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How Does Analysis of Competing Hypotheses (ACH) Improve Intelligence Analysis?

By Richards J. Heuer, Jr.

This paper identifies three different approaches to Analysis of Competing Hypotheses (ACH) and four major steps in the intelligence analysis process. It then examines how each of these three approaches to ACH affects performance of each of the four steps in the analytical process. It also compares these three approaches on two dimensions – the analytical benefit from its use and the cost (in analytical time and resources) to use ACH.

A simple model of how most intelligence analysts actually work involves four steps. When given an assignment, analysts (1) search for information, (2) assemble and organize the information in a manner designed to facilitate analysis, (3) analyze the information to make an estimative judgment, and (4) write a report.

The three approaches to ACH are (1) the original manual approach as described in my book *Psychology of Intelligence Analysis*, (2) the automated version developed with my assistance by Palo Alto Research Center (PARC) for the Intelligence Community, and (3) Bayesian and other advanced forms of ACH, of which there are now multiple versions. Bayesian inference is a statistical procedure for quantifying uncertainty. Probabilities are based on degrees of belief rather than frequencies. Hence it is an appropriate method for aggregating a series of subjective probability judgments by intelligence analysts or other experts.

Each of these three approaches provides some analytical benefit at all four steps in the analytical process, but the amount of benefit differs for each step with each type of ACH and involves different trade-offs between analytical benefit, ease of use, and cost in analytical time.

Step 1- Search for Information

The requirement to identify and examine simultaneously a full set of hypotheses is the essential element that is common to all forms of ACH. The goal is to help the analyst question his or her initial mindset. Consideration of alternative hypotheses drives a much broader search for information than busy analysts would otherwise pursue. The focus on rejecting hypotheses also

casts a different perspective on what information the analyst searches for and considers most valuable.

This first step in the analytical process is probably where any form of ACH does the most to help the analyst avoid being caught by surprise. When analysts are first exposed to ACH and say they find it useful, it is because the simple focus on identifying alternative hypotheses and how they might be disproved prompts analysts to think seriously about evidence, explanations, or outcomes that had not previously occurred to them. This benefit during the first step of the analysis is roughly comparable for all forms of ACH. The automated and Bayesian approaches to ACH provide some additional benefit as they facilitate iterative steps that require the analyst to reevaluate hypotheses periodically or conduct further search for disconfirming evidence.

If an analyst is working a new area or issue, ACH might actually save the analyst some time. If the analyst must start by simply immersing himself or herself in the data, ACH can provide direction to what otherwise might be a rather random search.

In most cases, however, using ACH during this first step does involve a substantial cost in analytical time. If the analyst is already generally knowledgeable on the topic, the usual procedure is to develop a favored hypothesis and then search for evidence to confirm it. This is a “satisficing” approach, going with the first answer that seems to be supported by the evidence. This is efficient, because it saves time and works much of the time. It is usually also a safe approach, as the result may differ little, if at all, from the conventional wisdom. However, the analyst has made no investment in protection against surprise.

The conventional satisficing approach provides no stimulus for the analyst to identify and question fundamental assumptions. It bypasses the analysis of alternative explanations or outcomes, which should be fundamental to any complete analysis. As a result, it fails to distinguish that much evidence seemingly supportive of the favored hypothesis is also consistent with one or more alternative hypotheses. It often fails to recognize the importance of what is missing, i.e., what should be observable if a given hypothesis is true, but is not there.

During this first step in the analytical process, ACH is a simple conceptual strategy for dealing with a complex problem, and the principal benefit from any form of ACH comes from this conceptual strategy. An analyst does not need any analytical tool or methodology to do it.

Identifying and thinking about alternative hypotheses and how they might be refuted can and should be ingrained as a standard analytical habit. It is clearly preferable to the satisficing approach whenever the issue is so important that the analyst cannot afford to be wrong, and for other estimative judgments when the analyst has time for systematic analysis as distinct from simply expressing an expert opinion.

Step 2 – Assemble and Organize Information

The second step in analysis is to assemble the collected information and organize it in some analytically useful way, so that it can be readily retrieved for use in the analysis. The simplest form of this is the analyst's shoebox with note cards.

