AVER: Argument visualization for evidential reasoning[1]

Susan W. VAN DEN BRAAK [a,2], Gerard A.W. VREESWIJK [a]
[a] *Department of Information and Computing Sciences, Utrecht University, the Netherlands*

Abstract. This paper reports on the ongoing development of a collaborative, web-based application for argument visualization named *AVER* (Argument Visualization for Evidential Reasoning). It is targeted at police officers who may use it to express their reasoning about a case based on evidence. *AVER* provides an interface which supports the construction and visualization of argument graphs and handles more advanced argumentation concepts such as schemes. Further, it is based on a known argument ontology and has a solid theoretical underpinning in formal theories of argumentation.

Keywords. argumentation software, argument visualization, evidential reasoning, crime investigation, argumentation schemes

1. Introduction

Recently, there has been a growing interest in software support tools for argument diagramming that enable their users to construct and visualize arguments in graphs of nodes and links. Such tools are designed to make this laborious task easier and are claimed to be useful to their users as they are guiding them when constructing the diagrammatic representation of an argument. Examples exist in the domain of argument analysis (e.g. Araucaria [1]) and computer-supported argumentation in teaching and learning (e.g. Belvedere [2], and Reason!Able [3]). However, previous research in this field has relatively neglected an area in which such systems may be of great potential use, namely, the law and more specifically crime investigations. Exceptions are ProSupport [4] and ArguMed [5] but these have their own shortcomings.

This paper presents a prototype of a web-based system *AVER* for collaboratively constructing and visualizing arguments that will be applied to the domain of crime investigations. *AVER* draws on general ideas from visualizing argumentation and the notion of argumentation schemes [6,7]. Moreover, its conceptual framework is to a large extent based on the Argument Interchange Format core ontology [8].

[1]Full-colored version of the JURIX 2006 paper
[2]Corresponding Author: Susan van den Braak; E-mail: Susanb@cs.uu.nl.

2. Application context

AVER is developed for crime investigators who may use it to visualize their reasoning about evidence. The tool possesses structuring features that allow investigators to maintain an overview of the evidence collected. We hypothesize that investigators will not only benefit from these features, but that they will also be forced to make their argumentative steps more explicit by using the charting method in combination with argumentation schemes. Thus, it becomes easier to pinpoint possible gaps and inconsistencies, and to identify strong and weak points in their arguments [9,10].

3. System description

AVER is an analytic tool that enables users to investigate cases by inputting claims based on evidence from source documents and by relating these claims by explicit inferential connections.

3.1. System interface

AVER is implemented as a web front-end to an SQL database. To assure support for multiple, simultaneous users, single users may work on more than one case and a single case may be edited by more than one user. If a user logs in, he will be presented with an overview of all available cases. He may then create a new case record or select an existing case. Each case is presented in a split screen where the upper half displays a global overview of the case and the lower half displays the attributes of a node that is selected by the user in the upper half of the screen. New nodes can be added to the screen by clicking the desired node type. Two nodes can be connected by drawing lines from node to node. If a node is clicked in the upper half of the screen, its attributes can be edited in the lower half of the screen. Thus, a case is built.

A case can be represented visually through multiple views, such as a directed graph view, a table view, a summary view, an argument summary view, a report view, and a linear view. The report view is a verbal and linear dump of the case, and can be used as an official print-out for off-line consultation.

3.2. Structure

Each case is a collection of nodes and documents. Documents are representations of uploaded files, with facilities to annotate and quote them. Nodes represent claims about a case that may be connected by directed links to represent inferential relations between claims. To link claims to the real world, some of them are coupled to external source documents from which text is selected. There are different types of nodes that may have different polarities, as described in Table 1.

AVER contains three node types, namely, data nodes, inference nodes, and scheme nodes. Data nodes, depicted as boxes in Figure 1, may be used to represent facts, quotes, hypotheses and other claims. Inference nodes, depicted as small ellipses, represent inferential links between different data nodes and between data nodes and other inference nodes. Finally, scheme nodes represent justifications for inference nodes that are not supported by other inferences. They are depicted as blue ellipses.

Table 1. Node types

Type / Polarity	***Data*** **(box)**	***Inference*** **(small ellipse)**	***Scheme*** **(ellipse)**
Positive (green)	Claim PRO main thesis	Inference from positive nodes	-
Negative (red)	Claim CON main thesis	Inference from negative nodes	-
Neutral (blue)	Quote from source document	-	Inference template

Nodes can belong to three mutually exclusive classes of interest or *polarities*, namely, positive, negative and neutral. Positive nodes (colored green) either directly or indirectly support the main claim, or oppose negative nodes. For example, in Figure 1 the node "A saw P took X" supports the claim that "P took X", while "P is a party concerned" opposes the claim from witness P that "Q sold X to P". Negative nodes (colored red) oppose positive nodes or support other negative nodes. For example, the claim that "Q sold X to P" attacks the claim that "Q owns X" and thus the main conclusion that "P stole X from Q". Finally, neutral nodes are colored blue. If an inference node supports a data node of an opposite polarity, it is called a rebutter (e.g. node "A is short-sighted" in Figure 1). If an inference node supports another inference node of an opposite polarity, is called an undercutter (e.g. "Q sold X to P").

