Reasoning with evidence

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The Process of Proof

The *process of proof* is the total process of discovering, testing and justifying hypotheses using evidence. In this process of proof, we essentially use two types of information, namely *evidence* (witness statements, statements by experts, photographs, documents, tangible evidence such as a knife or a wooden tablet) and *background knowledge* (generalizations or general schemes such as 'witnesses under oath usually speak the truth' or 'a Roman legal text ought to have the words AD QUEM').

The process starts when some initial evidence or clues are found. On the basis of this preliminary evidence one or more initial hypotheses will have to be imagined. These initial hypotheses will have to be tested by searching for further evidence and determining which of them are compatible with any new evidence. When a particular hypothesis has been chosen as the most likely, this choice should be justified by explicitly showing that it is most compatible with the evidence. A proper justification should provide a clear explication of one's reasons for the choice of hypothesis and should make sense not just to the reasoner but also to third parties.

Issues in the process of proof

Reasoning in the process of proof can be hard, as we are dealing with a mass of evidence, multiple hypotheses and quite specific and complex background knowledge. Here, it is important to critically analyse the evidence, hypotheses and background knowledge used. Incomplete, unexpressed or even false generalizations can lead to questionable reasoning. Furthermore, one must be wary of so-called *tunnel vision*, where the most likely hypothesis is taken as the leading hypothesis and alternatives are insufficiently considered.

Making Sense of Evidence

In the process of proof we are essentially trying to *make sense of evidence*. A good way of doing this is by making one's reasoning explicit and then (logically) structure and analyse this reasoning. In this way, sources of doubt in the reasoning can be identified and reasoned about. Furthermore, explicitly identifying and structuring hypotheses and the reasons for believing them lessens the danger of tunnel vision.

A relatively new development concerning sense-making and evidence is the emergence of computer-based support tools that allow for the electronic management of evidence and reasoning. Such *sense-making systems* do not contain a knowledge base and do not reason automatically, but instead help the user make sense out of a certain problem by allowing the user to logically structure and visualize his knowledge and reasoning in a case according to some specific underlying logical theory of reasoning.

Procedural heuristics for inquiry in the process of proof

Certain *heuristics* for performing an analysis of evidence can also help in making sense of evidence. These heuristics can be defined as rules and strategies for a dialogue between investigators; the rules ensure that the reasoning is correct and relevant and strategies can help in, for example,

choosing which (new) avenue of investigation to pursue. An *inquiry dialogue* in the process of proof consists of giving reasons (or *arguments*) for why a particular hypothesis should be believed and asking *critical questions* about specific arguments (see below) and the investigation as a whole (e.g. 'have all possible hypotheses been considered?'). Note that the main objective of an inquiry dialogue is not to convince the other participants but rather to increase the participants' collective knowledge.

Arguments

Arguments are constructed by inferring conclusions from sources of evidence. From these conclusions, new conclusions might be inferred, giving rise to chains of inferences and tree-structured arguments. Using arguments, hypotheses (e.g. 'this particular letter on the tablet is an A') can be *supported* by evidence (e.g. 'the experts all state that the letter is an A').

Argumentation schemes

Inferences in arguments are ideally warranted by generalizations or *argument schemes* representing stereotypical patterns of reasoning in a particular context. For example, in the current context one such scheme warrants the inference from an expert's percept of a certain letter to the conclusion that the letter is actually on the tablet, viz.

> *If an expert E sees some letter or word on a reconstructed image of a wooden tablet, then this letter or word is probably on the original wooden tablet*

Another scheme that can be used in reasoning about ancient texts is the expert scheme for philological knowledge:

> *If an expert E provides some philological knowledge, then he is usually right.*

Associated with each argumentation scheme are specific *critical questions* that represent typical ways in which an argument based on the scheme can be criticized. For example, the above scheme for an expert's percept has critical questions such as 'How credible is E as an expert?', 'Is P consistent with what other experts assert?' and 'Was the image of the tablet constructed using the right imaging techniques?'

Counterarguments and attack

Arguments can be critically evaluated by raising counterarguments. An argument can be attacked by an argument with an opposite conclusion (e.g. 'I have reasons to believe that this particular letter on the tablet is **not** an A') or an opposite premise (e.g. 'the experts did not all state that the letter is an A'). Counterarguments can also be based on critical questions, providing an *exception* to the general argument scheme. For example, one could argue that 'normally it is the case that *if an expert sees something on the reconstructed image then it is on the original wooden tablet*, but in this particular case the reconstructed image cannot be trusted because it was constructed using the wrong imaging techniques'. This does not deny the evidence (i.e. the expert's percept of an A) or the conclusion (that the letter is an A), but rather the inference from the evidence to the conclusion.

