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A Review of Argumentation for the Social Semantic Web

Jodi Schneider [a], Tudor Groza [a,b], and Alexandre Passant [a]

[a] *Digital Enterprise Research Institute, National University of Ireland, Galway, firstname.lastname@deri.org*

[b] *School of ITEE, The University of Queensland, Australia, tudor.groza@uq.edu.au*

Abstract. Argumentation represents the study of views and opinions expressed by humans with the goal of reaching a conclusion through logical reasoning. Beginning with the 1950's, several models were proposed to capture the essence of informal argumentation in different settings. With the emergence of the Semantic Web, this modeling shifted towards ontologies, while from the development perspective, we witnessed an important increase in Web 2.0 human-centered collaborative deliberation tools. Through a review of more than 100 scholarly papers, this article provides a comprehensive and comparative overview of the argumentation domain. We start from the early theoretical foundational models, then look into Semantic Web argumentation models, and finally end with Social Web tools for argumentation, also focusing on online applications combining Web 2.0 and Semantic Web technologies, following the path to a global World Wide Argument Web.

Keywords: Argumentation, Semantic Web, Social Web, Semantic Web, Ontologies

1. Introduction

In recent years, large-scale argumentation on the Web has attracted the attention of scholars from fields such as artificial intelligence [1], communication theory [2], business management [3] and e-government [4]. At the same time, argumentation researchers began establishing the foundations for a World Wide Argument Web (WWAW) as "a large-scale Web of interconnected arguments posted by individuals to express their opinions in a structured manner" [5].

Decision-making often requires discussion not just of agreement and disagreement, but also the principles, reasons, and explanations driving the choices between particular options. Furthermore, arguments expressed online for one audience may be of interest to other (sometimes farflung) audiences. And it can be difficult to re-find the relevant spot of an argumentative discussion in which we have participated. Yet on the Web, we cannot subscribe to arguments or issues, nor can we search for them. Nor can we summarize the rationale behind a group's decision, even when the discussion took place entirely in public venues such as mailing lists, IRC channels, and Web forums.

By providing common languages and principles to model and query information on the Web (such as RDF [6], RDFS [7], OWL [8], SPARQL [9], Linked Data principles [10], etc.), the Semantic Web [11] is an appropriate means to represent arguments and argumentation uniformly on the Web, and to enable for instance browsing distributed argumentation patterns that appear in various places on the Web. Indeed, researchers have shown that The Semantic Web can help visualize and compare in decision rationale [12].

In this context, this paper discusses argumentation in relation to the Social Semantic Web [13,14,15], focusing on foundational models of argumentation and on ontologies (as in Computer Science [16]) which either (i) use argumentation (from the knowledge engineering community), or (ii) describe argumentation (from the argumentation community). In particular, our purpose is to investigate ontologies and tools which may be useful for argumentation on the Social Semantic Web, a field where the aforementioned Semantic Web technologies support Social Web [17] applications, while at the same time Social Web paradigms are used to generate Semantic Web data collaboratively and at large-scale. This convergence aims at providing new and improved ways to integrate and discover data, following the vision of Social Ma-

chines provided by Berners-Lee [18], both on the Web and in the enterprise [19]. In the context of argumentation, this could help to aggregate arguments from various websites — for instance a discussion starting on Twitter and followed up on a mailing list, later frozen on a wiki once consensus is reached — providing new means to follow argumentative discussions on the Web.

Yet, Social Web does not yet have widely-used argumentative ontologies, though this problem has been noted [20], along with the need for federation infrastructures [21]. Then, in order to identify how different argumentation models and tools can be used for the Social Semantic Web, this paper offers a review of more 100 research papers on the topic from which we compare:

- 3 theoretical models from argumentation and decision theory
- 6 main approaches to argumentation from linguistics and communication theory
- 14 Semantic Web models for argumentation
- 34 tools for representing argumentation on the Web.

As the focus is on human-centered argumentation, with the goal of improving access and visualization, this article will briefly mention, but not analyze, the agent-based argumentation domain.

The rest of the paper breaks into three main parts: theory of argumentation, ontology-based models, and argumentation tools, and is organized as follows. Following the introduction, we discuss theoretical models of argumentation (§2) and approaches from linguistics and communication theory (§3). Next, we discuss Semantic Web models, distinguishing between twelve general Semantic Web models which incorporate some aspect of argumentation (§4), and two focused Semantic Web models developed by the argumentation community for the legal and argumentation domains (§5). In we compare these Semantic Web models. Then we move on to tools: we describe thirty-four tools in §7 and then provide a comparison table of the tools in §8. Finally we conclude the paper in §9.

2. Theoretical Models of Argumentation

2.1. Issue-Based Information System (IBIS)

IBIS, Issue-Based Information System, is a problem-solving structure first published in 1970 [22]. As the name suggests, IBIS centers around controversial *issues* which take the form of questions. Specialists from different fields may use the same words with different assumptions and intentions[1], hampering communication. IBIS is especially intended to support community and political decision-making. In this scenario, the participants in a discussion, the relevant experts and the decision makers may be three separate groups, who need to communicate with each other and who must also get information from existing records and documentation.

IBIS, as originally designed, is a documentation system, meant to organize discussion and allow subsequent understanding of the decision taken; this explains the use of "Information System" in its acronym. The context of the discussion is a *discourse* about a *topic*. Issues may bring up *questions of fact* and be discussed in *arguments*. Here, "*Arguments* are constructed in defense of or against the different positions until the issue is settled by convincing the opponents or decided by a formal decision procedure," [22]. IBIS also recognizes *model problems*, such as cost-benefit models, that deal with whole classes of problems.

Several kinds of relationships exist between issues: direct successor, generalization, relevant analogy, compatible, consistent, or inconsistent. The method also distinguishes issue content, as factual, deonic ("Shall X become the case?"), explanatory, or instrumental ("Shall we take approach X to accomplish Y?").

Originally implemented as a paper-based system, IBIS influenced several ontologies (as we will see later in Sections §4.5 and §4.6) and numerous tools as well as procedures such as dialogue mapping [23].

2.2. Toulmin

Informal argumentation originated in philosophy, with Toulmin's 1958 account of informal argumentation [24]. Toulmin sought to find a common underlying basis for arguments in every field of human activity. His model applies, for instance, to legal, scientific, and informal conversational arguments. In Toulmin's theory, evidence and rules called *Warrants* support *Claims*. *Claims* may also be qualified (i.e. with constraints or to indicate uncertainty); *Rebuttals* may be used to argue against an argument. Toulmin's ar-

[1] "Many central terms used are proper names for long stories specific of the particular situation, with their meaning depending very sensitively on the context in which they are used." [22]

gument pattern is shown in Figure 1: *Data* is supported by *Warrants* which have *Backings*, showing that a *Claim* holds with *Qualifiers* regarding the situation, unless there is a *Rebuttal*. Figure 2 shows Toulmin's now-famous argument, presented according to this structure.

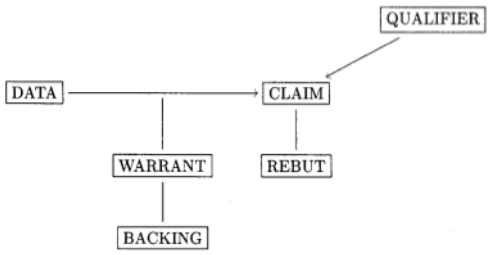


Fig. 1. An interpretation of Toulmin's argument pattern, from [25].

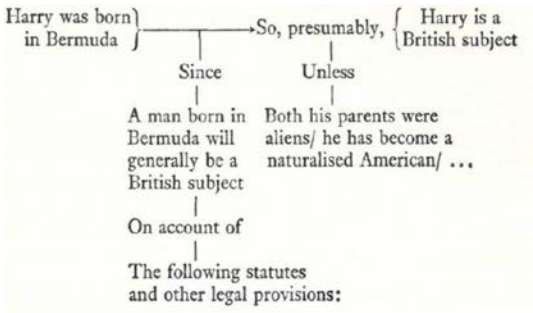


Fig. 2. Toulmin's example argument from page 105 of [24].

Toulmin is cited frequently and in numerous fields, from rhetoric (e.g. [26]) to education (e.g. [27]) to computer argumentation (e.g. [28]). While his model is a useful abstraction, scholars have argued about whether people actually think in terms of Toulmin's warrants [29].

2.3. Walton

The Canadian philosopher Walton has written extensively on argumentation for more than thirty years; a 2010 festschrift honoring his contributions [30] shows how his work has influenced and been applied to computer argumentation. Informal argumentation is one of Walton's specialties [31]. His seven types of dialogue are shown in Figure 3. These types are Persuasion, Inquiry, Discovery, Negotiation, Information-Seeking, Deliberation, and Eristic.[2] They are distinguished by the initial situation, the individual goals of the participants, and the overall goal of the dialogue. In our own view, these types of dialogue can be classified based on whether knowledge plays a large, middling, or minor role. Inquiry, Discovery, and Information-seeking dialogues are almost entirely knowledge-based, while knowledge plays only a minor role in Negotiation (aiming at a harmonious settlement) and Eristic (quarrels, beneficial mainly for venting emotions). Knowledge plays some role in the remaining two types: in Persuasion and Deliberation, opinion and belief also have a large role.

According to Rahwan [35], while many taxonomies of argumentation have been proposed [36,37,38,39], Walton's taxonomy [40] provides the point of departure for computational models of argumentation. In his detailed classification from 1995 [40], Walton describes each scheme with a name, a conclusion, a set of premises, and a set of critical questions. Critical questions address the points where this argument scheme may break down, and suggest attacks against the argument. For example, the following six critical questions are associated with the Argument from Expert Opinion [41][3]:

1. How credible is E as an expert source?
2. Is E an expert in the field that A is in?
3. Does E's testimony imply A?
4. Is E reliable?
5. Is A consistent with the testimony of other experts?
6. Is A supported by evidence?

Walton's 2008 book [42], coauthored with computational argumentation researchers, presents 96 general argumentation schemes, presumably updating [40].

In addition to validity and critical questions, Walton also describes additional rules of argumentation in such categories as relevance, cooperativeness, and informativeness. Relevance, for example, can be global, local, subject matter-specific, or probative. An argument may be relevant at one phase, but irrelevant at another point; for example an argument related to se-

[2] Walton's taxonomy has been revised several times. 'Discovery' was not in several earlier formulations, such as [32], page 183; it is motivated by choosing the best hypothesis for testing. Debate and Pedagogical appeared in an earlier formulation [33] which provides descriptions of the goals of each dialogue.

[3] [41] attributes this to page 49, D. Walton, Appeal to Expert Opinion, Penn State Press, University Park, 1997.

Type of Dialogue	Initial Situation	Participant's Goal	Goal Of Dialogue
Persuasion	Conflict of Opinions	Persuade Other Party	Resolve or Clarify Issue
Inquiry	Need to Have Proof	Find and Verify Evidence	Prove (Disprove) Hypothesis
Discovery	Need to Find an Explanation of Facts	Find and Defend a Suitable Hypothesis	Choose Best Hypothesis for Testing
Negotiation	Conflict of Interests	Get What You Most Want	Reasonable Settlement Both Can Live With
Information-Seeking	Need Information	Acquire or Give Information	Exchange Information
Deliberation	Dilemma or Practical Choice	Co-ordinate Goals and Actions	Decide Best Available Course of Action
Eristic	Personal Conflict	Verbally Hit Out at Opponent	Reveal Deeper Basis of Conflict

Fig. 3. Walton's seven types of dialogue, from [34].

lecting the topic of discussion is not relevant once the topic has been agreed upon. Further complexity arises because dialogue types may shift in an actual discussion, and argument schemes may be embedded in one another [34].

For our purposes, "the Walton model" is that a dialogical argument uses one or more dialogue types and one or more argument schemes and has an opening, a middle (argumentation) phase, and a closing.

3. Linguistic and communication theory approaches to argumentation

Approaches from linguistics and communication theory are relevant to argumentation in at least two ways. First, they provide a theoretical background for how texts are coherent and what they pragmatically communicate. Second, they provide algorithms for detecting the relationships between texts.

3.1. Coherence

Coherence is an essential part of text, and an essential part of argumentation. Knott compares the following two examples [43].

1. "Tim must love that Belgian beer. The crate in the hall is already half empty."
2. "Tim must love that Belgian beer. He's six foot tall."

While the first example is coherent the second example is more challenging to make sense of: the reader expects (but does not get) a sensible explanation or evidence for why Tim *must* love that Belgian beer.

Argumentation relies on coherence: Adding 'because' works in the first example but not in the second example. The word 'because' stresses the expected causal relationship, making the informal argument more evident.

3. "Tim must love that Belgian beer, because the crate in the hall is already half empty."

In Sentence 3, the reader must still infer some information, such as that the crate in the hall contains Belgian beer, and that Tim is the main person drinking the contents of the crate. Such missing premises are typical in informal argumentation.

The causal relationship (expressed in 'because') is one of the Cognitive Coherence Relations which Sanders uses to explain how readers understand text [44]. The four Cognitive Coherence Relations are: 'Basic Operation' (causal or additive), 'Source of Coherence' (semantic or pragmatic), 'Polarity' (positive or negative), 'Order of Segments' (for causal relations only: basic or non-basic, depending on whether or not the antecedent appears before the consequent). In these terms, the relationship in Sentence 3 is causal, pragmatic, positive, and basic.

Cognitive Coherence Relations contributed to the development of ScholOnto (§4.14) [45]. In separate work, Mancini's cinematic hypertext [46] used Cognitive Coherence Relations to develop a visual language for structuring hypertext links, increasing the coherence of argumentation conveyed in non-linear hypertext by clearly expressing the rhetorical relationships between chunks of text. Meanwhile, agent-based argumentation has used Cognitive Coherence Relations as a theory of pragmatics [47].

3.2. Speech Act Theory

Searle's Speech Act Theory [48] describes five categories of speech acts: assertives, directives, commis-

sives, expressives, and declaratives. Speech acts are about the force of a statement: what effect they seek to have on the hearer or the world. Assertives ('The sky is blue') assert that something is true. Directives ('Clean your room') order, permit, or request something. Commissives are vows or pledges ('I swear to tell the truth'). Expressives offer thanks or congratulations ('Great work!'). Declarations ('I now pronounce you man and wife') enact what they say, effectively changing reality.[4] Eemeren and Grootendorst further developed Searle's theory to model argumentation with Speech Act Theory (see, among others, their book [49]): in particular, (1) the speaker puts forward an opinion; (2) the speaker puts forward propositional assertions; (3) the propositions are meant to justify the opinion to the listener (i.e. the speaker believes that the listener does not necessarily accept his opinion but will accept the propositions as justification); and (4) the speaker believes his opinion and assertions are acceptable, and that the assertions justify his opinion. There are some limitations of this model of argumentation: as Jacobs [50] points out, these expected criteria for argumentation do not necessarily hold in question-and-answer based arguments and indirect argumentation.

In the Semantic Web context, where assertions can be modelled using RDF, Carroll et al. [51] use the idea of performative warrants, to describe assertions made legitimately by the authority signing a Named Graph. Speech acts are also used to model the flow of online conversation in several recent works. Jeong et al. [52] use semi-supervised machine learning to identify speech acts in email and forum posts. Ritter et al. [53] model Twitter conversations with Speech Act Theory in combination with topic modelling and show a Speech Act transition map with probabilities for each state.

3.3. Language/Action perspective

The Language/Action Perspective (LAP) [54] embeds Speech Act Theory in a task-based framework. Argumentation is found in each of the three types of conversations which accomplish goals in the Language/Action Perspective, according to de Moor and Aakhus: Conversations for action involve making commitments; conversations for possibility create a context for action; and conversations for disclosure allow participants to share their views and concerns [55].

[4] As with all speech acts, sincerity is a criterion, and social criteria, e.g. ceremony, may also hold.

