Abstract

In this paper, we present a survey of the development of the technique of argument diagramming covering not only the fields in which it originated - informal logic, argumentation theory, evidence law and legal reasoning – but also more recent work in applying and developing it in computer science and artificial intelligence. Beginning with a simple example of an everyday argument, we present an analysis of it visualized as an argument diagram constructed using software tool. In the context of a brief history of diagramming, it is then shown how argument diagrams have been used to analyze and work with argumentation in law, philosophy and artificial intelligence.

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la n g u a g e p r o c e s s in g (R e e d a n d N o r m a n , 2 0 0 3 ) . A n d n o w t h e m o s t e xc itin g a d va n c e s i n t h e s tu d y o f c o m p ute r m o d e ls o f r e a s on i n g a n d c o m m u n ic a tio n l ike t h o s e i n m u lti- a g e nt s ys te m s a n d n a tu r a l d ia g r a m m in g (P r a k k e n , R e e d a n d W a lton , 2 0 0 3 ) . A r g u m e n ta tio n i s b e in g us e d m o r e a n d m o r e i n a s y n e r g y a s i t ha s b e g u n t o c o n c e n tr a te o n a s p e c ts o f l e g a l r e a s o ni n g r e la tin g t o a r g u m e n ta tio n a n d c la im t o b e in g t h e o r ig in a to r o f i t, o r a t l e a s t o f t h e i d e a b e h in d i t a s a m e th o d o f a r g u m e n t a n a ly s is .

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e v e n t h o u g h i t h a s o f te n b e e n a s c r ib e d t o t h e e a r ly t e xt b o o k o f B e a r d s le y (1 95 0) . I t w a s h igh ly d i a g r a m m in g d o e s n o t a p p e a r t o h a v e b e e n i n v e n te d w ith i n i n f o r m a l l o g ic a n d a r gu m e n ta tio n t h e o r y , so m e s ig n if ic a nt p r o bl e m s . O n e s u r p r is e f o r i n f o r m a l l o g ic i s t h a t t h e t e c h n iq u e o f a r g u m e n t t r ia l. L a w s e e m t o b e a n a tu r a l a pp lic a tio n f or d i a g r a m m in g , a lth o u g h i ts a d a p ta tio n t o l a w p o s e s s o m e s ig n if ic a n t p r o bl e m s . O n e s u r p r is e f o r i n f o r m a l l o g ic i s t h a t t h e t e c h n iq u e o f a r g u m e n t d i a g r a m m in g d o e s n o t a p p e a r t o h a v e b e e n i n v e n te d w i t h i n i n f o r m a l l o g ic a n d a r gu m e n ta tio n t h e o r y , s o m e s ig n if ic a n t p r o bl e m s . O n e s u r p r is e f o r i n f o r m a l l o g ic i s t h a t t h e t e c h n iq u e o f a r g u m e n t
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Both informal logic and legal argument are coming from artificial intelligence. Thus, the comparison of argument diagramming in the representation of legal reasoning in evidence law with the use and development of argument diagramming within informal logic is a project of immediate value to AI. This survey will present the exposition in four parts. The first part introduces the reader to diagramming by presenting a simple example of argument from everyday conversational reasoning and shows how the argument in it can be analyzed using a new software tool. It also shows briefly how diagramming has been applied to philosophical argument. The second section presents some examples of uses of diagramming in analyzing legal argument. The third part presents a brief history of the development of diagramming. Finally, the fourth section explores the approaches to argument diagramming within artificial intelligence, relating it to the philosophical and legal foundations.

2. The Technique of Argument Diagramming

The diagramming technique is used to represent the reasoning structure in a given argument found in a text of discourse. An argument diagram is made up of two basic components (Freeman, 1991). One component is a set of circled numbers arranged as points. Each number represents a proposition (premise or conclusion) in the argument being diagrammed. The other component is a set of lines or arrows joining the points. Each line (arrow) represents an inference. The whole network of points and lines represents a kind of overview of the reasoning in the given argument, showing the various premises and conclusions in the chain of reasoning. In (Walton, 1996, chapter 6), a reasoning structure is modeled as a directed graph, made up of three components: a set of propositions (points), a finite set of inference steps from one point to another, and a function that maps each step into an ordered pair of points.

2.1 An Example of a Diagramming Using Araucaria

Araucaria is a software tool for argument diagramming based on a representation format, the Argument Markup Language, formulated in XML (Reed and Rowe, 2004). The user begins the process of constructing a diagram by inserting the text of the argument into a text document and then inserting it into Araucaria. The text of discourse will then appear in the left box on the screen. The next step is to identify each statement that is a premise or a conclusion in the argument by highlighting it. As each statement is highlighted and the mouse is clicked while the cursor is on the right-hand box, a letter will appear in that box. The third step is to use the software to draw lines representing each inference from the letters representing premises to those representing conclusions.

By this means an argument diagram is constructed of the kind illustrated in the example presented below.

Consider the following example of a kind one might commonly find everyday conversational discourse.