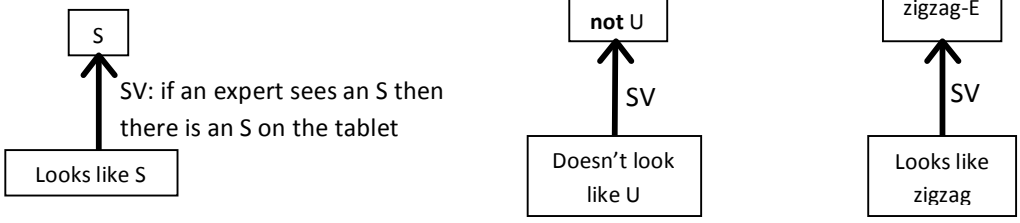
The Frisian tablet

The examples of argumentation produced below are based on the examples in Tarte's paper *Papyrological Investigations: Transferring Perception and Interpretation into the Digital World*. In this example, papyrologists developed hypotheses for the identification of a puzzling letter form on an ancient wooden tablet found in Friesland, the Netherlands. Tarte provided parts of an actual discussion between experts as they tried to determine what the letter form and the various words on the tablet meant.

Argumentation about the Frisian tablet

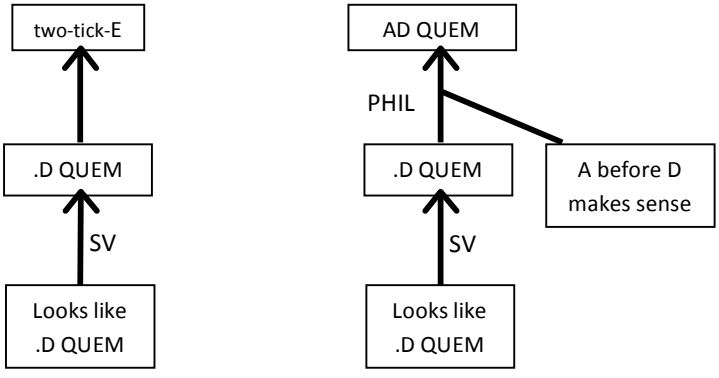
Constructing arguments

1. (P2)
    a. The letter in SECUND. looks like an S ***so*** it's an S
    b. The letter in SECUND. does not look like a U ***so*** it's not a U
    c. The letter in SECUND. looks like a zigzag ***so*** it's a zigzag-E



Chaining reasons

2. (P1)
    a. This looks like .D QUEM ***so*** .D QUEM ***so*** an E is written as two ticks
3. (P1)
    a. This looks like .D QUEM ***so*** .D QUEM
    b. .D QUEM and A before D makes sense (philological knowledge) ***so*** AD QUEM



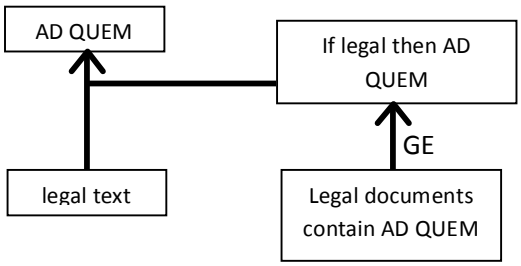
Arguments for schemes

4. (P2)

    a. It's general expert knowledge that legal documents usually contain AD QUEM

    b. This means that if it's a legal text you'd expect to find AD QUEM

    c. It's a legal text ***so*** it could be AD QUEM

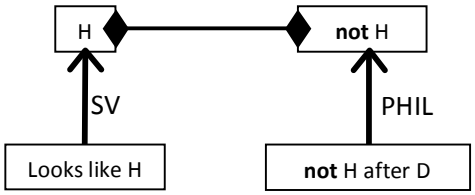


Rebutting attacks

5. (P1)

    a. The letter in SECUND. looks like an H ***so*** it's an H

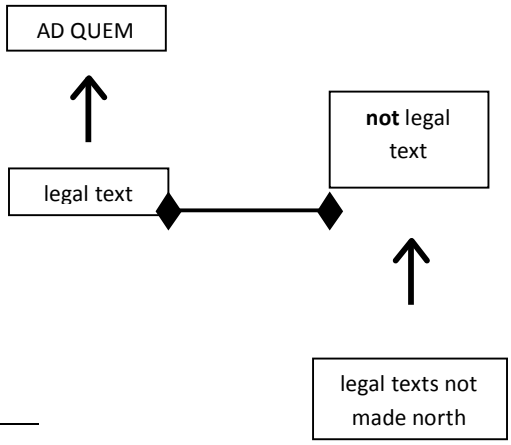
    b. H after D doesn't make sense (philological knowledge) ***so*** it's not an H



