are exchanged among entities involved in knowledge-sharing [18]. Hence, knowledge-sharing deals with ontological commitments, which decides how much knowledge is being revealed to the learner. The efficiency of knowledge-sharing process lies in the learner's ability to pick holes in the teacher's proposition and the ability of the learner to find appropriate defects in various aspects of the proposition and methods to defeat the propositions by attacking the identified defects in the proposition [16]. This paper utilises the above-mentioned concept of argumentation framework for reasoning through knowledge-sharing and describes a mechanism for defining ontologies that are usable over different argument representation systems.

3 Argumentative Procedures for Knowledge-sharing

From the perspective of knowledge-sharing, argumentation can be defined as a reasoning methodology based on the construction of arguments and counter-arguments and selection of the most acceptable ones to reach new conclusions. During traditional times, discussion was performed as a means to eradicate one's false beliefs or to prove one's scholarly knowledge over the subject of discussion [30]. The ancient school of Hinduism adapted a very similar strategy of argumentative procedures for learning where the conclusion is finally obtained by continually submitting questions and receiving answers in an acceptable manner by directing the flow of arguments with less deviation from the topic of discussion. This is similar to dialectical reasoning employed by certain ancient philosophers, notably Socrates [33]. The learner's ability to pick holes relies upon the efficient representation of world knowledge to perform basic common sense reasoning. Holes identified are put forth as counter-questions expecting further clarification on the subject matter of discussion. The teacher need not generate similar answers to the identical questions posed. The style of response to every question thrown as doubts by learners actually lies in the style and nature of finding holes (or) flaws that generated such questions, which differed from student to student. Practically, common sense and reasoning along with the ability to infer things from basic interpretations and to deliver them as questions varied on a large scale from person to person and are unique to every learner of its kind.

Efficiency of such reasoning and inferencing lies primarily in the language-independent representation of world knowledge. The approach discussed in this paper, handles classified world knowledge by syllogistic interactions as per Indian philosophy [34]. This paper attempts to define a mathematical representation that would use the Nyaya's shared

conceptualisation or ontological commitments and then proceed in the direction of establishing an argumentation framework for reasoning through knowledge-sharing.

4 Philosophical Perspectives for Argument Representation

Procedural argumentation tries to resolve knowledge inconsistencies by analysing arguments and providing suitable counter-arguments. Western philosophical systems treat argumentation in a different way. Western logic does not inquire whether the premises and conclusion of an argument are true. It is solely concerned with determining whether a given argument is valid. Indian logic does not possess the verbalistic view of arguments. Indian logic is based on the conviction that logic is an instrument for the discovery and understanding of reality [31]. The school of reasoning (Nyaya) has keen interest in the nature of perception and the ways in which the truth is established. In particular, the Nyaya concerns with the nature of inferential reasoning and constructed a system of rules for conducting debates.

4.1 Nyaya Tradition of debates

The importance of Nyaya tradition with Indian philosophy has its significance particularly in rational debate and clear, logical argumentation. Nyaya means ‘that by which one is led to a conclusion’ or ‘correct reasoning’ and is often referred to as ‘the science of reasoning’ [36]. Analysis of inferential reasoning was central in establishing the proper rules for scholastic debate, a prominent practice of Indian philosophy. The roots of Nyaya lie in aspects concerning the nature of debate and its formal procedures. Logic in India developed out of two slightly distinct traditions: 1. *vada* tradition i.e. the tradition of debate which was concerned with dialectical tricks, eristic arguments and sophistry, 2. *pramana* tradition, which was concerned with the criteria of empirical knowledge, the accredited source of knowledge [9]. According to Nyaya-Sutra, three kinds of *vada* were identified [8]:

1. Discussion: Good debate in which the proof and refutation of thesis and antithesis are based on proper evidence and without contradicting any background or already established assumptions.
2. Disputation: Devious or sly debate, in which the proof and refutation use unfair, measures such as hair-splitting empty pedantry, false rejoinders and defeat situations.
3. Destructive criticism: Purely destructive or refutation-only debate, in which no positive counter-thesis is proved.

4.1.1 *Vada* in Nyaya

Discussion or *vada* is primarily meant for the discernment of truth or the real nature of the thing under investigation and imparting the truth, as one understands it to the other party. According to Gotama, discussion is the adoption of one of two opposing sides. What is adopted is analysed in the form of five members, and defended by the aid of any of the means of right knowledge, while its opposite is assailed by confutation, without deviation from the established tenets [15]. In discussion, there is no consideration of victory or defeat [14]. The Nyaya-Sutra offered a five-step inference pattern for those who want to engage in an honest, friendly, fair, and balanced debate or *Vada*. This five-step inference schema is known as the *classical five-membered inference pattern for proper argumentation* [8]. The concern clearly

was to promote the notion and the practice of a good debate, and to differentiate it from the pointless, destructive debates.

4.1.2 Fallacious reasoning

Fallacies are logical errors, which are to be avoided in any discussion. The syllogistic method of argument formation as cited in Nyaya philosophy [36] states the possibility of defects that are found identifiable in stated arguments, through which any argument can be challenged for justification and existence. These defects, otherwise called reason fallacies, are connected with inferential reasoning, which is always seen as grounded in perception and the activity of the mind. In the west this has been described as ‘the fallacy of psychologism’ [32]. Fallacies can be present with the reason or with the manner in which the argument is proposed. The five types of fallacious reasoning accepted by Nyaya are: 1. wandering or indecisive reasoning 2. contradictory reasoning 3. unestablished reasoning 4. reasoning that requires as much proof as the thesis 5. reasoning that is mis-timed or sublated [15]. Overcoming these fallacies or defects is called “removing the holes” from the submitted argument. The defects when properly identified will aid in constructing the counter-argument as a measure of attack on the submitted argument [36].