The Milk Argument

The Araucaria software can be downloaded from Araucaria.computing.dundee.ac.uk
This is a typical everyday argument extracted from an advertisement, shown overleaf. Though there may be reasons for preferring a slightly different solution, one reasonable analysis yields the following Key List:

(A) (You should) Drink Milk

(B) Including enough milk in your reduced-calorie diet could provide the nutritional support you need for healthy, effective weight loss

(D) Emerging research suggests that drinking 3 glasses of milk daily when dieting may promote the loss of body fat while maintaining more muscle

(E) Calcium is part of the body’s natural system for burning fat

(F) Protein is essential for building and keeping muscle

(G) Milk is the only beverage that naturally provides the unique combination of calcium and protein for healthy, effective weight loss support

(H) No other single food item provides more calcium to America’s diet than milk

(I) (There is an extensive list of good things that milk can do for your body)

Now we need to analyze the argument, to figure out which statements are being used as premises to support the statements used as conclusions. The indicator words like ‘and’ are clues, but in many instances no such clue is explicitly given, and we have to make judgments, based on our understanding of what is being said. The key part of the argument is the support that B lends to A (this is emphasized by the graphic components and layout of the ad). B is supported by two distinct arguments, one from D, the other from a complex linked argument involving E, F, and G. G in turn is supported by the claim H. Finally, another almost-sure substitute argument for the conclusion comes from the claim I, and appears to be completely independent of the weight-loss argument. Note that where several premises are required together (as in E-F-G supporting B), the structure is referred to as “linked,” and where multiple premises act independently, the structure is referred to as “convergent.”
Many arguments of the kind found in everyday discourse are enthymemes, meaning they have premises or conclusions that were not explicitly stated in the given text of discourse. To get a better analysis, such missing statements often need to be provisionally inserted into the argument (subject to interpretation) as additional assumptions. To analyze the milk argument a bit further the following implicit premises have important roles and could be added.

(C) You want to lose weight.

(J) Providing a great deal of calcium is one of the things required to provide the appropriate combination of calcium and protein.

Once these implicit premises have been inserted, following the analysis indicated above, the Araucaria diagram for the milk argument can be seen below. Convergent arguments are represented as two separate arrows going into a conclusion one for each premise. Linked arguments are grouped together by a horizontal line that joins them. Enthymemes are marked by having their implicit premises shown in greyed boxes with dashed edges.
There are some other features on the diagram that also require explanation. First, there are shaded areas around the lines. These indicate argument schemes representing different types of arguments that function as warrants indicating how the premises are used to justify the conclusion. More about warrants and schemes is explained below. Second, various arrows are marked with words such as “probably.” These represent evaluations of how strong or weak each support is taken to be as a plausible argument. Evaluations can also be placed on individual claims, indicating the strength or...
weakness of specific assertions. Such evaluations are unrestricted, and can be qualitative or quantitative (that is, evaluations can be based on arbitrary "data dictionaries" (Krause et al., 1995)).

Finally, the diagram above represents the arguments in favour of conclusion A. If there were arguments against A, you could also represent these of the diagram using a Refutation. For example, you could add the following linked argument as a refutation of A.

The Milk Refutation Argument
Milk can contribute to high cholesterol, and eating foods high in cholesterol may not be part of a healthy diet.

The implicit conclusion of this argument is that milk may not be part of a healthy diet.

Key List for the Milk Refutation Argument
(L) Milk can contribute to high cholesterol.
(M) Eating foods high in cholesterol may not be part of a healthy diet.
(N) Milk may not be part of a healthy diet.

This refutation argument appears on the diagram on the left under N, which horizontally joined to A by a double arrow.
Figure 2. Araucaria diagram including the Milk Refutation Argument

We mention the refutation feature here because it is very important to represent legal argumentation of the kind found in a trial, as will be shown below.
Use of Diagramming to Analyze Philosophical Argumentation

The example of the ordinary argument from everyday conversational discourse is fairly simple, even though it represents many problematic aspects, like enthymemes and the distinction between linked and convergent arguments. As the reader can easily imagine, philosophical argumentation tends to be more difficult to analyze. It is often highly abstract and may contain all kinds of difficult terminology. Also, philosophers are typically highly disputatious, and often attack each other’s arguments, leading the arguee attacked to insist that his views were unfairly represented. Despite these difficulties, argument diagramming shows promise as an analytical tool for metaphilosophy, and not least for teaching critical thinking and philosophical methods to students.

Here we present one example of the effective use of argument diagramming as a tool for analysis in the history of philosophy and science. In his analysis of Galileo’s thought, Maurice Finocchiaro in 1980 introduced diagrams in order to better illustrate the reasoning and sequence of arguments used to reason to determine conclusions. The following example is from Finocchiaro’s Galileo and the Art of Reasoning.

Even if very schematic, this new approach to the study of philosophy may be an interesting application of the inference and argumentative theories.