There are a number of simple tools that analysts use to help overcome limitations in human mental machinery for perception, memory, and inference. They all use two basic principles – decomposition and externalization. Decomposition means breaking a problem down into its component parts. Externalization means getting the decomposed problem out of one's head and down on paper or in a computer in some simplified form that shows the main variables, parameters, or elements of the problem and how they relate to each other.

All three forms of ACH use a matrix for this purpose, breaking the analytical problem down into its component parts by showing the evidence and hypotheses and how they relate to each other. This is a valuable contribution, as it organizes the information in a manner designed to facilitate analysis. The complexity of this matrix and the judgments that go into its development clearly differentiate the three types of ACH.

Manual ACH

The original manual ACH matrix records only the estimated relationship between each item of evidence and each hypothesis. That is, the analyst notes whether each item of evidence is consistent or inconsistent, or very consistent or very inconsistent, with each hypothesis. To make this judgment, the analyst asks, if this hypothesis is true, how likely is it that I would be seeing this evidence?

This Inconsistency judgment is the key feature of the matrix. The matrix helps the analyst to identify which evidence is most diagnostic in refuting hypotheses and to gain an intuitive sense of the relative likelihood of the hypotheses.

Automated ACH

Automating the matrix enables the analyst to categorize and sort evidence in additional analytically useful ways. The categories include date or time, type of source, credibility of source, and relevance of the evidence in addition to the consistency or inconsistency of the evidence. Sorting the evidence by these categories makes it easy for the analyst to focus on the most diagnostic evidence, or to compare evidence from open sources with evidence from clandestine sources, compare the results of evidence from human sources versus evidence from technical sources, compare more recent evidence against older evidence, and to compare conclusions based only on hard evidence (intelligence reports) with conclusions based on soft evidence (the analyst's own assumptions and logical deductions).

The capability to categorize evidence in additional, analytically useful ways, and to assess the reliability and credibility of evidence, is a big plus for automated ACH as compared with the original manual ACH. One analyst described the ACH software as providing the benefits of an automated analyst's shoebox. These additional capabilities do take additional time, but the convenience of automated data entry saves time as compared with the original manual ACH. The process of completing a fuller matrix should contribute to a better intuitive understanding of the issue.

Bayesian ACH

Bayesian ACH differs from automated ACH at this stage of analysis in two principle ways. First, most of the advanced forms of ACH do not use the additional categories for date/time or type of evidence. Accordingly, it is not as effective as an automated analyst's shoebox and the matrix cannot be sorted by date/time, type of evidence, or weight assigned to individual items of evidence. Analytically useful comparisons by date or type of evidence are usually not available in Bayesian ACH, which is a negative point for that approach.

The second difference is that Bayesian ACH places far greater emphasis on a more precise evaluation of the relationship between evidence and hypotheses than either manual or automated ACH. This is a strong plus but leads to considerable complexity. It requires the analyst to make at least two and usually four probability judgments about the relationship between each item of evidence and each hypothesis, as compared with only one for automated ACH process. If one has just one set of four hypotheses and 40 items of evidence, this may be as many as 640 separate probability judgments, many of which are quite complex. Many Bayesian ACH analyses have multiple linked sets of hypotheses, which greatly increases the number of individual probability judgments that must be made.

The objective is to use this series of expert judgments about the evidence as inputs for calculating the probability of each hypothesis. Because of increased complexity, the preparation of the matrix is substantially more time consuming than in simple automated ACH. It also requires the assistance of an expert in Bayesian analysis and/or other methodological procedures to train the analyst and help the analyst work through the many complex judgments that go into the matrix. This is a big negative as compared with manual and automated ACH, because it pretty well rules out the use of Bayesian ACH by most mainstream analysts.