4.1.3 Futility in Procedural Argumentation

An argument is futile when the reverse of what it seeks to prove is established for certain by another proof [21]. Refutation can be defined as pointing out the defects or fallacies in the statements of the opponent, which causes defeat to the argumentator. Nyaya states 22 kinds of refutations like hurting the proposition, shifting the proposition, opposing the proposition, shifting the reason, etc. [36]. Apart from various categories of style and nature of arguments as specified by Nyaya’s primitive and advanced reasoning, Nannool also states further parameterisation and classification of nature of arguments. Causation, summarisation, classification, reference to a conclusion, postponing a reason, avoiding expansion, expansion at instance are quite a few among them [13, 28]. These refutations when combined with Nyaya school of argument structure, that incorporates the invariable concomitance method of finding the possible defects in the submitted arguments, frames a common method of handling arguments involved in knowledge-sharing. Our current work deals with only the Indian logic-based knowledge representation which can be made use for modelling philosophical refutations into automated arguing systems; therefore, more detailed discussion about the refutations is out of scope of this paper.

4.1.4 Rules of scholastic debate in Nyaya

To illustrate the formal procedures of an Indian vada or debate [32] let us examine the following scheme of scholastic argumentation. A scholastic formal debate involves two interactive participants – the proponent (one who holds the initial position) and a respondent. The order and procedure of the debate, according to Richard [32] follows eight basic steps:

- a. The initial proponent is asked to put forward his thesis
- b. If the thesis is thought to be erroneous the respondent may refute it immediately, but if the thesis is accepted, then the respondent asks the proponent to outline the reason for accepting the thesis
- c. The proponent then offers a proof outlining the reasons why the thesis should be accepted

- d. The respondent asks if the proof offered contains the logical relations required of a sound inference
- e. The proponent replies by “removing the thorns”, that is, he negates the faulty relations and erroneous reasoning that may have occurred in the outlining of the proof of his thesis

This concludes the first part of the debate. If the respondent accepts both the thesis and the proof then the debate concludes. However, if the proof is deemed erroneous for some reason, then the second part of the debate is required.

- f. The respondent offers a statement of refutation of the proponent’s thesis, which thereby constitutes the initial starting-point of his own exposition. The refutation that follows aims to demonstrate the errors and inconsistencies of the proponent’s position based upon the reasoning and evidence provided by the proponent. This stage, of course, may be entered much sooner (at stage 2) if the respondent does not accept the thesis of the proponent at the outset
- g. The proponent responds with a rejoinder if he thinks that his critic’s refutation is in some way erroneous. However, if the proponent accepts the soundness of the refutation, the respondent is asked to state a formal proof of the refutation in a positive form, that is, as an independent and formally stated inference
- h. Finally, the respondent offers a formal proof of the refutation in inferential form.

4.2 *Tarka* and Nyaya inferencing

In Indian philosophy, there are two types of inference, one that is designed to alleviate doubt for one-self and another that aims at convincing another. The ‘inference for the sake of oneself’ is an inference drawn in one’s own mind as a result of repeated observation earlier. However, the ‘inference for the sake of others’ is not an informal matter. It requires demonstration of the inferential process as well as the evidence or ground for making the inference. The elaboration of the formal proof constitutes of proving the opponent what one has inferred and also showing how such inference had been arrived at. For the sake of demonstration, according to the ancient Nyaya logic, the proper formulation of the inference should have *five* parts. It is technically known as the five-membered inference or argument schema [8]. This distinction reflects the Indian view that inference concerns the correct application of thought. A formal proof, therefore, is only required as a means of aiding the listener to direct their thought process in an appropriate manner [32]. The purpose of analysing inference was to establish rules of debate among philosophers, so that the best system of thought could be identified without question [22].

Nyaya postulates an additional category of debate, known as hypothetical reasoning or rational critique (*tarka*), which is the exchange of arguments between the proponent and opponent with the objective of attaining valid knowledge. The purpose of hypothetical reasoning is to test the validity of inferential reasoning by demonstrating the absurd consequences that follow from an opponent’s position and therefore eliminate doubt in the mind of the enquirer. There are five types of *tarka* according to Udayana [38], but more such variations of demonstrating absurd consequences in the opponent’s argument exist in other schools of Nyaya [15], which is out of scope of this paper. To test the validity of inferential reasoning, Nyaya follows the syllogistic method of five-step inference pattern that incorporates the unique property of invariable concomitance. Since *tarka* follows procedural

argumentation, which involves epistemological coherence, this implies application of correct syllogism or a definite set of arguments. By admitting different alternative hypotheses or counter-arguments to demonstrate the absurdity present in opponent's stand, the thesis of the opponent is rejected at any instant during the course of argumentation [16]. As a result correct combination of the members of syllogism and the exhaustive arguments of the opponent's objection bring about the discrimination of valid knowledge from the invalid knowledge. These methodological procedures constitute the notion of interaction by arguments.

4.2.1 Nyaya Syllogism

Inferential arguments of Nyaya primarily have only three members: probandum or the object of inference; proabns or the reason and the subject [29]. These three members may be stated in any order. Apart from these members, there are other two members of syllogism, the analogous object and the dissimilar object [26]. To arrive at a definite conclusion, the reason should "cover" the subject; be present in the similar objects; be absent in dissimilar objects [40]. In our work, the elements of arguments are modeled after the Nyaya syllogism of argument formation. The inference schema is utilised for proper reasoning among debaters who are engaged in a fair, friendly and balanced argumentation or *Vada*. Inference here means a cognitive process by which the knower wants to arrive at a correct knowledge. According to Nyaya Sastra [26, 32], an inferential proof is made up of the following members:

1. The statement, premise or position that is to be established
2. The cause or reason for the statement
3. The example
4. The application of that example
5. The conclusion

The example to illustrate the above five-membered syllogism is shown in example 1.

Example 1:

- 'This hill has fire' (statement)
- 'Because it has smoke' (reason)
- 'Since whatever has smoke has fire e.g. an oven' (example)
- 'This hill has smoke, which is associated with fire' (application)
- 'Therefore, this hill has fire' (conclusion)

After these five sentences have been employed there arises in the mind of the listener consideration of the form, 'this hill is full of smoke, which is in invariable concomitance with fire', from which follows the conclusion, 'this hill is full of fire'. Syllogism is therefore the name for the entire collection of these five sentences, each of which is called a part or member [35]. On the employment of five sentences there arises, at first, knowledge from each of them separately. Then arises collective knowledge from the five sentences combined together. This collective knowledge, which produces consideration, is based on each of the five sentences called a part or member, which is referred previously as the five membered syllogism. The following explanation of parts of Nyaya syllogism is taken from Vidyabhusana's discussion of Nyaya Sutra [35].

