A New Kind of Social Science:
The Path Beyond Current (IR) Methodologies May Lie Beneath Them

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Abstract

Existing formal models of political behavior have followed the lead of the natural sciences and generally focused on methods that use continuous-variable mathematics. Stephen Wolfram has recently produced an extended critique of that approach in the natural sciences, and suggested that a great deal of natural behavior can be accounted for using rules that involve discrete patterns. Wolfram's work generally does not consider models in the social sciences but given the similarity between many of the techniques for modeling in the natural and social sciences, his critique can readily be applied to models of social behavior as well. We argue further that pattern-based models are particularly relevant to modeling human behavior because human cognitive abilities are far more developed in the domain of pattern recognition than in the domain of continuous-variable mathematics. We test the possibility of finding pattern-based behavior in international behavior by looking at event data for the Israel-Palestine conflict for the period 1979-2003. Using a new web-based tool explicitly designed for the analysis of event data patterns, we experiment with three general patterns: the classic tit-for-tat, an "olive branch" pattern designed to detect attempts at de-escalation, and four "meta-rules" that look at the relationship between prior conflict and the propensity of the actors to engage in reciprocal behavior. Our analysis shows that these patterns can be found repeatedly in the data, and their frequency corresponds to changes in the qualitative characteristics of the conflict.

> *The world is a stupendous machine, composed of innumerable parts, each of which being a free agent has a volition and action of its own, and on this ground arises the difficulty of assuring success in any enterprise depending on the volition of numerous agents. We may set the machine in motion, and dispose every wheel to one certain end, but when it depends on the volition of any one wheel, and the corresponding action of every wheel, the result is uncertain.*
>
> *Niccolò Machiavelli*

For the past two centuries, the social sciences have aspired to produce law-like generalizations about human behavior comparable to those found in the deterministic study of mechanics in physics or the probabilistic models found in epidemiology. Unsurprisingly then, social science has embraced the view that "the stature of a science is commonly measured by the degree to which it uses mathematics" (Weinberg, 1975, 264, n.3/14) Considerable scientific work has been done over the past sixty years in International Relations (IR) -- the social science from whose vantage point we write this article, though its methods and conclusions can be applied to social science more generally -- but this effort has produced virtually no law-like generalizations, and what few might be said to exist give us almost no mileage in excess of what common sense already provides (Walt, 1999; Green and Shapiro, 1995).

Indeed, a deep-seated discontent is growing in IR, in political science, in economics, and in other social sciences: a deep *methodological discontent.* The most 'advanced' methods we can use seem an ill fit with the types of questions we would like to pose and to answer in social science. The more 'advanced' methodologically our fields become, the more removed from reality and the more irrelevant to pressing human concerns the research seems to become. The Post-Autistic Economics Movement in economics and the Perestroika Movement in political science are but two recent manifestations of the yearning of social scientists, especially young social scientists, to move beyond what is perceived to be the increasing barrenness of their respective fields (see *PS* special issue July 2003; Fullbrook, 2001, Kasza, n.d.).

Yet the alternative methodological standpoints most often articulated propose to refocus social science research on ancedotes, history and constructivism/discourse analysis, and thus seem to have similar potential for controversy and paralysis. The issue here becomes falsifiability and its relationship to causality (Yee, 1996). Unless some concept of a causal link, however that be defined, is maintained in a methodology, it seems difficult to decide when a particular historical or constructivist account is false, or at least less satisfactory than another account. And since the findings of social science aim to inform social practice and policy, which may have profound impact on the lives of individuals, some minimal falsifiability seems morally imperative, if not theoretically imperative.

Some have viewed the social science enterprise as fated to be mired in stasis and controversy, produced by the limitations of our available methodologies (Kuhn, 1962). Or is it? Perhaps there is another way to look at this situation; a way which would produce more hopeful possibilities. Rather than casting around the current landscape of methodologies, let us look *beneath* it. Let us look at the common root of all these epistemological approaches, and work upwards from there. Not only will we gain a new perspective on existing methodologies, but we may be able to develop new methodologies, as well. These new lenses may be just the prescription to move past stasis and controversy toward new social science capabilities.

In 2002, a methodological gauntlet was thrown done by Stephen Wolfram in his work, *A New Kind of Science*. Though his book was not written from or for a social science perspective, several of his assertions are pertinent to that endeavor. Wolfram asserts that most modern scientific methods used in the physical and biological sciences are but idiosyncratic and limited derivations from something much more basic, more fundamental, and more powerful. In place of the continuous-variable mathematical structures that underlie classical mechanics and statistics, Wolfram's approach focuses on the discrete transformation of patterns. Simple pattern-based models can, through iteration, produce surprisingly complex behavior in physical and biological systems. Biochemists, for example, search for patterns in amino acids as elements for understanding the functions of a strand of DNA, and then the patterns of those strands combine to produce the patterns formed by larger strands, then by chromosomes, then by the entire genome. Though the patterns themselves are simple, they can ultimately produce highly complex organisms, including human beings themselves.

Wonderfully for social scientists, humans do not only originate from patterns, but humans seem hard-wired to perceive patterns and to find meaning in patterns. Indeed, it is not far off the mark to suggest the ultimate basis of all human epistemology is discrete pattern identification. As Wolfram puts it, "observers will tend to be computationally equivalent to the systems they observe," an observation we will expound upon shortly (Wolfram, 2002, 737). Before we discuss these issues in more detail, however, let us understand more fully the nature of our methodological discontent in IR.

The Issue of Complexity as the Root of Discontent

When we measure too little, we need inference; when we measure too much, we need models

Willem Heiser[1]

All sciences are set up in such a way as to avoid, elude, and overlook complexity as much as possible. Complexity is the bane of the would-be scientist, and yet complexity is a characteristic of much, if not most, of the world around us.

> Science is . . . unable to cope with [complexity], though its success with systems of its own choosing has misled many scientists and politicians into thinking of science as a way of effectively dealing with *all* systems. . . . The fruits of science are simple fruits, or more precisely, the fruits of simplification. . . . We must begin to understand the limitations . . . for its principal method is to squelch [complexity]. (Weinberg, 1975, 20-21).

For the social scientist, of course, the object of study—human beings—is irreducibly complex:

> Social scientists have had even less success, because their main interest--"humanness"--is a [complex] property that disappears when the system is taken part or abstracted and averaged. . . . Perhaps we are reaching the useful limits of a science . . . whose philosophical underpinnings are techniques restricted to systems of small and large numbers. (Weinberg, 1975, 22)

We argue here that complexity is the root of our current methodological discontent in IR, political science, and other social sciences. Looking at Figure 1, we see that the areas of study justifiably approached through mathematical or statistical analysis and modeling are really quite small. The vast remainder of reality--including social reality--cannot be effectively approached in these ways.. For these approaches operate within very small confines, and if one's subject matter cannot reasonably be placed inside those confines, use of the approaches will feel, and indeed be, inadequate.

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[1] University of Leiden ISA-RC33 keynote address, Cologne, 5 October 2000. ISA-RC33 is the methodological sub-section of the International Sociology Association. *That* ISA, not *our* ISA...

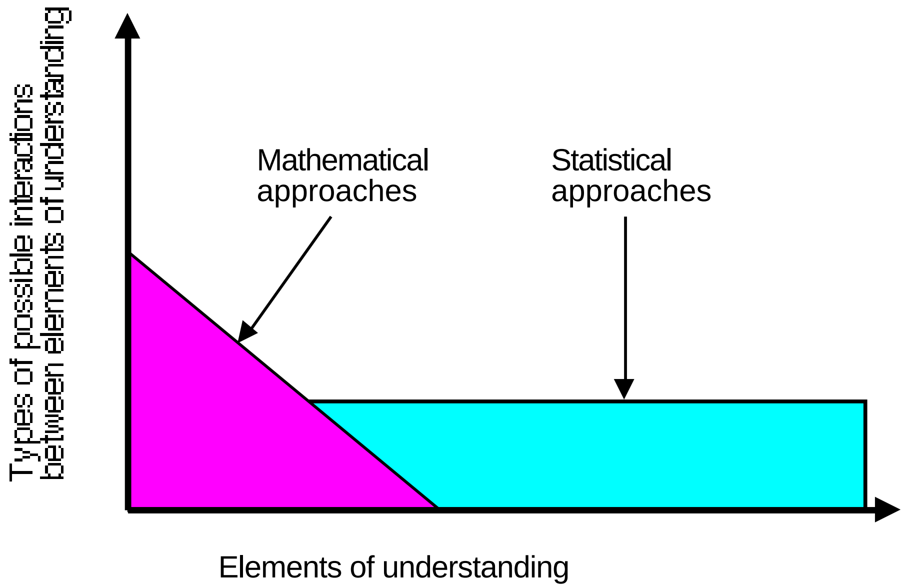

Figure 1: Complexity and the Confines of Mathematical and Statistical Analysis

To date, the response to this situation has also been less than helpful. One response, very common, is to simply apply mathematical or statistical methods beyond the confines where their use is justified. This results in a strange methodological anomie, where one uses these methods as if all is straightforward, while becoming ever more disengaged in one's questions and answers from the reality wrestled with on a day-to-day basis by those who live within it. Statistically speaking, we cannot justify assumptions of random or normal distribution in much of what we are studying as social scientists. These assumptions, when used without justification outside of areas noted in Figure 1 where aggregation and large-sample properties cause statistical regularities, are actually an effort to avoid the issue of complexity. Mathematically speaking, we have an enormous N-body problem—in the sense of the problem in astrophysics, not statistics—, for which we have very little in the way of methodological capabilities. In a sense, we also have a parallel problem in *small* N situations, where idiosyncratic factors such as the fact that the Al-Aqksa Mosque, the Western Wall and the Church of the Holy Sepulcher are within a 500-meter radius of each other is intensely important to this conflict but it is decidedly not a large-sample property subject to the normal or Poisson distribution. So we use simplifying assumptions that evade the complexity with which we cannot cope.

