Specializing the Logic of Multiple-Valued Argumentation to the Jaina Seven-Valued Logic

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***Abstract*—Argumentation is a dialectical process of knowing things (inquiry) and justifying them (advocacy) in general. Computational argumentation has been recognized as a social computing mechanism or paradigm in the multi-agent systems community. We have developed a computational argumentation framework that basically consists of EALP (Extended Annotated Logic Programming) and LMA (Logic of Multiple-valued Argumentation) constructed on top of EALP. EALP is a very generic knowledge representation language for uncertain arguments, and LMA built on top of it also yields a generic argumentation framework so that it allows agents to construct uncertain arguments under truth values specified depending on application domains.**

In this paper, we specialize such a generic argumentation system to an argumentation system that can deal with Eastern arguments based on the Jaina seven-valued logic. We illustrate this specialization using the implemented argumentation system: PIRIKA (Pilot of the Right Knowledge and Argument) based on EALP and LMA, which is now opened to the public as an open source software.

***Keywords*-multiple-valued argumentation, neural net argumentation, syncretic argumentation, argument mining, argument animation**

I. Introduction

Argumentation is a dialectical process of knowing things (inquiry) and justifying them (advocacy) in general. In the last years, argumentation has been accepted as a promising social computing mechanism or paradigm in the multi-agent systems community [1]. It has proven to be particularly suitable for dealing with reasoning under incomplete or contradictory information in a dynamically changing and networked distributed environment.

We have developed a computational argumentation framework that basically consists of EALP and LMA [2]. EALP (Extended Annotated Logic Programming) is an expressive logic programming language we formalized for argumentation. The basic language constituents are literals associated with annotations as truth-values or epistemic states of agents. LMA is a Logic of Multiple-valued Argumentation constructed on top of EALP. It has three notions of negation to yield a momentum or driving force for argumentation. LMA is a generic logic of multiple-valued argumentation that allows us to specify various types of truth values depending on application domains, and to deal with uncertain arguments. Such a feature brings us the extensive applicability of LMA that is considered the most advantageous point in comparison to other approaches to argumentation [1].

In this paper, we specialize such a generic argumentation system to an argumentation system that can deal with Eastern arguments based on the Jaina seven-valued logic. We illustrate this specialization using the implemented argumentation system: PIRIKA (Pilot of the Right Knowledge and Argument) based on EALP and LMA, which is now opened to the public as an open source software.

The paper is organized as follows. In Section 2 and 3, we overview EALP and LMA as background of the paper. In Section 4, we present an overall picture of PIRIKA which provides the basic features and various auxiliary ones for standard uses. Section 5 is concerned with how to specialize PIRIKA so that it can deal with arguments based on Jaina seven-valued logic. Then, we illustrate two intriguing argument examples in which Jaina seven-valued logic may work well. The final section includes concluding remarks and future work.

II. Overview of EALP

EALP is an underlying knowledge representation language that we formalized for our logic of multiple-valued argumentation LMA. EALP has two kinds of explicit negation: Epistemic Explicit Negation '$\neg$' and Ontological Explicit Negation '$\sim$', and the default negation '$\mathbf{not}$'. They are supposed to yield a momentum or driving force for argumentation or dialogue in LMA. We here outline EALP.

A. Language

Definition 1: (**Annotation and annotated atoms**[3]). We assume a complete upper semi-lattice $(\mathcal{T}, \leq)$ of truth values, where $\leq$ denotes the semi-lattice ordering on $\mathcal{T}$. It is often convenient to assume the existence of a greatest element in $\mathcal{T}$, denoted $\top$. The least upper bound operator is denoted by $\sqcup$. An annotation is either an element of $\mathcal{T}$ (constant annotation), an annotation variable on $\mathcal{T}$, or an annotation term. Annotation term is defined recursively as follows: an element of $\mathcal{T}$ and annotation variable are annotation terms. In addition, if $t_1, \ldots, t_n$ are annotation terms, then $f(t_1, \ldots, t_n)$ is an annotation term. Here, f is a total continuous function of type $\mathcal{T}^n \rightarrow \mathcal{T}$. If A is an atomic formula and μ is an annotation, then $A:\mu$ is an annotated atom. We assume an annotation function $\neg : \mathcal{T} \rightarrow \mathcal{T}$, and define that $\neg(A:\mu) = A:(\neg\mu)$. $\neg A:\mu$ is called the epistemic explicit negation(e-explicit negation) of $A:\mu$.

Definition 2: (**Annotated literals**). Let $A : \mu$ be an annotated atom. Then $\sim (A:\mu)$ is the ontological explicit negation (o-explicit negation) of $A : \mu$. An annotated objective literal is either $\sim A:\mu$ or $A:\mu$. The symbol $\sim$ is also used to denote complementary annotated objective literals. Thus $\sim\sim A : \mu = A : \mu$. If L is an annotated objective literal, then $\mathbf{not}\, L$ is a default negation of L, and called an annotated default literal. An annotated literal is either of the form $\mathbf{not}\, L$ or L.

