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How to formalize informal logic

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ABSTRACT: This paper presents a formalization of informal logic using the Carneades Argumentation System, a formal, computational model of argument that consists of a formal model of argument graphs and audiences. Conflicts between pro and con arguments are resolved using proof standards, such as preponderance of the evidence. Carneades also formalizes argumentation schemes. Schemes can be used to check whether a given argument instantiates the types of argument deemed normatively appropriate for the type of dialogue.

KEYWORDS: argument visualization, audience, computational models of argumentation, conductive argument, formal argumentation systems, modelling real arguments, premise acceptability, proof standards, relevance, sufficiency

1. INTRODUCTION

To attempt a formalization of informal logic, we need to decide what requirements something has to meet to be an informal logic. We take the following ten characteristics of informal logic as our guide. (1) Informal logic recognizes the linked-convergent distinction, (2) serial arguments and (3) divergent arguments. Informal logic includes three postulates of good argument in the RSA triangle: (4) relevance, (5) premise acceptability and (6) sufficiency. (7) Informal logic has recognized the importance of pro-contra (conductive) arguments. (8) Informal logic is concerned with analyzing real arguments. Johnson (2006, p. 246) expressed this characteristic as follows: "[Informal logic] may be seen as a turn toward seeing *argument in a real-life setting* as opposed to the artificiality of the examples associated with formal deductive logic". There is also a ninth characteristic, (9) the appreciation of the importance of argument construction: "If one is to teach students about real arguments, then it is not enough to focus only on evaluation; one must include the task of argument construction - an emphasis taken from colleagues

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in rhetoric" Johnson (2006, p. 248). Argument construction was traditionally called the art of argument invention in rhetoric (Kienpointner, 1997). (10) There is also possibly a tenth characteristic, one that is very important for rhetoric, the notion of audience. Blair (2001, p. 366) stated that there is general agreement among argumentation scholars that argumentation is a complex social, speech activity involving more than one party, adding "One cannot argue without at least an imaginary audience or interlocutor". This tenth characteristic is not a problem for Carneades, since the Carneades system uses a formal audience model in its argument evaluation procedure.

There are many automated systems to assist with argument diagramming (Scheuer et al., 2010). Carneades, however is one of the few argument diagramming tools based on a formal, computational model of argument. Carneades is named after the Greek skeptical philosopher (Gordon & Walton, 2006) and is open source software, available for downloading at http://carneades.github.com/.

The word 'formal', as used in writings on logic and philosophy, can have seven different meanings. One of these meanings, distinguished by Barth & Krabbe (1982, pp. 14-15), refers to a simple, fundamental general term referring to a concept. For example, one might cite the term triangle, which in the Platonic philosophy refers to a general concept of triangularity that is common to all triangles. The second meaning is that of a well-formed formula, for example in a propositional or predicate logic. This meaning is syntactic in nature. The third meaning is that of a formal system, with a set of axioms and inference rules used to derive theorems from the axioms. The fourth meaning refers to formal logic, which is a species of formal system. A fifth meaning is that of a formal theory, that is, an axiomatization of a theory in a formal logic. A sixth meaning is that of a mathematical structure consisting of sets and operations on the sets. An example would be an algebraic structure. The seventh meaning is that if a formal procedure, for example the kinds of procedures used in court cases.

The point is worth emphasizing that there are formal systems other than calculi for classical logic, and that Carneades is a formal, computational model of argument. It is computational, because the model consists of mathematical structure whose operations are all computable. It is formal, because there is a formal calculus for computable functions (lambda calculus).

The rest of this paper presents Carneades in more detail and then shows how Carneades can be understood as a formalization of informal logic, realizing all of its leading characteristics.

2. THE CARNEADES ARUMENTATION SYSTEM

Carneades formalizes *argument graphs*, as bipartite, directed graphs, consisting of *argument nodes* linked to *statement* nodes. Argument nodes are of two types, pro and con. Carneades argument diagrams (or maps) visualize these argument graphs. Conceptually it is important to distinguish such visualizations from the underlying mathematical structure being visualized. Argument graphs can be visualized in different ways and levels of abstraction, for different purposes.

Argument graphs define the structure of arguments in a particular stage of dialogue as follows.