(A1) Changes among terrestrial bodies enhance the perfection of the earth; for example, (A2) living organisms are more perfect than dead ones, and (A3) gardens more than deserts. But, (A4) heavenly changes would render heavenly bodies imperfect, since (A5) heavenly changes would be of no use or benefit to man, and hence (A6) they would be superfluous; therefore, (A7) unchangeable ability would enhance the perfection of heavenly bodies. Therefore, (A8) heavenly bodies are unchangeable. This is also shown by the fact that, since (A6) heavenly changes would be superfluous, and since (A9) nature does nothing in vain, (A10) there cannot be any heavenly changes.
Figure 3.

The two sections have demonstrated how argument diagramming works, and how it can be applied both to ordinary arguments, of the kind found in the popular media for example, and to philosophical arguments. Its utility is not a new phenomenon, and diagramming has a long history in theoretical approaches to reasoning and to more or less formal models of logic in particular.

4. The History of Diagramming in Logic

In this section we turn to the use of argument diagramming as it has evolved as a tool for the critical analysis of everyday argumentation through logic textbooks from the nineteenth and through the twentieth century. It began as a practical tool for use in teaching logic. Then in the second half of the twentieth century, it began to be developed theoretically into a more refined method.

4.1. Whatley
The first example of diagrams used to illustrate argumentative processes may be traced back to Richard Whately in 1859. Whately, an English logician and Archbishop of Dublin, in Appendix III of his textbook *Elements of Logic* (1836, pp. 420-430), entitled 'Praxis of Logical Analysis', described a method of argument analysis (pp. 421-423). He described it (p. 421) as a method of taking "any train of argument that may be presented to us", and reducing it to a form in which logical rules can be applied to it.

Basically, the method is first of all to try and figure out what the conclusion of the argument is supposed to be, and then trace the reasoning backwards, to try and see what grounds that assertion was made on (p. 421). Then once you have arrived at premises that represent this grounding, you can repeat the process, searching for further grounds for these premises (p. 422). The outcome is what Whately described as the construction of a "chain of arguments" (p. 422), a process he represented by a diagram. The diagram appears in a footnote on the same page. He wrote (p. 422) "Many students probably will find it very clear and convenient of exhibiting the logical analysis of a course of argument, to draw it out in the form of a Tree, or Logical Division; thus", and then he presented the following diagram.

**Figure 4.** Whately's diagramming (Whately, 1836, p. 422)

This diagram has many of the basic characteristics of the modern argument diagram. Statements are represented as nodes, joined by lines to make up a tree or graph structure. The structure represents a chain of argumentation with an ultimate conclusion at one end. Whately even labeled the statement at the root of the tree "Ultimate Conclusion". Each link or single step in the chain of argumentation takes the form of a conclusion backed up by premises at the next level.

Whately wrote that the Ultimate Conclusion is "proved by" two premises below it, grouped

[SUPPOSE admitted]

Z is X,
proven by
Y is X,
proven by
Z is Y,
proven by
A is Y,
[SUPPOSE admitted]
Z is A,
proven by &c.

the argument that and by the argument that

B is X,
&c.

Y is B,
&c.

C is X,
&c.

Y is C,
&c.
together. Then each premise is "proved by" a separate group of premises that appears below it. It is clear from Whately's representation of the diagram that the structure is expandable. Thus it is shown that the method so represented could be applied to longer and more complex examples of argument. Examining Whately's diagram carefully, along with his remarks about what it represents, it is evident that he has given a fairly clear and comprehensive presentation of the method of argument diagramming that pre-dates Wigmore's chart method. Thus a good case can be made, from what is known so far in the history of diagramming, for acknowledging Whately as the originator of the method of argument diagramming.

4.2 Beardsey

Whately represented an isolated case in the 19th century. After his first use of it, logic textbooks ignored argument diagramming until the 1950s. The reason is that the theory of argument in the first half of the century was taken wholly up by the predominant interest in formal logic. The first example of argument mapping we can find in this period is from Beardsey's Practical Logic. In the diagram below of an argument supporting the necessity of freedom in the arts, he divided the argumentative text into statements. He represented the statements as nodes, using circled numbers, and he represented the links between the premises and the conclusion as arrows joining the nodes. He drew what he defined as the "skeletal pattern" of the argument, representing its structure.

Beardsey identified different kinds of links proceeding from reason to conclusion: they may backtrack, shift gear in the middle, run in a circle, or go off in several directions (Beardsey, 1950, p. 18).

The following example represents a structure of a convergent argument (p. 21).

Figure 5. Beardsey's example analysis (Beardsey, 1950, p. 18)

"Though people who talk about the "social significance" of the arts don't like to admit it, music and painting are bound to suffer when they are turned into mere vehicles for propaganda." [Propaganda has to appeal to the crudest and more vulgar feelings: (for) look at the academic monstrousities produced by the official Nazi painters.] What is more important, art must be an end in itself for the artist, because the artist can do his best work only in an atmosphere of complete freedom because..."
Academic monstrities were produced by the official Nazis painters.

The artist can do his best work only in an atmosphere of complete freedom.

Propaganda has to appeal to the crudest and most vulgar feelings.

Art must be an end in itself for the artist.

Music and painting are bound to suffer when they are turned into mere instruments of propaganda.

Figure 6. Beardsley's convergent diagrammatic analysis.