Definition 3: (**Extended Annotated Logic Programs (EALP)**). An extended annotated logic program (*EALP*) is a set of annotated rules of the form: $H \leftarrow L_1 \,\&\, \ldots \,\&\, L_n$, where H is an annotated objective literal, and L_i $(1 \leq i \leq n)$ are annotated literals in which the annotation is either a constant annotation or an annotation variable.

For simplicity, we assume that a rule with annotation variables or objective variables represents every ground instance of it. In this assumption, we restrict ourselves to constant annotations in this paper since every annotation term in the rules can evaluate to the elements of $\mathcal{T}$. We identify a distributed EALP with an *agent*, and treat a set of EALPs as a *multi-agent system*.

B. Interpretation

Definition 4: (**Extended annotated Herbrand base**). The set of all annotated literals constructed from an EALP P on a complete upper semi-lattice $\mathcal{T}$ of truth values is called the extended annotated Herbrand base $H_P^{\mathcal{T}}$.

Definition 5: (**Interpretation**). Let $\mathcal{T}$ be a complete upper semi-lattice of truth values, and P be an EALP. Then, the interpretation on P is the subset $I \subseteq H_P^{\mathcal{T}}$ of the extended annotated Herbrand base $H_P^{\mathcal{T}}$ of P such that for any annotated atom A,

1) If $A:\mu \in I$ and $\rho \leq \mu$, then $A:\rho \in I$ (downward heredity);
2) If $A:\mu \in I$ and $A:\rho \in I$, then $A:(\mu \sqcup \rho) \in I$ (tolerance of difference);
3) If $\sim A:\mu \in I$ and $\rho \geq \mu$, then $\sim A:\rho \in I$ (upward heredity).

The conditions 1 and 2 of Definition 5 reflect the definition of the ideal of a complete lattice of truth values. The ideals-based semantics was first introduced for the interpretation of GAP by Kifer and Subrahmanian [3]. Our EALP for argumentation also employs this since it was shown that the general semantics with ideals is more adequate than the restricted one simply with a complete lattice of truth values [2]. We define three notions of inconsistencies corresponding to three concepts of negation in EALP.

Definition 6: (**Inconsistency**). Let I be an interpretation. Then,

1) $A:\mu \in I$ and $\neg A:\mu \in I \Leftrightarrow I$ is epistemologically inconsistent (e-inconsistent).
2) $A:\mu \in I$ and $\sim A:\mu \in I \Leftrightarrow I$ is ontologically inconsistent (o-inconsistent).
3) $A:\mu \in I$ and $\mathbf{not}\, A:\mu \in I$, or $\sim A:\mu \in I$ and $\mathbf{not} \sim A:\mu \in I \Leftrightarrow I$ is inconsistent in default (d-inconsistent).

When an interpretation I is o-inconsistent or d-inconsistent, we simply say I is *inconsistent*. We do not see the e-inconsistency as a problematic inconsistency since by the condition 2 of Definition 5, $A:\mu \in I$ and $\neg A:\mu = A:\neg\mu \in I$ imply $A:(\mu \sqcup \neg\mu) \in I$ and we think $A:\mu$ and $\neg A:\mu$ are an acceptable differential. Let I be an interpretation such that $\sim A:\mu \in I$. By the condition 1 of Definition 5, for any ρ such that $\rho \geq \mu$, if $A:\rho \in I$ then I is o-inconsistent. In other words, $\sim A:\mu$ rejects all recognitions ρ such that $\rho \geq \mu$ about A. This is the underlying reason for adopting the condition 3 of Definition 5. These notions of inconsistency yield a logical basis of attack relations described in the multiple-valued argumentation of Section III.

Definition 7: (**Satisfaction**). Let I be an interpretation. For any annotated objective literal H and annotated literal L and L_i, we define the satisfaction relation denoted by '$\models$' as follows.

- $I \models L \;\Leftrightarrow\; L \in I$
- $I \models L_1 \,\&\, \cdots \,\&\, L_n \;\Leftrightarrow\; I \models L_1, \;\ldots,\; I \models L_n$
- $I \models H \leftarrow L_1 \,\&\, \cdots \,\&\, L_n \;\Leftrightarrow\; I \models H$ or $I \not\models L_1 \,\&\, \cdots \,\&\, L_n$

III. Overview of LMA

In formalizing logic of argumentation, the most primary concern is the rebuttal relation among arguments since it yields a cause or a momentum of argumentation. The rebuttal relation for two-valued argument models is most simple, so that it naturally appears between the contradictory propositions of the form A and $\neg A$. In case of multiple-valued argumentation based on EALP, much complication is to be involved into the rebuttal relation under the different concepts of negation. One of the questions arising from multiple-valuedness is, for example, how a literal with truth-value ρ confronts with a literal with truth-value μ in the involvement with negation. In the next subsection, we outline important notions proper to logic of multiple-valued argumentation LMA in which the above question is reasonably solved.

