AVERs

Braak, S.W. van den; Vreeswijk, G.A.W.; Prakken, H.

Published in:
Proceedings of the 11th International Conference on Artificial Intelligence and Law, Stanford, 2007.

AVERs: An argument visualization tool for representing stories about evidence*

Susan W. van den Braak
Department of Information and Computing Sciences,
Utrecht University

Gerard A.W. Vreeswijk
Department of Information and Computing Sciences,
Utrecht University

Henry Prakken
Department of Information and Computing Sciences,
Utrecht University
Centre for Law & ICT,
University of Groningen

ABSTRACT

This paper proposes an architecture for a sense-making system for crime investigation named *AVERs* (Argument Visualization for Evidential Reasoning based on stories). It is targeted at crime investigators who may use it to explain initially observed facts by drawing links between these facts and hypothesized events, and to connect the thus created stories to evidence through argumentation. *AVERs* draws on a combination of ideas from visualizing argumentation and anchored narratives theory.

1. INTRODUCTION

This paper presents an architecture and a partial implementation of sense-making software named *AVERs* in which a human crime investigator can visualize possible stories about what happened and link these stories with available supporting or attacking evidence through arguments. We suggest that such graphical representation software has good chances of being useful while based on sound theories of the reasoning involved in crime investigations.

Such a sense-making system [7], unlike knowledge-based systems, does not reason itself but supports its users in making sense of evidence by allowing them to visualize their reasoning in a way that is meaningful to them and explore its consequences. In this way, investigators are forced to make their argumentative steps explicit and accordingly it should become easier to pinpoint possible gaps and inconsistencies, and strong and weak points in their arguments.

AVERs combines these ideas from visualizing argumentation with notions from anchored narratives theory [13] which stresses the importance of stories in explaining observations and the need to connect these stories to evidence using general world knowledge (anchors).

*Full-color version of the ICAIL 2007 paper.

In earlier work (e.g. [6]) on reasoning about legal evidence, usually abductive model-based reasoning has been used to allow for explanation. In these applications, the links that are stated are modeled as generalizations from cause to effect as in "fire causes smoke". In order to explain the observation "smoke" abduction is used to infer a possible explanation "fire". However, in these approaches, observations are simply assumed as given or not given, therefore they do not allow users to critically examine the evidential sources of these observations. Based on the theoretical research conducted by Bex *et al.* [3], we say that the observations itself are the result of a reasoning process from external sources, for instance, testimonies. In our framework, reasoning with such sources is modeled as the application of evidential generalizations ("if a witness testifies that an event happened, then it happened"), so by default testimonies are accepted until evidence to an exception is found.

Hence, in accordance with Bex *et al.* [3, 4] we propose to use a combination of both causal and evidential generalizations together with a combination of both abductive reasoning for explanation and default reasoning for anchoring. Stories about what happened are thus represented as networks of causal generalizations while the relations between the available evidence and events in the causal network are modeled as evidential generalizations. In modeling default reasoning we partly make use of argumentation schemes [14]. To our knowledge *AVERs* will be the first sense-making tool that supports a combination of these two kinds of reasoning.

2. SYSTEM DESCRIPTION

AVERs, an extended version of the *AVER* system [10], is implemented as a web front-end to an SQL database. A case can be represented visually through multiple views. In this paper we will focus on the two graphical views; the evidence view and the story view. It should be noted that the graph visualizations make extensive use of colors, which cannot be shown here. Therefore, in the figures presented here color indications are provided between square brackets.

In the evidence tab evidential arguments and causal networks can be drawn. It consists of a split screen where the upper half displays a global overview of the case (the argument graph containing nodes and links) and the lower half displays the attributes of a selected node. 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. The story tab provides several features that allow investigators to explore possible explanations. These features are based on the formal model described in [3, 4], which combines abductive inference to the best explanation with defealt reasoning.

2.1 Data model

Nodes represent claims about a case and 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.

Nodes can be of three different types and three different polarities. More precisely, nodes can be of the data, inference, or scheme type, and can either be positive, negative, or neutral. *Data nodes*, represented as square boxes, can in turn be of two subtypes. *Interpretation nodes*, either positive or negative, represent contestable claims. Neutral (blue) data nodes are called *quotation nodes* and represent quotes from textual sources. *Inference nodes*, depicted as small ellipses, are justifications for inferential links. This distinction between data and inference nodes is based on the Argument Interchange Format [5]. Finally, *scheme nodes* represent argumentation schemes and justifications for inference nodes that are not supported by other inferences. Scheme nodes are depicted as blue ellipses.