4.2.2 Parts of Nyaya Syllogism

4.2.2.1 Proposition

The proposition is a sentence which gives rise to an inquiry necessitating the mention of the reason, e.g. ‘This hill has fire’. (Why so? Because it is smoky.)

4.2.2.2 Reason or Probans

The reason or probans is a word which produces knowledge whose object is not the probandum but which contributes to the production of the entire knowledge that gives rise to consideration, e.g. because it is full of smoke. The loci of the reason can be in any of the three atomic states of existence: presence, which produces valid conclusion; absence, which produces invalid conclusion; presence in some part and absence in another part, which produces doubtful conclusion (almost equal to invalid conclusion) [6]. The reason is said to possess either one or more relations with the object of inference, analogous object and the dissimilar object. The presence and absence of these relations and nature of these relations define the strength and weakness of any argument. Technically speaking, the notion of *tarka* in the context of knowledge sharing is the means of assessing the validity of the relation of pervasion or universal concomitance between the thesis requiring proof and the reason offered. As such, it is the procedure for establishing the conclusion of an inference [32].

4.2.2.3 Example

An example is a word, which, while producing knowledge of connection of the form that the locus of probans is constantly occupied by the probandum, causes another knowledge, which, proceeds from the sentence expressive of consideration.

All that has smoke has fire, as a kitchen.
[So this hill has smoke]

4.2.2.4 Application

The application is a member that produces consideration, e.g. All that has smoke has fire, this hill too has smoke.

4.2.2.5 Conclusion

Conclusion is a sentence which, while causing the knowledge which gives rise to consideration, produces knowledge of the probandum as indicated by that of the probans through its invariable concomitance with the probandum and its nature of abiding in the subject, e.g. In this hill there is smoke, which is in invariable concomitance with fire. Therefore, in this hill there is fire, or therefore this hill is full of fire.

4.3 Invariable concomitance and *Tarka*

Before discussing about invariable concomitance, let us elaborate the notion of *tarka* in knowledge sharing. Classically ‘*tarka*’ means rational exchange of arguments with the objective of attaining valid knowledge. If the arguments require proof for syllogistic explanations to demonstrate one’s stand, supporting arguments are framed. These supporting arguments

actually refer to inferential evidences deposited in commonsense knowledge, like, invariable concomitance the relation between ‘smoke’ and ‘fire’. Supporting arguments are also exchanged in a debate fashion. Jonarden Ganeri emphasizes ‘tarka’ as follows:

“Knowledge is achieved through the elimination of doubt, and what eliminates doubt is the existence of a compelling reason.... Nyaya epistemologists develop a theory of what they called ‘suppositional reasoning’. It is a theory about the burden of proof and the role of presumption about the conditions under which even inconclusive evidence is sufficient for warranted belief..... In the early literature, tarka is synonymous with reasoned thinking in general. The free thinkers were called tarkikas or followers of reason....Such a person is a master in the art of evidence and the management of doubt, knowing when to accept the burden of proof and also when and how to deflect it. In its popular use, tarka is the nearest one gets to a Sanskrit synonym for ‘rationality’.”

– page: 151, *Philosophy in Classical India: The proper work of Reason*, by Jonarden Ganeri, Routledge publishers, 2001.

In the above example (see 4.2.2.3), the object to be inferred is ‘fire’ and the subject is, the ‘mountain’. A similar instance is kitchen, for it is well known that there is ‘fire’ in a ‘kitchen’. A dissimilar instance can be a ‘lake’, for it is well known that there is no ‘fire’ in a ‘lake’. The application informs us that the subject, i.e., the ‘mountain’, possesses the reason, i.e., ‘smoke’. More precisely, it informs us that the ‘mountain’ possesses ‘smoke’, which is ‘invariably’ connected with ‘fire’. The conclusion states that the hypothesis is deduced from the application.

The order of a five-membered syllogism is not in accordance with the process of getting inferential cognition. An inferer must first comprehend the relation between smoke (the reason) and fire (the object of inference), i.e., the invariable concomitance between smoke and fire, before starting to infer about fire. When the inferer sees smoke on the mountain (the subject), he remembers the invariable concomitance between smoke and fire. Then he gets the cognition that the mountain has smoke, which invariably coexists with fire. Finally he obtains the inferential cognition that the mountain has fire [37]. As seen from the earlier explanation, the instrument for generating this cognition is the knowledge of the invariable concomitance between smoke and fire. This knowledge is assumed to be available as part of the common-sense knowledge. This forms the intermediate operation for producing the inferential cognition i.e. the mountain has smoke which invariably coexists with fire, which is technically called confirmatory cognition [37]. To put it more precisely, the inference relates to the relation of smoke to fire, and not the relation of fire to smoke. This is because smoke invariably coexists with fire and the reverse is not true.

Thus, invariable concomitance is the relation by which the probandum and probans are related to one another in any proposition. Whether the enquirer infers this relation by the co-presence or co-absence of both probans and probandum, lies in the formal definition of invariable concomitance. The definition of invariable concomitance relation has too many variations: the five provisional definitions stated in *Vyaptipancakam* [35], objectionable definitions stated in *Purvapakshah* [35], conclusive definition of invariable concomitance in *Siddhantalaksanam* [35], invariable concomitance of special forms listed in *Visesa-vyaptih* [35]. The process of determining the nature of existence of invariable concomitance between the probandum and probans in the proponent’s argument, starts by exploration of argument in light of various fallacies relating to the elements of argument. This exploration further

results in identifying the possible defects in the proposition, for which the nature and definition of invariable concomitance is utilised. The proponent's argument if found defective, should be counter-opposed by the opponent in the form of a counter-argument and this process of argument – counter-argument exchange, called procedural argumentation continues rationally until the validity of the proponent's initial argument is proved.