This is an example of divergent argument (p. 19):

The station clock is slow

Something is wrong with the works

Many people will miss their train this morning

Figure 7. Beardsley's divergent diagrammatic analysis.

He defined a serial argument statement that is both conclusion and reason for a further conclusion (p. 19):

The room was sealed and empty when we entered

No one could have left it

The murderer was never in the room

Figure 8. Beardsley's serial diagrammatic analysis.

Finally, he gave an example of diagramming the fallacy of arguing in a circle: here is an example on the model of Beardsley (p. 389):
Beardley's fallacy diagram

Beardley diagrams are graphs meant to teach how to organize the reasons for a claim, by examining the different kinds of argument structures representing reasons supporting the claim as a conclusion.

He formulated some important general principles, such as the Rule of Grouping (if you have several reasons for a certain conclusion, they should be kept as close together as possible), or the Rule of Direction (if you have a serial argument, it should move in one direction, no matter which).

Beardley's use of diagrams, like the one above, was shown by him to be useful in aiding in the detection of fallacies like arguing in a circle (petitio principii).

We can observe, however, that arrows link reasons and conclusion: no support is given to the implication between them. There is no theory, in other words, of inference distinguished from logical deduction, the passage is always deemed not controversial and not subject to support and evaluation.

4.3 Toulmin

The main revolution in the theory of argument in the 1950s was carried out by Toulmin's "The Uses of Argument" in 1958. He can be considered the first in the theory of argument to take into consideration the defeasible generalization used as the step between the Ground (or Data) and the Conclusion of an argument. To analyze this step, Toulmin introduced the concept of warrant, which he saw as a hypothetical statement that can be defeated in some cases acting as a bridge or link between the two poles. The warrant can be considered as representing the reasons behind the inference, the backing that authorizes the link. He compared warrants with questions of law as opposed to questions of fact. For example, the fact that a man was born in Bermuda leads us to conclude that presumably he is British because there is a law that warrants that inference (Toulmin, 1958, p. 100). Warrants have different natures and support conclusions with different strengths.

Furthermore, he introduces the Qualifier representing the degree of force of the inferential link (necessarily, probably, etc.) and showing that the inference is defeasible because the link can fail to hold in some cases. Thus in his scheme other two factors are prominent: the Rebuttal, the exceptional
conditions that might defeat the conclusion, and the Backing, the assurance we have or we can provide to support our inferential passage.

The following diagram from Tolmin (1958, p. 111) (constructed using Araucaria) illustrates the general characteristics of his inferential theory:

Figure 10. Tolmin's diagram structure

The importance of Tolmin's approach lies in the function of the warrant. It provides the major term of the abbreviated syllogism of the form 'Petersen is Swede; No Swedes are Roman Catholic; So, certainly, Petersen is not a Roman Catholic.' He reduces what we define with enthymematic consequences to syllogisms with tentative conclusions. His interest is focused on the enthymematic relation, and he does not take for granted that the inferential link is necessary, as previous treatments tended to do.

Tolmin connected the notion of inference with the warrant, and with the warrant he reintroduced the concept of enthymeme. In his later work, An Introduction to Reasoning, he classified commonly used forms of argument, comparable to the ancient topos. The following example illustrates how he analyzed an enthymeme using what would now be called an argumentation scheme, the one called argument from analogy (Tolmin 1984, p. 218).
Figure 11.  Tolmin's analysis of an analogical argument.

Thus we can see how Tolmin was a man well ahead of his time. During the heyday of positivism, in which only deductive reasoning and inductive reasoning of the Bayesian kind were recognized as forming rational arguments of an objective kind that can command assent, Tolmin boldly set out a paradigm of rational argument that was defeasible, opening the way to the study of argument schemes that are not well cast into deductive or inductive form.

4.4 Scriven

In the representation of inference given by Scriven (1976), one of the most evident characteristics is the evaluation of the role of the premises in supporting the conclusion. He introduces the counterargument in his diagrams, taking into account what Tolmin defined as Rebuttal, and considering it to be a legitimate and important form of argument. Rebuttals are considered arguments leading to a conclusion contrary to the main one. They are what we called refutations, as illustrated above in Araucaria and, as noted there, they are especially important in legal argumentation. The following example shows Scriven's representation of the rebuttal as an independent and contrary line of argument. In the sequence of dialogue, an argument is presented for the conclusion "we should vote for a non-Democrat (a Republican) for President in 1976." Against this position (called NON-D), the statement W "The unfortunate affair of Watergate shows the Republicans (non-Democrats) distinctly inferior to the Democrats in their ability to govern" is advanced, leading to conclusion D "We should vote for a Democrat," opposite to NON-D. The development of this argument in a counterargument is provided by three additional premises, the disjunctive proposition E "Either
The Democrats or Republicans will win, the negative implicit conclusion of D, NON-B. "The Democrats are unlikely to be any better with Watergate-type occurrences," and the final argument V. "Voting Republican should not rule out…" The whole sequence of counterarguments can be represented in a diagram, showing the argumentative structure of the rebuttal (Freeman, 1991, p. 169, 170).