Given these node types, inferences can be expressed by connecting two or more nodes with inferential links, based either on casual or evidential relations. Evidential links are green or red with triangle-shaped arrowheads, while causal links are depicted as yellow links with diamond-shaped arrowheads. The polarities of the nodes that are connected determine the type of the link between them such that two nodes of the same polarity support each other and two nodes of opposing polarities attack each other (the polarity of a node is represented by its color). Moreover, nodes can be attacked in two different ways. A *rebuttal* attacks a data node, while an *undercutter* attacks an inference node. Based on the thus established inferential connections *AVERs* is able to evaluate the dialectical status of nodes, that is, whether they are supported by a justified argument or not, based on algorithms described in [12]. For an elaborate example of the mechanisms of support and attack based on polarities and the node evaluation algorithm we refer to [10].

2.2 Example case

We will illustrate the practical use of *AVERs* with an example; the King case discussed in [13] and previously analyzed by Bex *et al.* (adapted version by [3, pp. 13]). The prosecution presents the following story:

> On the 18th of November, Andrew King climbs over the fence of the backyard of the Zomerdijk family with the intention to look if there is something interesting for him in the family's house. Through this yard he walks to the door that offers entry into the bedroom of the 5-year-old son of the family. The door is not closed, so King opens it and enters the bedroom to see if there is anything of interest in the house. Because it is dark, King does not see the toy lying on the floor. King hits the toy, causing it to make a sound which causes the dog to give tongue. King hears the dog and runs outside, closing the door behind him. Mr. Zomerdijk hears the toy and the dog. He goes to the bedroom and sees King running away through the closed garden door. He shouts "there is a burglar, come and help me!" and runs into the garden after King. King, who wants to pretend he is lost, does not run away. In spite of this, Zomerdijk jumps on King and, aided by his brother, who is visiting the Zomerdijk family, molests King.

The suspect, King, offers an alternative story. He admits that he was in the backyard, but does not explain why, and claims that the toy made a sound, because of the wind that blew the door open, hit the toy, and blew the door shut.

2.3 Constructing stories and arguments

The story of the prosecution and King's alternative may be represented in *AVERs* as displayed in Figure 1 (for readability purposes this causal network is split into two parts at node `toy sound`) and Figure 2 respectively. Generally, such a graph representation is built as follows.

Let us suppose that in this example case the investigation started with the observation that King was molested by Mr. Zomerdijk and his brother in their backyard. The investigators will thus start their analysis by adding a new node `grab King` to the case. As an explanation for the fact that King was grabbed by Mr. Zomerdijk in his backyard, the police assumed that King had bad intentions, that is, he wanted to break into the Zomerdijks' house, and climbed into their backyard and opened the door in order to enter the house. The investigators may now add these events or facts that are not yet supported by evidence as nodes to the graph and connect them through causal links. This results in a causal chain from `bad intentions` to `climbs backyard`, `open door`, and `enter house`. Thus a story is built. Based on these hypothesized events, the police may refine and expand their story by predicting new nodes. For example, based on their causal assumption that King entering the house caused him to step on the toy, they may add a causal link from `enter house` and predict the node `step toy`, which in turn leads to the toy making sound and so on.

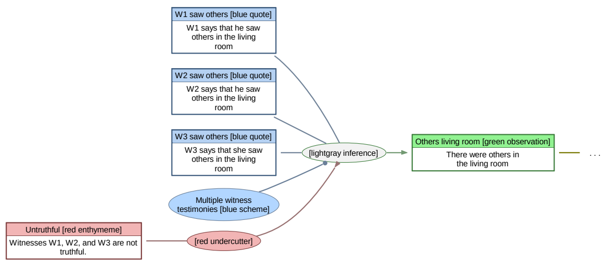

Figure 3: Observation based on biased witnesses

New observations can also be added to the graph based on evidence. Consider for example, witnesses 1, 2, and 3 who declared that they were in the living room. By selecting text from original source documents, quotation nodes are added to the graph, which results in evidence nodes `W1`, `W2`, and `W3 saw others` (see Figure 3). Subsequently, the witness testimony scheme for multiple witnesses may be used to infer `others living room` from them. While doing that, the