Definition (Argument Graph) An argument graph is a bipartite, directed, labeled graph, consisting of statement nodes and argument nodes connected by premise and conclusion edges. Formally, an argument graph is a structure $\langle S, A, P, C \rangle$, where:

- S is a set of *statement nodes*,
- A is a set of *argument nodes*,
- P is a set of *premises*, and
- C is a set of *conclusions*.

To see an example, look ahead to figure 3. The statement nodes are the rectangular boxes. The argument nodes are the two circles containing the plus signs. The two premises are the statements in the text boxes on the right. The conclusion is the statement that the death penalty is wrong.

Let L be a propositional *language*, consisting of a set of propositional letters. Each statement node in S is labeled with a propositional letter in the language L.

Each argument node in A is a structure $\langle s, d \rangle$, where

- s is a Boolean value which is true if the argument node is *strict* and false if it is *defeasible*.
- d is a Boolean value, representing the *direction* of the argument, which is true if the argument is *pro* its conclusion and false if it is *con* its conclusion.

The premises and conclusions of an argument graph represent the edges of the graph, connecting the statement and argument nodes. Each premise in P is a structure $\langle s, a, p \rangle$, where

1. $s \in S$,
2. $a \in A$,
3. p is a Boolean value denoting the *polarity* of the premise, i.e. positive or negative. If p is true, then the premise is positive, otherwise it is negative.

Each conclusion in C is a structure $\langle a, s \rangle$, where

1. $a \in A$, *and*
2. $s \in S$

Every argument node has exactly one conclusion. That is, for every argument $a \in A$ there exists exactly one $\langle a, \_ \rangle \in C$. An argument node may have zero or more premises. That is, it need not be the case that for every $a \in A$ there exists a premise $\langle \_, a, \_ \rangle \in P$.

Argument graphs are evaluated, relative to *audiences*, to determine the acceptability of statements in a stage (Gordon & Walton, 2009). Audiences are modeled as a set of assumptions and an assignment of weights to argument nodes. Where L is a propositional language as defined above, an audience is a structure <*assumptions*, *weight*>, where $assumptions \subseteq L$ is a consistent set of literals assumed to be acceptable by the audience and *weight* is a partial function mapping arguments to real numbers in the range 0.0...1.0, representing the relative weights assigned by the audience to the arguments (Gordon & Walton, 2011).

In (Gordon, Prakken, & Walton, 2007) the acceptability of statements was defined directly, via a set of mutually recursive functions, but only for acyclic argument graphs. Conflicts between pro and con arguments are resolved using proof standards, such as preponderance of the evidence and beyond reasonable doubt, inspired by the legal domain. More recently, we have found a way to evaluate cyclic argument graphs, in a way compatible with the semantics of the original system, via a mapping from argument graphs to Dung abstract argumentation frameworks (Dung, 1995), similar to the mapping of ASPIC+ (Prakken, 2010; Bin & Prakken, 2012).

Carneades also formalizes argumentation schemes. Schemes can be used to construct or reconstruct arguments, as well as to check whether arguments are "valid", i.e. whether they properly instantiate the types of argument deemed normatively appropriate for the type of dialogue.

In Carneades argument maps, statement nodes are shown as propositions in text boxes. Argument nodes are displayed as circles, with a + or – sign inside the circle, to distinguish pro and con arguments, respectively. Premises and conclusions are visualized as lines and arrows, respectively, connecting statement and argument nodes. For an example the reader can look ahead to figure 7, which represents three arguments leading to a conclusion. The top two arguments are pro arguments supporting the conclusion. The argument at the bottom is a con argument that gives a reason not to accept the conclusion.

Carneades is capable of representing instances of any kind of argumentation scheme, whether deductive, inductive or defeasible, such as argument from expert opinion. The conclusion of a defeasible argument is only presumptively true. Defeasible arguments can be defeated by counterarguments of various kinds. Carneades has mainly been tested on examples of legal argumentation, but it is open domain software, meaning that it can be applied in other contexts of use, including everyday argumentation.

3. SINGLE, LINKED, CONVERGENT, SERIAL AND DIVERGENT ARGUMENTS

The first step in understanding an argument diagramming system is to see how it represents linked and convergent arguments. A linked argument is one where the two (or more) premises go together to support the conclusion. A convergent argument is one where each premise (or group of premises) function together to support the conclusion.

As types of structures that appear in argument diagrams, informal logic recognizes five kinds of arguments, single, linked, convergent, serial and divergent.