But there is more. Most of these methods also derive from a strictly arithmetic view of what can be the form of an interaction and usually involve a firm quantity-based definition of all elements of understanding: models involving the analysis of interval-level variables are substantially more developed than those involving nominal-level variables.[2] But we as humans know from our own lives that there are plenty of interactions in the world that have no counterpart in continuous-variable operations[3], nor can we define every concept in terms of quantities. That is why we continue to have human diagnosticians, intelligence analysts, and police detectives. As pattern recognition devices, our own brains are more powerful—and utilize quite different mechanisms—than the most sophisticated mathematical and statistical methods, and at a deep level, we realize that anew every time we read a piece of quantitative research in the social sciences.

Mathematical and statistical approaches are a tiny and quite restricted subset of what the human brain is able to bring to bear on a subject matter in pursuit of understanding. This is not to say those approaches are not useful -- they are very useful, particularly in realms involving large samples, high levels of noise, and variables that can be naturally operationalized using continuous measures. But they are elementary methods compared to what we already know how to do. As Wolfram puts it, "the field of mathematics as it exists today will come to be seen as a small and surprisingly uncharacteristic sample of what is actually possible" (Wolfram, 2002, 821).

Humans were built to make sense of complexity. In a sense, the way to move past the methodological discontent in our social science disciplines is to discover more about how our minds in fact do this. "How we do this" is certainly the foundation of mathematical and statistical approaches, but that foundation supports *so much more* in a methodological sense. If we can explore that "more," we will give ourselves more powerful and less restricted

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[2] For example, most contemporary analyses of nominal variables use either dummy variable regression (nominal independent variables) or variations on logit analysis (nominal dependent variables). Both techniques are essentially mathematical tricks for treating the nominal variables as if they were interval, and their estimation is entirely in the domain of continous variables.

[3] As Wolfram puts it, "it is in many cases clear that the whole notion of continuity is just an idealization--although one that happens to be almost required if one wants to make use of traditional mathematical methods." (Wolfram, 2003, 729).

methodologies specifically geared towards the understanding of complexity (see *Political Psychology,* special issue 24:4, December 2003).

That, in a nutshell, is what we are about. In 1992, an issue of *Science* surveyed how several new techniques in the physical and biological sciences had revolutionized not just the methodologies, but also the theories, in their fields. The article observes:

> Not everybody appreciates the importance of technique. Many scientists, in fact, are "theory snobs" who dismiss technique as a kind of blue-collar suburb of science. ... [But there is], clearly, enormous transforming power in techniques. In the absence of an essential technique, a researcher or a field flounders, developing elegant theories that cannot be decisively accepted or rejected—no matter how many intriguing circumstantial observations are available. But with a key technique in hand, the individual and field move ahead at almost terrifying speed, finding the right conditions to test one hypothesis after another. Conversely, new techniques often uncover new phenomena that demand new theories to explain them. (Hall 1992,345)

We believe similar theoretical progress can be made in IR through the exploration of new methodologies.

Pattern Recognition, Human Understanding, and Human Action

> *It is becoming increasingly apparent that biological systems are much more complex than the technological systems usually considered by the control engineer. A technological system is usually designed on the basis of predesignated criterion of stability and response which are expressed in some analytical form. Physiological systems, on their other hand, have evolved slowly, continuously, adapting the performance of specific tasks to a wide variety of conditions. … Natural selection is not saddled with an expediency demand. The evolution of physiological control systems might, therefore, be expected to result in optimal systems chosen with the complexity of description not at all entering as a limiting factor.*
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> *B. Pennock and E.O. Attinger.*

Pattern recognition is the ability of an individual to consider a complex set of inputs, often containing hundreds of features, and make a decision based on the comparison of some subset of those features to a situation which the individual has previously encountered or learned.[4] In problem solving situations, *recall can substitute for reasoning*. For example, chess involves a

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[4]The literature on pattern recognition in human problem solving goes back to the 1960s, for example Newell and Simon 1972, Simon 1982, and Margolis 1987.

well-defined, entirely deterministic system and should be solvable using purely logical reasoning. Chess-playing computers use this approach, but Chase and Simon (1973) found that human expert-level chess playing is done primarily by pattern recognition.

Before going further, we pause here to note that the chess analogy also helps us recognize that pattern recognition by humans is also the basis for human action itself. Meaning for human beings comes from the recognition of patterns (which imply that phenomena are rule-based), and thus meaning in one's own behavior likewise comes from enactment of patterns, or, rather, the rules that produce them. That is how chess is played, but that is also how virtually all social behavior takes place, as well. To see the pattern-based nature of human understanding, then, is to simultaneously see the pattern-based nature of human behavior. They are two sides of the very same coin, and we ask the reader to keep this in mind for the discussion that follows.

Humans possess very large, albeit imperfect, long-term memories. Failures in the fidelity of this memory are compensated by the fact that it is associative: we can recall a large amount of information from a small number of features, even in the presence of noise. Information about the fruit "apple" can be invoked by a smell, a taste, a variety of objects, a variety of words (e.g. "apple", "Red Delicious", "Winesap", "cider") and a variety of social memories, as well as by the noisy stimuli "Aqple" or the highly stylized trademark on an Apple computer.

Over the past two decades, international relations theory has begun to reemphasize the importance of non-statistical patterns. The "international institutions" and "regimes" literature (Krasner 1983) is quite explicit on this point. Robert Keohane, in his 1988 presidential address to the International Studies Association, notes

> ..."institution" may refer to a *general pattern* or *categorization* of activity or to a *particular* human-constructed arrangement, formally or informally organized. Examples of institutions as general patterns of behavior include Bull's "institutions of international society" as well as varied patterns of behavior as marriage and religion, sovereign statehood, diplomacy and neutrality. ...What these general patterns of activity have in common with specific institutions is that they both meet the criteria for a broad definition of institutions: both involve persistent and connected sets of rules (formal or informal) that prescribe behavioral roles, constrain activity, and shape expectations. (Keohane 1988,383)

While neither Keohane nor most of the international institutions literature have provided formal definitions of these patterns, their emphasis on the importance of pattern in international behavior is unmistakable.

Recall is preferred to reasoning because working memory[5], which must be utilized in deductive reasoning, is slow and constrained to handling only a few items of information at a time. The long term memory used in pattern recognition, in contrast, is effectively unlimited in capacity[6] and works very quickly—on the order of seconds—even when solving a complex associative recall problems across thousands of potential matches. Purkitt notes:

> Generally speaking, the power and complex of human cognition is tied to the almost unlimited capacity of humans to store and combine vast amounts of information in long-term or associative memory. … Research has also demonstrated that the active processing of information is a serial process within the limited capacity of working memory. In moving from the level of pieces of information to the level of factors or indicators, it is now clear that individuals can only systematically process information on a few (probably two or three) factors without explicit cognitive aids (e.g. algorithms). (Purkitt 1991,40)

Associative memory is vast, effortless and quick; logical processing is limited, painful and slow. Consider the following four questions:

- Describe three uses of military force by the United States during the 1980s
- Who was attorney general during the 1963 Cuban Missile Crisis?
- What is 15% of $22.30?
- Prove the Pythagorean Theorem.

The answer to the first question will come to the international relations specialist more or less immediately "from memory". However, the method by which the answer was determined cannot be described—for example, were all instances of military force in memory searched, all actions by the United States, or all international events in the 1980s? One cannot say; this is instead done using "subcognitive processing", discussed below. The answer simply appeared,

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[5] Earlier known as "short term memory".