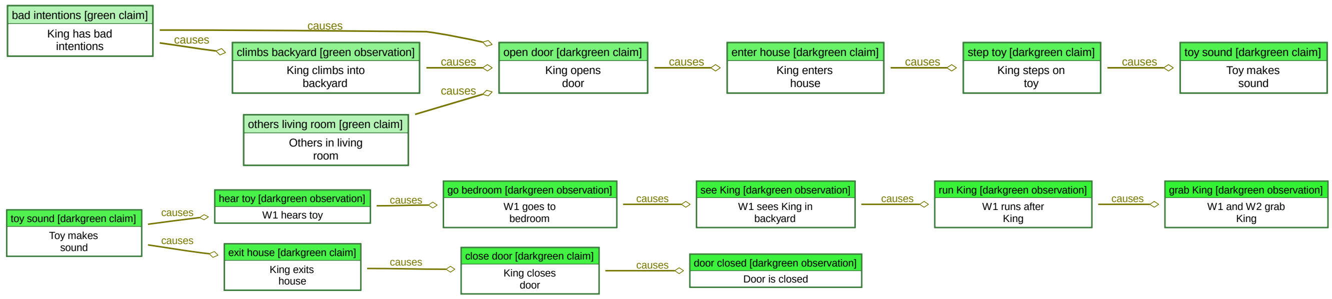

Figure 1: King case: prosecution's story

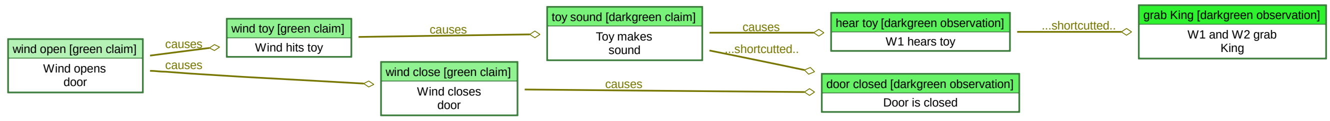

Figure 2: King case: King's story

investigators have to take into account the critical question of whether the witnesses are truthful. A negative answer to this question invalidates the instantiation of the scheme and is therefore added as an undercutter (see Figure 3), while a positive answer will result in a latent undercutter.

Scheme instantiations can also be used the other way around. If evidence for hypothesized events is found, the investigators may use an argumentation scheme in order to connect it to evidence. For example, if King declares that he climbed into the backyard, the witness testimony scheme can be used to expand the node `climb backyard` and add the quotation node `King` (see Figure 4). In this way *AVERs* is able to expand nodes both bottom-up and top-down. To our knowledge the possibility to expand existing data nodes by scheme instantiation is a unique feature. Araucaria [8] also incorporates schemes but in a different manner. Moreover, the system provides functionality to define links as being instantiations of a certain scheme. If two nodes are connected by dragging the mouse, the chosen scheme is added automatically.

Applying schemes to all testimonies results in a story that is anchored in evidence by evidential arguments as displayed in Figure 4 (also split at node `toy sound`). Note that here all inference nodes and scheme nodes are hidden for readability purposes. This shows how *AVERs* allows to collapse certain nodes based on their type or status (these nodes are depicted in smaller form without text) or to hide them completely, so that users maintain overview of complex graphs.

2.4 Exploring explanations

After completing their reconstruction of what might have happened, the investigators may use the story tab to check the quality of their hypothesis. This tab displays the causal network that was created by the investigators earlier using the evidence tab. It further uses this story to explain observations by hypothesized events through abductive inference to the best explanation. More formally, given a set hypotheses or possible explanations H and the set of causal generalizations T (the causal links that connect nodes), the story tab determines which of the observations O (the nodes supported by a justified argument) are explained.