4.4 Consciousness and Syllogism

The syllogistic approach of inferential reasoning as recommended by Nyaya, maps much closer to the cognitive method of handling arguments. Due to the presence of defects (see 4.1.2) in the submitted arguments, the arguer or counter-arguer is left in a doubtful state of mind during the interpretation and inference from the submitted argument. Vyasa in his YogaSutra Bhasya, outlines five levels at which consciousness functions: 1. unsteady 2. confused 3. distracted 4. one-pointed 5. restricted [32]. By adapting the above stages of meditative attainment, it can be seen that presence of certain types of defects makes an argument unsteady. Inference from such an argument leaves the opponent in a confused state of mind. Therefore the opponent puts forth the questions with the intention of clarifying the defects identified and the respondent addresses to it. The discussion becomes distracted when the arguer addresses a different issue. In a healthy knowledge-sharing scenario, the discussion should be focused or one-pointed about a particular subject for the right knowledge to be attained. Syllogistic interactions are a measure to resolve knowledge inconsistencies through argument analysis by which defects are thoroughly explored [10]. In other words, defect identification and elimination in a repeated manner keeps the discussion going, thereby, sharing the valid knowledge between the participants involved in discussion. Identification of defects becomes easier when they are neatly represented to facilitate their exploration. Therefore, not only the style and nature of argument defects but also the representation of defects packed in the syllogistic elements of arguments and the inference gained during the process of hole-finding aids to refinement in knowledge-sharing through procedural arguments.

5 Need for Indian-logic based Argument Representations

Though the representation formalisms like DL, has the capability to deal with uncertain knowledge, they do not consider the presence of member qualities as an inherent part of concept descriptions. In addition, relations defined possessed heavy limitations with respect to their scope and were only superficial, i.e., between atomic concepts. By enhancing the number and type of relations defined at the highest level of abstraction, inference becomes multi-relational rather than been restricted to the normal hierarchical, part-of and instantiation relations [36]. Due to the added requirements of ontology representation based on Nyaya, extensions were made both at the concept-constructor zone and the relation zone [1, 3].

Extended DL Systems dealt with the basic reasoning services from philosophical perspective but the ontological classification was present only as part of reasoning mechanisms [23]. However, many shared conceptualisations of Nyaya, like the invariable concomitance relation, which is the basis in generating the counter-arguments during the course of procedural argumentation, were not incorporated in extended DL Systems [2, 3, 36]. The organisation

and storage structure of knowledge is very important, because the representation method chosen can have a significant impact of the way in which the knowledge is applied. The representation formalism must be able to explain procedural argumentative functionality and justify decisions and thus, from the viewpoint of the argumentative procedures, concepts and relations between concepts described by the ontology should be enriched to perform reasoning and inferencing from arguments. Hence, there arose a need to propose the relation enhancement of extended DL systems, expressive enough to enable the mimicking of human inferencing.

Procedural argumentation in its very own Nyaya tradition demanded an improved ontology to handle the non-monotonic nature of argumentation. In addition, the analysis of strength of any argument in terms of holes (defects) associated with the elements of argument and the invariable concomitance (tautologies as specified by the fundamental Nyaya ontology) relation which is essential in determining the validity of inference obtained, were taken into consideration while constructing the Indianised logic-based argument representation formalism. The incorporation of invariable concomitance into the relation elements of arguments re-defines the argument representation formalism from Nyaya perspective.

Prakken [27] has focused on legal argumentation and has identified four layers with which such an argumentation framework must concern itself. These are:

- a. *The logical layer* which allows the representation of basic concepts such as facts about the world. Most commonly, this layer consists of some form of non-monotonic logic.
- b. *The dialectic layer*, in which argument-specific concepts such as the ability of an argument to defeat another are represented.
- c. *The procedural layer* governs the way in which argument takes place.
- d. *The heuristic layer* contains the remaining parts of the system. Depending on the underlying layers, these may include methods for deciding which arguments to put forth and techniques for adjudicating arguments.

The invariable concomitance representation between the reason and the object to be inferred serves as the logic layer of procedural argumentation and determines the necessity of proof during the analysis at a later stage, for supporting the existence of the object that is to be inferred. By the presence/absence of invariable concomitance relation between any two concept elements of arguments, the invariable co-existence/non-existence of the elements under discussion (e.g.: Smoke invariably co-exists with fire) can be easily determined in consultation with the available ontology. Thorough exploration of defects leads to removal of ignorance by removal of defects. Removal of ignorance provides the opportunity for valid knowledge to be attained by the arguer/counter-arguer. Hence, Indian Logics serves as the strong foundation for the mathematical support behind the construction of ontology for knowledge-sharing using procedural argumentation.

6 Mathematical Model for Argument Representation

The Indian-logic based mathematical model proposed in this paper deals with all the above-mentioned extensions with respect to ontological classification, viewed from multiple perspectives. This work is directed towards the first and second layer of argumentation framework as suggested by Prakken [27]. First is the logical layer where the main concern is about the use of appropriate logic to represent arguments. Second layer is the argument

framework or dialectical layer: here the relationships between arguments generated at the logical level are analysed, so that which arguments attack or support which arguments can be identified, and the arguments can be evaluated to assign them a status [24].

The procedural argumentation framework defined here follows Capon, in which a pair $AF = \langle X, A_T \rangle$, where X is a set of arguments and $A_T \subseteq X \times X$ is the attack relationship for AF . A_T comprises a set of ordered pairs of distinct arguments in X . A pair $\langle x, y \rangle$ is referred to as “ x attacks y ” [5]. In procedural argumentation, the arguments used do not always justify their conclusion and they are defeasible. Arguments can be defeated if they are attacked by a counter-argument. Argument attack implies a ‘battle’ of arguments and counterarguments. Attack is defined as a binary relation between already existing arguments within the argumentation framework. An argument x attacks argument y ($y \leftarrow x$), if the conclusion of x contradicts the conclusion of sub-argument y' of y and y' is not stronger than x .

$$y \leftarrow x; \text{ if } \text{conc}(y'/y) \neq \text{conc}(x) \&\& A_{\text{str}}(y') < A_{\text{str}}(x) \quad (1)$$

Arguments are defeated if and only if they are attacked by arguments that are themselves not defeated [24]. Defeat status is defined as a property of argument that possesses at least one attack relation and is denoted by A_{status} . Assignment of defeat status to an argument is generally derived from the result of various attacks it undergoes [4, 25]. There are four status of defeat: defeated, undefeated, ambiguous and undetermined [24]. The arguments and counter-arguments constructed as a result of A_T accumulate to form an argument hierarchy. The mathematical model described later explains the construction of arguments in terms of fundamental elements of argument procedures to suit the refutation strategies recommended in Indian philosophy.