A. Annotated arguments

Definition 8: (**Reductant and Minimal reductant**). Suppose P is an EALP, and C_i $(1 \leq i \leq k)$ are annotated rules in P of the form: $A\!:\!\rho_i \leftarrow L_1^i \,\&\, \ldots \,\&\, L_{n_i}^i$, in which A is an atom. Let $\rho = \sqcup\{\rho_1, \ldots, \rho_k\}$. Then the following annotated rule is a reductant of P.

$A\!:\!\rho \leftarrow L_1^1 \,\&\, \ldots \,\&\, L_{n_1}^1 \,\&\, \ldots \,\&\, L_1^k \,\&\, \ldots \,\&\, L_{n_k}^k$.

A reductant is called a minimal reductant when there does not exist non-empty proper subset $S \subset \{\rho_1, \ldots, \rho_k\}$ such that $\rho = \sqcup S$

Definition 9: (**Truth width [3]**). A lattice $\mathcal{T}$ is n-wide if every finite set $E \subseteq \mathcal{T}$, there is a finite subset $E_0 \subseteq E$ of at most n elements such that $\sqcup E_0 = \sqcup E$.

The notion of truth width is for limiting the number of reductants to be considered in argument construction. For example, the complete lattice $\mathcal{FOUR} = (\{\perp, \mathbf{t}, \mathbf{f}, \top\}, \leq)$, where $\forall x, y \in \{\perp, \mathbf{t}, \mathbf{f}, \top\}$ $x \leq y \Leftrightarrow x = y \vee x = \perp \vee y = \top$, is 2-wide, and the complete lattice $(\Re[0,1], \leq)$ of the unit interval of real numbers is 1-wide.

Definition 10: (**Annotated arguments**). Let P be an EALP. An annotated argument in P is a finite sequence $Arg = [r_1, \ldots, r_n]$ of rules in P such that for every i $(1 \leq i \leq n)$,

1) r_i is either a rule in P or a minimal reductant in P.
2) For every annotated atom $A\!:\!\mu$ in the body of r_i, there exists a r_k $(n \geq k > i)$ such that $A : \rho$ $(\rho \geq \mu)$ is head of r_k.
3) For every o-explicit negation $\sim A\!:\!\mu$ in the body of r_i, there exists a r_k $(n \geq k > i)$ such that $\sim A\!:\!\rho$ $(\rho \leq \mu)$ is head of r_k.
4) There exists no proper subsequence of $[r_1, \ldots, r_n]$ which meets from the first to the third conditions, and includes r_1.

We denote the set of all arguments in P by $Args_P$, and define the set of all arguments in a set of EALPs $MAS = \{KB_1, \ldots, KB_n\}$ by $Args_{MAS} = Args_{KB_1} \cup \cdots \cup Args_{KB_n}$ $(\subseteq Args_{KB_1 \cup \cdots \cup KB_n})$.

B. Attack relation

Definition 11: (**Rebut**). Arg_1 rebuts $Arg_2 \Leftrightarrow$ there exists $A\!:\!\mu_1 \in concl(Arg_1)$ and $\sim A\!:\!\mu_2 \in concl(Arg_2)$ such that $\mu_1 \geq \mu_2$, or exists $\sim A : \mu_1 \in concl(Arg_1)$ and $A : \mu_2 \in concl(Arg_2)$ such that $\mu_1 \leq \mu_2$.

Definition 12: (**Undercut**). Arg_1 undercuts $Arg_2 \Leftrightarrow$ there exists $A : \mu_1 \in concl(Arg_1)$ and $\mathbf{not}\, A : \mu_2 \in assm(Arg_2)$ such that $\mu_1 \geq \mu_2$, or exists $\sim A : \mu_1 \in concl(Arg_1)$ and $\mathbf{not} \sim A : \mu_2 \in assm(Arg_2)$ such that $\mu_1 \leq \mu_2$.

Definition 13: (**Strictly undercut**). Arg_1 strictly undercuts $Arg_2 \Leftrightarrow Arg_1$ undercuts Arg_2 and Arg_2 does not undercut Arg_1.

Definition 14: (**Defeat**). Arg_1 defeats $Arg_2 \Leftrightarrow Arg_1$ undercuts Arg_2, or Arg_1 rebuts Arg_2 and Arg_2 does not undercut Arg_1.

When an argument defeats itself, such an argument is called a *self-defeating argument*. For example, $[p : \mathbf{t} \leftarrow \mathbf{not}\, p : \mathbf{t}]$ and $[q : \mathbf{f} \leftarrow \sim q : \mathbf{f}, \ \sim q : \mathbf{f}]$ are all self-defeating. In this paper, however, we rule out self-defeating arguments from argument sets since they are in a sense abnormal, and not entitled to participate in argumentation or dialogue. In this paper, we employ defeat and strictly undercut to specify the set of justified arguments where d stands for defeat and su for strictly undercut.