Using the Language/Action Perspective and drawing from Speech Act Theory, Twitchell et al. [56] model online conversations to classify them and create visual maps, used for information retrieval:

> "Using current search engines, the searcher could search for the words Vietnam, war, and critique. However, many critiques of the war might not contain the word critique, and would thus be lost (or receive a low ranking) in such a search. **If the searcher was able to issue a query such as Vietnam war (critique) where critique is the purpose of at least one participant in the conversation, she would likely get better results.** The search for the semantic meaning of the words Vietnam war using conventional searching techniques would then be combined with the search for the pragmatic force of the word critique, yielding a search result with higher precision than searching on semantic meaning alone." [56](bold, underline added).

Attending to Speech Acts can also help predict deception, which uses 'fewer assertions and more expressives' [56].

3.4. Rhetorical Structure Theory

Rhetorical Structure Theory (RST) [57], a method for analyzing texts according to their structure and rhetorical role, was developed at the University of Southern California's Information Sciences Institute to assist with computer-based text generation. In RST, structures such as 'Concession', 'Evidence', and 'Justify', called 'relations', describe the relationship of two or more spans of text. Generally one span (the most important) is called the nucleus, while the less important spans are known as satellites. In some situations (such as sequences and contrasts), both spans are nuclei of equal weight. RST has been widely used and in 2006 a paper summarizing its applications [58] was published. Recently, Mentis et al. [59] used RST to analyze group decision rationale, comparing new and established groups using relations such as 'Interpretation & Evaluation', 'Evidence', 'Elaboration', 'Concession', and 'Antithesis'. Summarization research has frequently drawn upon RST [60,61].

3.5. Recent Approaches to Rhetorical Parsing for Arguments

New approaches to rhetorical parsing depart from RST. Rather than determining the relations between

text spans, Sándor uses her concept-matching framework to infer contrasts, novel information, etc. from the author's metadiscourse [62]. Teufel and Moens focuses on the document-level context, rather than the relationship between text spans. In their argument zoning, machine learning is used to extract and classify text from academic articles according to its rhetorical status [63]. Sándor and Teufel and Moens provide contributions in risk assessment, annotation, and audience- and task-specific summarization. Reuse of their work has included an application to find rhetorical features of related work sections, using classification algorithms, and then to apply ontologies [64]. However, their techniques are of interest here because of further work in argument mining drawing on these ideas.

3.6. Argument Mining

Drawing from rhetorical parsing, argument mining is a new area of study which seeks to detect and extract arguments from texts algorithmically. Mochales-Paulau's current dissertation work focuses on mining arguments [65,66,67] from the European Court of Human Rights and from the Araucaria annotated corpus [68], based on Context Free Grammars [67] as well as techniques from Teufel and Moens. Earlier Grover et al. [69] adapted Teufel and Moens' approach to determine the argumentative role of sentences drawn from a corpus of legal judgements.

In "Automatic Argumentation Detection and its Role in Law and the Semantic Web" [65], Mochales-Paulau and Moens suggest that argument mining could contribute to the World Wide Argument Web "a large-scale Web of interconnected arguments posted by individuals to express their opinions in a structured manner" [5], by extracting argument structures without human annotation. As they point out, automatic argument detection is needed at multiple levels: the inner structure of each argument as well as the overall structure of how multiple arguments are combined to contribute to the argumentative discourse.

For legal cases, one long-standing alternative to rhetorical parsing has been to classify and index cases according to the key dimensions or factors which "capture the legal relevance of a cluster of facts to the merits of a claim" [70]. Factors such as "Obligation to aid the victim" or "Failure to heed traffic signs" contribute to determinations of culpability, and have been recorded in manual constructed databases [70]; this is still an approach used by commercial providers of legal information [67]. More recently, automatic text mining has been used to identify these factors [67]. Generalizing factors, perhaps using argument schemes and critical questions, could provide another approach to argument mining; see for instance Heras' manual application of argument schemes to Amazon reviews [71].

3.7. Parsing Arguments Expressed in Controlled Natural Language

Restricting the discourse can facilitate argument mining: One alternative to argument mining from natural language is to use Controlled Natural Language, which adopts a more restrictive grammar and vocabulary in order to facilitate parsing. Controlled Natural Languages such as Attempto Controlled English [72] have been used to facilitate knowledge representation and reasoning on the Semantic Web. Wyner et al. [73] propose using Attempto Controlled English for high-stakes argumentative discussions; generating a first-order-logic representation of the discussion would allow inference and consistency-checking.

A related approach was used for incremental formalization in Trellis (§7.36). Trellis introduced "Annotation Canonicalization through Expression synthesis" [74], which applied an ontology to a user-supplied sentence, checked the computer's ontology application by presenting a paraphrase to the user, and solicited additions to the ontology from unknown or misunderstood words.

3.8. Other corpus-processing techniques and approaches

Additional corpus-processing techniques and approaches may be useful for detecting argumentation, because it shares rhetorical features with other sorts of speech. Relevant approaches may come from opinion mining [75], question answering and explanation [76], contradiction detection [77], and automatically typing links [78].

4. Semantic Web Models incorporating Argumentation

In this section, we discuss Semantic Web models which incorporate argumentation. These include ontologies designed for various purposes which include statements of agreement or disagreement. Ontologies

specifically designed to represent arguments are discussed in a subsequent section (§5). Thus, the scope is Semantic Web models with argumentation components propagated by ontology-centric communities in a variety of fields.

4.1. List of models to be considered

We order models roughly in terms of increasing richness[5], and consider the following models: the Annotation Ontology, bio-zen-plus, the NDR Ontology, IBIS RDF, DILIGENT, ChAO, the SALT Rhetorical Ontology, SIOC-Argumentation, SWAN/SIOC, CiTO, Trellis, and ScholOnto.

4.2. Annotation Ontology

Argumentation enters into the Annotation Ontology's[6] [79] curation use case. In that use case, an annotation created by a text mining service is then reviewed and in fact rejected by human curator. This curator subsequently changes her mind after a discussion with a second curator, and finally accepts the annotation after all. The statuses `Rejected`, `Discusses`, and `Accepted` express an argumentative workflow in this situation.

4.3. bio-zen-plus ontology framework

The bio-zen-plus ontology[7] [80] is an ontology for biology; as the name suggests, it is an extension of the bio-zen ontology. It includes two argumentative properties, `supported-by` and `in-conflict-with`, augmenting the argumentation-related `correlation-concepts`, such as `Positive correlation (unsigned)`, `Positive correlation (signed)`, `Negative correlation (unsigned)`, and `Negative correlation (signed)`, which are found within the bio-zen ontology[8].

[5] Change Ontology is the exception; for convenience, we discuss it following DILIGENT, on which it depends.

[6] `http://code.google.com/p/annotation-ontology/`

[7] `http://neuroscientific.net/bio-zen-plus.owl`

[8] `http://neuroscientific.net/bio-zen.owl`

4.4. The NDR Ontology

The Non-functional requirements and Design Rational (NDR) Ontology [12] addresses the visualization of non-functional requirements as Softgoal Interdependency Graphs. While some classes (such as `Softgoal`) are specific to this domain, the NDR Ontology introduces useful argumentative labels and causal relationships. For example, the label property can be used to indicate the extent to which goals are met (i.e. whether they are adequately 'satisficed'): Denied, Weakly denied, Undecided, Weakly satisficed, Satisficed, or Conflict. NDR also has classes for `Argumentation`, `Claim`, `Contribution`, and `Interdependency` (including a subclass, `Correlation`). The `Contribution` of child goals to the parent goal can be labelled as Break, Hurt, Unknown, Help, Make, etc.

4.5. IBIS RDF

IBIS RDF[9] is an RDF representation of the aforementioned IBIS model (§2.1). `refersTo` is modelled as a subProperty of `dcterms:reference` with two subproperties, `pro` and `con`. The larger IBIS vocabulary provides Published Subject Indicators for important terms, including pro, con, Idea, Question, Argument, Decision, and Reference.

4.6. Other variants on the IBIS model

Although many tools are described as 'using the IBIS model' or 'IBIS-like', there is significant variation in the underlying structure of these models [81]. In our view, these models use 'IBIS-like' to mean that they concern decision-making or design rationale, provide graphical representations, and use some form of polarity.

The IBIS model received early critiques from the design rationale community. One difficulty was that only deliberated issues were included; Procedural Hierarchy of Issues (PHI) modifies IBIS to allow inclusion of subissues which are not deliberated [82]. SEPIA, another early system using IBIS-based argumentation, also modified IBIS [83]. Another difficulty, representing the relationships and interdependencies of issues [82], remains challenging to resolve, though applying ideas from Softgoal Interdependency Graphs ([12]) might help in this regard.

[9] `http://purl.org/ibis`

IBIS has been used outside of design rationale. For instance, Gerosa et al. [84] discuss an e-learning message board system adopting a modification of IBIS, where message types are specified. In addition to the IBIS-analogues, Question, Argumentation, and Counter-Argumentation, the system adds two types: Seminar (a general topic for the week) and Clarification. IBIS has also influenced the design of modern ontologies, including DILIGENT (§4.7), ChAO (§4.8), the SALT Rhetorical Ontology(§4.9), and SIOC-Argumentation (§4.10), which we soon discuss.

4.7. DILIGENT ontology

The ontology design process inspired DILGENT; the acronym comes from the phrase DIstributed, Loosely-controlled and evolvInG Engineering processes of oNTologies. DILIGENT provides an argumentative structure for collaborative ontology construction.

DILIGENT draws from both RST (§3.4) and IBIS (§2.1), as shown in Figure 4. To improve the agreement, clarity, and satisfaction [85] of discussions for ontology creation and refinement, DILIGENT restricts the argumentation. Five argumentative relations — `alternative`, `counterExample`, `elaboration`, `evaluation and justification`, and `example` — were drawn from RST [86], based on the arguments that advanced the ontology creation process in an experiment [87].

4.8. Change Ontology (ChAO) in Collaborative Protégé

The Change Ontology in Collaborative Protégé was influenced by DILIGENT [88]. Castro et al. distinguish between an argument (which is well-focused and specific) and an elaboration (which provides support for the argument, possibly with file attachments) [88]. Positions become clear through the dispute-resolution process. With Protégé, various argumentation-related `Annotations` can be added, including `Explanation`, `Proposal`, and `AgreeDisagreeVote` [89].

4.9. SALT Rhetorical Ontology

SALT [90] is a rhetorical ontology for scholarly communication. In SALT, opposing arguments can be connected together with the relation `hasCounterArgument`, and a `RhetoricalElement` can also be connected with what it argues for (`hasArgument` the `Argument`). SALT's argumentation also includes `Reason`, which contains `Argument` (further specified to `PositiveArgument` or `NegativeArgument`) and `CounterArgument`.

4.10. SIOC-Argumentation

The SIOC-Argumentation[10] model [91] expands on the IBIS model with terms such as `Decision` and `Argument`. It is provided as an extension of SIOC — Semantically-Interlinked Online Communities [92] — a model focusing on representing online communities and the content shared within. While SIOC simply focuses on the notion of replies (`sioc:reply_to`) to represent connections between discussion items, the SIOC-Argumentation module goes further and provides finer-grained representation of discussions and argumentations in online communities. So far a modification of SIOC drawing from DILIGENT and OM-Doc (Figure 5) has been used in the math wiki system SWiM [86].

As opposed to IBIS-RDF, SIOC-Argumentation provide the means to easily integrate argumentation modelling patterns with Social Web applications since it relies on SIOC, already used in various applications (Drupal7, etc.). However, SIOC-Argumentation has limitations: it does not represent taxonomic, causal, or similarity relations, which prevents its use in contexts such as full-on argument analysis.

4.11. SWAN-SIOC

SWAN-SIOC [93] harmonizes the argumentation aspects of two pre-existing ontologies: the aforementioned SIOC and SWAN — Semantic Web Applications in Neuromedicine [94] — an ontology which focuses on scientific communication in neurology.

SWAN/SIOC uses twelve terms, as shown in Figure 4.11. The most general term is relatedTo, which has five direct descendents or subterms. These, in turn, may have subterms, until we reach the base terms in the ontology: `disagreesWith`, `agreesWith`, and `discusses`. SWAN/SIOC provides a simple model for the relationships between items. Tools using SWAN-SIOC include as PDOnline (§7.32).

[10] http://rdfs.org/sioc/argument

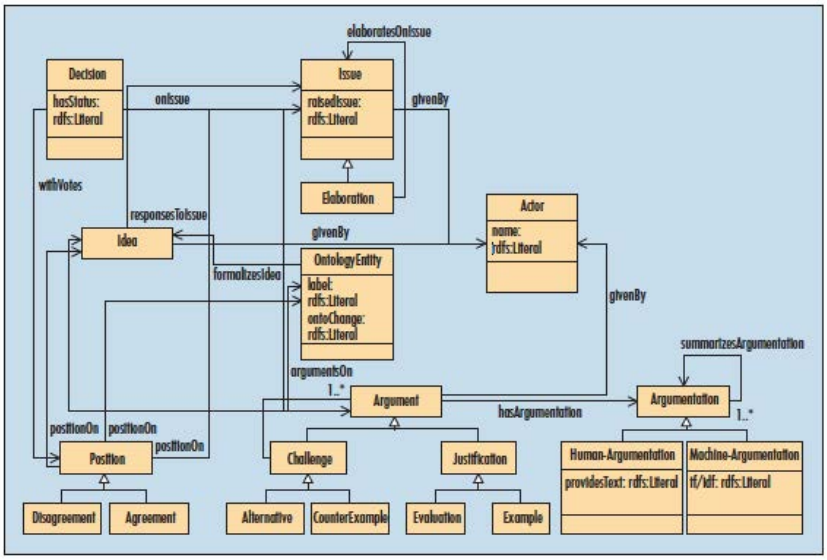


Fig. 4. An overview of the core DILIGENT ontology from [85].

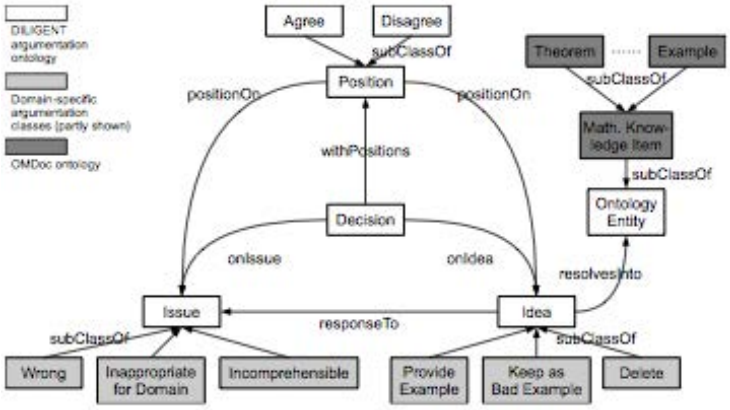


Fig. 5. The argumentation ontology from SWiM extends SIOC-Argumentation and DILIGENT Argumentation [86].

4.12. Citation Typing Ontology (CiTO)

CiTO[11] [96,97] is an ontology for citation networks in scholarly publications. Its argumentative terms include `corrects`, `confirms`, `gives support to`, `is agreed with by`, `is ridiculed by`, `qualifies`, and `refutes`. Papers can thus be semantically enhanced.[12] For example, an author could indicate in a paper that it `updates` a previous publication, and `critiques` a piece of related work, while using evidence from another paper (`citesAsEvidence`). Readers can assemble bibliographies using CiTO properties, for instance with the bibliographic management software CiteULike[13], showing the possibilities of semantic annotation.