[6] See Newell and Simon (1972), chapter 14. Newell and Simon argue that the capacity of associative memory is effectively unlimited because the amount of time required to store items is sufficiently long that life-span, rather than memory capacity, is the constraint.

without conscious operations, in a couple of seconds. Similarly, the second question can be answered quickly despite being stated in a factually inaccurate manner.[7]

In contrast, most people can articulate the algorithm used to solve the third question. This may be general-purpose school-book multiplication ("multiply 2 by 5, carry the one…") or a specialized algorithm developed because the problem is commonly encountered when calculating restaurant tips ("divide the total by ten by shifting the decimal point to the left, then divide that by two, then add these two amounts"). Failing these, one can solve the problem on a calculator, and in any case the manipulation of the information can be verbalized without difficulty. The final problem involves the logical manipulation of only a few axioms from plane geometry, virtually every literate person has learned the proof in high school geometry, and yet its solution is difficult for most people.

The latter two problems are far less information intensive than the first two—this is why the third can be solved on a calculator—but require deductive processing. In fact, the first two problems require a very large amount of historical information and complex associative links. The first problem could be solved using a large electronic data base such as NEXIS but constructing a query that duplicates only the three examples usually retrieved by experts (Grenada, Lebanon and Panama) is quite difficult. A slightly more difficult query, e.g. "Indicate three changes in the NATO alliance between 1952 and 1972" becomes almost impossible even for NEXIS. But such questions are nothing more than typical college examination questions and barely worthy of consideration as expert political knowledge.

Origins of Pattern Recognition

In all likelihood, the human brain evolved with a strong bias towards pattern recognition rather than deductive reasoning. This natural environment is comprised of two systems: the physical and the biological. Many aspects of the physical world can be usefully described by deductive axiomatic systems, and an information-processing system operating solely in a law-governed world would be able to survive with purely deductive reasoning; examples would include computer viruses and programmed trading systems.

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[7] Robert Kennedy, and the crisis was in 1962, not 1963. The fact that the attorney general was the President's brother and actively involved in the crisis aids in the recall; I suspect most people could not answer the same

The biological world, in contrast, is exceedingly complex and arbitrary. It is a world of individuals constructed from complex feature vectors made of DNA, with billions of components, and selected solely by the ability of their ancestors to reproduce, oftentimes in unusual circumstances such as the aftermath of asteroid collisions. Such a world cannot be described deductively in any practical sense, but because it is very repetitive, pattern recognition is an effective information-processing strategy. If one Tyrannosaurus Rex tries to devour you, the next one is likely to as well. Since critical decisions must be made in real time ("Is the object approaching me sometime I can eat, something that will eat me, or something I can ignore?"), evolution will select for high recall speeds under noisy environmental conditions. It does not select for theorem proving or the minimization of quartic polynomials.

This neural bias would emerge early in the biological record, well before the development of primates, or mammals, or even vertebrates. *Homo sapiens sapiens* is endowed with sophisticated pattern recognition capabilities honed through eons of evolution, and it is unsurprising that this capacity is put to use in social behavior. Deductive reasoning, in contrast, is a comparatively recent development and is much more difficult. While we are very proud of deductive reasoning, it is not necessarily more useful, particularly when dealing with social behaviors which may also have some evolutionary roots.

Anderson and Rosenfeld trace the pedigree of this idea to William James:

> As James points out [in *Psychology (Briefer Course)* (1890)] emphatically in several places, the brain is not constructed to think abstractly — it is constructed to ensure survival in the world. … [The design principles are:] do as good a job as you can, cheaply, and with what you can obtain easily. If this means using ad hoc solutions, with less generality than one might like, so be it. We are living in one particular world, and we are built to work in it and with it. (Anderson and Rosenfeld 1988, 1)

Pattern recognition, unlike deduction, is easy.

An important consequence of the survival value of pattern recognition is a brain is biased in favor of recognizing, rather than rejecting, patterns. As Hugh Kenner (*Byte*, November 1989,486) puts it, "The computer is a difference detector. The human mind is a similarity detector." The survival costs of fleeing in terror from a dimly perceived and ultimately nonexistent threat are substantially lower than the risks of not fleeing a genuine threat. The

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question for the U-2 crisis.

ability of the brain to perceive patterns in random data is the bane of statisticians, but arises quite naturally from the necessities of survival in a noisy environment.

Substantial parts of the brain are specialized for the social tasks of recognizing faces and that most cognitively complex of all social interactions, language. It would not be surprising if the brain had in addition some specialized hardware for handling at least some basic political interactions, for example the social hierarchies present in many vertebrates. Human associative memory may be able to handle, subcognitively, complex episodic political information such as precedent retrieval in part because the brain evolved in part to handle comparable problems.[8]

Subcognitive Processing: Seeing, Feeling, and Understanding

Studying associative recall is problematic because the process occurs in the non-verbal, unconscious or subcognitive[9] part of the brain: it is a form of information processing that we can do but not articulate. In the foreign policy field such reasoning is typically called "intuition" or "feel." But a better description might be "seeing" or "perceiving." A typical example of this approach to foreign policy analysis is found in the following quote from Kissinger:

> Statesmanship requires above all a sense of nuance and proportion, the ability to perceive the essential among the mass of apparent facts, and an intuition as to which of many equally plausible hypotheses about the future is likely to prove true.(Kissinger 1979,39)

Subcognitive information retrieval involves nothing mystical; the process can be, and has quite extensively been, empirically studied (see Collins and Smith 1988; Reber 1993). One can engage in very complex information processing without being aware of how one is doing it, *even using introspection*. Lashley notes:

> *No activity of the mind is ever conscious.* [Lashley's italics] This sounds like a paradox, but it is nonetheless true. A couple of illustrations should suffice. Look at a complicated scene. It consists of a number of objects standing out against an indistinct background:

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[8] Masters (1989) provides a thorough discussion of the possible connections between evolution and political behavior; Axelrod (1984) and Simon (1990) note that evolution may have predisposed humans to altruistic behaviors, a definite change for the bellicose "Social Darwinism" of a century ago.

[9] This term is from Douglas Hofstadter (1985) via Holland et al (1986). The word is attractive since unlike "unconscious" it implies active information processing; it avoids the Freudian overtones of "subconscious" and it is more general than the term "nonverbal". Jackendoff (1987), while dealing with an entirely different set of domains, provides an excellent discussion of subcognitive information processing and a guide to much of the relevant psychological literature in the linguistic and visual perception domains; Springer and Deutsch (1981) give a semi-popular review of the related literature on split-brain experiments.

> desk, chairs, faces. Each consists of a number of lesser sections combined in the object, but there is no experience of putting them together. The objects are immediately present. When we think in words, the thoughts come in grammatical form with subject, verb, object, and modifying clauses falling into place without our having the slightest perception of how the sentence structure is produced. (Lashley 1956,4; quoted in Jackendoff 1987,45).

As Lashley points out, the most obvious examples of subcognitive processing are sight and language. For example, an illiterate speaker with no formal linguistic knowledge can continuously and effortlessly assemble grammatically correct sentences consistent with a grammar of several dozen, if not several hundred, rules. This skill is learned entirely by example and can be observed in any average three-year-old child, in any culture. One can also construct grammatically correct sentences through rules—as is done when one is learning a second language or in a machine translation system—but this is slow, awkward and not characteristic of fluency.

Wittgenstein notwithstanding, a long series of empirical experiments demonstrate that one can know or see things one cannot say, where "know" or "see" is defined as the successful completion of complex information-processing tasks and "say" means verbalize. One of the consistent lessons from the machine learning literature is that verbal problem solving protocols provided by human experts are usually much more complicated than the set of rules logically sufficient to solve the problem. An expert usually perceives or "sees" that much more information is required to solve a problem than is logically needed, and when asked why will be unable to describe what that additional information provides other than "feel".

A likely explanation for this is that the expert actually does most of the problem solving using associative pattern recognition and therefore cannot articulate the process. The verbal protocol represents what the expert *thinks* he or she is thinking, rather than providing an actual description of the problem-solving process. Protocols are very useful in determining the *information* that an expert uses, but they cannot provide an accurate step-by-step description of the information *processing*.