Definition 15: (**acceptable and justified argument** [4]). Suppose $Arg_1 \in Args$ and $S \subseteq Args$. Then Arg_1 is acceptable wrt. S if for every $Arg_2 \in Args$ such that $(Arg_2, Arg_1) \in d$ there exists $Arg_3 \in S$ such that $(Arg_3, Arg_2) \in su$. The function $F_{Args,d/su}$ mapping from $\mathcal{P}(Args)$ to $\mathcal{P}(Args)$ is defined by $F_{Args,d/su}(S) = \{Arg \in Args \mid Arg$ is acceptable wrt. $S\}$. We denote a least fixpoint of $F_{Args,d/su}$ by $J_{Args,d/su}$. An argument Arg is justified if $Arg \in J_{d/su}$; an argument is overruled if it is attacked by a justified argument; and an argument is defensible if it is neither justified nor overruled.

Since $F_{x/y}$ is monotonic, it has a least fixpoint, and can be constructed by the iterative method [4]. Justified arguments can be dialectically determined from a set of arguments by the dialectical proof theory. We give the sound and complete dialectical proof theory for the abstract argumentation semantics $J_{Args,x/y}$.

Definition 16: (**dialogue** [5]).

An dialogue is a finite nonempty sequence of moves $move_i = (Player_i, Arg_i)$, $(i \geq 1)$ such that

1) $Player_i = P$ (*Proponent*) $\Leftrightarrow i$ is odd; and $Player_i = O$ (*Opponent*) $\Leftrightarrow i$ is even.
2) If $Player_i = Player_j = P$ $(i \neq j)$ then $Arg_i \neq Arg_j$.
3) If $Player_i = P$ $(i \geq 3)$ then $(Arg_i, Arg_{i-1}) \in su$; and if $Player_i = O$ $(i \geq 2)$ then $(Arg_i, Arg_{i-1}) \in d$.

In this definition, it is permitted that $P = O$, that is a dialogue is done by only one agent. Then, we say such an argument is a self-argument.

Definition 17: (**dialogue tree** [5]). A dialogue tree is a tree of moves such that every branch is a dialogue, and for all moves $move_i = (P, Arg_i)$, the children of $move_i$ are all those moves (O, Arg_j) $(j \geq 1)$ such that $(Arg_j, Arg_i) \in d$.

We have the sound and complete dialectical proof theory for the argumentation semantics $J_{Args,x/y}$ [2].

IV. Standard Uses of PIRIKA

PIRIKA[1] is an implemented system of EALP/LMA [6]. It is now open to the public as downloadable OSS together with video clips and operation's and users' manual.
http://www.cs.ie.niigata-u.ac.jp/Research/PIRIKA/PIRIKA.html

The argumentation scenario of PIRIKA basically consists of the following phases:

- Registering agents (as avatars of humans) with the argument server so that they can commit to argumentation
- Preparing a lattice of truth values for dealing with uncertainty depending on application domains
- Designing knowledge bases under the specified truth values in terms of EALP
- Starting argumentation on submitted issues/claims in LMA (see Figure 1 for the system architecture)
- Visualizing the live argumentation process and diagramming arguments
- Determining the status of an argument
- Storing arguments and their results in the argument repository for the future reuse

In addition, many other unique features proper to the logic of multiple-valued argumentation is integrated with the core part of PIRIKA. They are,

- Neural network argumentation for Dungean semantics [7]
- Pluralistic argumentation (Western and Eastern arguments) [8]
- Syncretic argumentation [9]
- Argument mining [10]
- Argument animation [11]

The overall architecture of PIRIKA is shown in Figure 1.

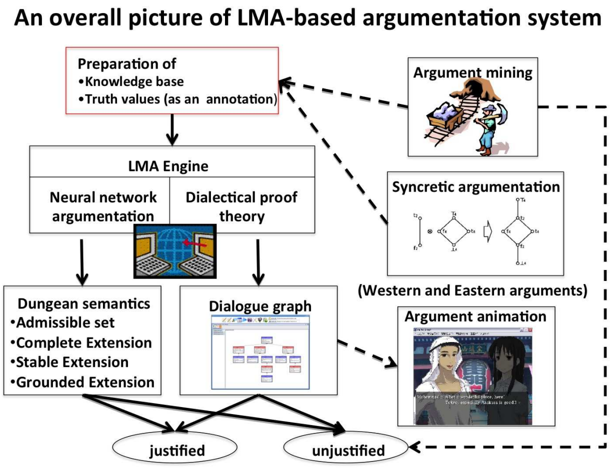

Figure 1. Architecture of PIRIKA

V. Jaina seven-valued logic

In this subsection, we deal with Jaina seven-valued logic [12][13], which is to be captured as an upper semi-lattice structure of the EALP/LMA framework.