4.13. Semantic Annotation Vocabulary

The Semantic Annotation Vocabulary [98] was developed for the Trellis system which we later describe §7.36. They used various dimensions: pertinence, re-

[11] `http://purl.org/net/cito/`

[12] `http://imageweb.zoo.ox.ac.uk/pub/2008/plospaper/latest/`

[13] `http://www.citeulike.org/`

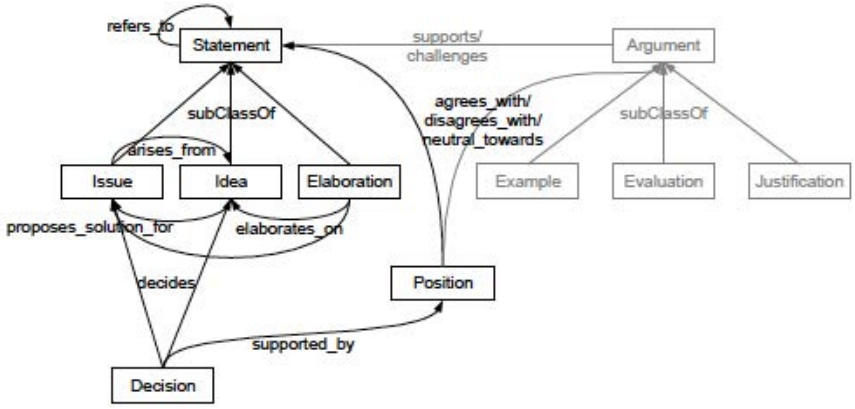


Fig. 6. An overview of the SIOC-Argumentation module from [91].

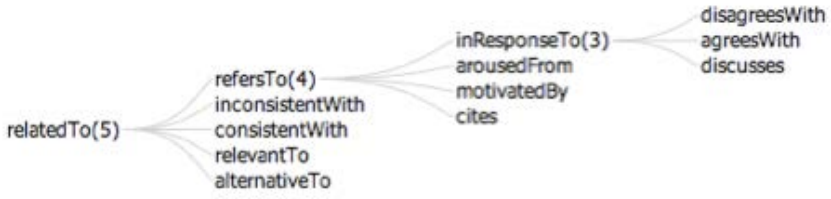


Fig. 7. An overview of the SWAN-SIOC ontology from [95].

liability, credibility, causality (e.g. contribute to, indicate), and temporal ordering, as well as structural relationships (such as part/whole, example-of, describes).

4.14. ScholOnto

The ScholOnto [99] [100] project, which ran at Open University's Knowledge Media Institute from 2001-2004, focused on modeling claims and arguments in scholarly communication. ClaiMapper, ClaiMaker, and ClaimSpotter were among the tools[14] developed in the project, which was seen as part of sense-making research. An open source web publishing tool called the Digital Document Discourse Environment[15], or D^3E [101] was also developed in related research. ScholOnto made an RDF Schema available, but database queries with SQL were preferred to querying based on this RDF Schema (SPARQL was first released as a working draft in 2004). The underlying ontology for these projects is shown in Figure 4.14.

[14] http://projects.kmi.open.ac.uk/scholonto/software.html

[15] http://d3e.sourceforge.net/

5. Semantic Web Models for Representing Arguments and Detailing Argument Structure

5.1. Introduction and Scope

Next we discuss Semantic Web models for representing arguments and detailing argumentative structures. Unlike the models discussed in §4, which provide a shallow view of arguments and are typically situated within a larger context, these models originate in the argumentation community, and typically focus on representing the arguments themselves, often including the internal structure of the arguments. Thus the scope in this section is Semantic Web models of argumentation itself.

The argumentation community's interest in the Semantic Web has been motivated in part by the idea of The World Wide Argument Web (WWAW), envisioned as "a large-scale Web of interconnected arguments posted by individuals to express their opinions in a structured manner" [5].

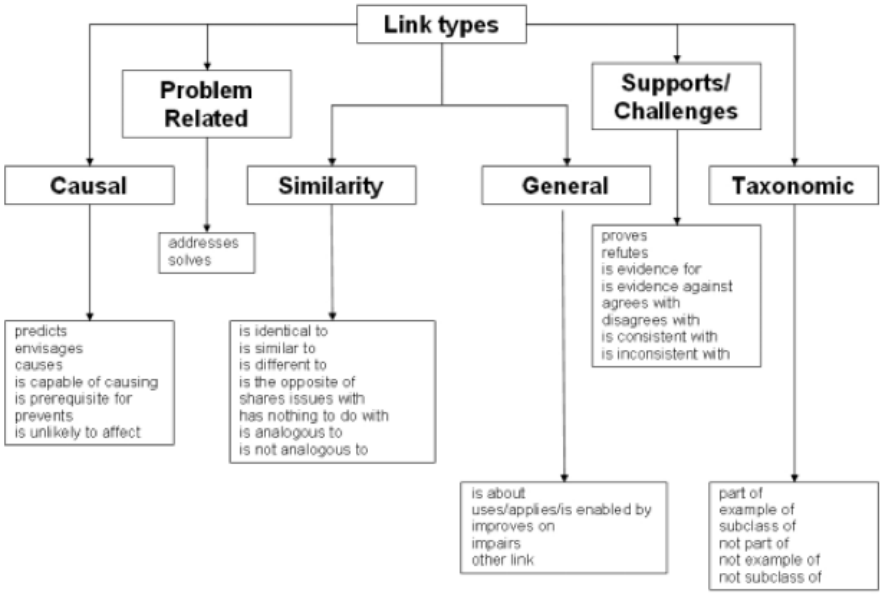


Fig. 8. Class structure of the Scholarly Discourse Ontology from [99] .

5.2. Legal Knowledge Interchange Format

Legal Knowledge Interchange Format (LKIF)[16], developed as part of the ESTRELLA project, is an OWL ontology [8] for the legal domain. Its Rules & Argumentation Module deals with Exceptions, Rules, Arguments, and Assumptions [102]. It also imports the LKIF Expression Module, which provides "a vocabulary for describing, propositions and propositional attitudes (belief, intention), qualifications, statements and media" [102]. It includes terms for Intention, Lie, and various Propositional Attitudes, for instance.

5.3. Argument Interchange Framework (AIF)

The Argument Interchange Format (AIF) [103] is an ontology which represents a (monological) argument. The original core ontology consists of two disjoint sets of nodes: *information nodes* (I-nodes) holding the content of the argument and *scheme nodes* (S-nodes) holding the relationships between arguments. Scheme nodes are further divided into three main types, for representing logical inference (RA nodes), preferences or values (PA nodes), and conflicts between I-nodes (CA nodes).

AIF forms the foundation for the World Wide Argument Web (WWAW). The WWAW is "a large-scale Web of interconnected arguments posted by individuals to express their opinions in a structured manner" [5], where RDFS and OWL are suggested to be used for AIF. The foundations of the World Wide Argument Web have been further discussed by Rahwan and others (e.g. [104,35,105]).

AIF has continued to develop, and several published extensions of AIF exist. Rahwan adds *form nodes* (F-nodes) [5] in order to more fully represent generic argument schemes (as opposed to the instantiations of those schemes). Then Walton's argument schemes can be represented, using ConflictSchemes to capture exceptions/Critical Questions. With AIF-RDF[17], Rahwan et al. [5] add RDFS extensions to an AIF implementation. In this implementation, edges are explicitly typed. Letia and Groza add a Context Node, used to evaluate the same argument in different contexts [106]. Rahwan et al. [107] present a new formalization of AIF in OWL-DL, implemented in Avicenna (§7.11).

Dialogue has been another area of interest in AIF extensions, with work from Modgil and McGinnis [108] and Reed et al. (most recently [109], with earlier work

[16] http://www.estrellaproject.org/lkif-core/lkif-rules.owl#

[17] http://argdf.org/source/ArgDF_Ontology.rdfs

in [110,111,112,113] extending monological AIF for use in representing dialogical argumentation.

The AIF is still under development with AIF2.0 expected to be released shortly [114].

6. Comparison of Semantic Web Models

In Table 1 we present a comparison of the Semantic Web models discussed in Sections 4 and 5. Topics addressed include are whether each ontology is centered on relations or concepts and whether it is IBIS-like (contains concepts functionally equivalent to IBIS' 'Statement', 'Issue', 'Position', and 'Argument'). We also cover what types of relations it contains, drawing from ScholOnto's types: causal, similiarity, generic, supporting, challenging, taxonomic, and problem related. Further, we describe whether polarity and weights are explicit or implicit and whether the ontology specifies other ontologies to use for content provenance and authorship provenance (such as from FOAF, SIOC, or PAV–the Provenance & Authoring and Versioning ontology[18]) and domain knowledge (such as from DOLCE, SKOS, or the PRotein Ontology). We have used a '?' to indicate that we were not able to find this information in publications, or when information was ambiguous, to reconcile it.

7. Tools

7.1. Introduction

Argumentation tools have been reviewed and overviewed in various publications, including two contemporary books. *Visualizing Argumentation* [115] presents eight chapters which cover the history and cognitive foundations of argumentation tools; describe tools for collaborative learning and deliberation; provide insight into map-based facilitation of in-person meetings; and describe mapping scholarly debates. Of particular interest in this exceptional volume is the chapter on "The Roots of Computer Supported Argument Visualization" [116]. *Knowledge Cartography: Software Tools and Mapping Techniques* [117] provides seventeen case studies of using mapping and argumentation tools, primarily in education, but also in science, politics, and organizational knowledge transfer.

Argumentation tools have also gained attention in e-government (e.g. [4] and education (e.g. [118]). Crossover interest in politics from the IEEE community is evidenced by a 'Trends & Controversies' section "AI, E-government, and Politics 2.0" [119].

Scheuer et al. [118] review 45 argumentation systems[19] used in Computer Supported Collaborative Learning and discuss 13 empirical studies involving the use of argumentation systems in education. Interesting results from their work are that arguments are constructed in learning applications in five main ways: free-form arguments, argumentation based on background materials, arguments rephrased (e.g. reworded and rekeyed) from a transcript, arguments extracted (e.g. copied/pasted) from a transcript, and system-provided units, wiith combined approaches also used in some applications. Further, they compare the advantages and disadvantages of user-controlled and system-controlled layouts for education. Their discussion of ontologies is limited.

This tools coverage in this paper differs from previous coverage in its scope of collaborative, Web-based tools with argumentation components, and in its attempt at comprehensiveness. A further bias has been software aimed at use by the public, rather than exclusively for government consultation, enterprise decision-making, or learning argumentation and critical thinking skills. However, we have deliberately included several research prototypes which focus on Semantic Web approaches to argumentation on the Web and on supporting the nascent World Wide Argumentation Web.

7.2. Scope: Collaborative, Web-based tools with argumentation components

Tools were considered in-scope if they were collaborative (i.e. involved sharing information among multiple parties who could build upon each others' work in some way), Web-based (i.e. allowed display of information on the Web), and had argumentative discussion components. By argumentative discussion, we mean discussion around disagreements, explanations, and reasons, coming from or including a rational (i.e. reason-based) standpoint.

Some prospective tools were excluded due to failing one or more of these conditions.

[18] http://swan.mindinformatics.org/spec/1.2/pav.html

[19] Six of these systems are also discussed in our review below: Argunet, ConvinceMe, CoPe_IT, Debategraph, Debatepedia, and SEAS.

Model name	NDR Ontology	IBIS RDF	Annotation Ontology	bio-zen plus	DILIGENT	ChAO	SALT	SIOC-Argumentation	SWAN/SIOC	CiTO	Semantic Annotation Vocabulary	ScholOnto	LKIF	AIF
Concept or relation centered?	relations	concepts	relations	relations	relations?	relations	concepts	concepts	relations	relations	relations	relations	concepts	AIF?
Statement	n	y	y	n	y	n?	n	y	n	n	n	n	y	n
Issue	n	y	n	n	y	y	n	y	n	n	n	n	n	n
Position	n	y	n	n	y	y	n	y	n	n	n	n	y	n
Argument	n	y	n	n	y	y	y	y	n	n	n	n	n	n
Causal	n	n	n	n	n	n	n	n	n	n	y	y	y	n
Similarity	n	n	n	n	n	n	n	n	n	n	n	y	n	n
Generic	n	n	y	n	y	y	n	n	y	y	n	y	y	n
Supporting	y	n	n	y	y	n	y	y	y	y	y	y	y	y
Challenging	y	n	n	y	y	y	y	y	y	y	y	y	y	y
Taxonomic	y	n	n	n	n	n	n	n	n	n	n	y	y	n
Problem-related	y	n	n	n	y	y	y	y	n	n	n	y	n	n
Polarity	Implicit	Explicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Explicit	Explicit
Weights	None	None	For correlations	None	None	None	None	None	Implicit	None	Implicit	Implicit	None	None
Content Provenance	None	None	FOAF, PAV	SIOC	Actor name? Human or machine argumentation?	system stores author, date, and time	None	SIOC	SIOC	None	reliability and credibility qualifiers	None	Agents	?
Authorship Provenance	None	None	SIOC, PAV	FOAF	Actor name (rdfs:Literal)	system stores author, date, and time	None	?	?	None	uses source-description	None	?	?
Domain Knowledge	None	None	PRotein Ontology, open?	DOLCE, SKOS, biological model	None	open?	None	None	None	None	None	None	?	?
Design Context	requirements engineering	general problem-solving	annotation	biology	collaborative ontology design	collaborative ontology design	scholarly communication	Social Web	Scientic Discourse	scholarly citations	Web of Trust	digital libraries of scholarship	legal	argumentation

Table 1

A comparison of the models incorporating argumentation.

Tools failing the 'collaborative' criterion included the EUProfiler[20], and the HealthCentral/Washington Post Poligraph 2008[21]. Users of these tools viewed personalized visualizations, based on their answers to a questionnaire, however they are not asked (or able) to share their comments on others' views, to interact with other users (adding to a larger debate), or to contribute to sensemaking or analysis of existing argumentation.

Tools failing the 'Web-based' criterion included the email tools such as WIT and Zest, SAIC's SIAM and Causeway, and the argumentation tools Carneades, Araucaria, and Convince Me[22]. WIT[23] [18] and Zest [120] focused on argumentation in email. SIAM[24] and Causeway[25] are Windows-based software for influence net modeling, designed for analyst use and primarily for collaboration inside the firewall; although HTML can be exported, Web-based collaboration is not supported. Similarly, Carneades[26] maps can be shared in LKIF, but not directly visualized online. Araucaria[27] [121,122,123] offers a searchable online argument corpus, but not online display of its arguments. While Convince Me[28] offers a Java applet for display, arguments cannot be saved or published via the applet.

Tools failing the 'argumentative discussion' criterion included general Web2.0 tools, Anekdotz, and Vox Populi. General Web2.0 tools (e.g. Twitter[29], Facebook[30]) and social software (generic mailing lists, forums) were excluded since their argumentation support is peripheral. Anekdotz[31] failed because the sites currently using it focus on the emotional, rather than the rational, aspects of argumentation. For example, the breakups section of When You Knew asks commenters to click on either 'Put their stuff on the curb' or 'Give em another shot' to solicit feedback, which is marked as positive, negative, or neutral. Vox Populi[32] [124] supports documentary filmmakers in generating argumentative film sequences based on annotated interviews.

Further, tools were treated differently depending on their origin and availability; for instance, it was considered helpful to include many contemporary research systems even though we were not able to interactively explore Web-based demo versions for some of those systems. We have inevitably missed some relevant systems, and would appreciate the reader's assistance in fixing this flaw.

7.3. Classifications of social tools

Aakhus and collaborators [55,125] classify argumentation software by use: issue networking, funneling, or reputation (Figure 9). Shum says that each tool is 'tuned' to a different task: "foraging for material, classifying and linking it, discussing it in meetings and online, and evaluating specific points in more depth" [114]. We later use this categorization, as 'Functional type' in our comparison of tools.

Scheuer et al. [118] compare the visualization and representation styles of argumentation tools used in computer-supported collaborative learning. They summarize the pros and cons of 5 representation styles, as shown in Figure 10. We later use this categorization, as 'Representation style' in our comparison of tools. Scheuer's representation styles are typically used for discussions (linear representation), modeling (container[33]), or both (threaded, graph). For instance, graph representations are highly expressive, with explicit labelling of relationships, but make it hard to see temporal sequences.