In the simplest kind of case, called the single argument, there is only one premise and one conclusion (Walton, 1996, p. 84). The following example of a single argument is cited in (Walton, 1996, p. 84): Webb was promoted to vice president, therefore she will move to Pittsburgh. How this example is represented by Carneades is shown in figure 1, where the plus symbol in the argument node indicates that this is a pro argument. Carneades uses a minus sign in the argument node to indicate a con argument.

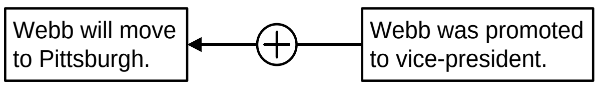

Figure 1: Single Argument in Carneades

A linked argument is an argument that has more than one premise, and its premises function together to give support to the conclusion (Walton, 1996, p. 85). According to (Copi & Cohen, 1990, p. 20) in a linked argument with two premises, each premise supports the conclusion through the mediation of the other so that neither supports the conclusion independently. One of the examples given in (Walton, 1996, p. 87) is an instance of practical reasoning: my goal is to get to Leiden, taking the Maaldrift is the way to get to Leiden, therefore I should take the Maaldrift.

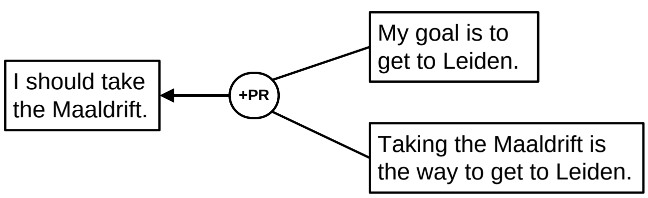

Figure 2: Linked Argument in Carneades

The argumentation scheme for practical reasoning is represented in the node by the **+**PR notation, where the plus sign indicates that it used as a pro argument. The practical reasoning scheme (in its bare-bones form) represents the following form of argument: I (an agent) have a goal *G*; carrying out action *A* is the way to obtain *G*; therefore I should carry out *A*.

In a convergent argument each premise gives independent support to the conclusion. An example (paraphrased from Copi & Cohen, 1990, p. 22) has the conclusion that the death penalty is wrong. The two premises given to support this conclusion are (1) there is not enough evidence to show that the death penalty is a deterrent and (2) there are better and more effective ways to deal with violent crime.

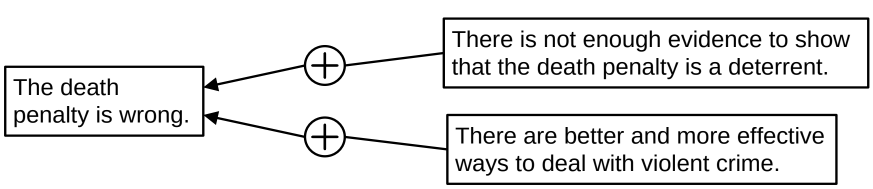

Figure 3: Convergent Argument in Carneades

As indicated in figure 3, convergent arguments are represented using multiple argument nodes, instead of using a bracketing line to join the premises together and then drawing the arrow from the bracketing line to the conclusion.

In a serial argument, often called a chain argument, the conclusion of one argument also functions as a premise in a second argument, and so forth, forming a chain of arguments. Typical Carneades argument maps display lots of chained arguments, as the example (from Walton, 2013) drawn by the Carneades visualization tool in figure 4 shows.