Step 3 – Analyze the Information

The third step in the analytical process is analyzing the evidence to make an analytical judgment or estimate. At this stage, Bayesian ACH differs fundamentally from either manual or automated ACH. Manual and automated ACH both provide a conceptual strategy or thought process for dealing with a complex problem, but the ultimate decision is a judgment by the analyst. Automated ACH adds the capability to facilitate analysis by sorting evidence by various analytically useful categories. Bayesian ACH provides a mathematical algorithm that gives the analyst the answer. The inputs to this algorithm are the hundreds or perhaps thousands of probability judgments made by the analyst, or by a group of analysts with different specialties,

Manual ACH

In manual ACH, there is little emphasis on this third step. The analyst is simply told to focus on refuting hypotheses, and that the most likely hypothesis will probably be the one with the least

evidence against it rather than the most evidence for it. ACH is used as a conceptual tool to help the analyst think through all the evidence before making an estimative judgment, not as an algorithm that gives the analyst a correct answer. It is assumed that by carefully evaluating a full set of hypotheses, assessing the diagnosticity of evidence, and seeking to disprove rather than prove hypotheses, the analyst has followed a systematic process that improves the odds of making a correct estimate.

Automated ACH

The ability to sort the evidence by analytically relevant categories is a significant aid to analysis. Sorting by diagnosticity of evidence enables the analyst to identify those items that appear to be driving the conclusion, so that these items can be double checked and alternative interpretations considered. One can look at change over time by comparing older evidence with newer evidence. Comparison of evidence from clandestine sources versus open sources, or evidence from human sources versus technical sources, can be helpful when looking for indicators of deception. This is an advantage over both manual and Bayesian ACH.

Like manual ACH, automated ACH is intended to help the analyst make an estimative judgment, but not to actually make such a judgment for the analyst. Automated ACH does, however, use the computer to add up the number of Inconsistency ratings instead of the analyst adding them up. This gives an Inconsistency Score. The automated version also makes it possible to assign weights – Credibility and Relevance ratings – to the evidence. The weights are optional, and their meaning can be redefined to fit the needs of a specific analysis as long as the scoring system is appropriate. When they are used, the calculation is a Weighted Inconsistency Score.

Both the Inconsistency and Weighted Inconsistency scores in the automated ACH software are broad generalizations, not precise calculations. Their use is likely to produce correct estimates more frequently than less systematic or rigorous approaches, but this scoring system does not eliminate the need for analysts to use their own good judgment. There are times, for example, when information is available from a well-established, unimpeachable source with access to another country's decision making at the highest level. A single report from such a source may trump all other evidence, and the analyst will need to recognize this. For criminal intelligence analysis, DNA or fingerprint evidence might have a similar decisive impact.

It would be possible to use the automated matrix to calculate the probability of each hypothesis, but it was decided not to do this for several reasons. First, the information is not sufficient for an accurate probability calculation, as discussed below; the Bayesian approach is preferable for that. Second, our testing of a probability calculation showed that it is vulnerable to a common analyst error. Because the probabilities for all hypothesis combined must sum to 100%, the probability calculations assume that all hypotheses are mutually exclusive (if one hypothesis is true, all other hypotheses must be false), and that the list of hypotheses must exhaust all the possibilities. Most analysts do not normally think in this way, and we saw too many sets of hypotheses that failed to meet this test. If two hypotheses overlap (i.e., they can both be true) or the list is incomplete, any probability calculation is skewed. The Inconsistency Score treats each hypothesis independently, so it avoids this problem. Third, the probability calculation would convey a false sense of precision, and inexperienced analysts are likely to give it too much credence. Again, the goal of automated ACH is to help the analyst reach a well-reasoned conclusion, not to make the decision for the analyst.

Bayesian ACH

Proponents of Bayesian and other advanced versions of ACH correctly point out that a probably calculation using only an Inconsistency Score, or even a Weighted Inconsistency Score, is based on incomplete information. From a mathematical perspective, Bayesian inference is clearly an optimal method for calculating probabilities based on a series of subjective probability judgments by intelligence analysts or other experts. In order to relate an item of evidence to a hypothesis, Bayesian ACH usually requires the analyst to make at least two and usually four separate judgments:

- What is the probability I would see this evidence if this hypothesis is true?
- What is the probability I would see this evidence if this hypothesis is not true?
- What is the probability that this hypothesis is true if I see this evidence?
- What is the probability that this hypothesis is not true if I see this evidence?