According to the mathematical model proposed in this paper, the fundamental elements of argument procedures are defined as follows: Any argumentation system is constructed from a set of input statements. A knowledge base basically consists of statements.

ϵ : Knowledge base

A statement is basically classified as two disjoint sets: propositions and assumptions.

$$\begin{aligned} \phi &= \{p_1, \dots, p_n\}, \text{ elements are propositions;} \\ &\quad (\text{actual definition of proposition is discussed later}). \\ \phi &= \text{Props}(\epsilon) \subseteq \alpha \vee \phi \text{ denotes all propositions appearing in } \epsilon. \end{aligned}$$

Here propositions are statements of facts that take part in an argumentative procedure. Propositions can be of two types: facts or proven facts. Factual propositional statements are extracted from current input statements; proven propositional statements exist in the knowledge-base [24]. A degree of belief or strength of proof factor is attached to each of the proven propositional statements. Propositions can be plain propositions discussing information regarding the current subject, or else, can be reasons that support or oppose the belief of already existing propositions

$$\begin{aligned} \alpha &= \{a_1, \dots, a_m\}; \text{ elements are assumptions;} \\ &\quad (\text{actual definition of assumption is discussed later}) \\ \alpha &= \text{Assu}(\epsilon) \subseteq \alpha \vee \phi \text{ denotes all assumptions appearing in } \epsilon. \end{aligned}$$

Here assumptions are special type of propositions defined as initial statements assumed to be true until proved otherwise. Assumptions do not possess strength of proof factor and are completely open for attack.

A knowledge base is the context in which the process of argumentation takes place and consists of assumptions α , propositions ϕ and a language L which is a set of combinations of assumptions and propositions. ξ is the statement whose truth is to be determined in the context of the knowledge base ε

$L_{\alpha\vee\phi}$: propositional language, ξ : arbitrary statement in $L_{\alpha\vee\phi}$,

then, triple (ξ, ϕ, α) forms the propositional argumentation system, ξ can be any element of $\alpha\vee\phi$; i.e. ξ can either be a proposition or an assumption

$$\varepsilon = \sum_{i=0}^r \xi_i \quad (2)$$

where $\xi_i \in L_{\alpha\vee\phi}$, $r = \text{max. no. of arbitrary statements } \xi \text{ in the knowledge base } \varepsilon$.

For the basic definition of proposition and assumption with respect to argumentation system, the discussion of concepts and relations between concepts are required. An ontological classification O_T is defined as the collection of all concepts under the given domain boundary

$$O_T = \sum_{i=1}^n C_i \quad (3)$$

An ontological commitment O_D is defined as the collection of all constraints defined by operator set O_p over concepts C of ontological classification O_T under the given domain boundary

$$O_D = O_D(O_p, O_T) - \text{collection of constraints} \quad (4)$$

Concepts in the argumentation system fall under three categories: subject C_S , the object of inference C_{OI} , and the reason C_R , whose relation with C_{OI} either variably or invariably helps to prove the existence of C_{OI} [24]. A concept C associated with an ontological classification O_T under ontological commitment O_D is defined as:

$$C = \langle C_{\text{name}}, C_{\text{cat}}, Q_M, Q_O, Q_E, C_{\text{pr}}, C_{\text{par}}, C_{\text{con}} \rangle \quad (5)$$

where

C_{name} is the name of the concept; $C_{\text{cat}} = \{C_S, C_{OI}, C_R\}$;

Q_M is the Quality Mandatory of type Quality Q ;

Q_O is the Quality optional of type Quality Q ;

Q_E is the Quality Exceptional of type Quality Q ;

C_{pr} is the Concept priority weight factor;

C_{par} is the parent concept C , $\text{par} = 0$ to n , max. no. of concepts in committed ontology and

C_{con} is the constraint set under which concept C is said to exist; $C_{\text{con}} \subseteq O_D$

Quality is the property associated with every concept and is said to describe the concept more expressively. This is made possible by associating a list of values for qualities with constraints of occurrences. Qualities can be mandatory, optional or exceptional when associated

with concept C. A quality Q associated with a concept C under an ontological classification O_T is defined as:

$$Q = \langle Q_{\text{name}}, V_i, Q_{\text{con}} \rangle \quad (6)$$

where, Q_{name} – is the name of the quality; V_i – the Quality value list; $i = 0$ to v , maximum number of values allowed for Q_{name} and Q_{con} – the constraint set of Q_{name} .

Apart from the presence of inherent quality associated to every fundamental concept, yet another shared conceptualisation of Nyaya, which is actually the basis in generating counter-arguments, is the invariable concomitance aspect of relation element of argument procedures. Relations explain the various means by which concept categories are related to one another. Relations are classified into three categories: R_{S-OI} , the relation between C_S and C_{OI} ; R_{S-R} , the relation between C_S and C_R ; R_{R-OI} , the relation between C_R and C_{OI} . Generally, R_{S-R} is observed and stated as a proposition. Hence, the proof of R_{S-OI} is obtained with respect to the variable or invariable nature of relation R_{R-OI} . Presence of invariable nature of relations between concept elements of argument procedures is recorded as the quality feature of relations denoted by R_{qual} . Derived relations not defined directly between concepts in either of the simple manner but defined indirectly across the classification hierarchy may also exist between concepts. A relation R associated with an ontological classification O_T under ontological commitment O_D is defined as:

$$R = \langle R_{\text{name}}, C_{Aq}, C_{Bq}, R_{\text{cat}}, R_{\text{qual}}, R_{\text{pr}}, R_{\text{con}} \rangle \quad (7)$$

where

R_{name} is the name of the relation

$C_{Aq}, C_{Bq} \subseteq C_{\text{cat}}$; $q = 1$ to n , maximum number of qualities for C_A, C_B in O_T ; $C_A = C_B$ permissible;