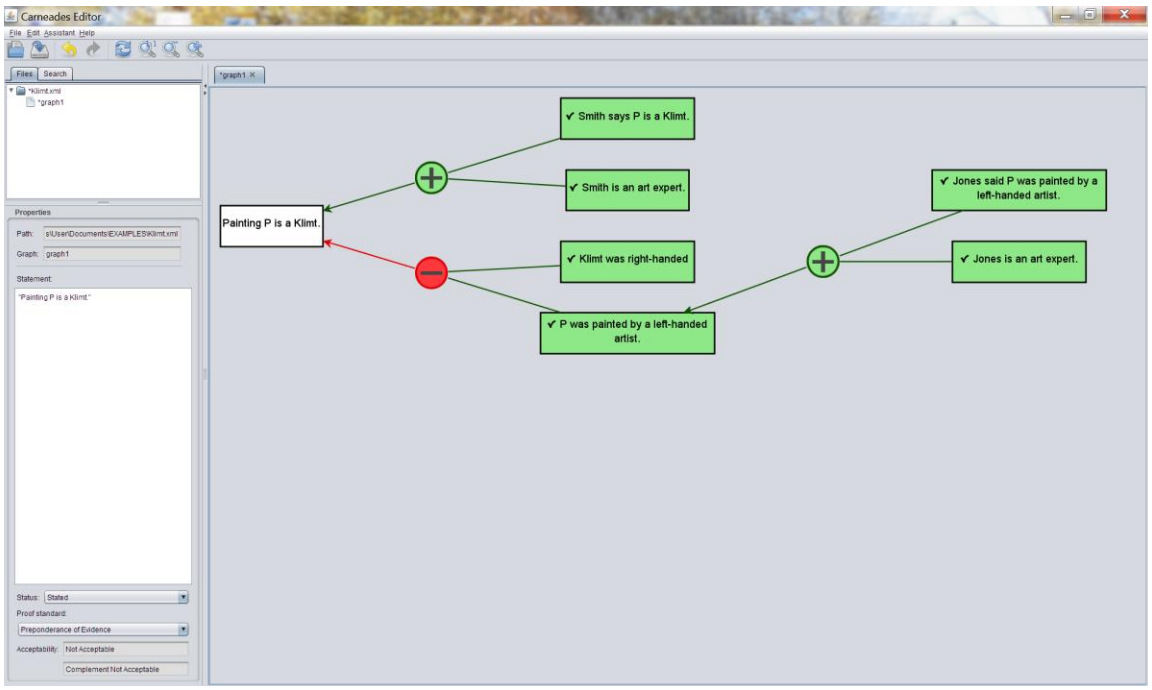

Figure 4: Screen Shot Showing an Argument Map with a Chained Argumentation Structure

This map includes an example of a con argument, indicated by the minus sign in the node at the bottom left. It also shows a chained argument. The linked argument at the right, an argument from expert opinion, leads to the conclusion that the portrait showed evidence of being drawn by a left handed artist. This proposition, in turn, serves as a premise in the linked con argument rebuttting the conclusion that painting P is a Klimt. Note that although argumentation schemes are not displayed in figure 4, they are represented in the underlying data model of the argument graph.

Figure 4 illustrates an argument graph that has been evaluated by the computational model. Statement and argument nodes are evaluated to be one of three values: *in*, *out*, or *undecided* . In argument maps, *in* nodes are shown filled with green color, *out* nodes with red color and *undecided* nodes with white color. Redundantly, to assist colorblind readers and enable black and white printing, *in* statement nodes also contain a ✔ mark, and *out* statement nodes an ✘ mark. Statements which have been accepted or rejected by the audience are in or out, respectively. The values of the remaining statement nodes are computed using proof standards and the weights assigned by the audience to the argument nodes.

A divergent argument (Walton, 1996, p. 91) is one in which two separate conclusions are each supported by the same premise. The following example from (Walton, 1996, 91) was originally taken from a Sherlock Holmes story. Smith is not the murderer, therefore (1) Robinson had nothing to do with the crime, and (2) Lady Gregg's display of grief was merely a tactic to cover up the finding of the revolver. Figure 5 shows how divergent arguments are modeled in Carneades.

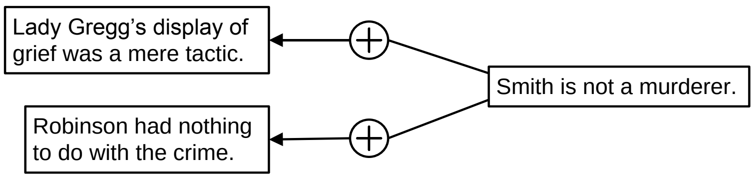

Figure 5: Carneades Argument Map of a Divergent Argument

In Carneades, premises and conclusions are *relations* between argument nodes and statement nodes. The same statement node can be a premise or conclusion of more than one argument node. Figures 3 and 5 provide illustrations. In Figure 3, the statement node for "The death penalty is wrong." is a conclusion of two argument nodes, with different premises. In Figure 5, the statement node for "Smith is not a murderer" is a premise of two different argument nodes, with different conclusions.

