Questions, Arguments, and Natural Language Semantics

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Abstract. Computational models of argumentation can be understood to bridge between human and automated reasoning. Argumentation schemes represent stereotypical, defeasible reasoning patterns. Critical questions are associated with argumentation schemes and are said to attack arguments. The paper highlights several issues with the current understanding of critical questions in argumentation. It provides a formal semantics for questions, an approach to instantiated argumentation schemes, and shows how the semantics of questions clarifies the issues. In this approach, questions do not attack schemes, though answers to questions might.

1 Introduction

Computational models of argumentation can be understood to bridge between human and automated reasoning, for both represent, reason with, and evaluate valid arguments. Arguments can be proposed and *attacked* by counter-arguments; where an argument either is not attacked or is defended from attack, we may accept that argument. While abstract argumentation, e.g. [5], focusses on abstract arguments with no internal structure, other approaches provide formal analyses of the internal structure of arguments [15, 3], where the propositions of the arguments are drawn from a knowledge base that people might use. Argumentation schemes are even closer to human forms of reasoning [21], for they represent stereotypical, defeasible reasoning patterns about everyday activities or considerations. Arguments are also used dialogically in that two (or more) users may discuss a topic, presenting statements that instantiate argumentation schemes, and arguing for or against claims. As individuals have only partial, conflicting, or alternative information, people use arguments to fill in information, resolve conflicts, chose among alternatives, or at least provide an explicit, rational explanation of the precise nature of the dispute.

A central aspect of argumentation schemes are *critical questions* associated with it, which are said to identify how arguments can be attacked such as [23]:

Argument from Expert Opinion
- Premise: Source E is an expert in subject domain S containing proposition A.
- Premise: E asserts that proposition A is true (false).
- Claim: A is true (false).

- CQ2: Field Question. Is E an expert in the field that A is in?
- CQ4: Trustworthiness Question. Is E personally reliable as a source?

Answer *no* to any of these questions, the reasoning to the claim fails.

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As we discuss later, there are a variety of ways that critical questions are discussed in the literature. But, there is more at stake in an analysis of them than distinguishing these ways or choosing among them. First, in our view, critical questions as *questions* and as presented in the argumentation literature are not straightforwardly compatible with formalised approaches to instantiated argumentation, e.g. ASPIC+ [15] or Logic-based argumentation [4]. Yet, it only makes sense to provide an approach to questions that does straightforwardly suit instantiated argumentation. Second, the analysis of critical questions is not formalised, structured, or systematic in and of itself: What is the logical space of critical questions relative to a given scheme?; What are the relationships between the questions and the schemes; Why is it that a critical question of one scheme cannot serve to attack some other unrelated scheme? Simply giving a list of critical questions relative to a scheme does not explain them or enable productive use of them. Third, the analysis of critical questions is not related to a well-developed formal semantics of questions in natural language [10]. If argumentation is to be a medium of broadly applicable man-machine communication, then questions ought to be consonant with how questions are used by humans and analysed by linguists, not as something specially defined in argumentation. Moreover, we argue that there are advantages to making a theory of questions formally related to linguistic analysis, for it makes explicit information which has been otherwise left implicit.

In this paper, we begin to address these issues. The novelty of the paper is that it applies a well-developed, widely adopted formal analysis of the semantics of questions to the discussion of argumentation and critical questions, thereby establishing a *baseline* on the treatment of questions. Furthermore, our proposal distinguishes and modularises the roles of questions, answers, arguments, and dialogue which elsewhere appear to be conflated. However, this paper does not attempt a systematic reconstruction or reanalysis of prior proposals, which is beyond the scope of this paper; this is left for future work. By furthering the integration of argumentation with computational linguistics, we further the cause of argumentative human-machine communication.