Undermining attacks[1]

6. (P3)

    a. legal texts were not drafted this far north of the empire ***so*** it's not a legal text



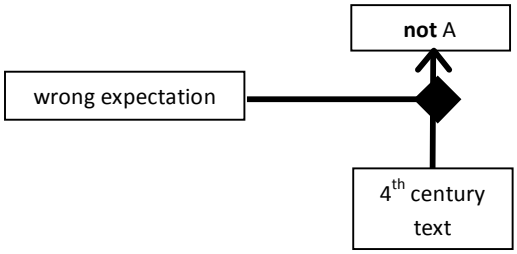
[1] This example argument was not in the original discussion and is based solely on the author's imagination.

Undercutting attacks

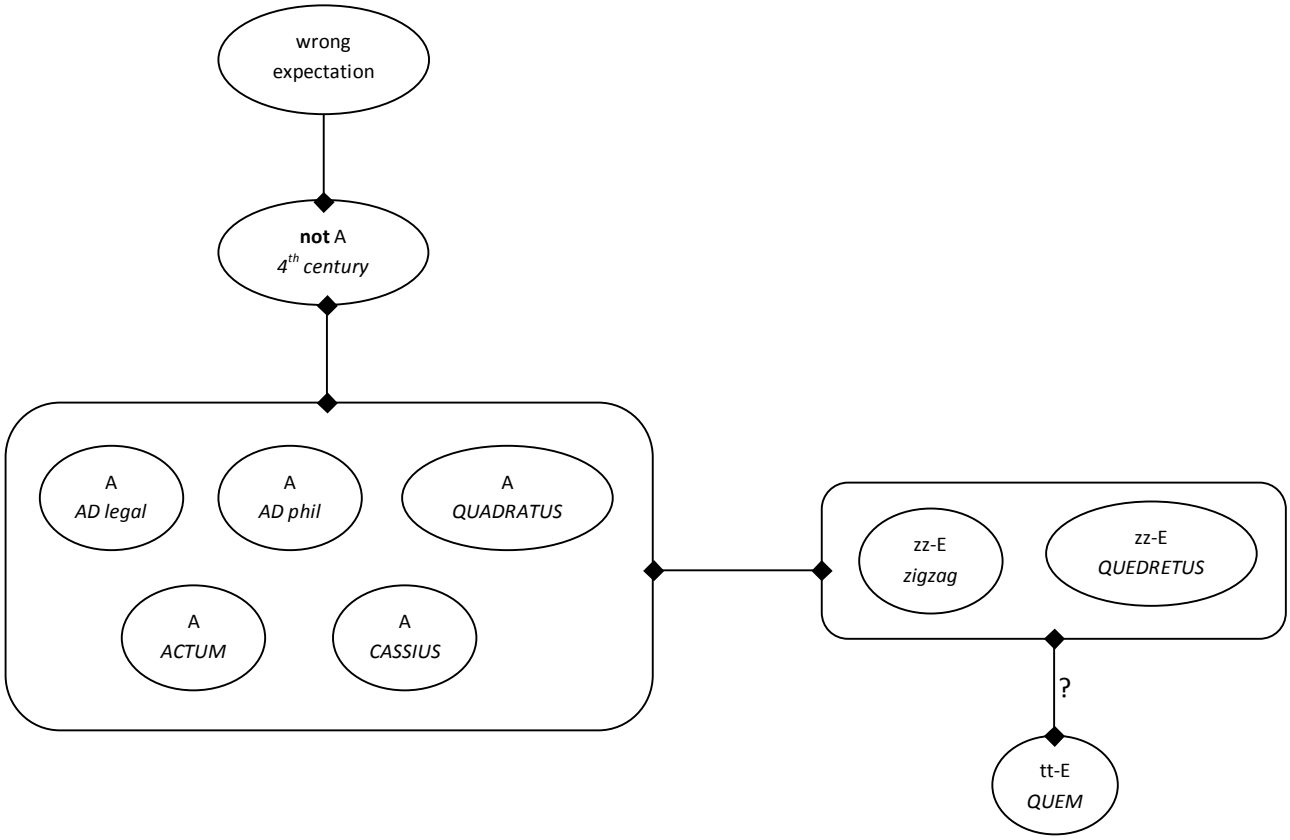
7. (P2)

    a. It's a 4th century text ***so*** it can't be an A

    b. This particular idea is prompted by a wrong expectation



Overview of hypotheses in the case



The overview shows some of the arguments made in the discussion, where the conclusion is at the top and the reason for that conclusion is summarized at the bottom in italics.