This leads to a situation that is very interesting from the social scientist's point of view. The more one's methods allow you to *see*, in a relatively unmediated way, complex social data, the more likely it is the social scientist will be able to tap into their powerful subcognitive processing abilities to uncover patterns, and by extension, rules that produced them. The more our methods take us away from a relatively unmediated "seeing," the more difficult it will be for social scientists to find the patterns that make possible human, and social science, understanding. While standard techniques of mathematics and statistics can help us confirm we are not imagining things, these techniques can only play a supportive role in social science, for social science is based upon these deeply rooted and profoundly powerful types of human processing.[10]

Political Behavior as Rule-Based

> *McNamara asked [Chief of Naval Operations George] Anderson what he would do if a Soviet ship's captain refused to answer questions about his cargo. At that point the Navy man picked up the* Manual of Naval Regulations *and, waving it in McNamara's face, shouted, "It's all in there." To which McNamara replied, "I don't give a damn what John Paul Jones would have done. I want to know what you are going to do, now."*
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> *Allison 1971,131*

> *One man alone can be pretty dumb sometimes, but for real bona fide stupidity there ain't nothing can beat teamwork.*
>
> *Edward Abbey*

We have noted in a previous section that pattern recognition and rule-based human behavior are but two sides of the same coin: the way that we impute meaning through pattern recognition is the way that we create meaning through our behavior. While this is easy to see for, say, individual chess players, most domestic and international political behavior is primarily the product of bureaucracies rather than individuals. An individual may influence the direction of a policy, but the implementation is still left to bureaucracies.[11] In everyday language this

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[10] Indeed, it is interesting to speculate that so many of our students have trouble understanding social phenomena through mathematics and statistics not because they are less intelligent, but because such techniques seem to the normal mind to be less powerful and less informative than “simple” social intuition which, far from being “simple” is in fact phenomenally complex. Perhaps the Post-Autistic Economics Movement may be seen as having chosen its name with care, for perhaps those who find these methods easy to use and particularly insightful may have brains that are somewhat atypical. This is not to necessarily suggest a pathological mental condition—the dramatic example of one of the giants of game theory, John Nash, notwithstanding—but rather that the tools through politics can be most comfortably understood may be quite different for those attracted to the contemplative abstractions of the academic life and those attracted to the rapid-paced, crisis-laden human interactions of the policy world.

[11] The focus here is on the Weberian "rational-legal" bureaucracy that dominates foreign policy decision-making structures in the modern era. This applies even in "revolutionary" situations: For example, the taking of American hostages in Iran during 1979-80 was outside the normal range of international behavior, but the attempts at resolving that issue were very much normal, including the unsuccessful rescue attempt and the eventually successful mediation by Algeria and other international agents. Similarly, the rhetoric surrounding the Iran-Iraq

organizational interaction is simplified—"Hitler decided to attack Poland"—but in virtually all cases (and certainly in systems which have a strong democratic and/or bureaucratic component) individuals are constrained to choose from a very small set of options that have been made available through a bureaucracy. While the "Great Man" [sic] model attempts to allow the cognitive processing of an individual replace bureaucratic decision-making in an organization, the individual is still dependent on an organization to supply (and filter) information and implement decisions. Behind every Great Man is a well-entrenched bureaucracy pleased to have someone else taking responsibility.

The shift from individual to organizational information processing produces a paradox: An organization, in order to obtain the capacity for large-scale information acquisition and policy implementation, must make substantial compromises in its information processing capabilities. Specifically, an organization must work within the bandwidth constraints of language, and it cannot directly invoke associative recall. In contrast, the sequential processing of *if...then* rules can be done within the constraints of working memory so this, rather than associative pattern recognition, is the preferred mode of information processing in organizations. In much of their behavior, the bureaucracies are not acting *as if* they followed rules; they are instead *explicitly* following rules and are expected to do so, rule-following being a *sine qua non* of bureaucratic behavior.[12]

Some of the early computational modeling projects in political science (for example Carbonell 1978, Thorson and Sylvan 1982, Sylvan and Chan 1984, Andriole and Hoople 1988) assumed that due to the rule-oriented nature of bureaucracies and the simplifications inherent in popular ideologies, one would be able systematically to extract an organizations rules and precedents from a sufficient quantity of debates, formal regulations and internal memoranda, and from these rules one could simulate much of the decision-making process. Based on the subsequent success of rule-based systems in replacing some routine managerial decision-making in business, this was not an unreasonable proposition. In fact, had the computational modeling

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war and the personal animosity between Saddam Hussein and Khomeini provided personalistic aspects to that conflict—as would the animosity between Saddam Hussein and various U.S. presidents named "George Bush" in the period 1990-2003 and between — but the military interactions were bureaucratically quite conventional.

[12] Thorough treatments of the role of rules and heuristics can also be found in Majeski (1987), Mefford (1991), and Sylvan, Goel and Chandrasekran (1990); the approach also permeates the Kahneman, Slovic and Tversky research.

projects focused on *routine* State Department activities, such as the processing of visa requests or arranging golf games for visiting members of Congress, the approach might have worked.

Instead, because an extensive set of documentary evidence was required, the typical focus of these projects was on critical decisions such as Vietnam. In crisis decisions explicit rules proved insufficient. Sylvan and Majeski's study of Vietnam decision-making quickly encountered the problem of "tacitness" and "tacit cultural rules" where many of the key elements required to understand the bureaucratic debate were absent from the recorded discourse:

> For example, the first few months of 1961 were marked by the eruption of a non-Vietnamese war in Indochina. The country, of course, was Laos, a subject on which Kennedy's advisers spent literally hundreds of hours. Yet the Vietnam documents of that time barely mention Laos. It is only after the crisis fades that explicit references to the Laos settlement are made, particularly in the form of 'lessons'. ... Our heuristics reflect very little of situation-specific interpretations, and this means we miss many of the allusions and other references in any given text. (Sylvan and Majeski 1986,11)

For example, the fundamental theme of anti-communism was never verbalized because it was a shared assumption:

> Most people employ a host of common sense rules for getting along in daily life; only a small handful of these will ever be verbalized. In part, this is because of their obviousness; in part, due to the embarrassment that would attend someone who reminded others about them. … If rules are shared in the [bureaucratic] culture as a whole (e.g. communism is bad), they will never (or almost never) be made explicit. (Sylvan and Majeski 1986,10)

Boynton noted a similar problem in trying to formalize the construction of narratives in Congressional hearings on the 1983-84 Lebanon policy:

> The apparent reason a narrative account was not constructed was that members of the committee knew what had happened. They had been arguing about Lebanon policy for well over a year, and they could take the knowledge of the events for granted. … My tentative conclusion is that narrative reconstruction is a fallback mode of reasoning. When the subject is well known [it] is not necessary (Boynton n.d.,8)

Because understanding involves matching observed events to a pattern, the function of political discourse is to provide sufficient information—in the forms of declarative knowledge, event sequences and substitution principles—to cause the audience to understand (i.e. pattern match) the situation in the same manner that the individual transmitting the information understands it. Political information transfer attempts to stimulate pattern recognition in the mind of the audience and thereby trigger a desired behavior. This process can occur between competing organizations as well as within them: Signaling in a conflict situation involves exchanging messages with an opponent in an attempt to get the opponent to take, or refrain from taking, certain actions. Thus, even the existence of bureaucratic actors does not diminish the human characteristics of pattern recognition as central to both understanding and action.

Agency, Computational Irreducibility, and the Question of Causality

If we as social scientists turn to this philosophical position--that pattern recognition is central to human understanding and action--and we build methodologies to take advantage of these powerful natural capabilities--we will have done more than simply proliferated methodological alternatives. We will have made possible the social scientists' embrace of human agency.

One of the most important critiques of quantitative social science methods is that they are incapable of explicitly embracing human agency. Indeed, it seems that agency is a nuisance, a perturbing variable and a source of noise, something complex that must be simplified out of consideration, rather than a central focus of investigation. This sacrifice of agency has seemed a justifiable trade-off for the ability to approach prediction, for prediction is seen as the side-door to causality.

For example, in the statistical approach the focus is almost always on aggregate behaviors. This is because such studies can take advantage of the Central Limit Theorem and other regularities that occur when one aggregates large numbers of variables that behave *as if* they were random—that is, the values of these variables cannot be predicted by the independent variables used in the study. This can yield some interesting insights, but they are insights of a different kind than the natural meaning-from-pattern-recognition process that we have discussed thus far. For example, one of the oldest and most solid statistical results in the study of war is the Poisson distribution of wars over time, first established by Richardson (1960). In sufficiently large samples, the distribution of wars occurs as if it was the result of a random selection of rare events. This is an interesting finding, worthy of note in any study of war. Nevertheless, this does not imply that the mechanisms or processes that led to any particular war are random: in fact, in all cases one can—and, indeed, the social scientist as human pattern recognizer may feel positively impelled to—assemble an extensive historical record indicating that the war resulted from a massively complex series of agency-produced decisions that were made for reasons that could be explicitly linked to various conditions in the world at the time. While those reasons may have some elements that might be considered random—messages get lost or misunderstood; individuals become incapacitated due to accident or disease; changes in the weather allow armies to move or force them to remain in place—in virtually all cases a narrative can be (and is) constructed that explains the war based on a probing of human (individual and bureaucratic) agency patterns linked to behavior, which provides meaning. Thus, although there are elements of the *aggregate* behavior that follow, quite precisely, a purely random model identifiable by statistical means, we cannot embrace human agency by using that pathway. We can only provide an account of human agency in social science by the *same* pathway we provide an account of it in daily life: seeing patterns and linking them to agency-based and meaning-providing rules.