7.4. List of social and Semantic Web tools to be considered

In this section we discuss 34 online argumentation tools: ArgDF, Arguehow, Argument Blogging, Argumentum, Argumentations.com, Argunet, Avicenna, bCisiveOnline, Cabanac's annotation system, Climate CoLab, Cohere, Competing Hypotheses, ConsiderIt, ConvinceMe, CoPe_IT, CreateDebate, Debate.org, Debategraph, Debatepedia, Debatewise, DiscourseDB, Dispute Finder, Hypernews, LivingVote, Opinion Space, Online Visualisation of Arguments, Parmenides, PDOnline, REASON, Riled Up!, SEAS, Trellis, TruthMapping, and Videolyzer.

[20] http://euprofiler.eu/

[21] https://www.washingtonpost.com/wp-srv/health/interactives/poligraph/

[22] Note that we do include the similarly named 'ConvinceMe' site.

[23] http://www.w3.org/WIT/

[24] http://www.inet.saic.com/inet-public/siam.htm

[25] http://www.inet.saic.com/inet-public/causeway.htm

[26] http://carneades.berlios.de/

[27] http://araucaria.computing.dundee.ac.uk/

[28] http://codeguild.com/convinceme/

[29] http://twitter.com

[30] http://www.facebook.com/

[31] http://www.anekdotz.com/

[32] http://homepages.cwi.nl/~media/demo/IWA/

[33] The container approach uses discrete visual areas to group related items. For example in Debatepedia each question is contained in a frame with pro and con arguments on that question.

Argumentation Design	Purpose	Orchestration	Systemic Rationality
Issue networking *Examples:* - HyperNews - QuestMap - Compendium	A clash of claims where the interaction is organized into a web of issues with relevant positions and reasons developed for each issue.	Enables a full exploration of the agreements, disagreements, and rationales for position but typically provides no functionalities for settling differences.	A situation calls for participants to share, explore, and learn about each others' positions and reasons and where these will be held accountable to the doubts of others.
Funneling *Examples:* - GroupSystems - SAMM - Other GDSS - Voting tools	Treat argumentation as active consensus formation where interaction is organized into a flow from broad differences toward an acceptable conclusion.	Sequences interaction into a series of activities that successively narrow a dispute or decision toward the most acceptable conclusion. The functionalities such as brainstorming, categorizing, and voting provide means to remove resistance to collective action.	A situation calls for a commitment by all participants to a particular course of action. This stands in contrast to issue-networking, which aims primarily at self-correction, not at consensus
Reputation *Examples:* - Experts-Exchange - Slashdot.com - Weblogs	Create a knowledge base for action by pooling and refining the expertise among a community of participants.	Provides means like ratings for individual participants to compete with each other over who provides the best answers to the questions the community most wants answered. The orchestration produces experts and a repository of answers.	A situation calls for discovering and cultivating trustworthy experts. It stands in contrast to both funneling, because it does not aim at consensus, and issue-networking because people are not separated from their standpoints.

Fig. 9. Issue-networking, funneling, and reputation, from [55].

Representation style	Typical uses	Pros	Cons
Linear (e.g., chat)	- Discussions (especially synchronous)	- Familiar and intuitive to most users, easiest to use - Best to see temporal sequence and most recent contributions	- Risk of sequential incoherence (McAlister et al. 2004) - Not suited to represent the conceptual structure of arguments - Lack of overview
Threaded (e.g., forums, *Academic Talk*)	- Discussions (especially asynchronous) - Modeling	- Familiar and intuitive to most users, easy to use - Easy to manage large discussions - Addresses issue of sequential incoherence	- Moderately hard to see temporal sequence (because of multiple threads) as compared to Linear - Limited expressiveness (only tree-like structures)
Graph (e.g., *Belvedere, Digalo*)	- Discussions - Modeling	- Intuitive form of knowledge modeling (Suthers et al. 1995) - Highly expressive (e.g., explicit relations) - Many graph-based modeling languages exist	- Hard to see temporal sequence - Lack of overview in large argumentation maps (need a lot of space, can lead to "spaghetti" images (Hair 1991; Loui et al. 1997)
Container (e.g., *SenseMaker, Room 5*)	- Modeling	- Easy to see which argument components belong together and are related	- Limited expressiveness (e.g., only implicit relations, only tree-like structures) - Lack of overview in large argumentation maps because of missing relations
Matrix (e.g., *Belvedere*)	- Modeling	- Easy systematic investigation of relations - Missing relations between elements are easily seen (Suthers 2003)	- Limited expressiveness (e.g., supports only two element types (row, column), no relations between relations) - Uncommon (Non-intuitive) way of making arguments

Fig. 10. Comparison of the visualization and representation styles of CSCL argumentation tools, from [118].

7.5. ArgDF

ArgDF[34] is a Semantic Web-based argumentation system using the AIF-RDF ontology described above [104,5,126]. ArgDB uses Sesame RDF for storage and querying and Phesame for communicating with the Sesame through PHP pages.

7.6. Arguehow

ArgueHow[35] is a argument-based discussion board aimed at a general audience. Its purpose is to help find the best points supporting a position. Discussion points are sorted by votes for ('Creds') and against ('Cruds') them. ArgueHow has a unique way of handling reputation: users start with a reputation of 50, which increases or decreases according to the votes their points accrue. Votes are weighted: for instance, points with 10 'cred' or 'crud' votes change less in response to further votes, and votes on users' first 20 discussion points affect their reputation less than later contributions, allowing them to learn the system.

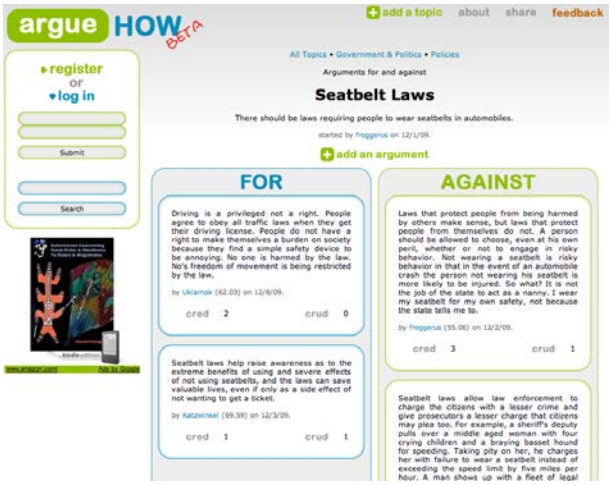


Fig. 11. Arguhow offers structured discussion.

7.7. Argument Blogging

The idea of argument blogging was proposed by Wells, Gourlay and Reed [127] as a way to bring blogs into the WWAW, based on standard Web technologies, and augmented by argument specific technologies. In addition to AIF, argument blogging relies on the AIF Database (AIFDB) and Dialog Game Description Language (DGDL). AIFDB is a MySQL database for storing AIF documents which can be serialized as RDF and accessed via a RESTful Web service. DGDL [113,128] is a grammar for describing the rules of dialogue games.

Argument blogging uses text from the current Web as a departure point for the WWAW. When browsing the Web, users select text and click a JavaScript bookmarklet, to indicate whether they will attack an inference, support or refute the selected text. This generates a fragment of embeddable JavaScript the user can paste onto his/her blog. Once a blogger opts in to the WWAW by adding JavaScript to a webpage, the page displays a badge which links back to argument blogging server, where the distributed dialog can be visualized or exported as text.

Earlier work on semantic blogging predates the WWAW but focused more attention on the visualization of reply graphs of messages from multiple blogs [129] or the possibilities for inference [130].

7.8. Argumentum

Argumentum[36] is an argument-based discussion site aimed at airing discussions. Debaters add topics and their arguments are colored to indicate the supporting (green) and opposing (red) arguments (Figure 12). Comments, but not their replies, are similarly colored to indicate agreement or disagreement. Users sometimes want to agree or disagree without leaving comments; currently this leaves a default comment that says "Type the reason why you oppose..."

Argumentum's most unique feature is that users can put their "2 cents" in literally: credibility, earned with good arguments, is measured in 'cents' and can be spent to influence a debate result. Users can also contribute arguments without starting from the Argumentum website, using bookmarklets[37] or through Gmail and Facebook[38]. Further, loggers and publishers can also contribute using Argumentum buttons or widgets.

[34] http://argdf.org/
[35] http://arguehow.com/
[36] http://arg.umentum.com/
[37] http://arg.umentum.com/share
[38] http://arg.umentum.com/wiki/more-ways-to-argue

Fig. 12. In Argumentum, users can indicate support for an argument with money. The left-hand color bars indicate the supporting (green) and opposing (red) arguments.

7.9. Argumentations.com

Argumentations[39] serves analysts who want to develop arguments collaboratively. Arguments, which are classified as either claims or open-ended issues, can be added or edited. To help suggest topics and build arguments, users can import news stories and extract statements (declarative sentences) from stories.

Argumentations offers several unique features. First, arguments–whether claims or open-ended issues–are evaluated depending on their type. *Claims* are evaluated with a truth value and confidence. *Open-ended issues* are evaluated based on Desirability, Importance, Volatility, Likelihood, and Confidence. Second, along with tag clouds, Argumentations uses 'tag spheres' (Figure 14). Further, arguments can be opened in Silverlight. Finally, they offer some interesting tutorials which display mindmaps[40].

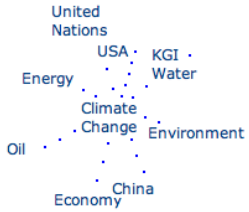


Fig. 14. The global warming 'tag sphere' from Argumentations.

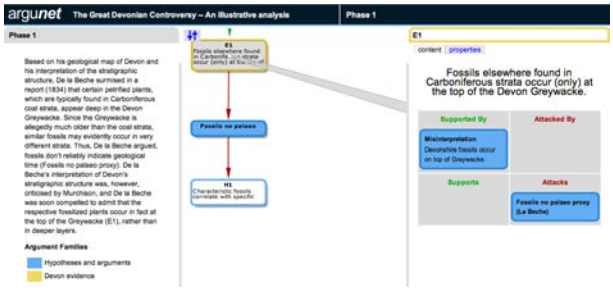
[39] http://www.argumentations.com/

[40] http://www.argumentations.com/Argumentations/Help/Tutorials/Tutorials.aspx

7.10. Argunet

Argunet [131] is a desktop tool[41] coupled with an open source federation system for sharing argument maps. A public server, Argunet.org[42], allows authors to make maps public or restrict viewing and/or editing to a specified group. Connecting to other servers is also possible; this focus on federation, makes Argunet unique.

(a)



(b)

Fig. 15. Argunet can show an (a) overview of several related argument maps; and (b) in each individual map, nodes can be opened up to show arguments they support, attack, are supported by, and are attacked by.

Argunet also has other unique features. Argunet is a multi-lingual environment which records the language of the map. Maps published at Argunet.org, must be released under the CC-BY license. An extensive online manual provides instruction, and they promote embedding debates. Users also have significant control over the presentation of arguments, such as colors and descriptions of different argument families. Related maps can be published in series, as shown in Figure 15(a). In the argument map representation, each node can be opened up to reveal a matrix listing which other ar-

[41] http://www.argunet.org/editor/

[42] http://www.argunet.org/debates/

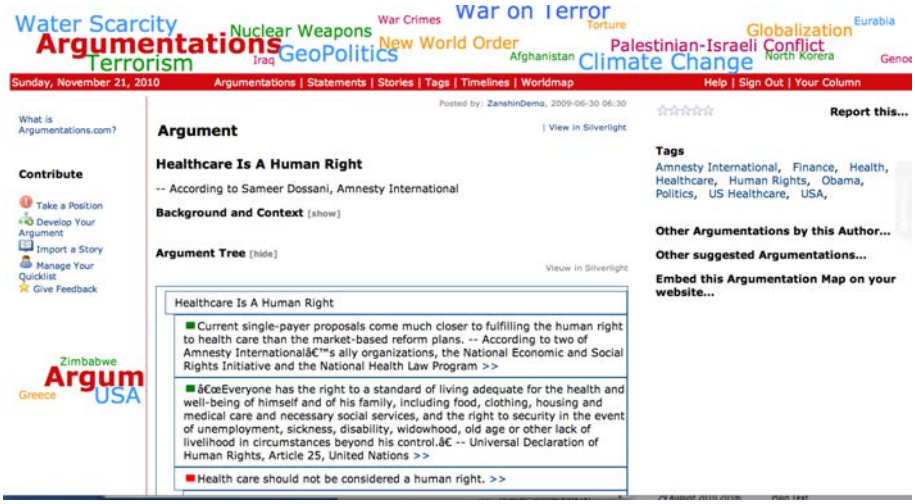


Fig. 13. In Argumentions, colored dots indicate the supporting (green) and opposing (red) arguments.

guments support, attack, are supported by, and are attacked by the given node (Figure 15(b)). Argunet appears to support incremental formalization since arguments can be quickly sketched or reconstructed as premises and conclusions.

7.11. Avicenna

Rahwan and Banihashemi's OWL-based argumentation system Avicenna (Figure 16) was demonstrated at COMMA 2008 [105] and recent descriptions and screenshots appear in [107]. Extending the work of ArgDF, Avicenna is a Web-based system using Jena[132], ARQ[43], and Pellet [133]. Since OWL supports inference over transitive properties, Avicenna can support argument chaining, such as retrieving all arguments that directly or indirectly support a given conclusion. Avcienna is also used to infer the classification hierarchy of argument schemes: for example, an appeal to expert opinion is a specialization of an argument from position to know.

7.12. bCisive Online

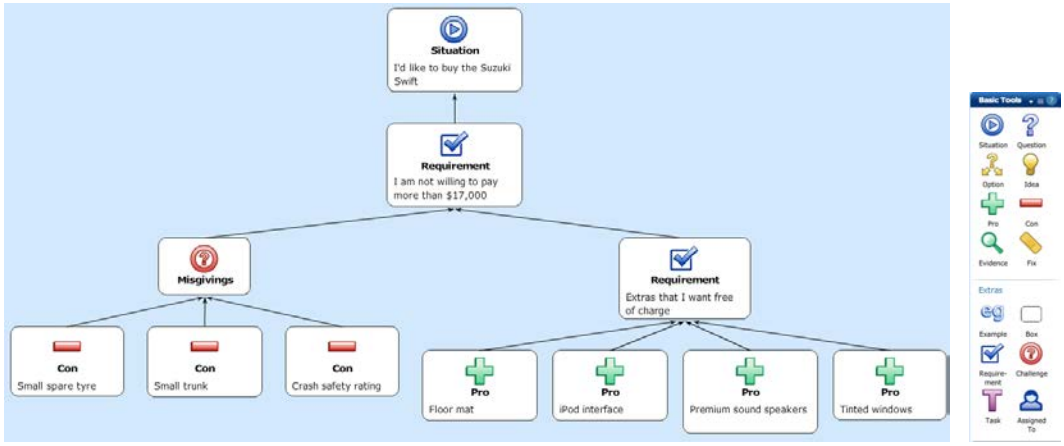
bCisive Online[44] is an online argument mapping and spatial hypertext environment for real-time collaboration and team problem-solving (Figure 17(a)). Aimed at the business market and individual decision-makers, bCisive Online is a commercial product from AusThink, the makers of the Rationale desktop tool; the free option allows up to three users to collaborate, or users can upgrade with a monthly subscription fee. bCisive Online is unique in that it is intended for real-time use with audio conferencing. One person edits the map at a time, adding nodes and connections between nodes (Figure 17(b)) while others can point with their cursor or request editing control. Maps can be embedded in blogs (which allows viewers to pan, zoom, hide and show parts of the map) or exported as PowerPoint. Snapshots can be saved as history items, to allow restoring to or reviewing a previous map.

7.13. Cabanac's annotation system

Cabanac used a Java-based system[45] to research social validation of the arguments in comments [134]. Users did not contribute new content to an ongoing public debate, but analyzed the argumentative status of document comments. Uniquely, sliders were used to indicate the extent to which items were refuted, neutral, or confirmed (Figure 18). In effect, users were asked to synthesize the discussion. Aggregated information was not viewed by the users, but held by the experimenter. However, in principle, this approach could be used to promote collaborative sensemaking not just of annotations but also of debate.