The Jaina logic is said to be an intellectual ahimsa in a word [12], and its doctrines consist of Anekāntavāda, Syādvāda and Nayavāda [14]. Anekāntavāda is one of the most important and fundamental doctrines of Jainism. It refers to the principles of pluralism and multiplicity of viewpoints, the notion that truth and reality are perceived differently from diverse points of view, and that no single point of view is the complete truth.

Syādvāda is the theory of conditioned predication, which provides an expression to anekānta by recommending that the epithet Syād be prefixed to every phrase or expression, and Nayavāda is the theory of partial standpoints.

Syād means 'in some ways', 'from a perspective', 'in some aspect', 'somehow', 'maybe', etc. As reality is complex, no single proposition can express the nature of reality fully. Thus the term 'syāt'(in composition 'syād') should be prefixed before each proposition giving it a conditional point of view and thus removing any dogmatism in the statement. Since it ensures that each statement is expressed from seven different conditional and relative viewpoints or propositions, syādvāda is known as the theory of seven conditioned predications. These seven propositions are:

1) syād-astiin some ways, it is.
2) syād-nāstiin some ways, it is not.
3) syād-avaktavyaḥin some ways, it is indescribable.
4) syād-asti-nāstiin some ways, it is, and it is not.
5) syād-asti-avaktavyaḥin some ways, it is, and it is indescribable.
6) syād-nāsti-avaktavyaḥin some ways, it is not, and it is indescribable.
7) syād-asti-nāsti-avaktavyaḥin some ways, it is, it is not, and it is indescribable.

Each of these seven propositions examines the complex and multifaceted nature of reality from a relative point of view of time, space, substance and mode. To ignore the complexity of reality is to commit the fallacy of dogmatism [14].

The vulgar (Aristotelian or Boolean) logic is based on the 'Laws of Thought.' The Jain theory of modes of truth (saptabhangivada, 'seven-division-ism,' perfected by the sixth-century Samantabhadra) recognizes seven truth-values [12].

We relate those seven propositions (or the seven modes of truth) to the seven truth-values : $\mathfrak{t}, \mathfrak{f}, \mathfrak{i}, \mathfrak{tf}, \mathfrak{ti}, \mathfrak{fi}, \mathfrak{tfi}$ respectively. Then, we can well capture the structure of the seven truth-values of Jaina logic as the upper semi-lattice as seen in Figure 2, that is,

[1]An acronym for PIlot for the RIght Knowledge and Argument

$$\mathcal{JAINA} = \langle\{\mathfrak{t}, \mathfrak{f}, \mathfrak{i}, \mathfrak{tf}, \mathfrak{ti}, \mathfrak{fi}, \mathfrak{tfi}\}, \leq\rangle.$$

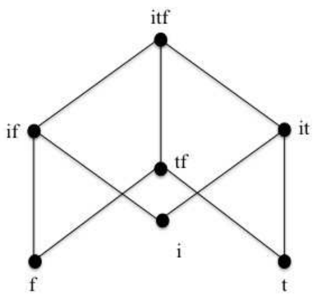

Figure 2. The upper semi-lattice of seven truth-values in Jaina logic

In what follows, we present argument examples in which intriguing language and logic phenomena can be captured on the basis of the Jaina seven-valued logic.

A. A pluralistic or multicultural argument example

We illustrate a pluralistic or multicultural argument by specializing LMA (Logic of Multiple-valued Argumentation) [2] to the upper semi-lattice $\mathcal{JAINA}$ in Figure 2. Let us consider the Western and Eastern arguments against Aristotle. Aristotle believed that the heavier a body is, the faster it falls to the ground. We simply represent this as $aristotle\_hyp : \mathfrak{t}$. Galileo's logical argument against this proceeds as follows: "Suppose that we have two bodies, a heavy one called H and a light one called L. Under Aristotle's assumption, H will fall faster than L. Now suppose that H and L are joined together. Now what happens? Well, L plus H is heavier than H so by the initial assumption it should fall faster than H alone. But in the joined body, L is lighter and will act as a 'brake' on H, and L plus H will fall slower than H alone. Hence it follows from the initial assumption that L plus H will both faster and slower than H alone. Since this is absurd, the initial assumption must be false." On the other hand, Easterners prefer a more holistic or dialectical argument like this: "Aristotle is based on a belief that the physical object is free from any influences of other contextual factors, which is impossible in reality." [15]

These are well translated into EALP [2] as follows:
[Galileo's knowledge]
$\sim aristotle\_hyp : \mathfrak{t} \leftarrow faster(l+h,h) : \mathfrak{tf}$
$faster(l+h,h) : \mathfrak{t} \leftarrow not\ aristotle\_hyp : \mathfrak{f}$
$faster(l+h,h) : \mathfrak{f} \leftarrow slower(l+h,h) : \mathfrak{t}$
$slower(l+h,h) : \mathfrak{t} \leftarrow brake(l,h) : \mathfrak{t}$
$brake(l,h) : \mathfrak{t}$
[Eastern agent's knowledge]
$\sim aristotle\_hyp : \mathfrak{t} \leftarrow distrust\_decontextualization : \mathfrak{t}$
$distrust\_decontextualization : \mathfrak{t}$