The prosecution's hypothesis (H_1) is as follows: King had bad intentions and wanted to burgle the Zomerdijks' house. The family was in the living room, so he had the opportunity to do so. H_1 thus contains the nodes `bad intentions` and `others living room`. After selecting this hypothesis (marked by an asterisk), *AVERs*' story tab displays Figure 5 which shows the facts or events that are supported by evidence (the set of observations O) in a gray color. The observations that are explained by the selected hypothesis are marked by a black box. Note that hypothesis H_1 should explain as many observations from O as possible. As displayed in Figure 5, the prosecution's hypothesis explains all elements of O and more. After all, this figure shows how all gray nodes are surrounded by a black box.

The story tab may now be used to compare the prosecution's story to King's alterative. In order to do so, the investigators should combine King's story with their own (see Figure 6; because of space limitations several links are cut short). The story tab will then show that the prosecution's hypothesis still explains all observations, since King's alternative did not add any new observations to O. If King's hypothesis (H_2) that the wind opened the door is marked in the story tab (H_2 thus only contains `wind open`), it displays which observations are explained (see Figure 6). This reveals two major problems with King's story. First of all, it does not explain why he was in the backyard. This means that King a) must provide an alternative explanation or b) has to admit that he had bad intentions. Secondly, H_2 explains that a loud bang must have occurred. However, this conflicts with testimonies of the Zomerdijks and is therefore defeated by a justified argument. So, using the figures displayed in the story tab of *AVERs* (Figures 5 and 6), it is fairly easy to see that H_1 is better than H_2, because it explains more (more nodes are surrounded by a black box) and does not explain defeated propositions (no red observations are marked by a black box).