Figure 12. Scribe's diagrammatic account of rebutting. They are divided in premises pro and contra (p. 47).

Figure 13. Scribe's premises pro and contra. He also indicated missing premises in his graphs, designed with an alphabetical letter instead of a number (p. 48, 56).
Figure 14. Scriver's account of missing premises

The diagrams become more complex when the conclusion is supported by several premises, which in turn are backed by other assumptions. They constitute, in such cases, an argument network. In the following example (p. 90), the conclusion, 1, is warranted by elements 8, 9 and 2. The latter is the conclusion of four branches of argument, proceeding from premises 3, 4, 5, 6, 7 respectively. The direction of the inferences is supplied, in his diagrams, with the numerical order of the sequences.

Figure 15. More complex argument diagrams in Scriver's approach

4.5 Freeman

One of the most innovative features Freeman introduced in his diagrams is the indication of supposition. A premise, according to Freeman, can be granted only provisionally, for the sake of the argument. Obviously, the status of conclusions following from them must be taken to be different from the status of the ones proceeding from assertions. Such premises are only provisional assumptions. The arguer accepts them tentatively in order to allow the dialogue to continue, and the conclusion can be considered only hypothetical, depending on the stated assumptions. In the following example (Freeman, 1991, p. 214), the box represents the reasoning based on the suppositions proceeding from 2, leading to the final hypothetical conclusion 1.
Figure 16. Freeman's approach to diagramming supposition

An important feature appears prominently in Freeman diagrams: the distinction between linked and convergent arguments cited above. He recognized two different structures for arguments, one as constituting independent units supporting the conclusion and the other as arguments linked forming one unit. He defined the first one as convergent arguments and the second as linked. For example, the syllogistic premises 'All humans are mortal' and 'Socrates is human', constitute one argumentative unit supporting the conclusion 'Socrates is mortal'. The model of diagram representing this linked type of argument is shown in the right-hand figure below (Freeman, 1991, p. 104).

On the other hand, the conclusion 'Socrates was a great man' is supported independently by the premises 'In his life he pondered the central question of meaning and value' and 'In his death he showed an exemplary courage'. The two lines of supporting the conclusion are separate, and thus the argument is classified as convergent. The model of this kind of arguments is graphically displayed in the left-hand figure below (Freeman 1991, p. 105).

The importance of this account lies in its theoretical explanation. The different role of the premises is connected with the application of the notion of relevance to argument evaluation: "if a premise is not relevant to the conclusion, then its being true does not increase the likelihood of the conclusion."
(Freeman, 1991, p. 105). In the case of a linked argument, the irrelevance of one or more premises is avoided only if they are connected with the others. For instance, in case of the syllogistic premises in the example above, 'Socrates is human' is irrelevant to the claim 'Socrates is mortal' because it does not support the conclusion at all, if taken as an independent argument. Only in connection with the premise 'All humans are mortal' does it become relevant, increasing the plausibility of the final claim. It is the link, the union of the premises that contribute to the conclusion. Freeman did not attempt to give a precise account of the calculus of probability or plausibility that can used to evaluate argumentation based on such links.

But he did show how, in convergent arguments, the standpoint is independently relevant on the basis that each of them adds separate weight to the claim. The probability that they convey is the sum of their own probability. The conclusion is as probable as the sum of their probability.

In Figure 18 (Freeman, 1991, p. 127) he introduced the concept of modality of the argument in the diagram, represented by the label M in a square box. It indicates the strength of the conclusion, that is, how strongly the premises support the conclusion. This concept of modality is extremely interesting, because it is not a value subject to a calculus of possibilities. Thus Freeman showed the way to open up new avenues for approaching the problem of evaluation.
5.  Legal Argumentation

This section offers a glimpse into the application of argument diagramming to legal discourse. There may be many such applications, but the work of the evidence theorist John H. Wigmore showed how the technique can be used in marshaling evidence in a case at trial.

5.1. Wigmore

If Whately is considered the pioneer of diagramming arguments in the logical field, Wigmore was the first to visually represent, in 1917, complex diagrams to represent proof-hypothesis in legal matters. His schemes were disregarded after his death, but his idea of organizing evidential arguments has recently been reconsidered and developed by David Schum, Terence Anderson and William Twin (Tillers, 2004). He can be regarded as the initiator of the current study of using diagramming to map facts and inferential links in a body of evidence in a case at trial in law.

Y died, being apparently in health, within three hours after the drink of whisky.

Y's Wife and the Northingtons witness to Y's death.

Y might have died by colic from which he had often suffered.

Colic would not have had symptoms like the leg cramps and teeth-clenching; only strychnine could produce these.

Y's wife and the Northingtons witness to Y's cramps and teeth-clenching.

Expert witness to significance of symptoms.

No testimony as to strychnine traces in the body by post-mortem.

An non-witness to his former attack.

Y might have died from the former injury to his side.

An non-witness to that injury.