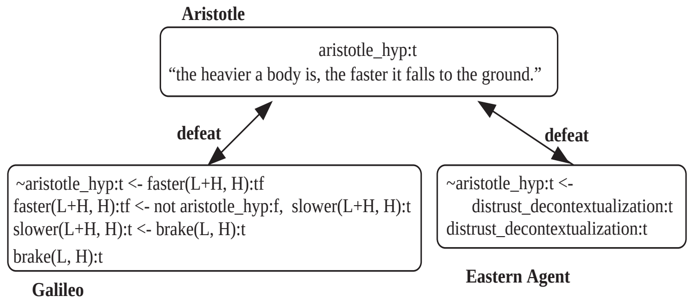

Figure 3. Western and Eastern arguments against Aristotle

Figure 3 depicts a dialogue tree constructed with the dialectical proof theory for EALP/LMA [2]. Obviously, Aristotle's argument $A_{Aristotle}$ is defeated (rebut) by Galileo's argument $A_{Western}$ and an Easterner's argument $A_{Eastern}$, and turns out not to be justified by two culturally different kinds of counter-arguments (actually defensible): an Western analytic argument and an Eastern holistic one, where the second rule in Galileo's argument is a reductant [3] made from his knowledge base. Note that Galileo made his argument by reductio ad absurdum for which the default negation 'not' has a crucial role in the rule representation. Furthermore, we note that the head $\sim aristotle\_hyp : \mathfrak{t}$ in the first rule of Galileo's argument does not undercut the assumption $\sim aristotle\_hyp : \mathfrak{f}$ of the second rule, that is, Galileo's argument is coherent or not self-defeating, and Eastern agent does not undercut the assumption $\sim aristotle\_hyp : \mathfrak{f}$ of the second rule in Galileo's argument. (Interested readers should refer to [2] for the technical terms used.)

In this example, all the arguments by Aristotle, Galileo and Eastern agent become defensible. Incidentally, let us consider a little modified version of the example. We first change Aristotle's belief as follows:
[Aristotle's belief]
$aristotle\_hyp : \mathfrak{t} \leftarrow not \sim empirically\_factual : \mathfrak{t}$.
And we make one more agent appear on the stage, who is a modern scientist having a firm belief on verificationism.
[Modern scientist's knowledge]
$\sim empirically\_factual : \mathfrak{t} \leftarrow$
$\quad not\ scientifically\_verified : \mathfrak{t}$.
Then, it is obvious that Aristotle's argument is overruled, and Galileo's, a modern scientist's ones and Eastern agent's one are all justified(see Figure 4).

B. Ethical argument example

We take up an ethical question 'Is homicide evil?' The knowledge bases of two agents: $A1$ and $CA1$ for the argument are shown in Table I. Agent A1 says '$homicide\_is\_evil :: [t\_i]$' with the ground "$when\_we\_say\_no\_we\_mean\_no :: [i]$". Then $[t\_i]$ means 'we cannot explain it, but it is so'. He also believes '$homicide\_is\_evil :: [t]$' with the definite ground. However, both of the assertions turn out to be defeated by the other Agent $CA1$. Agent $CA1$ has a wealth of knowledge compared with A1, quoting the famous words of Charlie Chaplin

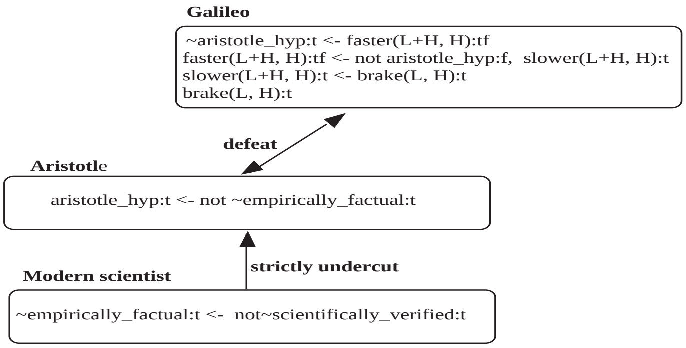

Figure 4. Galileo's argument is justified.