In section 2, we set the discussion in the context of a typology of questions, selecting only those that are relevant for argumentation. We outline a formal semantic analysis of questions in section 3. A formalisation of instantiated argumentation is outlined in section 4. In section 5, we apply the theory of questions in the context of instantiated argumentation. Other approaches to argumentation schemes and critical questions are discussed in section 6 and compared to our proposal. Finally, we close with some future work and general observations in section 7.

2 Natural Language Analysis of Questions

In Linguistics and Computational Linguistics, the syntax, semantics, and pragmatics of questions have long been studied [10]. Syntax means here the grammatical analysis of the form of questions, semantics relates to the content to of the questions, and pragmatics to the question/answer speech acts in dialogue. Each of these subtopics itself is the object of extensive research. For our purposes, we focus on the semantics, presume the syntax, and leave dialogical aspects largely to future discussion. We first narrow the discussion, separating out from the spectrum of kinds of questions and their answers those that are most directly and immediately useful for argumentation.

There are a wide variety of questions, not all of which (yet) appear to be relevant to argumentation. To set the context, we briefly mention some key issues. One distinction is between unembedded questions (main clause) and embedded questions (subordinate clause), where the embedded questions appear after a variety of verbs, e.g.*indicate, know, believe, wonder*, and others.

- When will Jill arrive?
- Bill knows [when Jill will arrive].

We look only at the main clause questions, for while subordinate clause questions may appear in an argumentation scheme, they do not serve as critical questions about a scheme. See [13] for more on this important distinction.

One particular sort of questions are yes/no questions:

- Is your mother at home?

The answers to such questions can be taken as elliptical for the corresponding declarative that gives a full answer to the question; that is, answering *Yes* is an elliptical form for *My mother is at home*, while *No* is *My mother is not at home*. Yes/no questions are restrictive in the sense that they only represent a *one* literal and its negation.

There are a range of other sorts of questions and issues about them. For example, WH-questions contain a *wh-word*, e.g. *who, what, when, where, why, how*.

- What did John buy?

This can be answered with a *short answer*, e.g. *War and Peace*. Alternatively, this can be answered with a *propositional answer*, e.g. *John bought War and Peace*. Here we can take the short answer as elliptical of the propositional answer. There are a range of additional issues about the syntax and semantics of questions, but yes/no questions serve as good starting point into a formal analysis of questions in argumentation.

3 A Formal Semantic Theory of Questions

In this section, we briefly outline a well-developed, widely adopted formal semantic analysis of questions [10]. A range of interpretations of questions are reviewed, particularly the success and satisfaction conditions of the illocutionary act of asking a question. It is argued that dialogical interpretations of interrogatives *presuppose that questions have a distinct type of semantic object*. Thus, the key task is to define this semantic object and to know what it means to answer a question. A simple, yet explanatory analysis is provided, which then helps us better understand the role of questions in argumentation.

A core claim is that there is a semantics of questions related to a semantics of propositions, and that we can provide a *static* analysis, which then can provide the basis of a *dynamic* (e.g. dialogic) analysis, where other issues arise such as processing a question, selecting an optimal answer, shifting roles of the discussants, and so on. As with a semantics of indicatives, the two most important criteria of adequacy for a theory of questions are that it specify a notion of equivalence between two questions (*semantical identity*) and of entailment (*meaning inclusion*). In the following, we provide the background intuitions to such a theory, followed by a formalisation in intensional propositional logic.

The analysis is based on leading intuitions from [11], called *Hamblin's picture*:

i An answer to a question is a sentence.
ii The possible answers to a question form an exhaustive set of mutually exclusive possibilities.
iii To know the meaning of a question is to know what counts as an answer to that question.

Postulate [i] focuses on *propositional* meanings for answers, where sentences are represented as propositions in a logic. Postulate [ii] means that the set that is the union of the answers exhaustively and completely fills the logical space of the question so that no possible answers are left out. The logical space is the space of possibilities that the world could be like. Consequently, one answer to a question *excludes* other answers. Where we leave aside the issue of presuppositions that we assume are fulfilled, the possible answers to a question *partition* the logical space; consequently, the answer to a question in a context is the unique proposition that is true in the context from amongst the possible answers. Postulate [iii] identifies the meaning of the question with the partition itself, so while questions are related to propositions, they are not reduced to them. Where no partitions are possible, e.g. propositions that are true at every world in the model, we suppose a Gricean explanation for the absence of the question since its answer is uninformative.