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**ISSUE: DID Y DIE OF POISON?**

- **Negative Explanatory Probandum**
- **Prosecution Corroborative Probandum**
- **Probandum**
- **Interim Probandum**
- **Prosecution Affirmative Evidence**
- **Evidence**
- **Provisional Probative Force**
- **Strong Probative Force**
- **Corroborative Ancillary Evidence**
- **Probative Force**
regarding the role of inferences, is the concept of generalization and of ancillary evidence supporting based on Bayesian probabilities and on Toullmin's analysis of inferences. The most important feature, 5.2 Schu (1994, p. 191) modern theories this notion has developed, through the theories of probabilities and inferences, in ones furnishing proof for the explanation of the death of Moses Young. Ancillary evidence, affect the probability of the evidence. In Wigmore's example, items of ancillary evidence are the other kinds of affirmative evidence (squares). These proofs are called "ancillary"—that is, they are of probabilities is only based on proofs (nodes), not on the strength of the inference. Consideration of the relationship evidence—conclusion. They do not need to be warranted: the calculus of probabilities. Arrows, in his diagrams, connect nodes (evidence), but not the links themselves. In conclusion, for this reason, is the result of a complex calculus of probabilities and factual conditionality of arguments. Arguments are related each other by dependence links, and between nodes, influencing each other's probabilities. Inference networks, introduced what now is being analyzed by the term "inference networks": nets of links complex (or cascade) inferences recognized (Tilhors, 2003, p. 37). Wigmore, by utilizing complex the 1960s were source uncertainty theories developed, and the importance of linked arguments and be acceptable as a conclusive proof. This conception, in Wigmore's time, was revolutionary. Only in with the hypothesis is constituted by a complex argumentation where facts are probandum.

Finally, Wigmore, in his diagrams, introduced triangles to indicate a form of evidence distinct from theory. It proceeds from the evidence to the hypothesis, the latter being proved or disproved by the evidence. The direction, consequently, is upward, from evidence to hypothesis (Tilhors, 2003, p. 32).

Another interesting feature of Wigmore diagrams is the notion of complex inference. The focus of Wigmore's interest is proving the validity of the hypothesis given the factual materialization of the hypothesis. If the hypothesis is correct, then the assumption is that the evidence must occur in the predicted way. This is an experimental view of hypothesis formation and materialization of the hypothesis. If the hypothesis is correct, then the assumption is that the evidence must be confirmed (Tilhors 2003, p. 32).
The passage from evidence to conclusion is defined as a "generalization." We can interpret generalizations as proper forms of warrants that in some cases fall under the main categories of argument schemes. Generalizations function in the same way as warrants in argumentation. They allow a conclusion to proceed from premises that function as evidence, and for this reason their function and nature cover the role of the ancient topos. Schum offers examples of maxims like "The events reported by police officers testifying under oath usually occurred" (Schum, 1994, p. 87). These kinds of principles are useful to understand Schum's original way of building diagrams. His interest is focused on the probability of the link between the nodes, and ancillary evidence acts like Toulmin's backing, i.e., it strengthens or weakens the inferential step. The following example (Schum, 1994, p. 154) clarifies the function of ancillary evidence. In this case, the inference from E to E is weakened by the ancillary evidence A3. The function of this kind of evidence is very close to the notion of critical questions in Walton's theory (for example, Walton, 1996, p. 51): they provide critical elements to evaluate the reliability of the proof. The conditions are indicated beside the line connecting the circles (evidence). For example, Mike's observational sensitivity is related to the conditions of evaluation of witness testimony. The black circle represents the directly relevant evidence, while the black squares represent the direct ancillary evidence.
In the following scheme (Schum, 1994, p. 157) showed three of the strategies to support the thesis: by providing support to the inferential link (generalization support), or to the passage from the testimony to the evidence (credibility support), or to strengthen the evidence with supplementary proofs (corroboration).

E*: Evidence from Mike that Joe's car was at the scene
H: Joe did it
E: Joe's car was at the scene
D: Joe was at the scene

Mike's Veracity
Mike's Objectivity
Mike's Observation
Sensitivity

E: Mike obtained sensory evidence
A1: Mike was not at the scene
A2: Mike hated Joe
A3: Mike has very poor eyesight

Evidence from Harry
Evidence from Tom
Evidence from Dick
Figure 21. Further features of Schum's approach.

From these diagrams, another important feature of Schum's graphs is illustrated: the inference networks. The pieces of evidence may depend on each other. They may, in other words, be connected forming dependencies networks. This notion became extremely important after the introduction of the probabilistic calculus based on the Bayesian approach.

6. Argument Diagrams in Artificial Intelligence

There is a natural relationship between arguments expressed in diagrams and knowledge in AI systems represented using an argumentation theoretical basis. This relationship is bidirectional. On one hand, existing argumentation theoretical structures in AI are often presented and explored using argument diagrams, with those diagrams acting as an abstraction mechanism. In this way, examples of propositional databases built with Dung-style semantics (Dung, 1995) are presented and investigated for properties such as circularity. For this sort of presentation, internal structures of arguments are relatively unimportant (and are sometimes simply conflated to triangles), while the attack relationship between propositions forms a central focus of both the theory and its diagrammatic exposition.