The first of these judgments is relatively easier for analysts to make than the others. Compare this to automated ACH, which asks only the first of the above questions. The development of a

Bayesian ACH matrix is considerably more time consuming and, as noted above, requires the assistance of a Bayesian methodologist to guide the analyst through the process. Most Bayesian applications of ACH use Bayesian belief networks, which means multiple sets of hypotheses are analyzed, with the results of one analysis being used as a data input for other analyses. This makes the analysis even more complex and time consuming

Proponents of Bayesian ACH say this reflects the true complexity of the problem, and there is no way an individual analyst can handle such complexity in his or her head. The analyst makes many very specific judgments about the evidence and hypotheses, and these judgments are then combined using the Bayesian algorithm.

The result is a mathematically accurate analysis. Whether the conclusion is an accurate reflection of reality depends upon the accuracy of the analyst's judgments that go into the calculation and the appropriate adaptation of the methodology to the circumstances of the individual case. If the Bayesian analysis assumes that all items of evidence have equal weight, for example, this can be a problem under some circumstances. The selection of evidence to be used in the analysis can also be problematic. If the situation may be changing over time, it may be necessary to limit the analysis to more recent evidence. Inclusion of older evidence would bias the result in favor of continuation of the status quo. These are potential problems with all three approaches to ACH.

Step 4 – Writing the Report

All three ACH procedures provide benefits when it comes time to writing the report. CIA analytical products have been criticized for failure to consider alternative viewpoints and provide sound rationale for conclusions. A recent press report notes that the President's Daily Intelligence Briefing is being revamped to correct these faults. (Diamond & Keen, 2005).

By its very nature, any form of ACH provides a more careful consideration of alternative explanations of past events or estimates of future events than does conventional analysis. Another attribute of good reporting is clear identification of the evidence or driving forces that lead to the analytical conclusion. By focusing on the diagnosticity of evidence, all practitioners of ACH generate this kind of information.

Conclusion

A principal point made in this paper is that much of the benefit from ACH comes during the course of Steps 1 and 2 of the analytical process – the search for information and then the organization of this information in preparation for analysis. This is true for all three forms of ACH. Automated ACH is a significant advance over manual ACH because it saves time and provides greater capability to sort data inputs in analytically useful ways.

One question is whether increased accuracy gained through the Bayesian calculation in Step 3 is sufficient to offset the additional time required and the need for methodological support to create the matrix. If an analyst has already followed a conceptual process of identifying a full set of hypotheses, sought information to refute each of these hypotheses, arrayed this information in the form of a matrix, and made a simple judgment about the consistency of each item of evidence with each hypothesis (i.e., used the ACH software), how much more is the analyst likely to learn by going through the more granular Bayesian analytical process to make a mathematically correct calculation. How often will this process cause the analyst to change his or her judgment about the most likely hypothesis?

It would be nice to know the answers to these questions, but it is not necessary at this time as there is no need to choose between the two types of ACH. Automated ACH and Bayesian ACH are both intended to improve intelligence analysis, and both are successful, but they go about it in very different ways and there is a clear need for both.

Automated ACH is a tool that mainstream analysts in a wide range of fields can use now to aid them in analyzing a variety of issues. Most analysts like it because they find it helpful, easy to use, and transparent in how it handles their data inputs. The time required to use it is appropriate for the benefits obtained.

From the perspective of Bayesian researchers, automated ACH does not address the true complexity of the issues, and they may be correct. It is not intended to. It is intended as a significant, incremental improvement over current conventional (non-quantitative) methods of analysis in a number of fields.

Proponents of Bayesian ACH tend to believe that critical intelligence issues, especially an issue such as deception, are so complex that they are beyond the cognitive ability of the human analyst. To measurably and substantially improve analytic performance, they seek to build an external model of an ideal analytical process, with the individual analyst providing inputs but the system as a whole providing the final analytical judgment. They have a vision for radically changing how intelligence analysis is done. That is an important and worthy goal for the future, but it does not help the mainstream analyst today.

Until decisions made by Bayesian ACH or any other advanced algorithm are proven more accurate than decisions made using the automated ACH software, experienced analysts are unlikely to be willing to abdicate their judgment to a computer. Moreover, most current Bayesian ACH procedures are not easily adapted to an analytical environment in which intelligence judgments and estimates are made under considerable time pressure. Their role seems to be for research to learn more about how to analyze highly complex issues such as detection of deception, plus experimental support to conventional analysts on a few selected issues. It is hoped that this research will also develop insights about how to analyze these issues that can be taught to and used by mainstream analysts.

References

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