It is fair to say, then, that this orientation suggests a whole new way of looking at causality in social science, a way that allows for an explicit embrace of human agency and the change it produces in human affairs. In a sense, this new approach redefines causality, falsifiability, and other important concepts in science and the social sciences.

If pattern recognition is the basis of human understanding of human behavior, then while one can specify rules that govern human behavior, it will be impossible to know for a surety in advance all of the consequences produced thereby. *Many* consequences can be known, but never all. As a result, there is, as Wolfram puts it, a "computational irreducibility" about rule-governed human behavior. This means that there is a limit to prediction in any theoretical science of social phenomena. In dealing with complex phenomena such as social behavior, a theorist will have to readjust his sights: specification of the rules, and an understanding of less than all of the consequences thereof, will now be his aim. Wolfram puts it this way:

> When viewed in computational terms most of the great historical triumphs of theoretical science turn out to be remarkably similar in their basic character. For at some level almost all of them are based on finding ways to reduce the amount of computational work that has to be done in order to predict how some particular system will behave. . . . If one views the evolution of a system as a computation, then each step in this evolution can be thought of as taking a certain amount of computational effort on the part of the system. But what traditional theoretical science in a sense implicitly relies on is that much of this

> effort is somehow unnecessary--and that in fact it should be possible to find the outcome of the evolution with much less effort. . . . In traditional science it has usually been assumed that if one can succeed in finding definite underlying rules for a system then this means ultimately that there will always be a fairly easy way to predict how the system will behave. . . . But now computational irreducibility leads to a much more fundamental problem with prediction. For it implies that even if in principle one has all the information one needs to work out how some particular system will behave, it can still take an irreducible amount of computational work actually to do this. . . .And this, I believe, is the fundamental reason that traditional theoretical science has never managed to get far in studying most types of systems whose behavior is not ultimately quite simple. [A]t an underlying level this kind of science has always tried to rely on computational reducibility, [s]o when computational irreducibility is present it is inevitable that the usual methods of traditional theoretical science will not work. And indeed I suspect the only reason that their failure has not been more obvious in the past is that theoretical science has typically tended to define its domain specifically in order to avoid phenomena that do not happen to be simple enough to be computationally reducible. (Wolfram, 2002, 737-742)

Our modified aims will then modify our definition of causality when attempting to understand human behavior. The act of imputing causality *is the act of identifying rule-based patterns in the phenomena we study*, with the caveat that the complete consequences of the rules specified are probably not going to be knowable in advance. Wolfram states, "whenever computational irreducibility exists in a system it means that in effect there can be no way to predict how the system will behave except by going through almost as many steps of computation as the evolution of the system itself" (Wolfram, 2002, 739). In general, then, there are no valid shortcuts to take, for we are not operating in a context of computational reducibility (generally speaking) in the social sciences.

Here is another way of approaching this redefinition of causality in the social sciences:

> "[A]bstract descriptions will never ultimately distinguish us from all sorts of other systems in nature and elsewhere. And what this means is that in a sense there can be no abstract basic science of the human condition--only something that involves all sorts of specific details of humans and their history. So while we might have imagined that science would eventually show us how to rise above all our human details what we now see is that in fact these details are in effect the only important thing about us. . . [The computational irreducibility of social phenomena] is what allows history to be significant--and what implies that something irreducible can be achieved only by the evolution of a system. Looking at the progress of science over the course of history one might assume that it would only be a matter of time before everything would somehow be predicted by science. But . . . the phenomenon of computational irreducibility now shows that this will never happen. There will always be details that can be reduced

> further--and that will allow science to continue to show progress. But we now know that there are some fundamental boundaries to science and knowledge. And indeed in the end [computational irreducibility] encapsulates both the ultimate power and the ultimate weakness of science. For it implies that all the wonders of our universe can in effect be captured by simple rules, yet it shows that there can be no way to know all the consequences of these rules, except in effect just to watch and see how they unfold." (Wolfram, 2002, 846)

We will adopt this new view of causality in the empirical work that follows. To wit, we will aim to see patterns in social behavior, and we will aim to specify rules that we have good reason to believe the human agents involved are in fact using to produce those patterns. Unlike model specification in traditional quantitative approaches, we cannot content ourselves with specifying the model that produces the highest r-squared, to use an analogy. Our attempts at understanding the behavior in question will only be successful if we embrace the human agency involved in producing those patterns in the first place. We can only understand if we understand via agency.

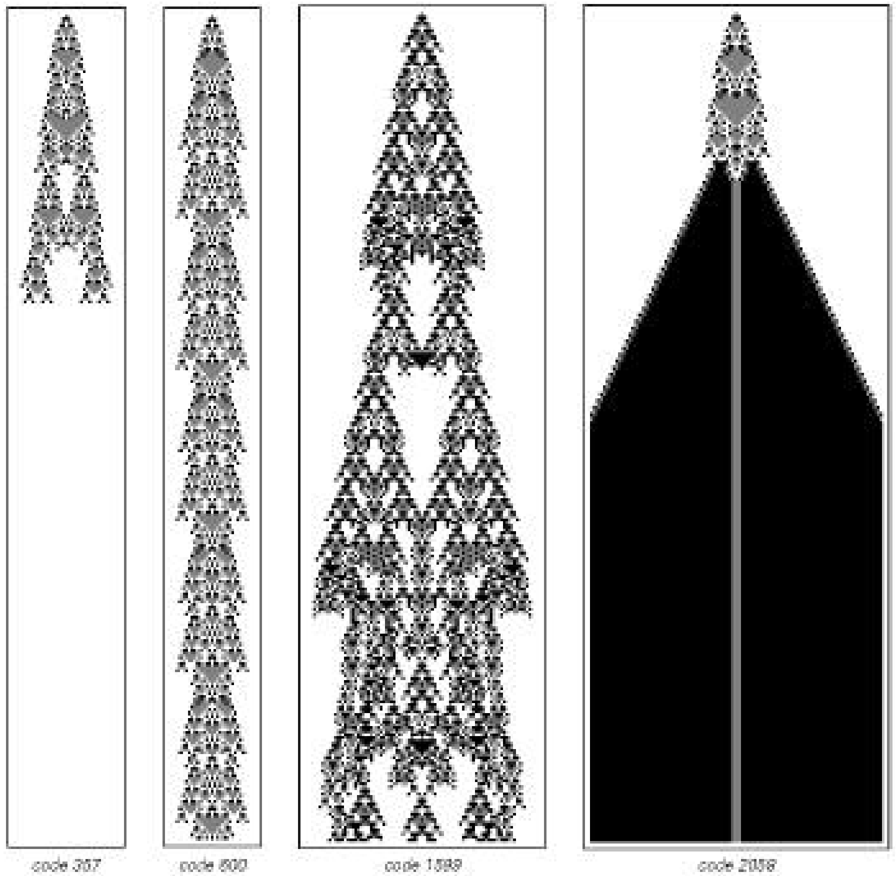
Even with this new definition of causality, we previously spoke of the moral imperative in social science to preserve a concept of falsifiability, for social science seeks to inform social policy. What does falsifiability now mean in the context of this new view of causality? Fortunately, we can still claim a form of falsifiability, while simultaneously asserting that falsification cannot be completely determinable. Unlike the situation where one has asserted "all swans are white," and then comes upon a black swan that falsifies the assertion in a universal, time-independent sense, our new view of causality imposes a temporal boundedness to our ability to falsify. Thus, while it is still possible to determine for a given period of time whether one specific set of rules is more or less satisfactory than another specific set of rules in accounting for the behavior during that period, we would no longer be able to say with any degree of certainty that that judgment would hold outside of that time period. In a sense, then, falsifiability is not a one-shot process. As the system evolves and unfolds, what was a less satisfactory rule specification in one time frame may prove to be the most satisfactory specification in another. As these judgments change, so we would expect policy to change, thus meeting the moral imperative we have spoken of previously.