R_{cat} belongs to the set $\{R_{S-OI}, R_{S-R}, R_{R-OI}\}$

R_{qual} can be one of $\{Ic_i, D, X, Xp\}$, where

Ic is the Invariable concomitance; $i = 0$ to 3 , over $\{\text{symmetric}, +Ic, -Ic, \text{neutral}\}$;

D , the direct; X , the exclusive; Xp , the exceptional;

R_{pr} , the relation priority weight factor;

R_{con} , the constraint set over defined relations;

$\{R_{\text{con}}[i], R_1, R_2\}$; $R_1, R_2 \in R$; $i = 0$ to 4 , over $\{\text{reflexive}, \text{symmetric}, \text{anti-symmetric}, \text{asymmetric}, \text{transitive}\}$ [24].

The hybrid elements of argument procedures are defined in terms of native elements. The disappearance of current subject of discussion, shifting of discussion to concept other than the current subject, say reason or object of inference at hand, and *appearance* of further reasons from the following arguments in support or opposition of the previous subject, are all said to occur in this hybridness.

Assumptions are statements expressing information about two primitive concepts and the relations between them. An assumption a in ε is defined as a tuple

$$a = \langle a_{\text{num}}, C_1, C_2, R_{1-2} \rangle \quad (8)$$

where

a_{num} , the assumption index; $C_1, C_2 - \{C_S, C_{OI}, C_R\}$;

R_{1-2} , the relation from C_1 to C_2 and can be one of the form $\{R_{S-OI}, R_{S-R}, R_{R-OI}\}$, the interdependencies between elements of a defined and controlled by R_{1-2} .

Propositions are statement of facts whose strength of proof factor is to be determined through the course of argumentative procedures. A proposition p in ε is defined as a tuple

$$p = \langle p_{\text{num}}, C_1, C_2, R_{1-2}, p_{\text{bel}} \rangle \quad (9)$$

where,

p_{num} the proposition index

C_1, C_2 of the type $\{C_S, C_{OI}, C_R\}$; absence of C_1, C_2 permissible;

R_{1-2} of the type $\{R_{S-OI}, R_{S-R}, R_{R-OI}\}$ and

p_{bel} the degree of belief or strength of proof factor, interdependencies between elements of p defined and controlled by R_{1-2} .

Propositions can be reasons, which support or oppose the belief of already existing propositions. The absence of concepts C_1, C_2 are allowed when propositions play the role of reason in the procedure of argumentation.

An argument is a set of propositions related to each other in such a way that all but at least one of them (the premise) are supported to provide support for the remaining (the conclusion). An argument A over argumentation framework AF is defined as a tuple

$$A = \langle A_{\text{id}}, C_S, C_{OI}, C_R, R_{S-OI}, R_{S-R}, R_{R-OI}, A_{\text{state}}, A_{\text{status}}, A_{\text{str}} \rangle \quad (10)$$

where

A_{id} is the argument index; C_S, C_{OI}, C_R – concept categories;

$R_{S-OI}, R_{S-R}, R_{R-OI}$, the relation categories;

A_{state} , the state of argument; $A_{\text{state}} \subseteq \{\text{premise, inference, conclusion}\}$;

A_{status} , the defeat status of arguments; $A_{\text{status}} \subseteq \{\text{defeated, undefeated, ambiguous, undetermined}\}$ and

A_{str} , the strength or conclusive force of the argument.

The transition or movement from premises to conclusion, the logical connection between them, is the inference upon which the argument relies. Defeated arguments have zero strength, conclusive arguments have maximal strength and the other arguments are somewhere in-between [24, 41]. The following section discusses briefly about utilising the Indianised logic representation of procedural arguments in sharing the valid knowledge among the participants involved in discussion. The main feature to be noted here is that the necessity of proof can be avoided for concepts that can be proved by consulting the invariable nature of their existence.

7 Knowledge-sharing using mathematical model based on Indian Logics – a case study

As stated above, the world knowledge utilised for inferencing, when stored in a more methodical, categorised manner as per Indian logics, facilitates better inferencing, which is explained later. Initially, a sample argument is submitted for analysis which is broken down into its elementary counterparts [24] (Fig. 1(a)). The example depicts the support of C_{OI} by implicitly

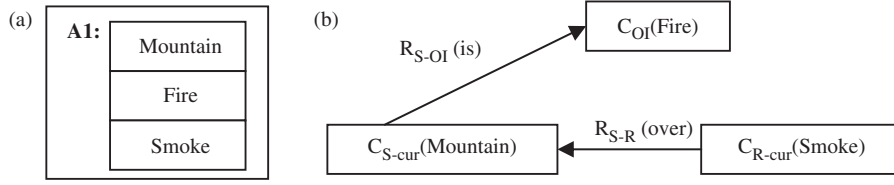


FIG. 1. (a) Argument concepts (b) knowledge capturing from A1

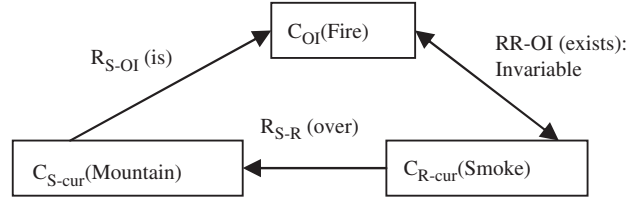


FIG. 2. Implicit expansion of A1

expanding the invariable presence of **C_{OI}** with **C_R** by means of the invariable concomitance relation supplied from the existing knowledge base.