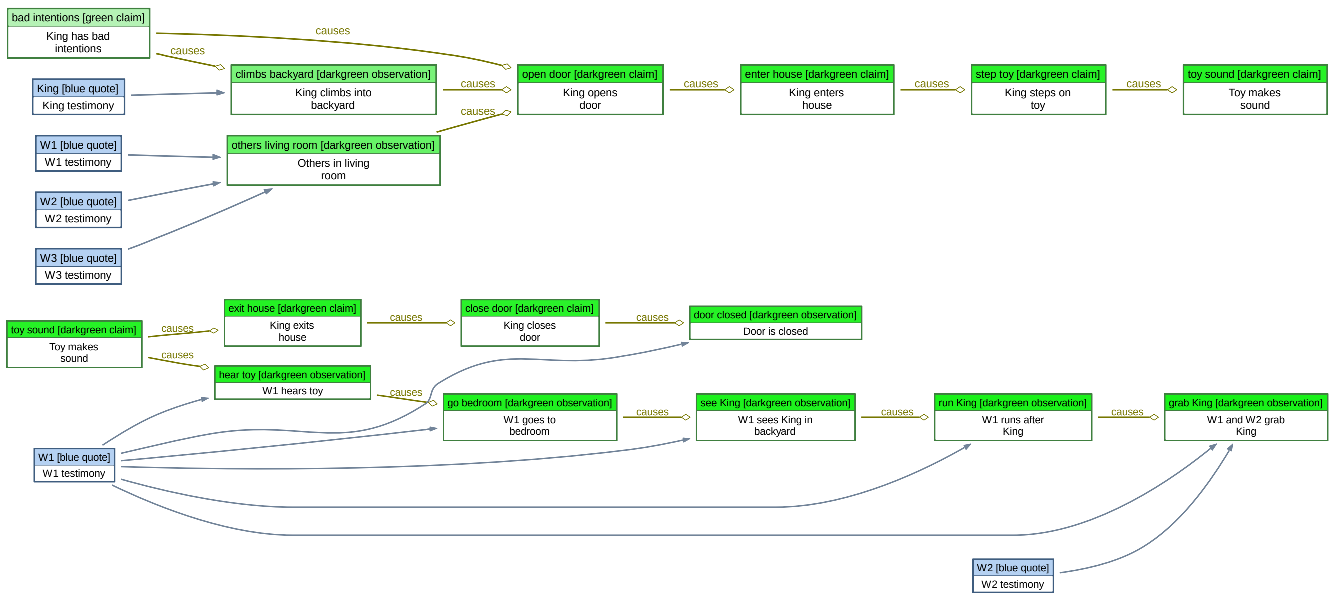

Figure 4: King case: prosecution's story supported by evidence

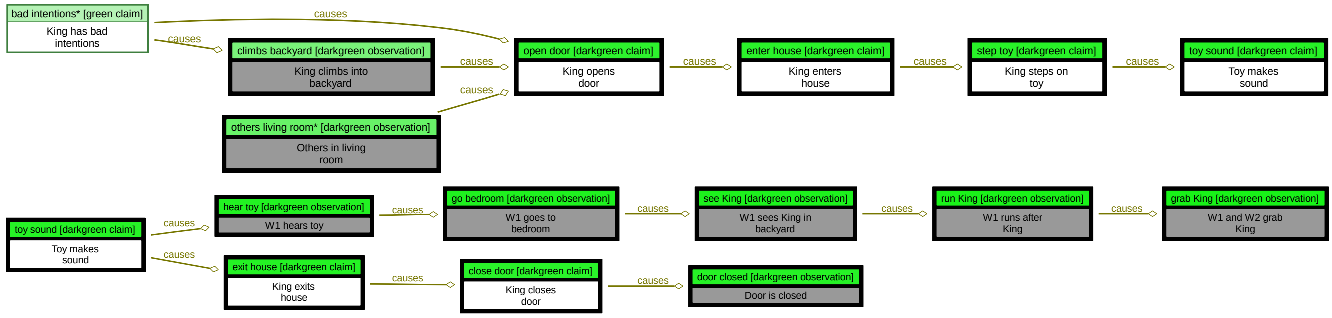

Figure 5: King case: prosecution's hypothesis with explained observations

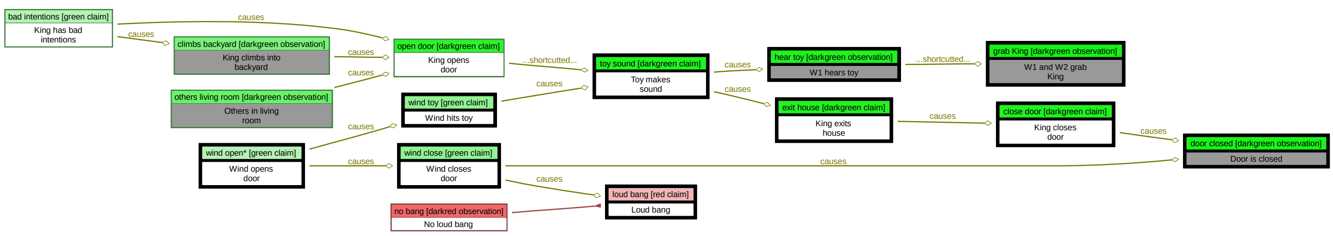

Figure 6: King case: King's hypothesis with explained observations

2.5 State of implementation and evaluation

Features that have been implemented in *AVERs* include the ability to create nodes, the ability to create and apply (causal and logical) inference schemes and the possibility to compute the dialectic status of individual nodes. Additionally, *AVERs* currently offers elementary functionality to perform explanatory reasoning. More advanced features of the story tab, such as the ability to infer possible explanations for the observed facts O which satisfy certain criteria, are currently being developed and implemented.

A usability study was conducted on *AVERs*' predecessor *AVER* in which 11 students and academic staff members, mainly from the faculty of law, participated. Preliminary results showed that this system scores fairly well on user-friendliness ($M = 21,91$ with $MIN = 7$ and $MAX = 35$), ease of use ($M = 16.14$ with $MIN = 4$ and $MAX = 20$), and understandability ($M = 12,50$ with $MIN = 4$ and $MAX = 20$) based on rating scales. It was found that the way in which nodes and links are added to the graph is especially intuitive and easy. The use of argumentation schemes seems to be harder to understand; three participants were not able to use scheme instantiation to add nodes to the graph. We are currently developing a more intuitive method to instantiate argumentation schemes.

3. CONCLUSIONS AND RELATED WORK

This paper is based on the hypothesis that crime investigations involve two kinds of reasoning, namely storytelling and anchoring. We proposed a graphical representation format for stories and evidential arguments in which stories are modeled as causal networks that are anchored in evidence by argumentation. *AVERs* therefore uses both causal and evidential generalizations and reasons with them in different ways. The support that *AVERs* thus provides to investigators is twofold. Firstly, the system enables them to construct, evaluate and compare their stories (or hypotheses) about what happened. Secondly, the tool allows them to connect their story to the available evidence and in this way to represent how this evidence supports or attacks their hypotheses.