The formal semantic theory for Hamblin's picture is set within *Propositional Intensional Logic*. A fundamental notion is *possible world*, which is a notion of *an alternative way that things could be* [19]. In an *extensional theory*, a model M specifies the denotations of the terms, relations, and complex expressions; it can be understood as a singular specification of a world. In intensional logic, we have several such worlds; a model M in intensional logic is a set of possible worlds. The meaning of an indicative ϕ is the extension relative to a model M and a world w, $[\phi]_{M,w}$, which is a function from M, w, and ϕ to the truth value (indicated with 0 or 1) assigned in w to ϕ. The intension of ϕ in the model M, called a proposition, is the *set of worlds in the model where ϕ is true*: $[\phi]_M = \{\text{w in M} \parallel [\phi]_{M,w} = 1\}$. In a complete model, every proposition is exclusively either true or false in every world; the intersection of $[\phi]_M$ and $[\neg\phi]_M$ is empty, while their union is the set of worlds in the model. Logical equivalence and entailment can be defined set-theoretically relative to a model.

The intensional interpretation of interrogatives is constructed from the intensional interpretation of propositions. Syntactically, an interrogative is indicated with a question mark prefixed to the proposition - $?\phi$. We have the meaning of an interrogative in a world, which is equivalent to the propositional answer in that world:

Def (Interpretation at M,w). $[?\phi]_{M,w} = \{w' \in M | [\phi]_{M,w'} = [\phi]_{M,w}\}$

The extension of a yes/no-interrogative in a world is the meaning of the proposition in that world, providing a complete and precise answer to the question posed by the interrogative. The intension of $?\phi$ in a model M is the set of its extensions in M:

Def (Interpretation in M). $[?\phi]_M = \{[\phi]_{M,w} | w \in M\}$

Since the subsets of meaning of $?\phi$ do not intersect, the question has *partitions*.

A proposition is an *answer* to a question where the meaning of the proposition (a set of worlds) is a subset of the meaning of the question:

Def (Answerhood). $\phi| = ?\psi$ iff $\forall M \exists w : [\phi]_M \subseteq [?\psi]_{M,w}$

For our purposes, saying *Yes* in answer to a yes/no question is to accept that the indicative form of the question is true, while *No* is to accept the indicative is false. For example, the question *Did Bill leave?* and answered *Yes* means, in the context where the question is answered, that *Bill left* is true, while *No* means *Bill left* is false. The question abstracts over these contexts, thus, *Did Bill leave?* denotes the partition of propositions {*Bill left*, *Bill did not leave*}.

This analysis corresponds to Hamblin's picture. An answer to a question is a proposition (derived from a sentence); for yes/no interrogatives, the answers to the question are the propositions that are mutually exclusive and that exhaust the logical space consisting of all possible worlds in M; the meaning of the question is just the partition of answers. The theory is formally adequate as logical equivalence and entailment can be defined in set-theoretically, much like the indicatives. This theory is an initial, formal basis for the analysis of questions in argumentation.

4 Argumentation

In this section, we discuss instantiated argumentation with respect to a knowledge base (of literals and rules). For our purposes, we work with the *logic-based* approach of [3], which represents arguments in terms of classical propositional logic. We review how arguments are constructed and how attacks between them are identified in a logic-based approach. In particular, in instantiated argumentation, we have positive and negative literals. Where the literals are semantically interpreted as in intensional logic, we can use them to form questions as outlined above. Argumentation schemes can be represented in an instantiated argumentation theory.