Blue data nodes contain quotes from external (hence unmodifiable) source documents. Such nodes are also referred to as *quotation nodes*. Green or red data nodes represent claims about a case and may be filled with arbitrary text. These are also referred to as *interpretation nodes*, because such nodes are used to interpret the case. Large blue ellipses represent schemes nodes that represent uncontestable schemes of inference. Small red or green ellipses represent inference nodes. These nodes are either green or red, because inference nodes are always used to connect non-neutral nodes.

3.3. Example case

As an example, we discuss a case of theft. In order not to complicate the example too much, all cited code sections are fictitious.

Suppose a case editor E decides to investigate the tenability of the claim "P stole X from Q". This initial proposition is then the main claim. Suppose, for the sake of the example, that one possibility to support the main claim is through Section 310 from the Penal code which says that in order to consider something as stolen at a specific point in time, say $T2$, it should be argued that (1) P took X, (2) Q did not permit P to take X, and (3) that Q owned X at $T2$. At this point E selects the inference scheme "Penal code Section 310" from the scheme repository of *AVER*. As a result, four nodes below the main claim appear, that is, three data nodes supporting the main claim and one scheme node appear below the main. These four nodes are connected to the main claim through an inference node (the small green ellipse). This inference node indicates that Section 310 from the Penal code appears to hold for this particular case. The possibility to expand existing data nodes by scheme instantiation is a unique feature of *AVER*. Araucaria also incorporates schemes but in a different manner.

Let us further suppose that E (and perhaps co-editors of the case) take sub-claims (2) and (3) for granted but wishes to investigate sub-claim (1) further. One way to underpin the claim "P took X" is to use a witness testimony in which this is declared. E may now choose to start with a quote from the witness testimony taken from witness A, who declared that he (or she) saw P took X at $T2$. E may use this to work bottom-up to subclaim (1). Alternatively, E may choose to seek support from sub-claim (1) by creating an interpretation node in which E states that he believes A saw P took X, thus working top-down to a factual quote from a paper document.

Inferences are sanctioned by inference templates called *schemes*. Most schemes possess a certain number of critical questions (CQs). Negative answers to such CQs may invalidate an instantiation of an inference scheme. For example, a CQ to the inference "A saw P took X" to "P took X" is "Had observer at all times a clear view on the scenery at issue?" In *AVER*, critical questions are implemented as latent undercutters that may be resuscitated by data nodes that support the inference (in this diagram there are two such data nodes, that is, "A is shortsighted" and "P is a party concerned"). The latter piece of evidence helps to defeat the inference to the conclusion that "Q sold X to P".

3.4. Node evaluation

Based on inferential connections, nodes can be evaluated as being "IN" or "OUT", where nodes that are "OUT" are depicted by a lighter shade and quotation nodes are always "IN". *AVER* is able to evaluate the status of the other nodes of a graph. For example, in Figure 1, the node "Q sold X to P" is "OUT" (its color is shaded) since it is undercutted by "P is a party concerned". As a result, its conclusion, the node "Q owns X" is "IN", because its rebutter is "OUT".

Several semantics for node evaluation exist and *AVER* uses the grounded and the admissibility semantics, respectively [11,12]. A detailed description of the algorithms used for graph "consistency checking" is beyond the scope of this paper, but more detailed descriptions of various of such algorithms can be found in the formal argumentation literature [12].

4. Related work

To summarize, *AVER* is the first collaborative, web-based system that supports not only argument construction and visualization but also argumentation schemes (in a more advanced way than other similar tools), a distinction between rebutters and undercutters, and the evaluation of the dialectical status of nodes. Moreover, *AVER* has a solid theoretical foundation in AI models of argumentation and is suitable to be used by police officers while investigating a case.

As remarked above, several argument visualization tools already exist. Two of them are strongly related to *AVER*, because of their data model and approach. Legal Apprentice [13] is a case analysis system that visualizes evidence in so-called legal implication trees. A similar case analysis tool is Araucaria [1]. It is relevant because it uses argumentation schemes and is able to maintain links between nodes and original source documents. Similar to *AVER* both systems are able to model evidential reasoning to a certain degree. The former through legal implication trees, the latter through Wigmorean diagrams.

Besides these tools that focus on the visualization of arguments, specific support tools for crime investigation exist, such as DAEDALUS [14], FLINTS (Forensic Led Intelligence System) [15], MarshalPlan [16], Holmes 2 [17], and Analysts' notebook [18]. Some of these tools are useful because of their graphics, whereas others support users by allowing them to make their argumentative steps explicit. Above all, they are particularly useful because of their structuring, storage and search abilities. *AVER* is designed to be used in connection with such tools to reuse their information management functions. It adds new functionality on top of these tools so that users are able to represent how the stored evidential data support or undermine hypotheses about what has happened.