[43] http://jena.sourceforge.net/ARQ/
[44] http://www.bcisiveonline.com/
[45] http://www.irit.fr/~Guillaume.Cabanac/expe/

Fig. 16. Avicenna uses Walton's critical questions and argument schemes [107].



(a) (b)

Fig. 17. (a) Collaborative maps for bCisive Online can be used for decision-making and requirements analysis. (b) bCisive Online's node types show the kinds of discussions that it facilitates.

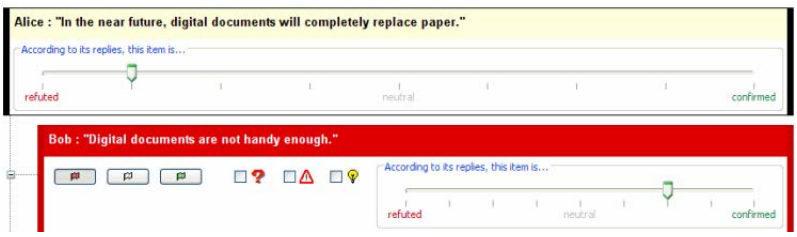


Fig. 18. Cabanac had users flag items (refuted, neutral, confirmed) and indicate their types (question, modification, example).

7.14. Climate CoLab

The Climate CoLab[46] is a deliberation platform under development at MIT, building on former projects such as the Deliberatorium and the ClimateCollabatorium [3,135]. The community runs an annual contest to gather proposals for mitigating global warming from the general public; once proposals are filtered by experts, everyone is invited to discuss the finalists.

Users deliberate in the Positions tab, which facilitates constructing an argument map, voting, and commenting on each of five key topics. Moderators are expected to review comments and add new ideas to the argument map; users can also add Pros, Cons, and Issues directly to an argument map. The Climate CoLab is unique for integrating argument maps into a larger debate, and for its moderator support, which allows users to benefit from argument maps without necessarily needing to understand how to edit them.

7.15. Cohere

Cohere is open source software for sensemaking which integrates annotation and argumentation for the general public [136]. At the Cohere website[47], users can view and create maps, or import them from the Compendium desktop software. Maps consist of ideas, which users can add directly on the site (Figure 20), draw from Cohere's global pool of public ideas, or clip via a Firefox plugin while browsing.

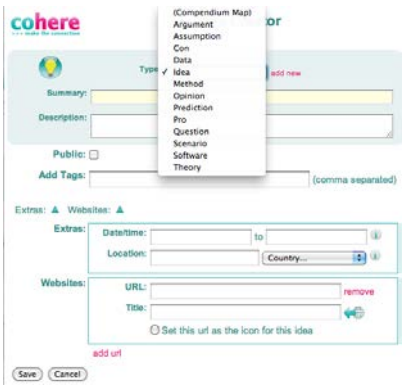


Fig. 20. Adding an idea to Cohere.

Cohere is unique for its integration with the Compendium desktop software, its incorporation of social bookmarking, and the ability to mark information as private, public, or shared with a group. Cohere also offers an API[48].

7.16. Competing Hypotheses

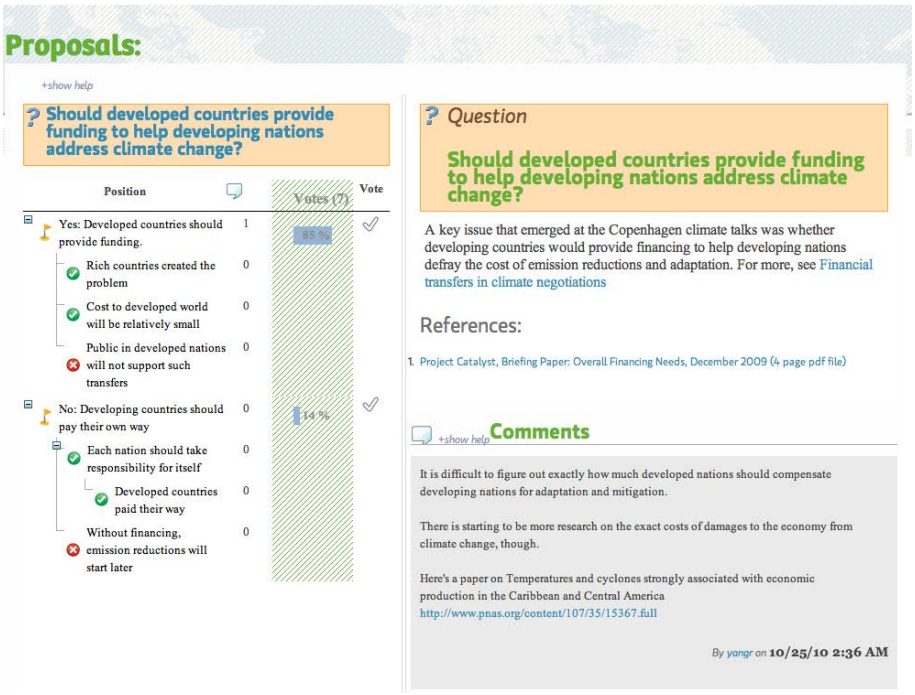
Competing Hypotheses[49] is open source analysis software based on the CIA methodology "Analysis of Competing Hypotheses" (ACH). The software supports breaking down information into hypotheses, evidence, and analysis, which are entered into a matrix as shown in Figure 21(a). The matrix can help visually indicate the most likely and least likely scenarios.[50] Multiple analyses can be combined to provide a group view (Figure 21(b)), or compared pairwise. Competing Hypotheses has persistent chat (essentially a comment thread) for the entire project as well as message boards for each hypothesis, evidence item, and evidence-hypothesis pair. We excluded earlier ACH implementations such as PARC ACH[51]. Unlike these systems, Competing Hypotheses has a testing server[52] which allows online collaboration. It is unique for its visualization structure and its use of both individual and group information.

7.17. ConsiderIt

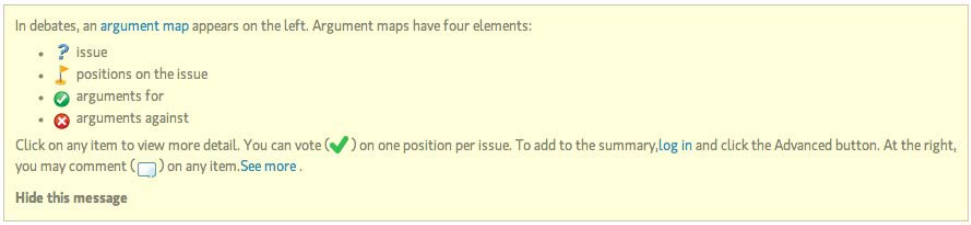
ConsiderIt[53] is a new open source deliberation platform under development at the University of Washington. It powers the Living Voters' Guide[54], a deliberation and voter-information platform for Washington State voters.

What is unique is the possibility to drill down to understand other voters' perspectives. In addition to seeing pros and cons on an issue from all voters, regardless of their stance, (Figure 22(a)), the Living Voters' Guide can show the key points for a particular group of voters (Figure 22(b)), such as those undecided on the issue or strongly supporting it. This can help users understand what makes an issue controversial. Users

[46] http://climatecolab.org/
[47] http://cohere.open.ac.uk/
[48] http://cohere.open.ac.uk/help/code-doc/
[49] http://competinghypotheses.org/
[50] More sophisticated ACH-based software uses matrices as input to Bayesian probabilistic reasoning.
[51] http://www2.parc.com/istl/projects/ach/ach.html
[52] http://groups.google.com/group/ach-users/browse_thread/thread/d87a5ec4df8be6c0
[53] http://www.livingvotersguide.org/considerit
[54] http://www.livingvotersguide.org/

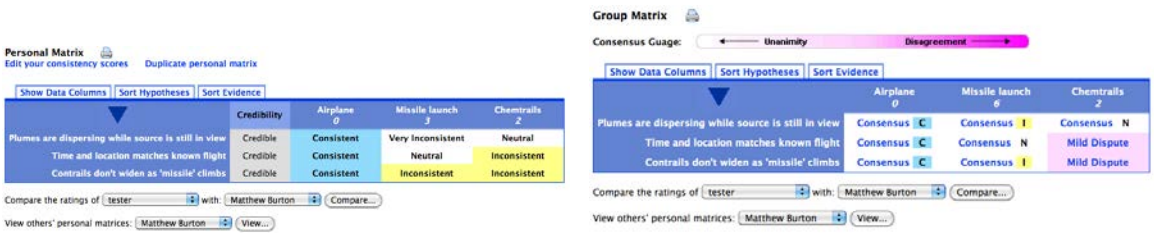


(a)



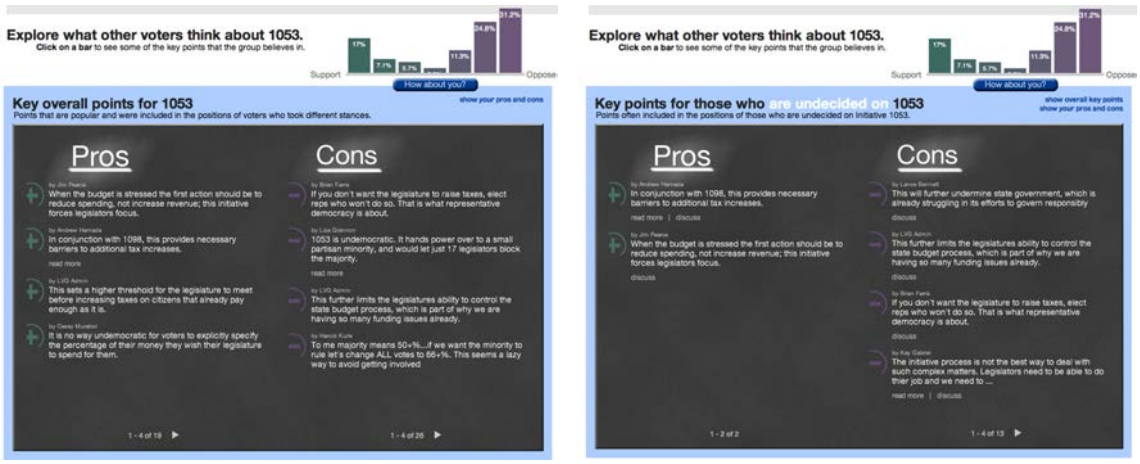
(b)

Fig. 19. At Climate CoLab, (a) the positions tab shows an argument map which users can edit or comment on. (b) argument maps are introduced with contextual help.



(a) (b)

Fig. 21. In Competing Hypotheses, (a) each individual's analysis is represented in a consistency matrix; (b) multiple analyses can be combined to create a group matrix. In the group view, darker shades of purple indicate more disagreement.



(a) (b)

Fig. 22. The Living Voters' Guide compiles pro and con lists on each issue. They give (a) an overview of what all voters think about the issue; as well as (b) the key points for undecided voters.

indicate how they feel about an issue before and after reading an argument (deliberative polling), which could also be used to find the most convincing arguments.

7.18. ConvinceMe

ConvinceMe[55] is a competitive debating environment which uses a point scheme and user rankings to motivate contributions to several types of debates. In the *King of the Hill* game, the most popular choice (and the debater who suggested it) wins. *Battles* are one-on-one debates between two users, who add arguments and evidence in hopes of getting readers' votes; the debate ends when one side gets a pre-agreed number of votes. *Open debates* (Figure 7.18)are ongoing and accept pro or con arguments from any registered user, as well as rebuttals to existing arguments; users convinced by an argument vote for it. These various types of debate games make ConvinceMe unique.

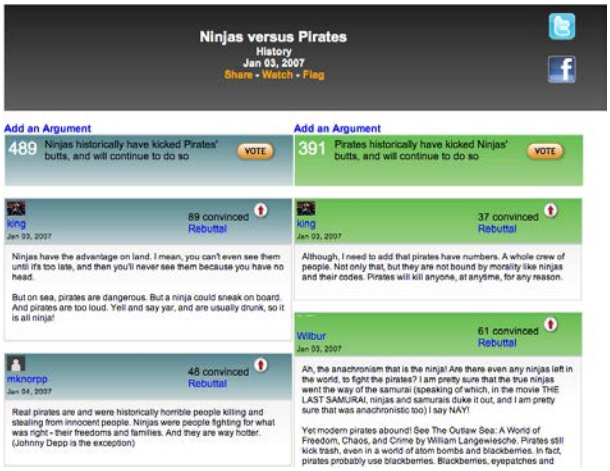


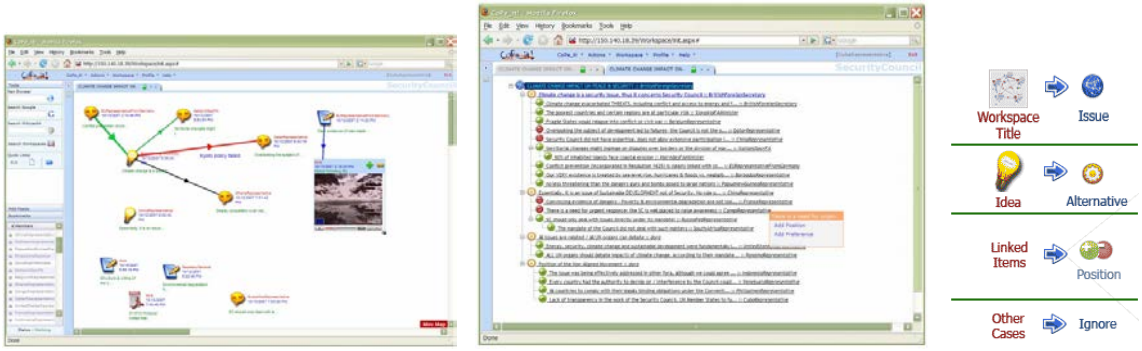
Fig. 23. In ConvinceMe's *Open Debates*, users can vote for an argument that convinced them

7.19. CoPe_IT

CoPE_IT[56] [137] is a spatial hypertext environment for collaboration, aimed at the learning and e-government domains. Users can form groups to share maps, but communicate only through email on the site. Maps can be imported from Compendium, and entire discussions from external webforums in phpNuke format can be imported using a URL.

One unique aspect of in CoPe_IT is its approach to incremental formalization. CoPe_IT transforms the user-created informal spatial hypertext view (Figure 24(a)) into an issue chart Figure 24(b) according to rules shown in Figure 24(c). Users can also customize the transformation rules.

[55] http://www.convinceme.net/
[56] http://copeit.cti.gr/



(a) (b) (c)

Fig. 24. CoPe_IT has (a) an informal spatial hypertext view; and (b) a formalized view, created by (c) automatically transforming items.

7.20. CreateDebate

CreateDebate[57] is a social debate community, aimed at the general public as well as K-12 classes[58]. The highest-rated arguments are shown at the top, based on user votes (and ignoring the down votes), which are also used to determine a point score for the user. They offer bookmarklets and promote JavaScript buttons to webmasters[59]. Some unique features are that the debate moderator can add a 'Topic Research' section with RSS feeds from other sites, and that, in addition to pro/con debates, CreateDebate has Perspective debates, which generally have more than two sides, are scored based on user-applied tags. A wordcloud and various statistics (Figure 25), including the language grade level, average word lengths, and vocabulary overlap are calculated for each debate.

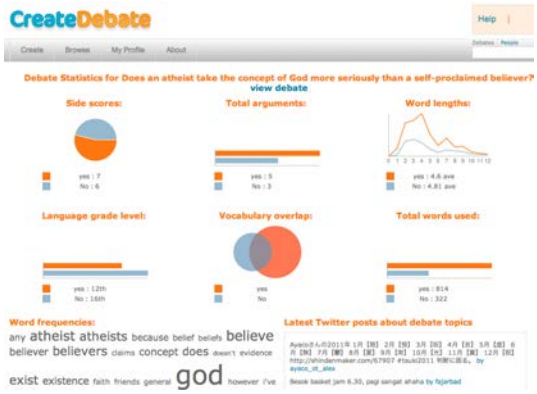


Fig. 25. At CreateDebate, users add and comment on pro and con arguments.