A1: Mountain is fiery because there is smoke over the mountain

In the above argument A1, the current subject of discussion is Mountain, denoted by **C_{S-cur}**. Fire the thing to be proved is called object of inference, denoted as **C_{OI}**. Smoke is the reason stated for the cause of fire, denoted as **C_{R-cur}**. Thus, the **C_S** (or **C_{S-cur}**), **C_R** (or **C_{R-cur}**) and **C_{OI}**, along with the relations (indicated by arrows) that exist among them, are stored in the knowledge elements across the classification hierarchy (see Fig. 1(b)).

Let us assume, the knowledge base already contains a relation of type invariable, between smoke and fire, which is the key relation to be proved for A1 in support of the existence of **C_{OI}**. Thus, the concept hierarchy after A1 is implicitly expanded incorporating the invariable type of relation from the knowledge base as shown in Fig. 2. This implicit expansion of A1 by **R_{R-OI}** from the knowledge base provides strength to the existence of **C_{OI}** since the invariable nature of a relation prioritises anything else and hence A1 is proved.

Now, let us consider the following counter-argument CA1, which discusses about lake, smoke and fire. Since the concepts common between A1 and CA1 are smoke and fire, and since fire is the **C_{OI}** to be proved, smoke is said to be the topic of discussion that follows from A1. Thus, **C_{S-cur}**, mountain of A1 is shifted to **C_{R-cur}**, smoke of A1, now indicated by **C_{S-new}**, when CA1 is introduced. Also, in CA1, mountain is referred as **C_{S-old}**. Lake is the optional subject around which CA1 can be existing. Here, we refer lake as **C_{S-opt}**.

In Figure 3(a) CA1 is analysed for its member elements of arguments. The presence and absence of all type of relations between lake and smoke is clearly stated. The absence of invariableness between fire and smoke, stated by CA1 is recorded and updated with the existing knowledge base from A1. The relation between smoke and fire **R_{R-OI}**, which was *invariable* has now turned to *Not invariable* as an indication of existence of smoke without fire. Generally, a relation introduced by an argument can be over-ridden by other relations introduced by the subsequent arguments, because of the non-monotonic nature of argumentation. But, **R_{R-OI}** (*exists*): *invariable* is not purely introduced by A1, but implicitly

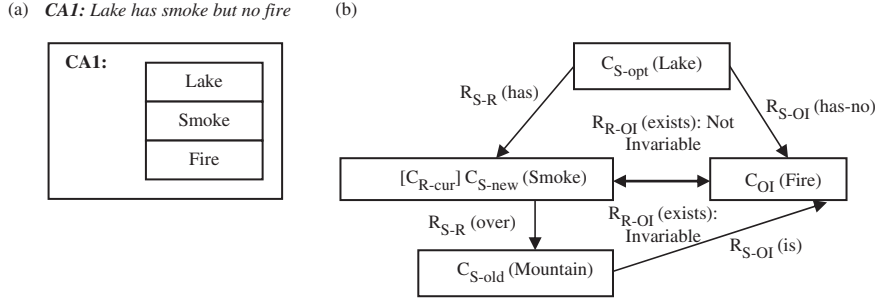


FIG. 3. (a) Argument Concepts and 3(b) Conflict in Knowledge base after Knowledge Capturing from CA1

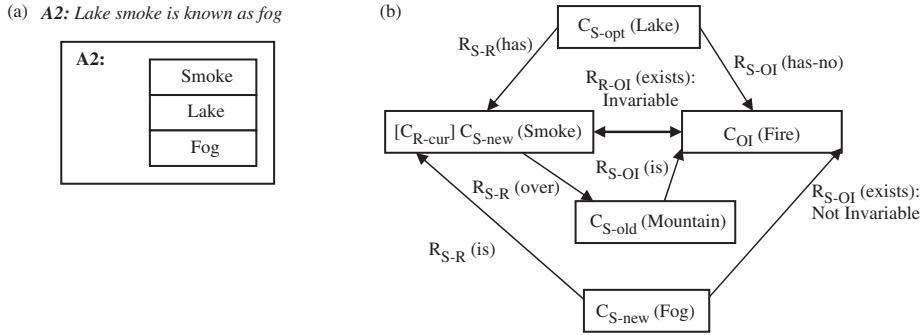


FIG. 4. (a) Argument Concepts and (b) Conflict-release in Knowledge base after A2

expanded out of the abstract fundamental world knowledge at the time of introduction of A1. Hence, relation overriding is not possible. Also, recent CA1 insists the insertion of \mathbf{R}_{R-OI} (*exists*): *Not invariable* between smoke and lake. Therefore, during the mapping of CA1's part of world knowledge with that of the existing knowledge base, CA1 is said to generate a hole or flaw with respect to mismatch of invariableness between fire and smoke (Fig. 3(b)). The type of hole identified and the mechanism with which further counter-arguments are produced to best defeat CA1 is out of the scope of this work and are discussed later. Due to the analysis of holes and production of possible defeat strategies, let us assume, A2 is projected highlighting the flaw in CA1.

Now, let us consider A2 that discusses about lake, smoke and fog (Fig. 4(a)). Since the concepts common between A2 and CA1 are smoke and lake, A2 can be placed around both smoke and lake. But smoke was the earlier topic of discussion and hence we assume A2 also to be around smoke. Thus smoke attains the status, \mathbf{C}_{S-cur} . Also, Fog is referred as \mathbf{C}_{S-new} due to the presence of is-a relation with smoke. Status of other concepts and relations remain the same. The classification hierarchy stores the lake-smoke as fog. Assuming the presence of detailed representation about fog in the concept hierarchy as part of common sense knowledge or already existing knowledge, lake-smoke now referred as fog by A2 alters the absence of invariable relation between smoke and fire, as introduced by CA1, to that of the relation between fog and fire (Fig. 4(b)) i.e., smoke cannot invariably co-exist with fire over the locus, lake; since the locus here is mountain, there are chances of invariable

co-existence between smoke and fire. Thus the invariable relation conflict has been removed. The claim of relation $\mathbf{R}_{\mathbf{R-OI}}$ (*exists*): *Not invariable* between smoke and fire as per CA1 is proved false and CA1 is hence rejected. Also, we are interested only in proving the existence of $\mathbf{C_{OI}}$ over $\mathbf{C_{S-old}}$ and therefore, the new $\mathbf{R}_{\mathbf{R-OI}}$ (*exists*): *Not invariable* between fog and fire is currently of no relevance to participate in this proof of $\mathbf{C_{OI}}$. Thus, the proof obtained to substantiate $\mathbf{C_{OI}}$ follows some form of inference with the represented knowledge from the classification hierarchy by attempting the approval and disproof of the available knowledge. The example continues in course of argument procedures to a definite conclusion.