4. THE RSA TRIANGLE

Blair (2012, p. 87) wrote that when he and Ralph Johnson first wrote their textbook *Logical Self-defense* (first edition, 1977), they used the relevance sufficiency acceptability (RSA) triangle to determine whether an argument is a good one. According to the RSA principle, an argument is a good one if its grounds (or premises) singly or in combination meet three criteria. First, the argument needs to be relevant as a support for the conclusion. Second the premises have to be individually acceptable. Third, taken together the premises have to be sufficient to support the claim that is the conclusion of the argument. Blair (2012, p. 88) wrote that he and Johnson had the RSA criteria in mind as a replacement for what he called the traditional soundness criterion, which maintains that a good argument is a sound argument, and a sound argument is one that is deductively valid and has true premises.

5. ACCEPTABILITY

A simple example of how the evaluation procedure will work is shown in figure 6.

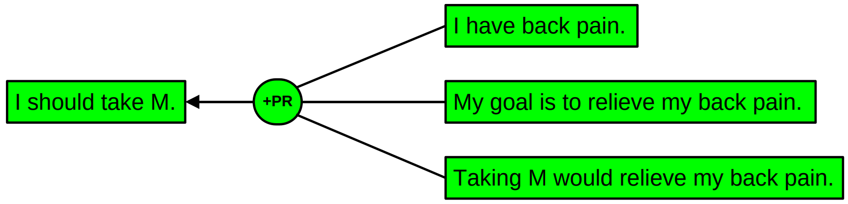

Figure 6: Proving the Conclusion by an Argument with All Premises Accepted

In this example, all the premises have been accepted by the audience and are thus *in*, as indicated by their appearing in the three darkened boxes on the right. The argument node containing the scheme for practical reasoning is also *in,* since all of its premises are *in*. Finally, the conclusion of the argument is *in*, because it is supported by an *in* pro argument and has no con arguments. The values (*in*, *out*, *undecided*) of the nodes in the argument graph are computed by the model.

6. SUFFICIENCY

Carneades is built around the idea of modeling sufficiency by using proof standards to aggregate pro and con arguments (Gordon & Walton, 2009). The conclusion of an argument is *in* (acceptable) if has been accepted by the audience or it satisfies the proof standard appropriate for the type of dialogue. Proof standards have a legal flavour, and the notions of proof standards and burdens of proof modeled in Carneades are motivated by our interest in legal applications. Several legal standards of proof exist, for example the preponderance of the evidence standard, also known as the balance of probabilities, the standard applicable in civil cases. The preponderance standard is meet by the proposition at issue if its pro arguments are stronger than its con arguments, no matter how much stronger they may be. The beyond reasonable doubt standard, the highest standard used in Anglo-American jurisprudence, and the standard applicable in criminal law, requires that the arguments supporting the claim must not be amenable to any opposing arguments from critical questions that can leave any doubt open on whether the claim is acceptable. This standard does not require a proof to show that a claim is true with absolute certainty. It is not a standard of beyond all doubt. It only needs to be strong enough to overcome a reasonable doubt that can be raised by arguments or questions put forward by the defense. The clear and convincing evidence standard, lying between the other two standards, is higher than the preponderance of the evidence standard but not as high as the beyond reasonable doubt standard. The substantial evidence standard requires that there are at least some reasonably strong arguments supporting the claim, in contrast to the scintilla of evidence standard, which requires only the smallest bit of evidence to have been brought forward by supporting arguments. These are just some examples of standards of evidence that are applicable in legal argumentation. The kinds of standards of evidence that might be applicable in everyday conversational arguments might not necessarily be perfectly coextensive with these standards. The default proof standard in Carneades is preponderance of the evidence, but can be changed by the user. The menu for changing the proof standard is visible at the bottom on the left in figure 4, showing the preponderance of evidence standard.

7. ARGUMENT CONSTRUCTION AND RELEVANCE OF ARGUMENTATION

Ballnat and Gordon (2010) provided a method of argument construction for Carneades, and Walton and Gordon (2012) have shown how the method can be applied to arguments of the kind that are of central interest for informal logic. To apply the method, the arguer needs to build his argument with the goal of getting the audience to accept some designated proposition that represents his thesis to be proved by basing his arguments on premises that his audience either accepts or can be led to accept by argumentation. If the audience accepts the premises, and if the argument is structurally correct by application of argumentation schemes, the audience will also need to accept the conclusion, or give arguments to show why it should not. To use the system, an arguer provides input on which premises the audience has accepted or not. Then it searches for a path leading from these premises (along with others) to the ultimate *probandum*. When it finds such a path, it tells the user which premises remain to be accepted. If it finds no such path, it gives advice on what positions could be useful to work towards finding a path.