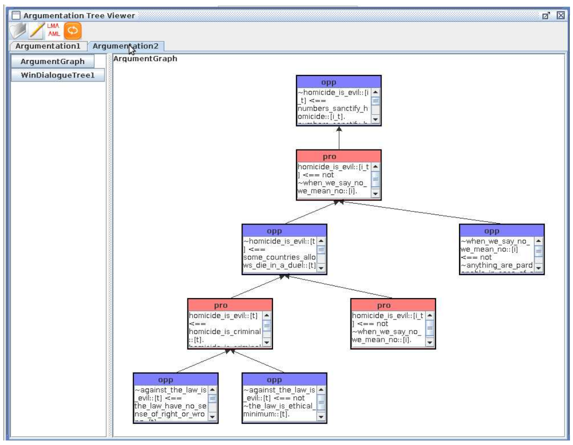

Figure 6. $\sim homicide\_is\_evil : ti$ $is\ justified$

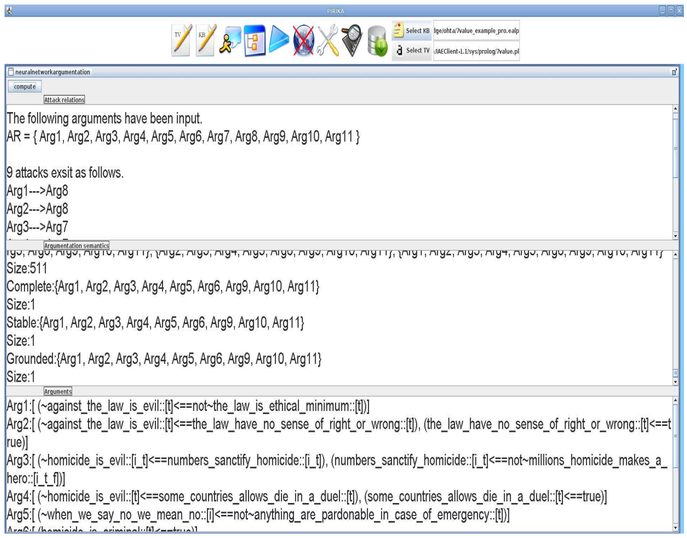

Figure 7. Computing other argumentation semantics by the neural network

and Georg Jellinek, and exploiting that there is a scene where homicide is permitted. Furthermore, he also has such a unique assertion that '$millions\_murder\_makes\_a\_hero$ :: $[i\_t\_f]$'. $[i\_t\_f]$ means that if it is stated from a viewpoint of the meaning of the word, it is so, but if it is stated from a viewpoint of one homicide, it is not so, and if it is stated from a viewpoint of a hero's definition, it is indescribable. Actually it is a statement that gets involved in three perspectives.

The arguments on the issues '$\sim homicide\_is\_evil$ :: $[i\_t]$' and '$\sim homicide\_is\_evil$ :: $[t]$' are justified since they are defeated (rebut) from $A1$, but $A1$'s ground are defeated (undercut) too. We can see the winning dialogue trees in Figure 5 and 6 respectively.

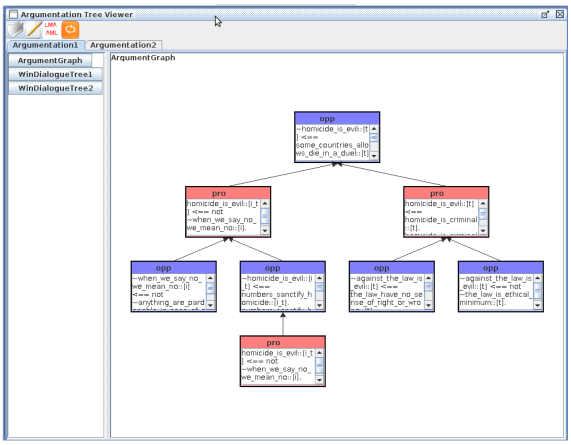

Figure 5. $\sim homicide\_is\_evil : t$ $is\ justified$

Figure 7 displays the result of the neural network argumentation [7] computing Dungean semantics [16] of the Jaina argument example by PIRIKA. It includes the results of other argumentation semantics such as the admissible extention, stable extention and complete extention as well as the grounded extention. The neural network argumentation has such an advantage that it can deal with all the basic Dungean semantics and compute in a uniform way.

VI. Related Work

PIRIKA is only one argumentation system that allows uncertainty in computational argument system in a full-fledged manner, and is integrated with such unique features as neural network argumentation, syncretic argumentation, argument mining, and argument animation. Chesñevar's possibilistic argumentation might be only one exception, but its argumentation model deals with uncertainty over the real numbers only [17].

VII. Concluding Remarks and Future Work

EALP is a very generic knowledge representation language for uncertain arguments, and LMA built on top of it also yields a generic argumentation framework so that it allows agents to construct uncertain arguments under truth values specified depending on application domains.