Seeing Human Behavior

As we noted previously, humans perceive patterns. There is a *feeling* or a *seeing* of patterns that cannot be verbalized because of its strong dependence on associative reasoning. Thus, if we wish to build new social science methodologies based on human pattern recognition capabilities, we must invent a way of seeing human behavior. Wolfram encountered much the same challenge in analyzing his cellular automata, which he created with the specification of arbitrary rules:

> [O]ne of the major features of the new kind of science that I have developed is that it does not have to [confine itself to computationally reducible systems]. . . .And that is why--unlike most traditional works of theoretical science--this book has very few mathematical formulas but a great many explicit pictures of the evolution of systems. . . But if one has such a system, how does one decide what questions are interesting to ask about it? Without the guidance of known theorems, the obvious thing to do is just to look explicitly at how the system behaves--perhaps by making some kind of picture." (Wolfram, 742, 793)

Wolfram himself has run hundreds of thousands of rules and sets of rules, noting the behavioral outcome over a given time stream. This decades-long enterprise has yielded the understanding that some rules and combinations thereof produce patterns that grow and predominate, whereas others create patterns that dwindle and die out. Some patterns display a complexity nearly completely understood from the rules themselves, while others are unexpectedly complex and not completely comprehended by an examination of the rules themselves. Figure 2 is an example shows an example of each general pattern: from left to right, code 357 dies out; code 600 produces a complex but repeating pattern; code 1599 produces a complex pattern that does not repeat for the duration of the run displayed, and code 2058 produces a pattern that does not repeat (it continues to expand beyond the limits of the display shown here) but ceases to produce complexity.



Source: Wolfram, pg. 69

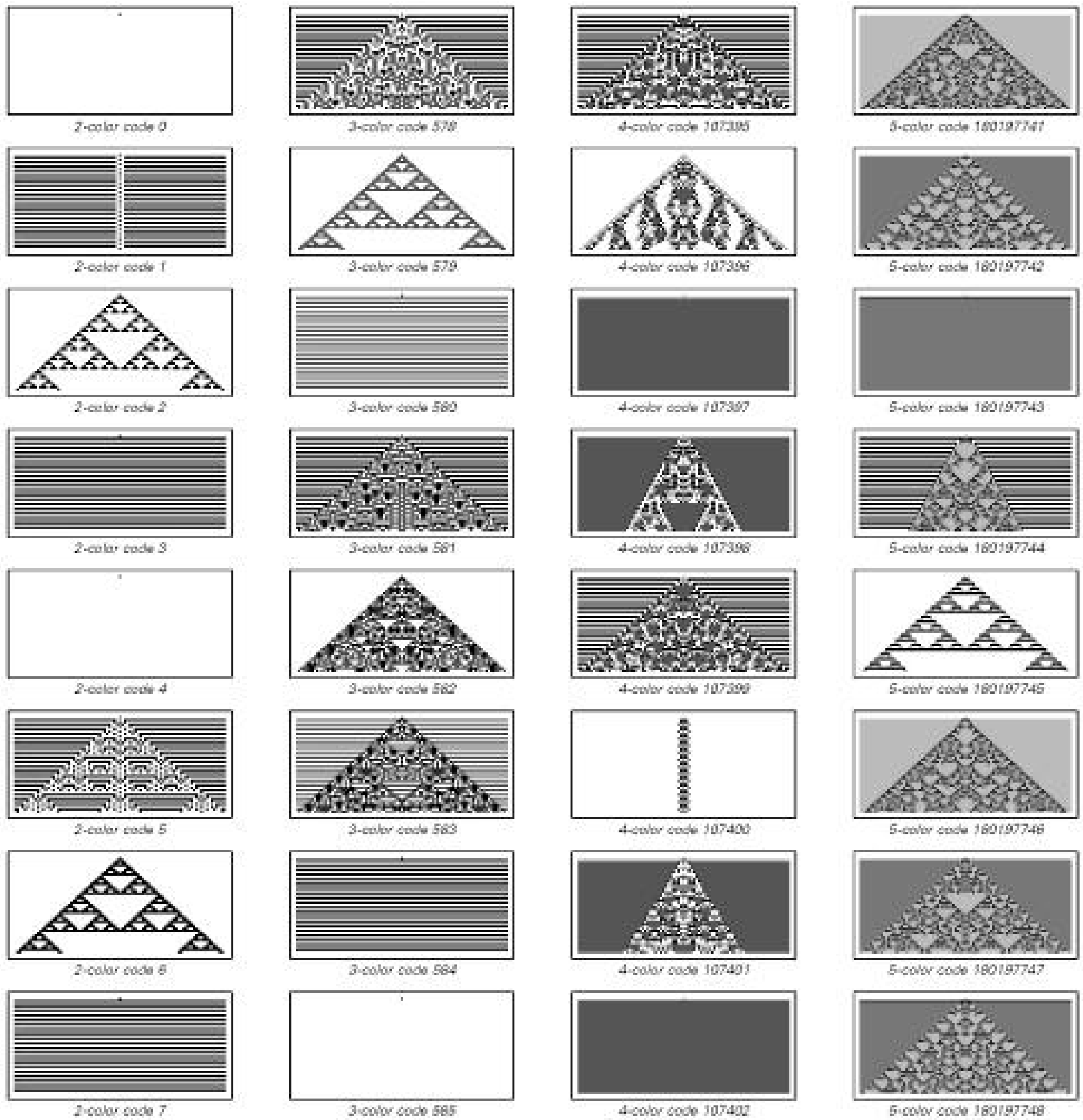
Figure 2: Examples of general categories of patterns

Patterns can also be analyzed at several levels when one is dealing with more than one rule. Wolfram found that complexity reached its peak with three or four rules, and that additional rules did not create additional levels of complexity, a finding whose significance we will discuss in a moment. Yet in systems using, say, three rules, it is possible to look at the patterns of each rule in isolation, and then in combinations of two, and then in the final amalgamation of all three. Patterns at lower levels may produce unexpected patterns at higher levels of observation, producing, if you will, meta-patterns from the contributions of the individual rules. Figure 3 shows a wide variety of different patterns that can be produced from relatively simple rules, along with Wolfram's commentary on this.

In our quest to move towards this new methodological approach, we have had to confront several challenges in devising a plausibility probe:

- do we have time stream data of human behavior in IR that we could use for a test?
- can we create a system of seeing that human behavior?
- can we specify a small set of rules understood to be used by the human agents involved?
- can patterns and meta-patterns be discerned in this way, thereby accounting for the behavior in question?

It is to these questions that we now turn.



Examples of cellular automata with rules of varying complexity. The rules used are of the so-called totalistic type described on page 60. With two possible colors, just 4 cases need to be specified in such rules, and there are 16 possible rules in all. But as the number of colors increases, the rules rapidly become more complex. With three colors, there are 7 cases to be specified, and 2187 possible rules; with five colors, there are 13 cases to be specified, and 1,220,703,125 possible rules. But even though the underlying rules increase rapidly in complexity, the overall forms of behavior that we see do not change much. With two colors, it turns out that no totalistic rules yield anything other than repetitive or nested behavior. But as soon as three colors are allowed, much more complex behavior is immediately possible. Allowing four or more colors, however, does not further increase the complexity of the behavior, and, as the picture shows, even with five colors, simple repetitive and nested behavior can still occur.

Source: Wolfram, pg. 107

Figure 3: Wolfram's example of the diversity possible with simple rules

Why Events Data? Why the Israelis and Palestinians?

A mathematician may say anything he pleases, but a physicist must be partially sane.
Josiah Willard Gibbs

In this exercise, we attempt to show the possibilities and pitfalls of Wolfram's approach to understanding human behavior in the arena of international politics. We selected events data, not because we are not familiar with the weaknesses of events data, but because the noisy time stream of events data closely resembles the types of inputs humans are constantly processing in social pattern recognition. Data was coded into the WEIS scheme using TABARI, a computer program from the Kansas Event Data System (KEDS) project that creates event data from machine-readable text.[13] The events were coded from Reuters News Service lead sentences obtained from the NEXIS data service for the period April 1979 through May 1997, the Reuters Business Briefing service for June 1997 through September 1999, and Agence France Presse from October 1999 to December 2003. The coding software, coding dictionaries and data are available at the KEDS web site, `http://www.ku.edu/~keds`.

For the event counts, we use the following categories based on the WEIS two-digit cue categories:

verbal cooperation: WEIS categories 02, 03, 04, 05, 08, 09, 10
material cooperation: WEIS categories 01, 06, 07
verbal conflict: WEIS categories 11, 12, 13, 14, 15, 16, 17
material conflict: WEIS categories 18, 19, 20, 21, 22

This reduces the number of distinct event categories that can be used as independent variables to a manageable amount and eliminates the problem of three-digit WEIS categories that have very low frequencies. It is also likely to reduce the effects of coding error somewhat: Several of the "verbal conflict" codes in WEIS are ambiguous even for human coders, and the automated coding probably generates some misclassification within those categories.

For this first exercise, we also wished to choose a dyad whose behavior was highly reactive one to another and has been the focus of sufficient media attention that we can be

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[13] Discussions of machine coding can be found in Gerner et al. (1994), Schrodt and Gerner (1994), Huxtable and Pevehouse (1996), and Bond et al. (1997).

confident that the event data are a reasonably accurate description of the actual behavior in the system. The dyadic relationship between the Israelis and Palestinians, while certainly affected by the initiatives of third parties, is nevertheless quite internally reactive, as many scholars have noted (see for example Bickerton and Klausner 1998, Gauss 1998, Gerner 1994, Goldstein et al 2001, Tessler 1994). Again, this particular dyad is a good place to start for this exercise.