Relevance of arguments has not yet been formally modeled in Carneades, but here we can briefly outline how this research project could plausibly be carried out, based on some previous work in the informal logic area. According to the analysis of relevance in argument given in (Walton, 2004), relevance needs to be defined and evaluated in a tree structure comparable to argument graphs in Carneades. There needs to be a central claim, often called an ultimate *probandum* in law, at the root of the tree. This framework follows the classical stasis theory well known in rhetoric (Hohmann, 1989; Tindale, 1999). Let AG be an argument graph containing a statement node, C, for the claim. We conjecture that an argument node, A, in AG is *relevant* to C if and only if there is a path from A to C in AG. Many examples of relevance, both in legal and ordinary arguments, are provided in (Walton, 2004). But of course there are other theories of relevance as well.

Our proposed model of relevance, determined by the existence of a path between the argument and claim in an argument graph, seems plausible to us but remains a project for future work.

8. CONDUCTIVE ARGUMENTS

We take conductive arguments to be the same as pro-contra arguments. Whatever term you choose, the characteristic of them as a class is that they need to be evaluated by taking into account both the arguments for (pro) some contested claim as well as the (contra) arguments against it, and weigh the one side against the other. The term 'conductive argument' is taken to have been coined by Wellman (1971), but actually the way the word is used currently in informal logic is different from the narrower meaning of it given by Wellman. Wellman defined conductive reasoning as meeting four requirements (1971, p. 52). (1) It is about a conclusion in some individual case. (2) It is drawn inconclusively. (3) It is drawn from one or more premises about the same case. (4) It is drawn without appeal to other cases. Amplifying the fourth point tells us as well that the most striking feature of all the examples of conductive reasoning he has given is that they all deal with particular cases. This definition clearly excludes arguments from analogy as fitting under the conductive category, since arguments from analogy compare two different cases. However, this restriction is widely ignored in current discussions of conductive argument. Argument from analogy is a very important kind of argument for informal logic, on our view. Much then depends on whether we stay with Wellman's meaning of the term or use it a broader way to refer to all pro-contra argumentation. This broader way does not exclude deductive arguments. A deductive argument rebuts any opposing defeasible argument. Opposing pro and con deductive arguments are also possible, but cannot be *in* simultaneously unless the statements accepted by the audience are inconsistent.

Wellman tells us that there are three patterns of conductive reasoning. The first is one where a single reason is given for the conclusion. He cited this example: "You ought to help him for he has been very kind to you" (1971, p. 55). This would be the single type of argument, of the four types classified above. The second one is where several reasons are given to support the conclusion. He cites this example: "You ought to take your son to the movie because you promised, and you have nothing better to do this afternoon" (1971, p. 56). This would be a convergent argument. The third one draws the conclusion from both positive and negative considerations. He cites this example: "Although your lawn needs cutting, you want to take your son to the movies because the picture is ideal for children and will be gone by tomorrow" (1971, p. 57). The third pattern shows the paradigm pro-contra feature of conductive arguments.

The last example can also be classified as a convergent argument, but has an additional feature of interest. It is associated with the "balancing" notion of weighing the arguments on both sides of a disputed issue. This notion is one that many in the informal logic community have found so appealing while others dismiss is it as metaphorical (Blair & Johnson, 2011). This balance notion of deciding an issue by weighing one side against the other has also been found highly appealing in law, but there too, others have strongly criticized it as an inadequate substitute for deciding cases on the legal rules and the facts of a case (McFadden, 1988).

Either of these arguments can be modeled by Carneades, and that may remove some of the doubts about pro-contra argument on the ground that they are merely metaphorical. Carneades models it using the pro-contra feature, but in a different way than the arguments that McFadden objected to. He objected to it as a balance of interests, or as a balancing of factors on either side of a disputed issue. But Carneades models it as a balance between opposed arguments. Carneades can map the lawn example as shown in figure 7.