In a logic-based approach, statements are expressed as atoms (lower case roman letters), while formulae (greek letters) are constructed using the logical connectives of conjunction, disjunction, negation, and implication. The classical consequence relation is denoted by $\vdash$. Given a knowledge base Δ comprised of formulae and a formula α, $\Delta \vdash \alpha$ denotes that Δ entails α. Δ can be inconsistent, containing contradictory propositions. We assume a set of formulae Δ from which arguments are constructed. Where $\bot$ denotes inconsistency, $\Delta \vdash \bot$ denotes that Δ is inconsistent. An argument is an ordered pair $< \phi, \alpha >$, where $\phi \subseteq \Delta$, ϕ is a minimal set of formulae such that $\phi \vdash \alpha$, and $\phi \nvdash \bot$. ϕ is said to support the claim α. For example, where *p* and *q* are atoms, and where the knowledge base is comprised of *p* and $p \rightarrow q$, then $< \{p, p \rightarrow q\}, q >$ is an argument, where $p, p \rightarrow q$ is the support for the claim *q*. For our purposes, argumentation schemes *are* arguments in a logic-based approach, presuming that the rule from which we draw the claim is implicit in the argumentation schemes, but explicit in the argument. Arguments in this approach are *defeasible* because it is possible for one argument to attack the support or the claim of another argument.

With contradictory propositions from Δ, we can construct arguments in *attack* relations, where the propositional claim of an argument is contradictory to the propositional claim of another argument or is contradictory to some proposition in the support of another argument. These are the *attack* relations between arguments $< \Psi, \beta >$ and $< \Phi, \alpha >$ such as *undercutter* and *rebuttal*; attacking arguments are referred to as *counterarguments*. $< \Psi, \beta >$ is an undercutter for $< \Phi, \alpha >$ where β is $\neg(\phi_1 \wedge \ldots \wedge \phi_n)$ and $\{\phi_1 \ldots \phi_n\} \subseteq \Phi$; in essence, the claim of one argument is the negation of a set of formulae in the support of another argument. $< \Psi, \beta >$ is a rebuttal for $< \Phi, \alpha >$ if and only if $\beta \leftrightarrow \neg\alpha$ is a tautology; the claims of the arguments are inconsistent. For example, supposing the following in a knowledge base (from [4]): *p*, $p \rightarrow \neg q$, *r*, $r \rightarrow \neg p$, $\neg p \rightarrow q$. From this, we can construct an argument to support the claim $\neg q$: $< \{p, p \rightarrow \neg q\}, \neg q >$. With respect to this argument, we have an undercutter $< \{r, r \rightarrow \neg p\}, \neg p >$ and a rebuttal $< \{r, r \rightarrow \neg p, \neg p \rightarrow q\}, \neg p >$.

In this theory, a yes/no question is expressed as $?\Phi$, which denotes the partition that is the denotation of Φ and the denotation of $\neg\Phi$. In a Logic-based approach, as with ASPIC+ [15], there is one knowledge base which is used to instantiate the argumentation schemes. Dialogical models, where there are different participants, may be defined as subsets of this knowledge base, and because of this the analysis of questions in a dialogical setting is defined with respect to the union of each participants' knowledge base. In the next section, we give several points that hold of our semantic theory of questions with instantiated arguments.

5 Questions and Argumentation Schemes

To this point, we have reviewed a semantic theory of questions in section 3 and instantiated arguments with attacks in section 4. In this section, we apply our theory of questions to the approach to instantiate arguments.

Models in intensional propositional logic may be used to represent inconsistent knowledge bases, as contradictory propositions denote distinct sets of possible worlds. This approach to questions appears to be all that is required by logic-based argumentation, for questions denote the partition of contradictory propositions. This is a very straightforward result. Following [10], it leaves aside issues bearing on the *dialogical issues* of questions in the context of argumentation.

Several key points hold of this analysis of questions and instantiated arguments.