Conclusions and further ideas

Reasoning in the process of proof can be structured and criticized using arguments. With these arguments, hypotheses can be both *supported* and *attacked* in a dialectical inquiry. Argumentation schemes and their associated critical questions can aid in this inquiry. However, we should not let the reasoning in the process of proof be guided too much by patterns we think of as stereotypical, lest we fall in to the trap of tunnel vision.

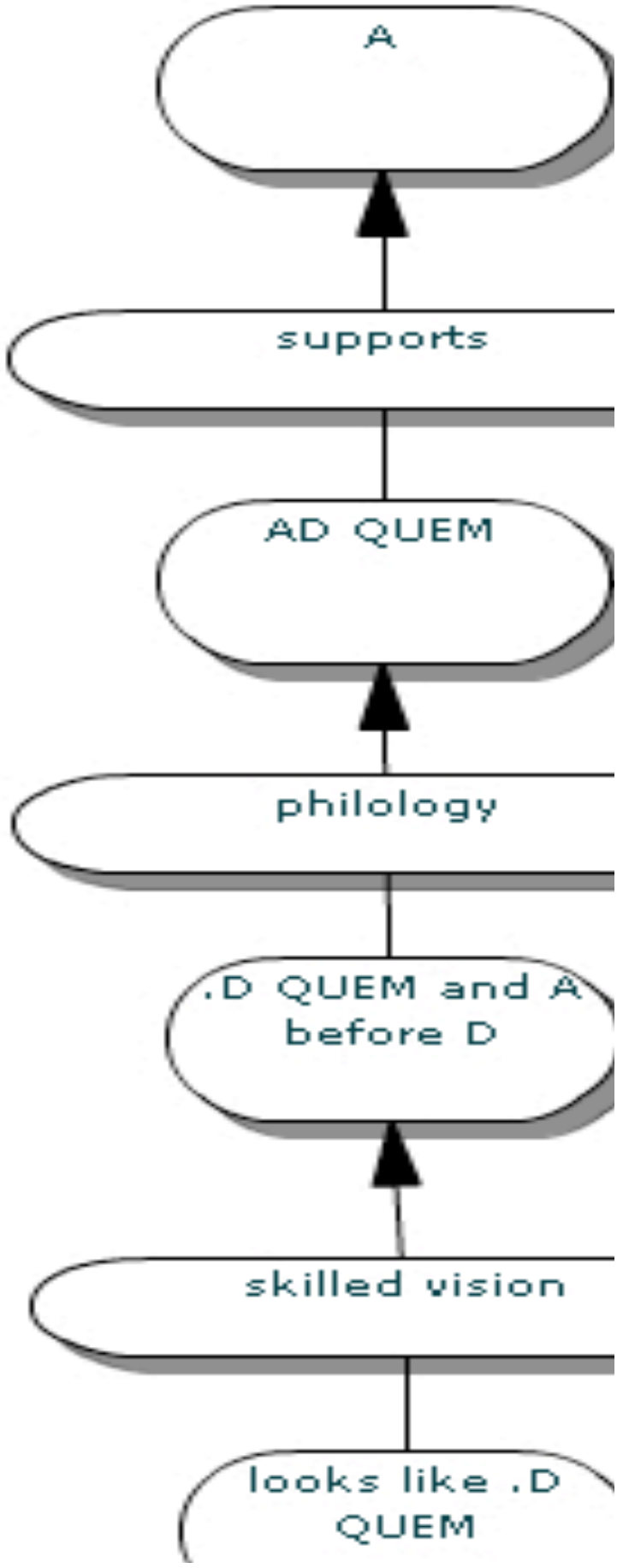
Argumentation (with evidence) is a fairly well-developed area of research. However, rules and strategies for inquiry dialogue are less well-developed.

Current sense-making systems often do not yet fully integrate dialogue and argument.

Argumentation about evidence as shown today is inherently *atomistic*: the various pieces of evidence and their conclusion are analysed separately and the complete picture (e.g. the complete text on the tablet) is not considered. The separate elements of text on the tablet are not only supported or attacked by evidence, but are also influenced by each other. Other argumentation techniques are needed to reason about the ways in which the elements of a text cohere.

Demo: constructing arguments for an interactive dialogue

Construct arguments online using OVA (http://www.arg.dundee.ac.uk/?page_id=143)


A
supports
AD QUEM
philology
.D QUEM and A before D
skilled vision
looks like .D QUEM

In the future: engage in (online) dialogues about arguments, construct arguments by engaging in dialogue.