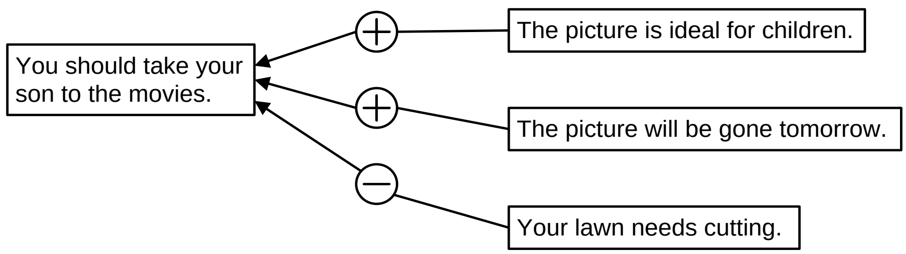

Figure 7: Carneades Argument Map of Wellman's Lawn Example

As shown in figure 7, the two pro arguments are "balanced" by the con argument, meaning that all three arguments are "good" arguments that carry some evidential weight even though none of them individually, nor any subset of them, is decisive in proving or disproving the conclusion. Even though there are two pro arguments against one contra argument, the number of arguments is not the deciding factor. What is the deciding factor is the audience. Let us presume the audience has accepted all three of the premises. Should the conclusion be acceptable (in) or not? Even though there are two pro arguments against one contra argument, the number of arguments is not the deciding factor. What is the deciding factor is the audience. Let us presume the audience has accepted all three of the premises. Let's assume that family values outweigh home care values. Then the two pro arguments, taken together, should prevail over the contra argument.

The proof standards we have modeled thus far in Carneades do not compare the set of pro arguments against the set of con arguments, but rather only compare each pro argument against each con argument. Summing the weights of arguments to check if the sum of the weights of the pro arguments outweigh the sum of the weights of the con arguments only makes sense if the arguments are independent, to avoid double counting. Carneades can be easily extended with further proof standards for comparing sets of pro and con arguments, but users would need to take responsibility to assure that these proof standards are used only when the arguments are independent. These issues are discussed more thoroughly in (Gordon & Walton, 2009).

More can be said about how to model this case. For example we could put in an enthymeme stating that lawn-cutting would leave no time for movie-going, and so forth. But basically Carneades can handle the pro-contra aspect, however you decide on the details or put in more information about what the propositions the audience accepts, how they weigh the arguments, and what proof standards are required.

There remain some differences of opinion within the informal logic community on what conductive argument is, and whether it is essential for informal logic. In answer to an email query of mine (Sept. 12, 2012), Ralph Johnson agreed with the definition of conductive argument as evaluating argumentation by taking into account the arguments for some contested claim as well as the arguments against it, and weighing the one side against the other. He also agreed that this type of argument was characteristic of informal logic. Tony Blair (also on Sept. 12, 2012) had a different approach. He specified a conductive argument as one where the arguer has decided (or already determined) that the arguments for the claim in question are good reasons for accepting it, and has also decided that the arguments against the claim in question are good reasons for rejecting it, but none on either side is decisive, and the strength of the combined arguments for accepting the claim outweighs the strength of the combined arguments for rejecting it. He remarked that he didn't see a commitment to conductive arguments as essential for informal logic. These matters might be clarified in Blair's OSSA paper on conductive argument.

9. CONCLUSION

In this paper we have formulated ten characteristics of informal logic, based on at least some of the literature that has attempted to set them out in an orderly and clear manner, and showed why they are identifiable with the discipline of informal logic as a school of thought and methodology for logic. We have made our case that the Carneades Argumentation System can model all of these characteristics within its formal structure. We do not claim that Carneades is the only formal argumentation system that can formalize informal logic, but we hope we have shown that it has some advantages for doing it in a useful way as applied to "real" arguments. In this paper we did not use Carneades to model the argumentation in a fairly large real case, but this has already done elsewhere, for example in (Walton, 2013).

The weakest link in our chain of argumentation is our hypothesis that Carneades can be used to model relevance. We admit this claim requires further research. According to Johnson (2009, p. 29) although there have been many attempts to develop a theory of relevance, none of them has been entirely successful. However, he also added (29) that sufficiency is the RSA criterion that has received the least attention, and that is where Carneades is the strongest. We claim that a strong point of Carneades is its use of proof standards to evaluate arguments. This move is unusual in logic and epistemology, fields that have long suffered from their failure to use proof burdens and standards to determine when defeasible argumentation can be closed off.

Carneades argument graphs are evaluated in stages of dialogue. The process of argumentation in dialogues is something else that in our opinion should be a characteristic of informal logic. However, there are some in the informal logic community, and very many in the formal logic and epistemology communities, who might disagree that evaluating an argument properly always requires reference to a conversational (dialogue) setting. Hence we have not included dialogues in this paper as an essential characteristic of informal logic.

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