Similarly, Bayesian and rhetorical networks used in language generation (Grasso et al., 2000; Carena and Moore, 2001) are used to summarise the knowledge a system exploits in producing text.

On the other hand, diagrams are also used informally to visualise and explore problems of interrelated knowledge, with these diagrams informing and framing the subsequent development of theoretical and implemented machinery for handling such information. So for example, the multi-faceted arguments diagrammed idiocratically in (Crosswhite et al., 2003) lead to a unique form of implemented context-based argument representation.
There is thus a close tie between diagrammatic and computational representations of argument with the theoretical assumptions of each one framing and constraining development of the other. A good example is offered by comparing (Krause et al., 1996) with (Parsons and Jennings, 1996), both relatively early AI papers making use of argument. Despite common roots, in the former, there is a strong formal association with the Toulmin model, and in the latter a similarly strong association with the Beardsey type model (though this is not made explicit in that work). These different theoretical frameworks inevitably lead to alternative ways of explaining and developing the two models.

Perhaps one of the most influential theoretical frameworks is that of Pollock (2001). Pollock focused his interest on the phenomenon Toulmin defined as Rebuttal (Toulmin, 1958). Using tree diagrams to represent reasoning, a method often used in AI (Pearl, 1984), he analyzed how a conclusion can be defeated, weakened, or refuted by a counterargument. A counterargument can attack the argument to which it is aimed in two ways: it can refute the conclusion itself or it can attack the inferential link between the premises and the conclusion. The first kind of refutation is defined as a rebutting defeater. Its meaning is close to Toulmin’s Rebuttal. A given proposition $S$ concluded on the basis of a premise $R$ is rebutted when another proposition $Q$ is a reason for denying $S$. A rebutting defeater attacks the conclusion, whereas an undercutting defeater aims to undermine the inferential link between premises and conclusion. As his leading example, Pollock considers the case of an object $x$, looking red, illuminated by red lights. The inference is from the perception to the reality of the observed phenomenon: if the object looks red, it is red. The undercutting defeater intervenes by attacking the passage between perception and reality. However, this is not a rebuttal, because a red object illuminated by red lights looks red. It gives reasons, instead, for doubting that $x$ wouldn’t look red unless it were red: in other words, the premise guarantees the conclusion (Pollock, 2001, p. 3). He represents the undercutting defeaters as propositions leading to the formula $P \Box Q$, that is, $P$ does not guarantee for $Q$.

Such defeaters are defined (Pollock, 1995, p. 57) as Reliability Defeaters, for their action works against the reliability of a reason.

The different kinds of defeaters are shown in the following diagram. In the first figure, the conclusion $S$ is rebutted by proposition $Q$. In the second diagram, the conclusions following from $P$ and $R$ are opposite and equivalent: in this case they are both rebutted. The third case is an example of how undercutters work. As Pollock explains (2001, p. 7), $P = “Jones says Smith is unjustly worthy”, $R = “Smith says Jones is unjustly worthy”, $Q = “Smith is unjustly worthy”, $S = “Jones is unjustly worthy”.

The two arguments conflict with each other on the level of the reliability of the reasons. The argumentative reason to accept $Q$ or $S$ is reciprocally undermined.
Figure 22. Pollock diagrams

Another important topic raised by Pollock concerns the defeaters and the relationship between strength and rebuttal. A defeater, in order to rebut a conclusion, must be as strong as the argument supporting the original conclusion. In other words, its premises must be as justified (likely to win an argument) as the ones supporting the conclusion. If a defeater is not as strongly justified as its target, it cannot defeat it but only diminish it. In the diagrams, in these cases, the red arrow is not present, while the red character of the contrasting arguments remains to indicate the weakening (Pollock, 2001, p. 25).

Pollock’s theory has been influential in many implemented models of AI reasoning (see, e.g., (Cheinavare et al., 2000) for a thorough review), but reasoning is not the only use to which argument diagramming has been put in AI. One key area is “computer supported collaborative argumentation” (CSCA), in which the focus is upon developing tools that help people work together using computer infrastructure. (Kirschner et al., 2003) provide a good overview of the area. Conklin (2003) and Selvin (2003) both explore how QuestMap has been used not only in academic domains, but also for supporting commercial decision making. QuestMap takes a very broad approach, integrating materials often ignored by more traditional diagramming techniques (including background resources such as articles, spreadsheets, pictures and so on) and allowing exploration of a domain in an intuitive and fairly unstructured way.
Figure 23. Question Map

But perhaps the single most successful use of argument diagramming has been with AI tools in education, both in the teaching of critical thinking and argument skills themselves, and also as a means to teaching in other subject areas.