7.21. Debate.org

Debate.org[60] is a social networking site for debate lovers. Debates take place between two members and have four cycles: the challenge period, debating period, voting period, and post voting period. The debating period consists of 1-5 time-limited rounds in which debaters post arguments. While comments can be added at any time, votes are only accepted during the voting period. Voting involves choosing one of the debators (or 'tied') for each of the following six questions: (1) Agreed with before the debate: (worth 0 points) (2) Agreed with after the debate: (worth 0 points) (3) Who had better conduct: (worth 1 point) (4) Had better spelling and grammar: (worth 1 point) (5) Made more convincing arguments: (worth 3 points) (6) Used the most reliable sources: (worth 2 points) [(1)]. Points are awarded, with the most importance given to using reliable sources and making convincing arguments.

Another unique feature is Debate.org's focus on user profiles, where various user details are displayed including information such as income, location, ideology, gender, president, religion, and who they are interested in and looking for. These can be used to search for for people with particular profile attributes, and aggregate user demographics[61] are also available. Debate.org also determines the percentage to which other members agree with you on "the big issues" (cultural, religious, and political hot topics). Individual members

[57] http://www.createdebate.com/
[58] http://www.createdebate.com/about/sites/school
[59] http://www.createdebate.com/share/buttons
[60] http://debate.org/
[61] http://www.debate.org/about/demographics/

are also ranked by their percentile, based on the outcomes of previous debates.

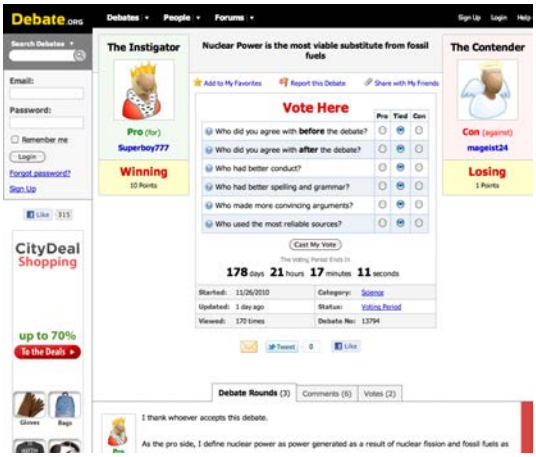


Fig. 26. Debate.org is a social networking site promoting debate.

7.22. Debategraph

Debategraph[62] [138] is a wiki debate visualization tool which has been adopted for use at the Kyoto climate change summit and is being tested by EU projects such as WAVE[63]. Debategraph offers several visualizations, including the Debate Explorer view shown in Figure 27(a) and a text-based outline shown in Figure 27(b). Visualizations can be embedded in other websites, and Debategraph encourages users to add links to related webpages within graphs.

7.23. Debatepedia

Debatepedia[64] bills itself as the “the Wikipedia of pros and cons". Sponsored by the International Debate Education Association, Debatepedia is a collaborative community effort to summarize arguments. Each argument page provides an overview, then a list of issues, with pros and cons supported by news articles and similar sources. It provides an intuitive editing environment, where users can edit just the relevant section, such as the pro or con for a topic. Debatepedia is unique for providing an easily-editable wiki of pros and cons.

[62] http://debategraph.org/
[63] http://www.wave-project.eu/
[64] http://debatepedia.idebate.org/

7.24. Debatewise

On Debatewise[65], everyone can collaborate in creating the strongest case both for and against a given issue. As part of a partnership with iDebate, they provide links to Debatepedia and iDebate’s reference site Debateabase. Karma, teams, and lists of recent participants and new editors help motivate participation.

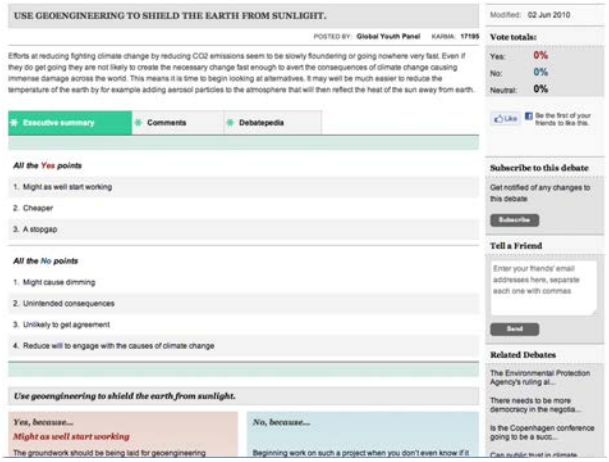


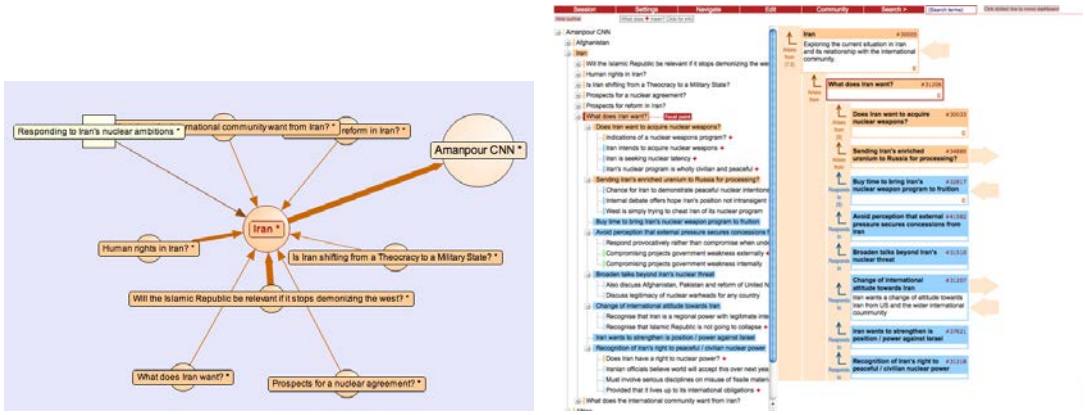
Fig. 28. Debatewise offers an executive summary, followed by a detailed pro/con debate.

There are several unique features. The site makes it easy to get involved by providing suggestions of 5-minute, 20-minute and 1-hour tasks and showing “7 things you should have an opinion on" in rotating images on the homepage. Edit histories are available for each pro and con point. Debates are structured as adjudicated debates between two teams; other users can make comments, vote, and subscribe to debates.

7.25. Discourse DB

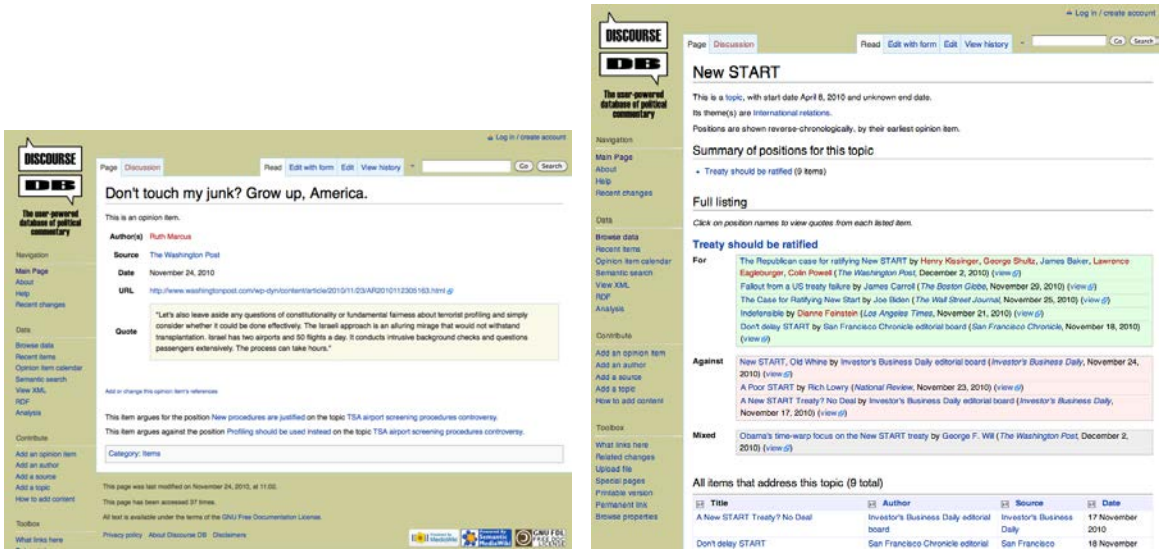
DiscourseDB[66] is used to collaboratively collect policy-related commentary. Opinion pieces (Figure 29(a)) are collected from notable sources, newspapers and websites with at least 50,000 circulation/unique visitors per month. Users categorize these opinion pieces, selecting a quote, indicating the topic and position, along with whether the author’s argument is for, against, or mixed on the position.

[65] http://debatewise.org/
[66] http://discoursedb.org/



(a) (b)

Fig. 27. Debategraph for CNN's Amanpour TV shown in (a) Debate Explore view; (b) text view.



(a) (b)

Fig. 29. In DiscourseDB, (a) users catalog opinion pieces; (b) this generates an overview of the positions for, against, and mixed on a topic.

DiscourseDB uses Semantic MediaWiki [139] with the SemanticForms[67] extension. This makes it possible to list all commentary written by particular person, published in a particular venue, and so forth.

Further, since items indicate the position they take on a topic, DiscourseDB can list all commentary for or against a given position as shown in Figure 29(b). When a topic has multiple positions (e.g. Darfur[68]), DiscourseDB is especially helpful in summarizing the discussion.

7.26. Dispute Finder

Dispute Finder[69] [140,141] is a browser extension that alerts users when information they read is disputed, based on a database of disputed claims. The disputes database was first populated by hand-annotation by activists (interested in informing or convincing others) and then extended algorithmically. While the Dis-

[67] http://www.mediawiki.org/wiki/Extension:Semantic_Forms

[68] http://discoursedb.org/wiki/Darfur_conflict

[69] http://ennals.org/rob/disputefinder.html

pute Finder plugin remains available[70], it notes that the project has ended; unfortunately, the plugin no longer highlights phrases such as the "abortion reduces crime" phrase used in paper examples.

7.27. Hypernews

Hypernews[71] [142] is a general purpose Web forum, inspired by Usenet news. Its use of message types distinguishes HyperNews from other forums. Users are asked to indicate what kind of message they are posting (None, Question, Note, Warning, Feedback, Idea, More, News, Ok, Sad, Angry, Agree, Disagree) as shown in Figure 30(a); the message type is then displayed as an icon in the forum's thread view (Figure 30(b)).

7.28. LivingVote

At Living Vote[72], the general public can discuss pro and con arguments of issues, creating argument maps, as shown in Figure 31 A tree view provides a coherent view of the argument, which can be drilled down, where arguments and their counterarguments are presented side-by-side. Users can add arguments, and voting colors the nodes according to whether you agree (green), disagree (red), or haven't voted (white).

Living Vote is unique in the way that it handles and uses votes. To vote, users must answer questions designed to test whether they've read the arguments. Living Vote also prunes unhelpful arguments and aims to provide a "complete, persistent, constantly changing and up-to-date record" of everyone's opinions and the most convincing arguments.

7.29. Opinion Space

Opinion Space is software developed by UC Berkeley's Center for New Media "designed to collect and visualize user opinions" on a variety of topics [143]. The U.S. Department of State is using Opinion Space[73] to aggregate opinions about foreign policy and create a "virtual town hall" as shown in Figure 32.

Opinion Space is unique in its use of deliberative polling and visualization. With deliberative polling,

Fig. 32. Opinion Space maps comments in a constellation view.

participants are polled both before and after deliberation, to better understand how public opinion can change based on increased understanding of the issues. Users move sliders to express their opinions on five issues. The system then maps the user's opinion, using principal component analysis, to show the user where they stand. Each point in the visualization represents a perspective; larger points represent more popular perspectives. Users can also view and rate others' comments (Figure 33). Ratings can be used to choose the most informative comments for display.

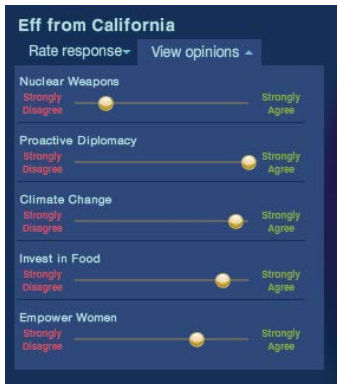
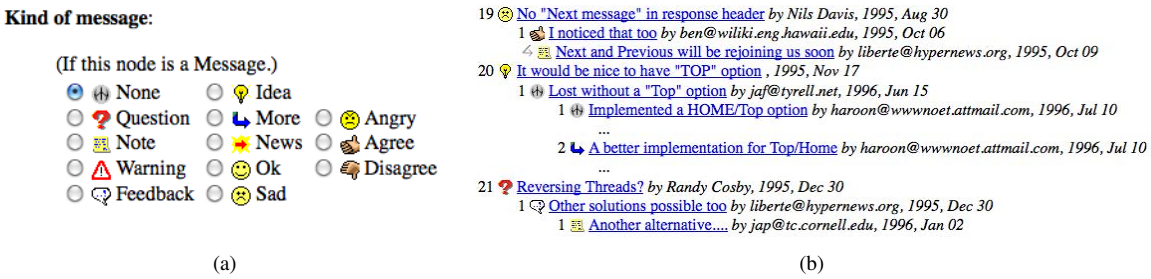


Fig. 33. Opinion Space uses sliders to collect and display users' opinions on five issues.

7.30. Online Visualisation of Arguments (OVA)

Online Visualisation of Arguments[74] (OVA) is an online argument analysis and mapping environment [144] which exports AIF. In OVA, web pages can be displayed adjacent to an argument mapping canvas,

[70] http://addons.mozilla.org/en-US/firefox/addon/11712/
[71] http://www.hypernews.org/HyperNews/get/hypernews/reading.html
[72] http://www.LivingVote.org/
[73] http://www.state.gov/opinionspace/
[74] http://ova.computing.dundee.ac.uk



(a) (b)

Fig. 30. (a) Users are asked to specify their message type, using this Hypernews taxonomy; (b) Part of a Hypernews discussion thread.

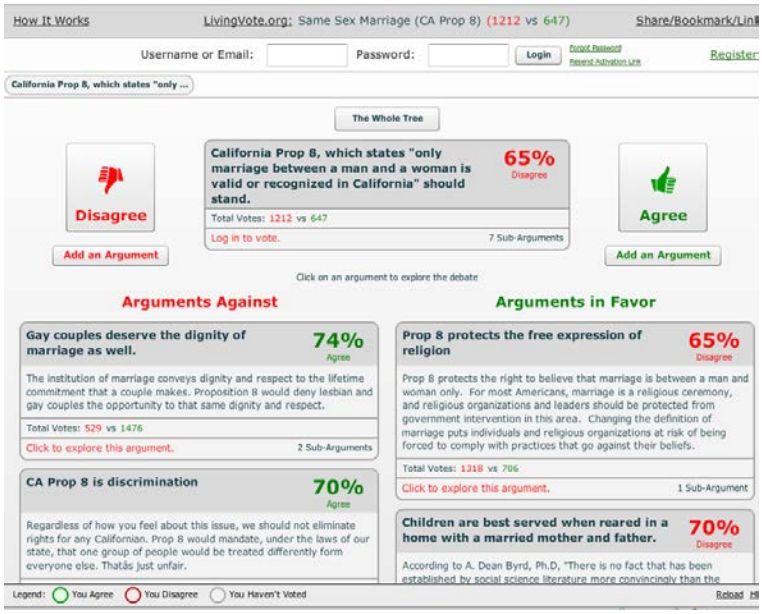


Fig. 31. At Living Vote, the weight given to a user's votes increases as they read and vote on more arguments.

helping analysts create a graphical representation of the arguments in online forums or news stories. The resulting argument maps can show the relationships between premises (supporting or attacking) as well as the participants responsible for each point of view. In addition to AIF, users can export JPEG and SVG images of the argument.