To our knowledge *AVERs* is the first sense-making tool to combine a story-based approach with an argument-based approach, while similar tools only allow for default reasoning (e.g. ArguMed [11], Araucaria [8], Belvedere [9], and Rationale [1]) or abductive reasoning (e.g. Convince Me [2]) and not a combination. Compared to these argument visualization tools, *AVERs* offers additional functionality, such as argumentation schemes (in a more advanced way than similar tools), a distinction between rebutters and undercutters, and the evaluation of the dialectical status of nodes. Further, it is able to maintain links between data nodes and external source documents and to collapse or hide certain nodes based on their type or status. Finally, *AVERs* has a theoretical foundation in anchored narratives theory. In subsequent research we will examine the user-friendliness and effectiveness of the system as it is currently being developed.

4. ACKNOWLEDGMENTS

This research was supported by the Netherlands Organisation for Scientific Research (NWO) under project number 634.000.429. Henry Prakken and Gerard Vreeswijk were also supported by the EU under IST-FP6-002307 (ASPIC).

5. REFERENCES

[1] Austhink Rationale (www page). `http://www.austhink.com/rationale`, 2006.

[2] S. T. Adams. Investigation of the "Convince Me" computer environment as a tool for critical argumentation about public policy issues. *Journal of Interactive Learning Reseach*, 14(3):263–283, 2003.

[3] F. J. Bex, H. Prakken, and B. Verheij. Anchored narratives in reasoning about evidence. In T. M. van Engers, editor, *Legal Knowledge and Information Systems. JURIX 2006: The Nineteenth Annual Conference*, pages 11–20, Amsterdam, The Netherlands, 2006. IOS Press.

[4] F. J. Bex, H. Prakken, and B. Verheij. Formalising argumentative story-based analysis of evidence. In *Proceedings of ICAIL '07*, 2007.

[5] C. I. Chesñevar, J. McGinnis, S. Modgil, I. Rahwan, C. A. Reed, G. Simari, M. South, G. A. W. Vreeswijk, and S. Willmott. Towards an argument interchange format. *The Knowledge Engineering Review*, 21(4):293–316, 2006.

[6] J. Keppens and B. Schafer. Knowledge based crime scenario modelling. *Expert Systems with Applications*, 30:203–222, 2006.

[7] P. A. Kirschner, S. J. Buckingham Shum, and C. S. Carr, editors. *Visualizing Argumentation: Software Tools for Collaborative and Educational Sense-Making*. Springer-Verlag, London, UK, 2003.

[8] C. A. Reed and G. W. A. Rowe. Araucaria: Software for argument analysis, diagramming and representation. *International Journal of Artificial Intelligence Tools*, 14(3-4):961–980, 2004.

[9] D. D. Suthers, A. Weiner, J. Connelly, and M. Paolucci. Belvedere: Engaging students in critical discussion of science and public policy issues. In *AI-Ed 95, The 7th World Conference on Artificial Intelligence in Education*, pages 266–273, 1995.

[10] S. W. van den Braak and G. A. W. Vreeswijk. AVER: Argument visualization for evidential reasoning. In T. M. van Engers, editor, *Legal Knowledge and Information Systems. JURIX 2006: The Nineteenth Annual Conference*, pages 151–156, Amsterdam, The Netherlands, 2006. IOS Press.

[11] B. Verheij. Artificial argument assistants for defeasible argumentation. *Artificial Intelligence*, 150(1-2):291–324, 2003.

[12] G. A. W. Vreeswijk. An algorithm to compute minimally grounded and admissible defence sets in argument systems. In P. E. Dunne and T. J. M. Bench-Capon, editors, *Proceedings of the First International Conference on Computational Models of Argument*, (Frontiers in Artificial Intelligence and Applications, 144), pages 109–120, Amsterdam, The Netherlands, 2006. IOS Press.

[13] W. A. Wagenaar, H. F. M. Crombag, and P. J. van Koppen. *Anchored Narratives: Psychology of Proof in Criminal Law*. St Martin's Press / Prentice-Hall, New York, NY, 1993.

[14] D. N. Walton. *Argumentation Schemes for Presumptive Reasoning*. Lawrence Erlbaum Associates, Mahwah, NJ, 1996.