In summary, the exchange of arguments has finally defined the locus of smoke more particularly than only the first argument would do. Thus, a clearer knowledge about the reason, smoke is obtained while trying to prove the existence of fire in the locus, mountain. The wrong notion that smoke can also be present without fire is ruled out by counter-defeating about the state of smoke in that locus, lake. Thus the knowledge about smoke is shared between the arguer and counter-arguer. The above exchange of arguments introduced the absence of invariableness between smoke and fire by mentioning another loci, lake and thereby the conflict (in the presence and absence) of invariableness. The identification of fog over the lake cleared the conflict and therefore, the presence of invariableness is proved by itself, stating the existence of fire due to smoke. This invariableness can be modelled in European tradition as in Example 2 [16].

Example 2:

“All smoky mountains are fiery,
This mountain is smoky,
Hence, this mountain is fiery”

This example is a kind of application of deduction over ‘smoky mountains’. When represented as common sense knowledge, the ontological relation ‘has-a’ would exist between ‘concept: smoky mountain’ and ‘concept-fire’. This further proves the argument, ‘the mountain is fiery’; however, with some other argument like ‘the woods are fiery because woods are smoky’, the pervasion of ‘smoky woods’ has no representation in the common sense knowledge. Logically, the ‘smoke’ invariably coexists with ‘fire’ and the ‘smoky mountain’ has no invariable co-existence with ‘fire’. But since we do not rely on invariable concomitance and rather have attempted to represent the relation as ‘has-a’ between ‘smoky mountain’ and ‘fire’, we need to represent another ‘has-a’ relation between ‘smoky woods’ and ‘fire’ to prove the argument in European logic. It would rather be a better treatment in Indian logic, i.e. the invariable connection between ‘smoke’ and ‘fire’ which is already a part of the knowledge base would suffice this issue.

As an application, both the arguers can be modelled as knowledge-sharing agents in a procedural argument based knowledge-sharing scenario about any given domain where argument gaming is used for spontaneous knowledge sharing in resolving knowledge inconsistencies. The procedural and continuous exchange of arguments between two participating knowledge-sharing agents and the system of defect exploration and elimination are made possible only by the effective representation of procedural arguments as inspired by Indian philosophy. The extent of intense questioning and exploration of defects by checking the presence or absence of invariable concomitance relation has a special significance in deciding the refutation strategy. Upon such refutation strategies, appropriate counter-argument that covers possibly every defect, is constructed and projected as a forward move to the opponent. This scheme of argumentative discussion continues until a definite conclusion is reached. Thus,

the discussing agents, at the end of the discussion would have elaborated the seed knowledge by automatically performing some amount of procedural reasoning.

8 Future Directions

Defects arising out of the invariable presence or absence of the element can further be analysed based on concept-affecting or relation-affecting nature of defects. The holes projected in terms of the member elements of arguments can be grouped in several combinations to suit one or set of recommended refutation strategies of Indian philosophy. The defeat techniques recommended for the removal of existing holes can be evaluated based on the nature and type of defeats in constructing suitable counter-argument(s) which is again said to undergo the same cycle of hole-finding and refutation selection through which the knowledge between the teacher and learner is shared. The above-mentioned directions over procedural arguments are being explored and are not elaborated here since it falls beyond the scope of this paper.

Absence of invariable type of $\mathbf{R_{R-OI}}$ if any, is projected as a hole and reasoning then takes deviation to other forms of inferencing. Thus, the proof obtained to substantiate $\mathbf{C_{OI}}$ follows some form of inferencing with the represented knowledge from the classification hierarchy by attempting the proval and disproval of available knowledge. This technique of representing knowledge through Indian logics discussed above successfully highlights the holes or flaws present in the submitted argument and hence can be utilised to construct a suitable counter-argument with the intention of defeating the argument(s) submitted previously. Such arguments and counter-arguments built with the objective of obtaining some agreed upon conclusion form an argument hierarchy through which the knowledge base is continuously updated.

9 Conclusion

The procedural approach of argumentation as per Indian philosophy is made possible by the definition of fundamental concept and relation elements of argument procedures represented based on Indian logics. This refinement of concept and relation definitions allow for the application of different types of defect finding mechanisms and defeat strategies involved in construction of counter-arguments through the procedure of argumentation. The mathematical framework described in this paper is designed to enable the attack and defeat of elements of arguments. Indian philosophical method of attacking arguments is essentially concerned with finding flaws in concept definitions, relation definitions and the absence or contradiction of invariable concomitance. The mathematical model for argument representation provides detailed definitions of fundamental elements of arguments, and, their associations with a conceptual ontology has been modified so as to enable alternate cycling of attack and defeat of arguments until a definite conclusion is reached. Therefore, *tarka* or rational discussion reveals non-monotonicity by eliminating the doubts in the mind of the enquirer through valid and convincing conclusions. The mathematical model for argument procedures discussed above, concentrates in expressing world knowledge in terms of fundamental elements of arguments from the Indian philosophical viewpoint and reasoning from the represented knowledge is made very effective when compared to the other knowledge representation formalisms. In order to cater to the fundamental aspects (like incorporation of invariable concomitance and the tautological existence of relations between concepts) as a

defined part of ontology and the description of an argumentative framework that uses such ontological definitions, the mathematical model ‘Indianised logics’ proposed in this paper is specially designed for expressing world knowledge completely from Nyaya viewpoint and is expressive enough for the argumentative procedures of reasoning as per Indian philosophy. Automated reasoning systems performing analysis over the represented knowledge may apply this style of knowledge representation based on Indian philosophy to imitate human inferencing.

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Received 27 April 2006