OVA is part of a pipeline of argumentation tools [145] which starts to bridge the gap between human-oriented argumentation tools and calculation-based agent argumentation. Mixed initiative discussions are enabled by the argument maps created by OVA or any other AIF-based tool. Thus, instead of representing one's point of view countless times in a forum or FAQ, it would be possible to delegate these conversations to a machine agent using an underlying argument map, as prototypes like MAgtALO[75] [111,146] and the Google Wave discussion bot Arvina show.

7.31. Parmenides

Parmenides[76] [147,148,149] is a structured survey tool for gathering public opinion on a proposal. Based on argument schemes and critical questions from argumentation theory, Parmenides can pinpoint the source of the disagreement, by having participants respond to a series of questions. In a Parmenides debates, participants are first asked to agree or disagree with a position on a question such as "Should laptops be banned in lecture theatres?" (Figure 34(a)). Those who disagree are

[75] http://www.arg.dundee.ac.uk/?page_id=61
[76] http://cgi.csc.liv.ac.uk/~parmenides/

stepped through several screens (such as Figure 34(b)) of yes/no questions to determine the source of the disagreement. Limited free text boxes allow users to add further information. At the end of the survey, users are offered the choice of submitting an alternative proposal, and are shown the answers they chose. Administrators can then analyze the group's responses, which are displayed in graphical argumentation frameworks [150]. A greater understanding of the most popular reasons for disagreement could support further discussion and debate about the key issues.

7.32. PDOnline

PDOnline[77] is an online community for scientists, funders, and medical professionals working in Parkinson's disease science, which is funded by the Michael J. Fox Foundation. PDOnline uses SWAN/SIOC (§4.11).

Fig. 35. Part of an argumentative discussion at PDOnline

Figure 35 shows a PDOnline discussion about a recently-published paper and indicates how the topic fits into the "PD Guide" taxonomy of research and communication topics. The discussion links both forward to responses and related contributions and back to a thread on Papers of the Week (itself contained within a Research Question board). Members' full names, credentials, and institutional affiliations are listed, with links to user profiles and institutions. Members' profiles link to their publications, and throughout the site explicit references to the literature are given. It is unique it that it uses scientific argumentation.

7.33. REASON

REASON —Rapid Evidence Aggregation Supporting Optimal Negotiation [151,152] — is a Java applet for group deliberation, used to arrive at a consensus decision. Drawing from decision theory, group-decision support systems, and argumentation, REASON is intended to improve information pooling. An argument map is used to organize group evidence shared during the decision-making process; further, in an adaptive version of REASON, aggregate weights expressing the group's view of each alternative are displayed. Uniquely, arguments start as threaded discussions in REASON, and are colored based on whether they agree (blue) or disagree (yellow) with their parent in the thread.

7.34. Riled Up!

Riled Up![78] is a debate-centered site which motivates participation with a point-based authority system. Aimed at people who enjoy debate, Riled Up!'s tagline is "Like Raising Cain? So Do We." Users can add debates, arguments, and comments, and vote for others' arguments, as well as add friends and enemies.

Riled Up! is unique in its comment system–users can respond with positive (green), neutral (grey), or negative (red) comments. In addition to a standard layout, a contributor view gives an overview of the arguments but not the comments.

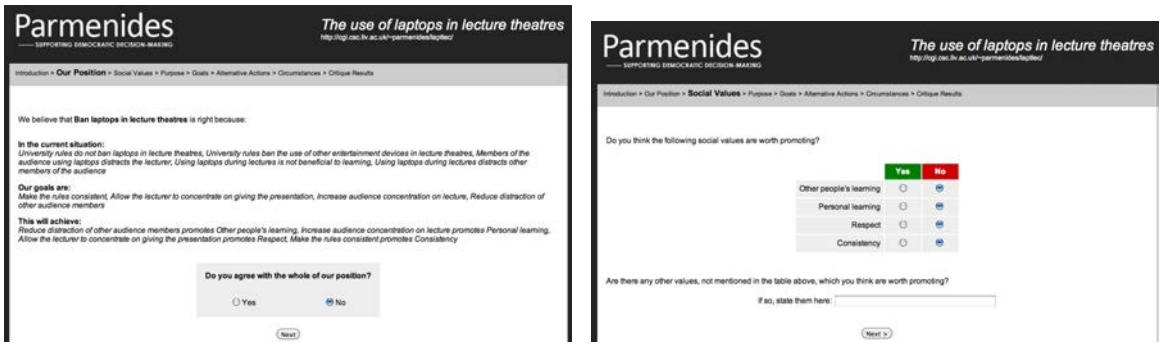
7.35. SEAS

SRI International's SEAS[79] [153,154] is a template-based structured argumentation tool originally designed for collaborative intelligence analysis. It has since been tested in other domains such as by IRS tax auditors and in a simulated public health emergency. SEAS's most unique feature is its emphasis on templating; users can author templates which provide

[77] http://www.pdonlineresearch.org/

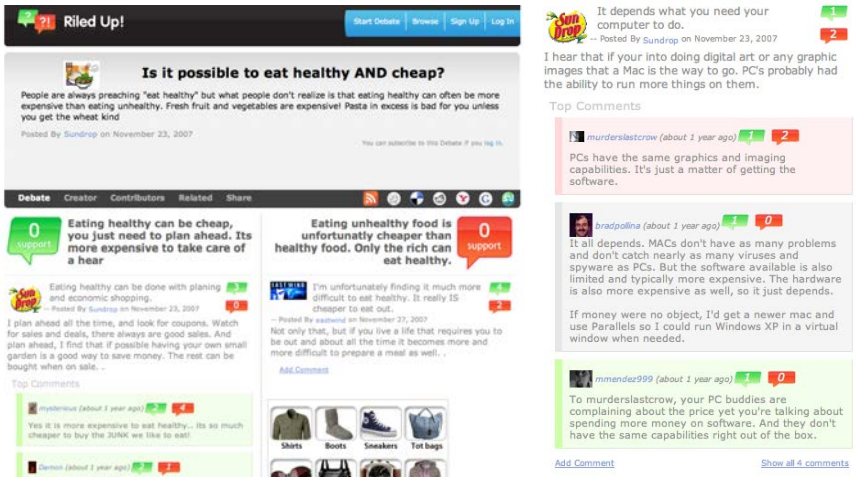
[78] http://riledup.com/

[79] http://www.ai.sri.com/~seas/



(a) (b)

Fig. 34. (a) In Parmenides, participants are asked to agree or disagree with a starting position. (b) Next Parmenides steps participants through a series of yes/no questions to pinpoint the source of their disagreement.



(a) (b)

Fig. 36. RiledUp (a) debates allow structured discussion on a topic; and (b) readers can respond with positive (green), neutral (grey), or negative (red) comments.

transferrable notions of how to make an argument, and specify authorized coeditors. Figure 37 shows one question from such a template. These templates, which are in essence domain-specific argument schemes, allow non-experts to make sound reasoning. SEAS automatically answers some questions based on earlier responses. The developers report that a threat-assessment template originally developed by U.S. intelligence analysts was successfully applied by non-experts in their laboratory. SEAS visualization features are also considerable: to visualize multiple dimensions, SEAS uses starburst, constellation, and table views. SRI International runs a SEAS server with paid accounts and SEAS server software is available.

7.36. Trellis software

The argument analysis system Trellis[80] [155,156, 157] was built on Semantic Web technologies, including the Semantic Annotation Vocabulary §4.13. Trellis, inspired by intelligence analysis, began as a credibility and analysis system to help structure decisions, for example to construct a family geneology based on contradictory information [155].

Originally, Trellis was designed to help capture argumentation, grounded in documents, whose reliability the user rated, and from which the user extracted statements; although users did not work directly with

[80] http://www.isi.edu/ikcap/trellis/

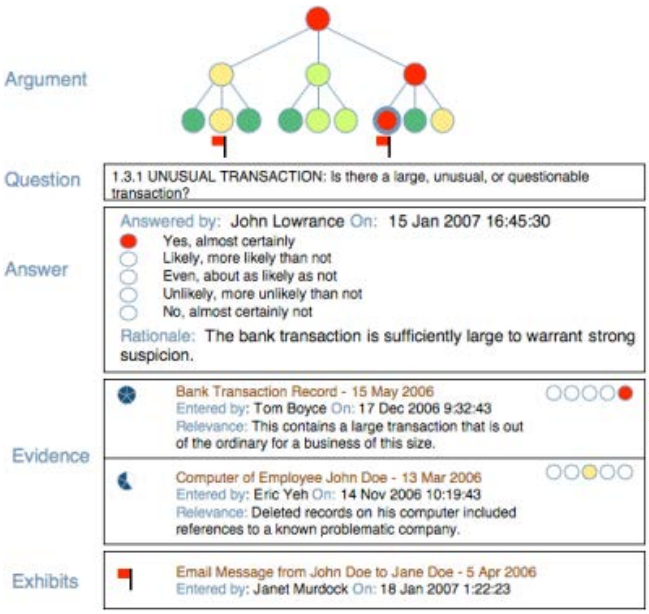


Fig. 37. SEAS uses a series of questions to structure the argument [153].

the underlying ontology, arguments could be exported into XML, RDF, DAML, and OWL. In addition to the original version, now called Rich Trells, two other modes, Tree and Table Trellis, described in [157], are now supported, for incremental formalization.

In Rich Trellis, statements are given likelihood-qualifiers such 'surprise' (indicating the analyst's subjective reaction); reliability-qualifiers such as 'completely reliable'; and credibility-qualifiers such as 'possibly true'. Statements may also be associated with a document providing evidence. The source for each document, including creator, publisher, date, and format, is recorded. Originally, in Rich Trellis, users added rich relationships such as `is elaborated by`, `is supported by`, `is summarized by`, and `stands though contradicted by`, which the system stored in XML, RDF, and DAML+OIL.

In contrast to the detailed argumentation of Rich Trellis, Tree Trellis uses only `pro` and `con`, and collaborative discussion is supported, while Table Trellis allows feature and value pairs to be arranged in a matrix, allowing the user to compare and evaluate alternatives according to their own criteria.

7.37. TruthMapping

TruthMapping[81] is an online deliberation tool which seeks to structure the conversation to focus around the "aha!" moment, avoiding digressions and soapboxes, and making hidden assumptions explicit. TruthMap facilitates structured conversations which use argument maps, critiques and rebuttals (Figure 38(a)). Users can vote on and rate topics, and watch particular conversations Only one user, the original arguer, modifies the map; feedback comes in critiques attached to each premise and conclusion (Figure 38(b)), which can be rebutted. One unique aspect of TruthMapping is that users can continually modify each contribution, but can only post one critique on each node. This is designed to make it easier to contribute a persistent comment to the discussion, which can not be drowned out by a single opponent. The system indicates when comments are out of sync, and a wiki-style history is available. Another unique aspect is the use of votes to color the map: as shown in Figure 38(a), each node is colored based on the percentage of votes agreeing (green) and disagreeing (red).

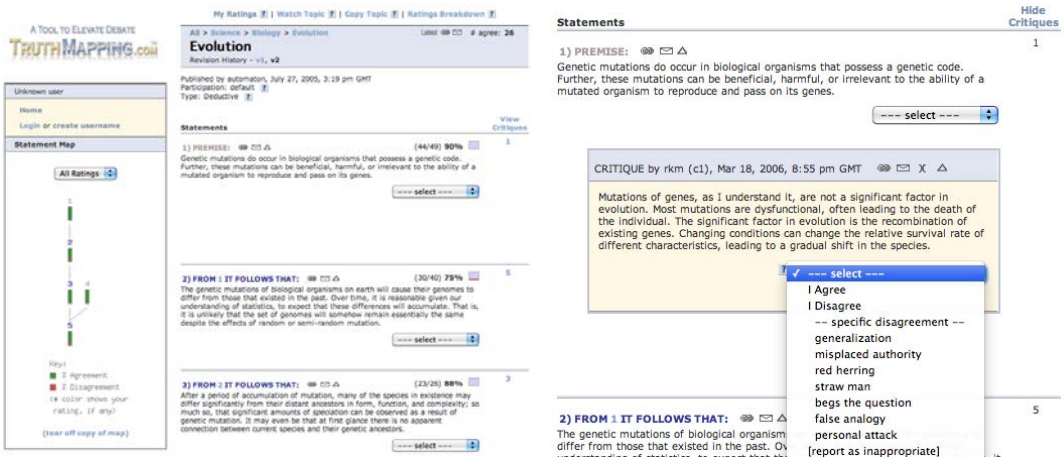
7.38. Videolyzer

Videolyzer[82] [158] allows the general public to have sensemaking and argumentative discussions about the quality of online videos. It builds on gamelike-creation of video transcripts and on machine tagging of areas of interest in either the transcript (claim verbs, people, money, and comparison) or the video itself (faces) (Figure 39(a)), to provide an integrated discussion forum for annotating and challenging the claims a video makes (Figure 39(a)). Videolyzer is unique in its focus on integrating argumentative discussion into a video platform.

8. Matrix Comparison of Tools

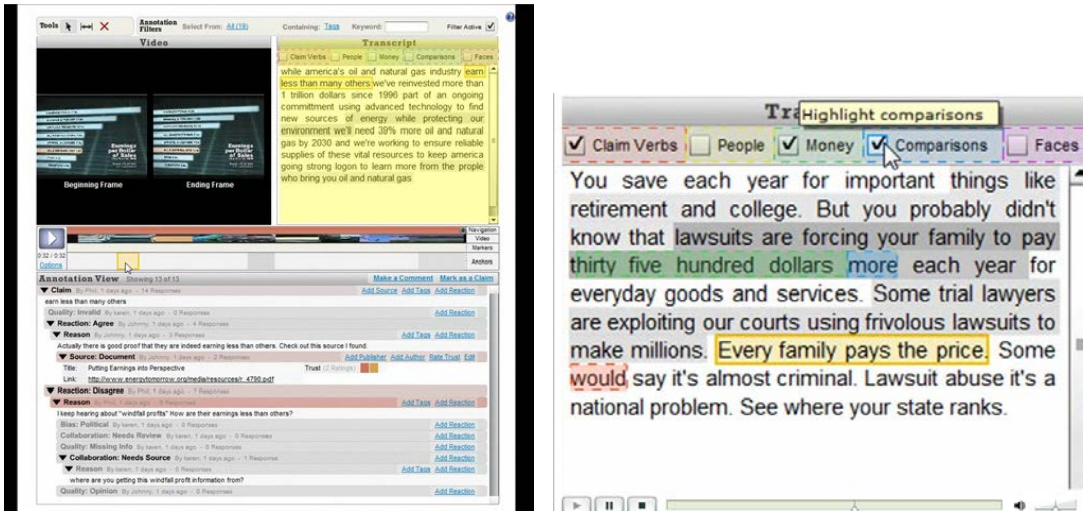
We now present comparison charts of the tools discussed in §7. Table 3 shows an overall comparison, in which tools are compared according to various features, which we outline shortly. For the downloadable tools, Table 2 provides the license, programming language(s) and data storage. In both tables, we use '?' to

[81] `http://www.truthmapping.com/`
[82] `http://videolyzer.com/`



(a) (b)

Fig. 38. Truthmapping (a) allows users to construct an argument by laying out premises and conclusions. Each node is colored based on the percentage of agreement (green) and disagreement (red). (b) Each premise and conclusion can be critiqued in comments, and critiques can be responded to with rebuttals.



(a) (b)

Fig. 39. Videolyzer (a) allows users to comment on the points made in a video; and (b) algorithmically determines segments of possible interest to help focus the discussion: in the transcript these are claim verbs and comparisons as well as mentions of people and money, and in the video these are peoples' faces.

indicate that we could not locate a piece of information.