Table I
KNOWLEDGE-BASE OF SEVEN-VALUED ARGUMENTATION

agent A1 knowledge base : KB_{A1}
$homicide\_is\_evil :: [it] <== not \sim when\_we\_say\_no\_we\_mean\_no :: [i].$
$homicide\_is\_evil :: [t] <== homicide\_is\_criminal :: [t] \& not \sim violation\_of\_law\_is\_evil :: [t].$
$homicide\_is\_criminal :: [t] <== true.$
agent CA1 knowledge base : KB_{CA1}
$\sim when\_we\_say\_no\_we\_mean\_no :: [i] <==$ $not \sim anything\_are\_pardonable\_in\_case\_of\_emergency :: [t].$
$\sim violation\_of\_law\_is\_evil :: [t] <== not \sim law\_is\_ethical\_minimum :: [t].$
$\sim violation\_of\_law\_is\_evil :: [t] <== law\_has\_no\_sense\_ofright\_or\_wrong :: [t].$
$the\_law\_have\_no\_sense\_ofright\_or\_wrong :: [t] <== true.$
$\sim homicide\_is\_evil :: [it] <== numbers\_sanctify\_murder :: [it].$
$numbers\_sanctify\_murder :: [it] <== not \sim killing\_millions\_makes\_a\_hero :: [itf].$
$\sim homicide\_is\_evil :: [t] <== some\_country\_allows\_die\_in\_a\_duel :: [t].$
$some\_country\_allows\_die\_in\_a\_duel :: [t] <== true.$

In this paper we manifested the standard uses of PIRIKA, an implemented system of EALP/LMA, and revealed its potential usefulness by specializing it to the Jaina seven-valued logic. Particularly, we showed that PIRIKA can deal with not only Western arguments but also Eastern arguments such as somewhat complicated Indian Jaina logic.

In the near future, we will port PIRIKA on Linux, Windows and Mac OX to pervasive personal tools such as iPhone and iPad, in order to attract a wide range of people and allow them to use PIRIKA in their daily lives. We hope that such an attempt will open up a new horizon for computational argumentation research.

REFERENCES

[1] I. Rahwan and G. R. E. Simari, *Argumentation in Artificial Intelligence*. Springer, 2009.

[2] T. Takahashi and H. Sawamura, "A logic of multiple-valued argumentation," in *Proceedings of the third international joint conference on Autonomous Agents and Multi Agent Systems (AAMAS'2004)*. ACM, 2004, pp. 800–807.

[3] M. Kifer and V. S. Subrahmanian, "Theory of generalized annotated logic programming and its applications," *J. of Logic Programming*, vol. 12, pp. 335–397, 1992.

[4] P. M. Dung, "An argumentation semantics for logic programming with explicit negation," in *Proc. of 10th Int. Conference on Logic Programming*, 1993, pp. 616–630.

[5] H. Prakken and G. Sartor, "Argument-based extended logic programming with defeasible priorities," *J. of Applied Non-Classical Logics*, vol. 7, no. 1, pp. 25–75, 1997.

[6] S. Tannai, S. Ohta, T. Hagiwara, H. Sawamura, and J. Riche, "The state of the art in the development of a versatile argumentation system based on the logic of multiple-valued argumentation," in *Proc. of International Conference on Agents and Artificial Intelligence (ICAART2013)*. INSTICC, 2013, pp. 217–224.

[7] Y. Goto, T. Hagiwara, and H. Sawamura, "Neural networks computing the dungean semantics of argumentation," in *IJCCI (NCTA)*, K. Madani, J. Kacprzyk, and J. Filipe, Eds. SciTePress, 2011, pp. 5–14.

[8] H. Sawamura, T. Takahashi, and K. Matsunaga, "An eastern specialization of logic of multiple-valued argumentation to tetralemma originated in india," in *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, B. Prasad, Ed., 2005, pp. 1274–1291.

[9] Y. Maruyama, T. Hasegawa, T. Hagiwara, and H. Sawamura, "Syncretic argumentation for multi-agents by lattice homomorphism, fusion and sum," in *ArgMAS*, ser. Lecture Notes in Computer Science, P. McBurney, S. Parsons, and I. Rahwan, Eds., vol. 7543. Springer, 2011, pp. 46–65.

[10] Y. Seino, H. Sawamura, and T. Hagiwara, "Towards argument mining," in *Proceedings of 2011 International Conference on Data Engineering and Internet Technology (DEIT 2011)*. IEEE, 2011, pp. 27–34.

[11] T. Narita and H. Sawamura, "An attempt to argument metamorphosis from symbols to moving images," in *Proceedings of 2008 Joint Agent Symposium (JAWS2008)*, 2008.

[12] G. B. Burch, "Seven-valued logic in Jain philosophy," *International Philosophical Quarterly: An Intercultural Forum*, vol. 4, no. 1, pp. 68–93, 1964.

[13] J. Ganeri, "Jaina logic and the philosophical basis of pluralism," *History and Philosophy of Logic*, vol. 23, pp. 267–281, 2002.

[14] Wikipedia, "Jainism," *http://en.wikipedia.org/wiki/Jainism*, 2013.

[15] R. E. Nisbett, *The Geography of Thought: How Asians and Westerners Think Differently... and Why*. The Free Press, 2003.

[16] P. Dung, "On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logics programming and n-person games," *Artificial Intelligence*, vol. 77, pp. 321–357, 1995.

[17] C. I. Chesñevar, G. Simari, T. Alsinet, and L. Godo, "A Logic Programming Framework for Possibilistic Argumentation with Vague Knowledge," in *Proc. of the Intl. Conference on Uncertainty in Artificial Intelligence (UAI2004)*, 2004.