While we will be using event data in this analysis, one could use this approach on almost any information on human behavior over time. One could look at the time stream of memoranda that comprises the Pentagon Papers, for example. One could look at market behavior over time. One could look at negotiation moves between the parties involved in the North Korean talks. And one need not only look at monads or dyads, but could examine N-ads, as well. Any human behavior, or artifact thereof, that can be laid out in a time stream can be viewed from this perspective. The data need not be at any level of measurement precision beyond categorical. And one can combine types of data; one could look at patterns made by time streams composed of behavior found in presidents' speeches and currency values, for example. Unlike mathematics-based methods where data must be at the same or nearly the same level of measurement precision to be combined, there is no such stricture in this method.

A Way of Seeing: Introducing the Website

We needed a mechanism by which we could "see" what the Israelis and Palestinians were doing to each other. Accordingly, using the KEDS data, we created a web-based instrument of sight, which is to be found at `http://ep.jhax.org` and which is entitled "Event Patterns." Please use your browser to go there now.[14]

When you access the site, you will see its basic format is a variety of inputs to the system, some set by default, some requiring input to proceed. At the end of this list of inputs, you activate the "seeing" mechanism by hitting one of three buttons: "None," "Graphic," or "Text." With "none" you will get no display. With "graphic" you will get a time stream graphic using symbols to denote types of behavior by the Israelis (blue) and the Palestinians (green). With

[14] There is a guidebook to using the website, which is provided in our appendix, but is also online at that same URL. As of 15 March 2004, the default values in the web site are set to the rules analyzed in this paper, and therefore it

"text," you will receive a raw coding output of the KEDS data. For our purposes in this paper, we will be choosing "graphic."

However, before you hit "graphic," there are a minimal set of inputs that you must provide. At the very least, you must input a starting data and an ending date to bound the display. The possible range is 19790415 (15 April 1979) to 20031231 (31 December 2003), the limits of the data that we have available.[15] Dates are entered full year first, then month, then day. If your computer is not very powerful, we suggest you upload one year's worth of display first to test your machine's capabilities. More capable machines should be able to handle the entire two decades, if so specified.[16] Try inputting a time frame and then hitting "graphic" now. Once you hit that button, your computer may display generic "image icons" for a moment as it performs its computations, but in a few moments those will resolve into graphic symbols.

The more interesting possible inputs are entitled "patterns" and "display." It is here that you have the capability to perform discrete pattern transformations on the graphic output. This is where you may "try out" putative rules that you believe the Israelis and Palestinians are using, and then you may "see" whether those patterns account for any of the behavior in the set. We will demonstrate those capabilities in a moment.

At the time of this writing, we have partially instantiated the capability to look at any of the actors in any of the KEDS events data sets. When you click the button to the right of the default "data source" input, you will see options of looking at events in the Balkans, Africa, China, Iraq, and many arenas. What is not fully instantiated at the time of this writing is to provide a list to you of alphabetic actor codes and subnational codes. That will come before we submit this paper for publication; they can also be obtained by downloading the appropriate coding dictionaries from the KEDS web site..

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can be used to generate a complex display without entering any specific values. The discussion that follows assumes that you want to look at something other than the default rules.

[15] The Kansas Event Data System project has a Levant data set at http://www.ku.edu/~keds/data.html/levant.html that is updated every three months, and at the present time (March 2004) is current to 31 December 2003. However, due to a change in the availability of Reuters report, that data set switches to Agence France Presse as a source after 30 September 1999, and the frequency of events reported by AFP is substantially greater than that reported by Reuters. In addition, the final months of the Reuters data appear to be extremely sparse—probably due to the gradual deterioration of Reuters services that eventually led us to switch to AFP—and consequently the apparent absence events in 1999 may be an artifact of the data.

[16] Which is to say the display works just fine on Schrodt’s Macintosh G5 but crashed Hudson’s Dell.

There are other possible inputs to play with. Most concern the size and characteristics of the graphic display itself. But there are others that may have more substantive use when probing for rules-based patterns in the data, such as "days per unit."

Rule Specification and Visual Inspection in this Probe

In this initial probe of the approach, we desired to specify some very simple rules and then see how well they "accounted for" the behavior of the Israelis and Palestinians. Respecting agency as the source of both Israeli and Palestinian behavior, we needed to specify rules that we could justify as having meaning and making sense for the actors involved. Thus, as noted previously, rather than selecting rules on the basis of how well they conformed to an event stream, we selected rules on the basis of how well they corresponded to what experts in the field assert are the rules these actors do use.

Wolfram himself provides encouragement that the rules need not be many, and neither do they need be complex. For example, he states, "Simple and definite underlying rules can produce behavior so complex that it seems free of obvious rules" (Wolfram, 2002, 752) and then goes on to elaborate that in his years of experience analyzing complex systems,

> But when in general does complexity occur? [I]f the rules for a particular system are sufficiently simple, then the system will only ever exhibit purely repetitive behavior. If the rules are slightly more complicated, then nesting will also often appear. But to get complexity in the overall behavior of a system one needs to go beyond some threshold in the complexity of its underlying rules. The remarkable discovery that we have made, however, is that this threshold is typically extremely low. [I]t ultimately takes only very simple rules to produce behavior of great complexity. . . . Instead, once the threshold for complex behavior has been reached, what one usually finds is that adding complexity to the underlying rules does not lead to any perceptible increase at all in the overall complexity of the behavior that is produced. (Wolfram, 2002, 105-6)

Indeed, Wolfram found that the most complex behavior could be obtained with the use of approximately three rules. We feel that there is reason to believe that the set of rules being employed by the Israelis and Palestinians in enacting what they feel to be meaningful behavior toward one another is also not very large, nor very complex. Signalling between organized human collectives, especially those in conflict, almost mandates that only a small set of simple rules be used in order to maximize the chances that the other group will understand the meaning intended by the action.

Furthermore, because international politics is a complex problem solving environment, heuristics—simple rules used to partially solve complex problems—are of particular importance. Purkitt observes:

> To cope with limited cognitive capabilities, individuals selectively process information and use a limited number of heuristics or mental rules of thumb as cognitive aids in their effort to manage information. This apparently universal reliance on intuitive heuristics to solve all types of problems seems to be due to the need to compensate for the limitations of short-term memory and information processing capabilities. By using intuitive mental heuristics, people can develop a problem attack plan which permits them to develop a subjectively acceptable problem solution. (Purkitt 1991,43)

In fact, rational choice and balance of power theories are both heuristics in the sense that they are relatively simple; they come with a complex set of side-conditions; and they are intended as general rules to guide decision-making, without providing a complete specification of actions to be taken. To the extent that an heuristic is shared by the decision-makers in a political system—for example balance of power in 19th century European diplomacy or the Chicken game in 20th century nuclear deterrence—it reduces uncertainty and becomes self-validating.

Therefore, we endeavored to come up with a small set of fairly simple rules that could be justified on the basis of scholarship concerning Israeli and Palestinian actions.

The first rule we used was the classic "tit-for-tat" approach immortalized by Anatol Rapoport and, more recently, Robert Axelrod (1984). Country experts have asserted that the Israelis and Palestinians consciously use this rule. If the Israelis followed Palestinian aggression (or cooperation) of a certain threshold and in a certain time period by aggression (or cooperation) of their own (or vice versa), then we could account for such behavior using the tit-for-tat rule. We could also identify instances where tit-for-tat was not operating, thus providing a way of "seeing" which behaviors could be accounted for by the rule and which could not.

But we also wanted to compare tit-for-tat with another rule, for two reasons. First, we wanted to see the comparative ability of two rules to account for Israeli and Palestinian behavior. That is, we wanted to demonstrate that such a comparison, which is necessary for our modified definition of falsifiability, is possible. Second, we wanted to see the operation of two actor-based rules operating simultaneously. We wanted to know if it was possible to "see" such a simultaneous operation of more than one rule.

Therefore, the second rule we used was one that we have labeled the “olive branch”: one side responds to a period of conflict with cooperation rather than reciprocating the conflict. The olive-branch rule is the standard gambit for breaking out of the mutually-destructive DD/DD/.../DD sequence in the classical prisoners’ dilemma game.

In addition to analysis of actor-based rule specification, we also believed it was possible that the Israelis and Palestinians were creating a "meta-pattern." Now, to this point, we have only been interested in using rules defined by actor agency to account for that actor's own behavior. But what if we performed a discrete pattern transformation that allowed us to see what behavior the Israelis and Palestinians were, to use an analogy, weaving together? The combination of the idiosyncratic use of the actor-rules might be producing a pattern all its own--a pattern that neither party intended. Viewing such a meta-pattern might allow us to reflect not on the meaning each actor intended, but the meaning produced together—which might have an altogether different character.