First, we record the intended purpose of the tool. Next we provide the representation style and fucntional type. As introduced in §7.3, representation style is drawn from linear, threaded, graph, container, and matrix (including combinations of these styles); functional type is drawn from issue networking, funneling, and reputation. Then we indicate what sort of advanced visualization is offered; '-' indicates that no examples were found (i.e. that the question does not apply). The perspective column records whether an individual user has a personal perspective distinct from the group view. Next we consider whether a tool has a distributed architecture (allowing multiple copies to synch with one another).

Then we distinguish downloadable and hosted systems (noting that some tools are in both categories or

Tool name	License	Language	Data storage
ArgDF	?	PHP	Sesame
Argument Blogging	?	Python, Django, JavaScript, JQuery	AIFDB
Argunet	open source (unspecified)	Java	Db4O
Avicenna	author copyright	Java with Jena, ARQ, Pellet	SQL Server database
bCisiveOnline	commercial	Python/Django	?
Cohere	LGPL	PHP	MySQL
Competing Hypotheses	GPL v3	PHP5	MySQL
ConsiderIt	AGPL v3	Ruby on Rails	?
CoPe_IT	various	C# in .NET framework	Microsoft SQL Server 2005
Dispute Finder	Apache	Python, Ruby, Scala, Java	Microsoft SQL Server
HyperNews	MIT	Perl	document directory
SEAS	commercial, free to U.S. government	?	?
Trellis	GPL	Perl	?

Table 2
Downloadable tools: License, language, and data storage.

use a combined method). To understand their current integration with the Social Web, we record whether they use a site-specific login, or allow external credentials (such as OpenID, Twitter, or Facebook). We further indicate whether they have any integration with third party services; a single column does not do justice to the wide range of integration we found. For tools with social networking capabilities, we provide an example of the interaction users can have with each other, or the information they can find out about each other. Stable URLs indicates our success in finding reusable bookmarks: in fact these URLs can be at multiple granularities, such as the entire argument map, issue, or conversation; each individual comment or critique; etc.

On the second page of Table 3, we first indicate, in the tags column, whether users can provide tags for content. We also indicate which tools have a bookmarklet for use while browsing, and which promote embedding on external sites. The remaining columns describe features related to the site's interaction style, starting with whether it is possible to attach media in discussions and the input type (such as point and click visual controls or form-based editing). We also indicate which have consistency checking (i.e. avoiding obvious contradictions) and credibility metrics (usually, but not always, voting) as well as export capabilities. Tools which export AIF can take advantage of an existing infrastructure.

Tool name	Purpose	Representation style	Functional type	Advanced visualization?	Perspective?	Distributed architecture?	Downloadable or hosted?	Registration?	Examples of integration with third party services	Example of social networking capability	Stable URLs?
ArgDF	put argumentation schemes on the Semantic Web	text	issue networking	(from AIF)	single	n	hosted, downloadable	site-specific	-	-	?
Arguehow	"distill the best points to support your position and brace	linear	reputation	-	single	n	hosted	site-specific	'addthis' plugin for sharing	user's comment history	y
Argument Blogging	enable argumentative responses on the WWAW	argument map	issue networking	-	single	y	combination	no login	blogs and publishing platforms	-	?
Argumentum	"prove you're right"	threaded	reputation	-	single	n	hosted	Google, Facebook, Twitter	Argumentum Facebook App	compare users	y
Argumentations.com	gather and use news stories	threaded	issue networking	tag spheres	single	n	hosted	site-specific	-	user's comment history	y
Argunet	sketch and share argument maps	argument map	issue networking	map items are associated with detailed	personal	y	hosted, downloadable	Argunet Server Account	'addthis' plugin for sharing	attribution but no user profiles	y
Avicenna	express arguments in OWL to allow hierarchy and	argument map	issue networking	-	single	n	hosted	site-specific	-	-	?
bCisiveOnline	real-time collaboration for decision-making	argument map	issue networking, funnelling	-	single	n	hosted	site-specific	Skype	lists skype usernames	y
Cabanac's annotation system	sensemaking of arguments in annotations	threaded	funnelling	-	personal	n	hosted	site-specific	-	-	n
Climate CoLab	collective intelligence on climate change	threaded	reputation	-	single	n	hosted	Facebook	Facebook like	discussion, profiles	y
Cohere	connect and share ideas	argument map	issue networking	map, timeline	personal	n	hosted, downloadable	site-specific	RSS, send messages to Twitter, import	groups, profiles	y
Competing Hypotheses	analysis and cross-checking	matrix	funnelling	sort by most likely hypotheses	personal	y	hosted, downloadable	site-specific	Find us on Twitter	persistent chat, message board for each item	y
ConsiderIt	understand the pros/cons behind your opponents' opinions	container	issue networking	show points according to who holds	single	n	hosted, downloadable	Facebook	Find us on Facebook, Twitter	attribution but no user profiles	y
ConvinceMe	have fun debating	container	reputation	-	single	n	hosted	Facebook	RSS, send messages to Facebook, Twitter	forum discussions, user profiles	y
CoPe_IT	e-learning, collaboration	argument map, threaded	funnelling	automatically formalize the view	personal	n	hosted, downloadable	OpenID	import phpNuke webforums, Compendium maps	groups	n
CreateDebate	K-12 education, debating	container	reputation	summary graphs and statistics	single	n	hosted	site-specific	API, pull in external RSS feeds, Facebook fanpage	list friends and enemies	y
Debate.org	meet people through debate	linear	reputation	-	single	n	hosted	site-specific	Facebook Like, post to Twitter, send email	extensive user profiles	y
Debategraph	help groups collaborate on complex issues	argument map, threaded	issue networking	automatically change the view	single	n	hosted	site-specific	RSS, email	user profiles	y
Debatepedia	clarify public debate, engage citizens	container	issue networking	-	single	n	hosted	site-specific	RSS, post on Facebook, Twitter, delicious, Digg,	user's contribution history,	y
Debatewise	help make informed decisions	container	reputation	-	single	n	hosted	OpenID	addthis' plugin for sharing, Facebook like	-	y
DiscourseDB	collect opinions of commentators and journalists about	container	reputation	-	single	n	hosted	site-specific	-	user's contribution history,	y
Dispute Finder	discover what's widely disputed when browsing the web	-	reputation	highlight disputed sentences	personal	n	combination	no login	Facebook	profiles who flagged information as	n
HyperNews	argumentative Web-forum with an email gateway	threaded	issue networking, discussion	-	single	y	hosted, downloadable	site-specific	-	discussion-based	y
LivingVote	"an up-to-date record of what we believe and why we believe it"	argument map	issue networking	-	single	n	hosted	site-specific	AddtoAny plugin	vote on others' opinions	y
Opinion Space	exchange perspectives	-	reputation	uses principal component analysis to	personal	n	hosted	site-specific	-	rate comments	n
Online Visualisation of Arguments	analyze and diagram arguments	argument map	issue networking	(from AIF)	personal	n	hosted	no login	-	-	y
Parmenides	get feedback on proposals for e-participation	argument map*	funnelling	analysis toolset using Value-based	personal	n	hosted	no login	-	-	y
PDOnline	speed scientific communication	threaded	reputation	-	single	n	hosted	site-specific	link to Facebook page, Twitter	profiles, comments	y
REASON	support information pooling	argument map, threaded	funnelling	-	personal	y	hosted	site-specific	-	discussion	n
Riled Up!	debate & discuss; show that you're an authority on a topic	container	reputation	-	single	n	hosted	site-specific	digg, delicious, reddit, yahoo, google, stumble	profiles, comments	y
SEAS	intelligence analysis	multiple	funnelling	starburst, constellation	personal	y	downloadable, hosted	site-specific	-	-	?
Trellis	analysis	linear	funnelling	-	single	n	downloadable	site-specific	-	-	?
TruthMapping	overcome "loudest voice" and "last word"	argument map, threaded	funnelling	shows % agreement and disagreement	single	n	hosted	site-specific	-	discussion	y
Videolyzer	collaboratively evaluate online videos	threaded	issue networking	-	single	n	hosted	site-specific	-	discussion	y

Tool name	Tags?	Bookmarklet?	promote embedding?	Attach media?	Input methods	Consistency checking?	Credibility metrics?	export formats
ArgDF	n	n	n	n	forms-based	use AIF tools	n	AIF
Arguehow	n	n	n	n	forms-based	n	y	none
Argument Blogging	n	y	n	y	HTML	n	n	?
Argumentum	n	y	y	n	forms-based, depends on the type	n	y	none
Argumentations.com	y	n	n	n	forms-based, depends on the type	n	y	none
Argunet	y	n	y	n	visual controls	n	n	locally stored
Avicenna	n	n	n	n	visual controls	use AIF tools	n	AIF
bCisiveOnline	n	n	y	y	visual controls	n	n	PowerPoint
Cabanac's annotation system	n	n	n	n	visual controls	y	y	?
Climate CoLab	n	n	n	not in argument map discussions	forms-based; some HTML and wiki formatting	n	y	none
Cohere	y	y	y	URLs only	forms-based	n	n	none
Competing Hypotheses	n	n	n	n	forms-based	y	n	none
ConsiderIt	n	n	n	n	visual controls	n	n	none
ConvinceMe	y	n	y	n	forms-based	n	y	none
CoPe_IT	y	n	n	y	forms-based, WYSIWYG	n	n	none
CreateDebate	y	y	y	URLs, embedded videos only	forms-based, WYSIWYG	n	y	none
Debate.org	-	n	n	n	text with HTML	n	y	none
Debategraph	n	n	y	URLs, embedded videos only	forms-based	n	n	none
Debatepedia	n	n	n	y	wiki formatting	n	n	none
Debatewise	n	n	n	n	forms-based, wiki-style	n	y	none
DiscourseDB	n	n	n	y	wiki formatting	n	n	RDF
Dispute Finder	n	n	n	n	roll over text in user mode; forms-based for activist	n	y	none
HyperNews	n	n	n	n	forms-based	n	n	?
LivingVote	n	n	n	n	forms-based	n	y	none
Opinion Space	n	n	n	n	forms-based	n	y	none
Online Visualisation of Arguments	n	y	n	n	visual controls	use AIF tools	n	ArgDB, AIF
Parmenides	n	n	n	n	forms-based	y, in admin view	n	?
PDOnline	n	n	n	y	forms-based	n	y	none
REASON	n	n	n	n	visual controls	n	n	none
Riled Up!	y	n	n	n	forms-based	n	y	none
SEAS	n	n	n	n	forms-based	?	y	Argument Markup Language, HTML, Word
Trellis	n	n	n	URLs only	forms-based	n	y	none
TruthMapping	n	n	n	n	forms-based	n	y	none
Videolyzer	y	n	n	URLs only	forms-based	n	y	none

9. Discussion & Conclusion

We have reviewed argumentation theory, existing ontologies using argumentation and specifying argumentation, and Web tools for argumentation. We now discuss three main gaps. First, the ontologies given need further adaptation to meet the existing variety of social tools and purpose. In particular, arguing is a social activity. The varieties of argument tools on the Social Web–issue networking, funneling, and reputation–need distinct types of interface support and social engineering. The remaining question is whether a single Social Web ontology for argumentation should tie these together.

9.1. Arguing is a Social Activity

As argumentation scholars have long realized, humans argue for a variety of reasons, not always to solve "wicked problems". Rather, arguing is a social activity people may use to position and establish themselves. This kind of arguing is important in the Social Web, where people play by arguing such as with ConvinceMe's the 'King of the Hill' game, or create networks of friends and enemies, such as on Riled Up! and Create Debate. Arguing can also be used to connect people such as on Debate.org. An ontology for the Social Semantic Web will need to respect these social aspects, and may need to incorporate emotive indicators such as the heat of the debate as well as the manner in which the outcome will affect the participants.

The notion of debate, where two parties face off, is also well-represented in existing social tools. Debate may allow individuals to show their expertise, to find the best arguments, or simply to practice their rhetorical skills. Debate topics may be reused, for ongoing issues with two or more defendable positions, especially when a topic is controversial. This suggests two opportunities. First of all, future Social Semantic Web prototype tools for sensemaking and argument mapping could be tested with for argumentation for some common debate topic in order to find a large audience of potential evaluators. Second, providing meaningful ways to discover new debate topics, and potentially record and share the outcome of these debates, could be helpful. Frequent debaters may also provide an interesting class of users since we might expect them to be more familiar with fallacies and argument diagramming, making them potentially more savvy about argumentation schemes and similar abstractions.

9.2. Bridging the Social Web and the Semantic Web to Manifest the World Wide Argument Web

Argumentation is used in many contexts and while formal argumentation can be represented with ontologies such as AIF, argumentation on the Social Web can be quite informal, with missing premises and unexpressed argument schemes. While human analysis can sometimes bridge the gap between AIF and the Social Web, facilitated by tools such as OVA, more scalable solutions are needed. Several approaches will be needed to more routinely express the existing argumentation on the Social Semantic Web.

First, ontologies mapping between the social world and the argumentative world are necessary. Reusing existing work, both in domain knowledge and in Social Web modeling, will be necessary: often argumentation and decision-making are situated in a larger context. Examples we have reviewed include the climate change discussions on Climate CoLab and the scientific discourse in PDOnline. Linguistic pragmatics dominate in much argumentation, so one form of progress would be to find unassailable features which mark argumentative contexts on the Social Web.

Second, bootstrapping the existing Social Web into the World Wide Argument Web would benefit from automatic detection. In the scholarly communication and legal fields, argument detection relies on rhetorical features. Argumentative markers would also help in modifying these argument detection approaches for use on the Social Web. Analyzing existing Social Web corpuses, such as DisputeFinder's claims database and the Discussion Fora from the Aracaria corpus may help in determining such markers.

Third, analyst-oriented tools can be brought onto the World Wide Argument Web with comparatively little effort. Motivated users and defined argumenation schemes ease this process. SEAS, for example, already uses argument templating. Such templates appear to be specialized argument schemes, which could be expressed in shared repositories and even classified (for instance using OWL as Avicenna does). Once the argument schemes can be referenced, SEAS might provide another source of AIF data, as well as point to further enrichment needed. The ACH process underlying Competing Hypotheses seems to use a narrower set of reasoning; its data, similarly, might be encompassed by understanding and expressing the ACH argument scheme. The analyst community is also a good place to start with interface interventions such as using Controlled Natural Language (CNL); whereas on

the general Social Web, CNL would restrict input, in analysis tools, CNL might open the vocabulary.

While abstract argument schemes may not be well understood by users, Parmenides shows that stepwise processes based on these schemes can be powerful. Opening up the analysis tools, so that a group could view aggregate responses, would take Parmenides to a new level of collaboration. While Parmenides focuses on gathering multiple responses on the same set of issues, a different approach would be to crowdsource work based on an argument scheme. Many groups already do this informally with checklists and procedures, for instance in Wikipedia's article promotion process. Providing templates where users could indicate which critical questions they have asked and answered, and at what point in time, might help to distribute and share this work, while making the underlying process more transparent.

9.3. Social Arguing: issue networking, funneling, and reputation

The varieties of argument tools on the Social Web–issue networking, funneling, and reputation–currently have distinct types of interface support. Their 'social engineering'–the reasons and ways they are used–are also different. In this paper we used three classifications of argumentation: issue networking, funneling, and reputation. These categories may need to be revised and updated. For instance, classically, issue networking served to separate the people contributing issues from the issues themselves. One social benefit of this approach is that people might become more open-minded and less attached to ÔwinningÕ with their ideas.

Yet some tools are difficult to place in this categorization. For instance, ConsiderIt, shows peoplesÕ names alongside their ideas: this personalizes the ideas, humanizing the opposing side and providing a motivation to contribute. Since online social situations have different affordances than offline situations, further types of interfaces and interaction strategies may prove useful, even for general support. One remaining question is whether a single Social Web ontology for argumentation should tie these diverse platforms for argumentation and decision-making together.

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