1. Questions denote partitions of answers, where answers are propositions. Such partitions reflect conflicts of information in the model; questions arise where ever such conflicts exist.
2. Questions are answered with respect to a world, and the answer indicates what holds in that world.
3. Answers, as propositions, may be *justified* just as with any other proposition. In this theory, questions *cannot* be justified.
4. Questions reflect the model in that there can only be yes/no questions if there are contradictory propositions in the model.
5. Only propositions can introduce attack relations between arguments since attack is defined in terms of contradictory propositions, and only propositions can be negated. Questions do not bear truth values and cannot themselves be negated; thus, it is a category mistake to say that a *question attacks an argument*. However, the *answer* to a question may give rise to an attack.
6. To ask a question with respect to an argumentation scheme implies that *the model can represent the meaning of the question (i.e. the propositions)*. Moreover, it implies that *the argumentation scheme itself represents the relevant proposition (either in a positive or negative form).* This follows from the meaning of a question, instantiated arguments, and attack; if this were not the case, the question would be *irrelevant* with respect to the argumentation scheme.

7. The number and kind of questions is entirely dependent on the number and kind of propositions that (possibly implicitly) specify the scheme.
8. Given a model and an argumentation scheme with all premises explicit, yes/no questions could generated, so would be formally redundant.

In this approach, the knowledge base represents domain knowledge, lexical semantic information, and so on. With respect to the knowledge base, argumentation schemes are instantiated. As the knowledge base is inconsistent, questions can be generated. The analysis is abstract, as the possible worlds analysis provides a static view on all alternatives. It makes no claims about changes of the knowledge base can be changed, growth of knowledge, extensions of argumentation schemes, or dialogical issues. The approach also makes no claims about the necessary or sufficient conditions for an argumentation scheme; rather, if it is felicitous to ask a question with respect to an argumentation scheme, then one of the answers to the question is a premise of the scheme. However, the approach outlined above is proposed as a basis for such dynamics, following a similar trajectory dialogue [7] and dynamic semantics [12].

In the next section, we mention previous approaches to critical questions

6 Comparison

We are not aware of previous research that relates a formal theory of instantiated argumentation with a formal theory of questions that is based on a formal linguistic analysis. However, there has been a body of work that discusses critical questions, which we may take as representative, e.g. [22], [8], [2], and [18].

First, it is important to reiterate a point made in section 3, where it is claimed that there is a semantics of questions that is *presumed* by dialogical/discourse approaches to questions [10]. There are dialogical approaches to argumentation [17], [14], [9], and [1]), among others. And questions are discussed in these contexts. However, it is our view that modularising the analysis, e.g. separating out questions from their dialogical function, such as is done in the formal semantics of questions, helps to isolate and clarify the overall analysis. The dialogical analysis should be seen to overlay or apply to the semantics of questions. The same move is made in the analysis of the semantics of sentences in static and dynamic modes. In the literature that we have reviewed, the semantics of questions seems often to be conflated with their dialogical role.

In [22], several approaches to critical questions are reviewed - [20] and [9]. The proposal is made that critical questions can be understood as implicit premises of an argument. As we have discussed in section 5, in formally representing the knowledge of argumentation schemes, we make all information as explicit and overt as possible. This applies as well to the various subtypes of questions proposed in [20]. We have also discussed that argumentation schemes only have propositions in premises and claim, which precludes questions: an *answer to a question (or its negation) may be a premise of an argumentation scheme, but not the question itself*. Yet, as we discuss in the conclusion, there are interesting topics about questions in arguments. In addition, there is a discussion about how critical questions are tied to shifts in burdens of proof and to proof standards, which we have not discussed in this paper, but see [16]; whether all argumentation schemes are associated with burdens of proof and proof standards is an open question in our view. Dialogical aspects are discussed, e.g. sorting the premises according to their role in dialogical investigation of the acceptability of the argument.