5. Future work

The current version of the tool is domain independent and generally applicable. We are planning to add specific crime-related features to tailor it to crime investigations. Our first adaptation will be the incorporation of inference schemes that apply to crime investigations.

Another extension that we envisage is functionality to represent stories and to relate stories to arguments. Bex [19] is currently developing a more precise definition of the representation of stories and the role of arguments in the anchoring of stories in evidence. The authors and Bex have committed to integrate their work.

Finally, we are currently organizing experiments to test the effectiveness of *AVER* during crime investigations. Experiments that measure the effectiveness of such tools are relatively sparse. Moreover, experiments that are conducted are often not valid and not aimed at evidential reasoning [20]. Such an experiment will therefore be the first of its kind.

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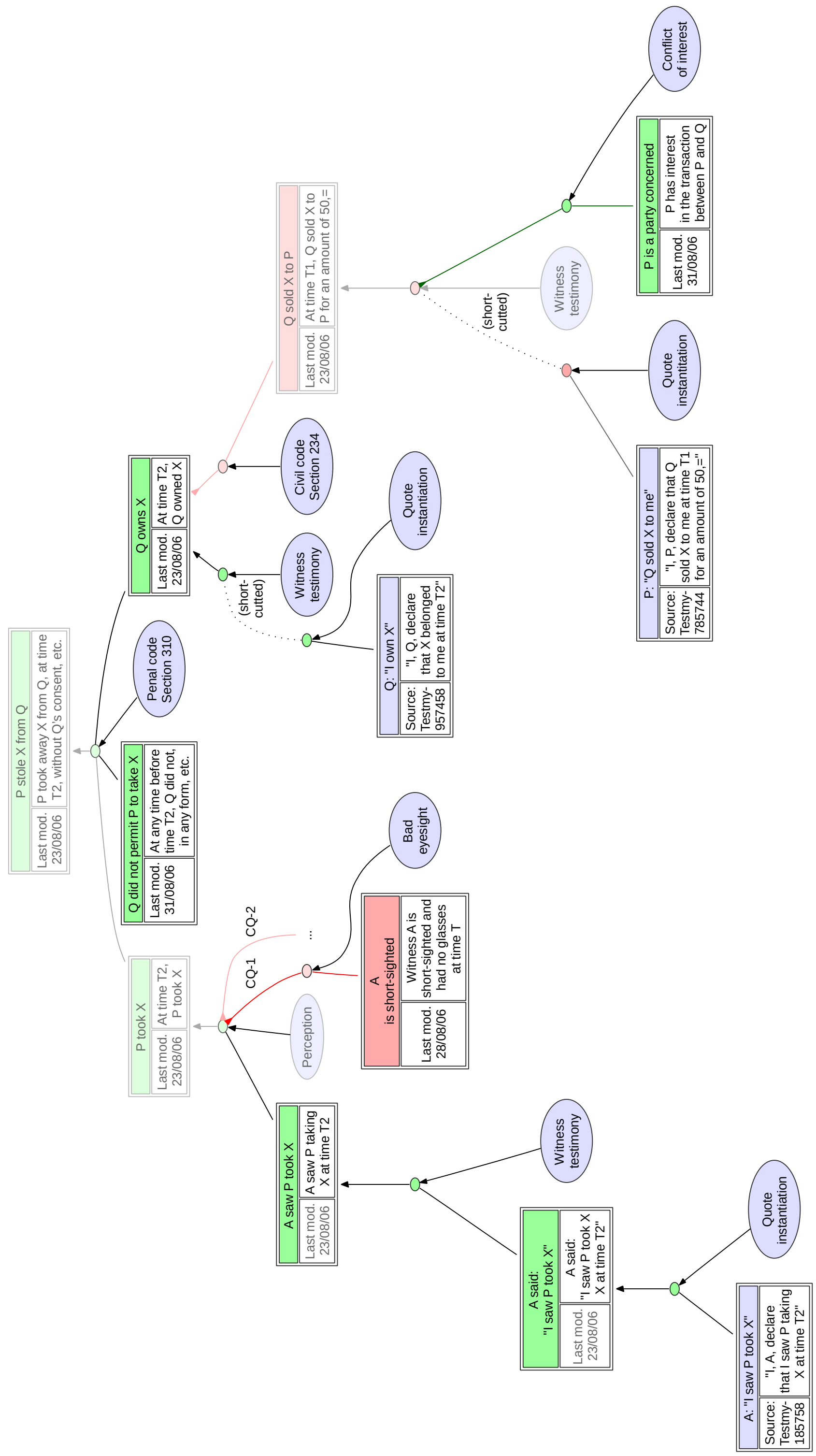

Figure 1. Example of a theft case