In the pedagogy of argument, there are a number of important examples of tools developed under the auspices of AI. First is the Araucaria tool introduced in the previous section. It has been deployed in several courses and universities where it has played a practical role in providing opportunities for examples, students' independent study and automated assessment. Further tools such as Athena (Rolff and Magnusson, 2002) follow a similar route, but investigation of the impact of Athena and Araucaria in the classroom is rather immature by comparison to the studies concerning a third tool, Reason! Able (Van Gelder, 2001). Reason! Able is designed specifically for pedagogic use (as opposed to Araucaria and Athena which are more orientated towards research), and empirical studies have shown that students taught argument skills using Reason! Able improve significantly faster and further than those taught using other, traditional techniques (Van Gelder and Rizzo, 2001). (A more detailed comparison of Athena, Araucaria, Reason! Able and several other packages in the context of teaching philosophy can be found in (Harrell, 2005)).
Argument diagrams have also been used for some time as a way of abstracting, summarising and presenting complex domains for pedagogical purposes, with Horn's vast argument maps one of the best examples (Horn, 2003): Figure 24. Horn's argument maps

It is perhaps unsurprising, therefore, that AI models of argument diagramming have also been put to work in a variety of educational domains. Belvedere (Pau locci et al., 1995) offers one of the earliest examples, with argument diagrams making concrete the abstract ideas of scientific theories. More recently, the large SCALE project (Hirsch et al., 2004) has investigated both diagrammatic and dialogic argumentation in high school classrooms. Law pedagogy, in particular, has been a fertile area of investigation. Aleven (2003) describes one of the most high-profile systems, CATO, a case-based reasoner that is designed to support law students as they explore cases. It organises on the basis of issues, and supports a variety of argument structures, but targets text rather than diagrams (interestingly, Aleven's presentation makes significant use of diagrams to explain his examples – e.g. Figs. 11 and 15 for example) – even though those diagrams are hand-rather than system-generated. Diagramming plays a much more central role in systems such as ArguMed (Verheij, 2005), where the focus is on diagramming dialectical argument. For Verheij, a range of diagrammatic conventions are required to uniquely represent each of: support, attack, assumptions,
isssues, defeat and specificity. This produces complex diagrams such as the following, after (Verheij, 2005: 69):

Figure 25. Verheij’s defeasible argument diagrams

One of the key foci of Verheij’s work is in capturing Pollock style undercut ters and subsequent defeat status in his diagrams (shown in the example above by dashed lines and crossed arrows), which makes the approach particularly useful for those AI models derived from Pollock’s theory.

7. Conclusions

Use of argument diagrams to aid in the identification and analysis of argumentation has now been well established, both as applied to everyday argumentation and in law. Increasingly, these same techniques are being deployed in artificial intelligence for the representation of knowledge and for reasoning.

The problem for the future for philosophical, legal and computational development of these techniques is how to evaluate the argument once the structure has been identified or represented in a diagram. Though automated techniques of defeasible reasoning of the sort reviewed by Chesn evar et al. (2000) are now maturing in AI, what is vital according to the argument approach is to look at each argument in a given chain of reasoning, and identify the form of the argument, or so-called argument scheme. Then you need to ask the critical questions matching that argument scheme. For example suppose the evidence is expert testimony, and the form of the argument is that of appeal to expert opinion. But these are defeasible arguments, as analyzed on the Toulmin model. They tend to be arguments that hold tentatively as acceptable, subject to critical questioning. Matching the argument from appeal to expert opinion, or any other defeasible argument scheme, there is a set of appropriate critical questions. Each of these questions needs to be considered, in finding the weakest part of the appeal to expert opinion, the aspect of the argument most open to critical doubt. These techniques should of course not replace those of Bayesian calculation, defeasible reasoning and other non-classical processing methods, but both practical diagramming and automated reasoning techniques derived from it need to be extended. Processing
Argumentation schemes represents a significant opportunity for developing more finely grained theories of argument, for enhancing legal process, and for increasing efficiency of computational systems.

In this paper, a comparison has been made between a technique for modeling reasoning as used in three different fields - informal logic (argumentation theory), AI and evidence law (legal reasoning). This comparison has produced some revelations that are quite startling for all three fields. One surprise for informal logic is that the technique of argument diagramming was not invented within recent research in informal logic and argumentation theory. It was highly developed well before that time, by the legal evidence theorist John H. Wigmore. But perhaps another surprise is that it was not invented by Wigmore, and was used by Whately, though not so well developed for a form. It may also be a surprise for legal evidence theorists that there is quite a widespread use of argument diagramming within informal logic, and quite a literature showing how the technique can be modeled by argument systems. Evidence theory, and the study of legal reasoning generally, can benefit from this literature. Although Wigmore did base his theory of evidence on leading writers of his time, argumentation theory was not on the scene yet, and Wigmore's diagram method did not have a theoretical backing and practical sophistication of the kind that has now been provided by the recent growth and advancement of argumentation theory. And finally, though AI is a much younger discipline, it is building models and tools for education, law, philosophy, science, engineering, e-government, and more, drawing on the full gamut of argument techniques developed in philosophy and law.

This paper has brought together these previously unrelated bodies of literature, with the hope of showing how each field can benefit from the other. In light of the recent lively and productive research in artificial intelligence in law that concentrates on aspects of legal reasoning relating to argumentation, and the increasing use of argumentation in computer models of reasoning and communication, it is high time that such beneficial interaction start to grow.

References


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