In [8], we find an overview of philosophically oriented analyses of argumentation schemes and critical questions. They consider the role of critical questions in the evaluation of schematic arguments, the correct number and kind of critical questions accompanying a scheme, and burdens of proof and proof standards. We have addressed some of these issues in 5. We agree that questions can be *used* to test three aspects of argument cogency: relevance, acceptability and sufficiency. However, it is the *answer*, not the question, that plays the crucial role. Moreover, just how these aspects are to be defined remains an open issue. A general topic is raised about whether argumentation schemes are intrinsically *open textured* in the sense that we cannot define the necessary and sufficient conditions for them. This is a general problem for the representation of human knowledge and arises in analysing language, vision, and other higher cognitive functions. For our purposes, we can take schemes as *prototypes* subject to *refinement*. Our proposal about questions makes no claim on these matters.

A different approach to critical questions is taken in [2] and [18], concerning the *Practical Reasoning with Values* argumentation scheme of the form:

> In the current circumstances R, we should perform action A, which will result in new circumstances S, which will realise goal G, which will promote value V.

A semantic model is provided with a domain of actions, agents, states, and values as well as relations and constraints. The scheme is an abstraction with respect to the model, where the variables can be instantiated. We do not have the space here present the formal analysis, but sketch the treatment of critical questions.

The core idea is that in posing a critical question, an opponent attacks an the element of the instantiated scheme. The scheme has 16 associate critical questions, among them:

- CQ1: Are the believed circumstances true?
- CQ5: Are there alternative ways of realising the same consequences?

Answering *no* to the first or *yes* to the second is said to attack a presumption of the scheme such that the presumed claim does not follow. However, the presumptions are not represented in the scheme itself, but are incorporated into the meaning and function of the answer to the question. That is, if we answer *yes* to CQ5, this means that relative to the way of realising the consequences given by the instantiation of the scheme, and relative to what is available in the semantic model, there are alternative ways of realising the same consequences. Moreover, having such alternatives implies that we cannot presume the proposed action should be done. In [18], we have formalisations of all 16 critical questions, where each is presented as an argument instantiation that attacks the target scheme.

This approach is not consistent with our proposal concerning the relationship between questions and argumentation schemes. Questions are represented as arguments, for which there is no justification or evidence. The attack on the instantiated scheme is "directly defined", but not with respect to Logic-based argumentation or ASPIC+, since there is no component of the instantiated scheme that is attacked. Furthermore, it allows that that an arbitrary question could be defined so as an attack on the argument. An alternative approach would be to take the semantic information encoded in a critical question and make it specifically part of the argumentation scheme as a premise. Then the answer to the question serves as an attack on the scheme, consistent with the semantics of questions and Logic-based argumentation and ASPIC+. Arbitrary attacks cannot be defined in

this approach since there can only be attacks on premises that are part of the presumptive reasoning of the scheme. The dialogical aspect could still be overlain the questions.

7 Conclusions

The paper discusses the role and representation of questions with respect to argumentation schemes. In contrast to research in argumentation *per se*, the formal semantics of questions does not treat questions as *attacks*, but as partitions of answers. It is the answers, not the questions, from which we derive argument attack. The semantics of questions is compatible with current approaches to instantiated argumentation. The analysis clarifies the role of questions in identifying auxiliary premises of schemes, which would be best made explicit. It also separates the semantics of questions from their dialogical role. We compared our analysis against extant analyses, showing how questions, attacks, premises, and dialogue are conflated.

There are many issues that remain to be investigated. First, the existing critical questions ought to be converted into explicit premises, leaving aside the issue of implicit representation. The formal semantics of questions ought to be integrated into a dialogical system. It would be worth investigating the nature of the questions that can be asked about schemes, what type and range they may have. Finally, we should consider *Erotetic Logic*, where questions can be the premises of rules, in the context of argumentation since they challenge fundamental assumptions both of the semantics of questions and of argumentation [6]. As part of the investigation, we should see how such questions are related to those from which attacks are derived.

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