Patterns and Meta-Patterns in the Israeli-Palestinian Dyad: Accounting for Behavior with Rules

All of the analyses that follow are derived from a set of rules implemented at the default web page at `http://ep.jhax.org`.(accessed 12 March 2004). As noted above, these combine a tit-for-tat (TFT) analysis with several meta-rules based on whether or not the actors are adhering to the TFT pattern of behavior. We define TFT with respect to behaviors aggregated over a six-day period, and look only at material conflict and cooperation; these are compiled separately. An actor is defined as showing the behavior only if the number of events exceeds a set threshold—this is 4 events in a six-day period for Israel and 2 event for Palestine (the asymmetry is used because the media report Israeli action with a much greater frequency than Palestinian actions). The various other indicators and meta-rules are built from these threshold events. The indicators were downloaded from the web site using the “Text” option, and then reading those results into MS-Excel.

Because there are 4485 points in the complete data set (15 April 1979 to 31 December 2003 in two-day intervals), it was necessary to construct some means of summarizing the results. The figures below give 32-day moving totals of the number of times that a pattern was matched:

this measure has the value of 16 if the pattern matched in every one of the two-day periods in the 32-day interval. The values for Israel and Palestine are “mirrored” across the X-axis, with the counts for Israel above the axis and Palestine below.

As we anticipated, there is a very large discontinuity in all of the graphs following 1999. Unfortunately, this is likely due to two factors, one involving the situation and one involving the data. The situational discontinuity was the outbreak of the second Palestinian intifada in September 2000. The level of violence during this period was substantially greater than that experienced during the first intifada in 1988-1991, and consequently the number of reports of violence is objectively higher. In addition, the Palestine Authority had achieved some degree of international legitimacy following the Oslo peace agreement, and the international response in to the second intifada has been more sustained and open than that during the first intifada, where the U.S. in particular engaged in negotiations with the Palestinians very reluctantly. Objectively, one would expect the two periods to appear different.

However, we also have a change in data sources here, with Reuters prior to October 1999 and Agence France Presse (AFP) following that period. As discussed in Schrodt, Gerner and Simpson 2001, AFP generally has a much higher density of coverage of the Israel-Palestine conflict than Reuters has in the periods where we can examine the coverage of both sources. Consequently some of the increased intensity of coverage is, in all likelihood, due to the change in data sources.

Whatever the cause, the net effect of these two changes is that the data during the period 2000-2003 generally overwhelm our indicators, which either spike to their maximum values for the entire period or go to zero. Because we frequently see this occurring for measures of *both* conflict and cooperation, it seems more likely to be an artifact of the increased coverage of AFP. The solution to this problem would be to use higher thresholds for the AFP data; we intend to experiment with this adjustment at a later date.

Tit for Tat Analysis

The first analysis that we undertook was to look for the classical tit-for-tat behavior. Tit-for-tit is one of the most widely studied patterns of political behavior, and in addition it has long been known that reciprocity is one of the strongest patterns in event data (see for example Dixon 1986, Ward and Rajmaira 1992, Goldstein and Freeman 1992, Goldstein and Pevehouse 1996).

We were confident that we would find tit-for-tat patterns; the question was whether they would occur in a meaningful fashion.

Figures 4 and 5 show the 32-day moving totals for incidences of conflictual and cooperative tit-for-tat, which were compiled separately (i.e. conflictual TFT refers to a period of material conflict by one side followed by a period of material conflict by the other). Several characteristics are evident in these displays.

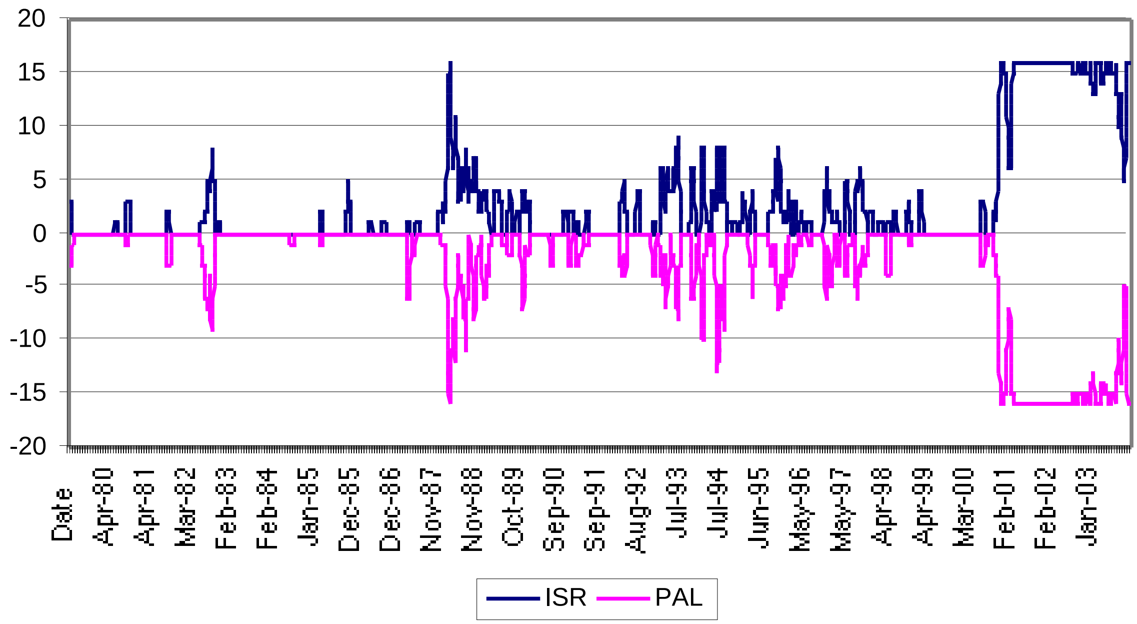

Figure 4. Tit-for-tat conflict

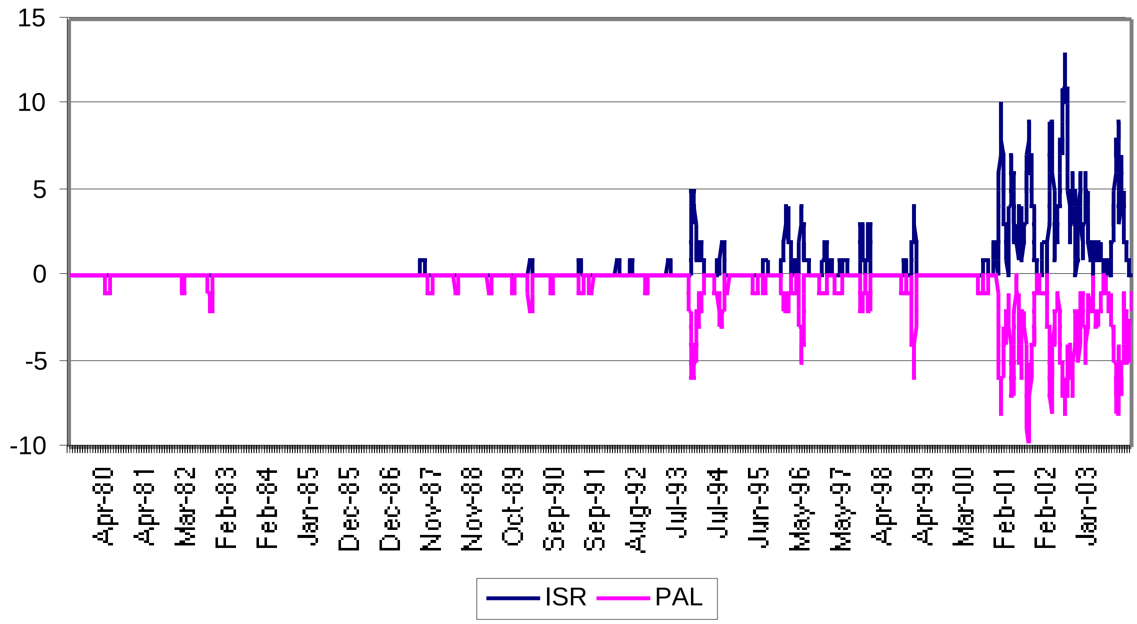

Figure 5. Tit-for-tat cooperation

First, the behaviors are generally, but not totally, symmetric—generally when one side is engaging in TFT, whether cooperative or conflictual, the other side is doing so as well. There is no reason that this must be the case, but the fact that we observe it suggests that the two antagonists are implementing a classical TFT solution to the prisoners' dilemma game. Unsurprisingly, give our qualitative understand of the conflict, they are far more likely to be playing DD than CC.

Second, most of spikes in the conflictual TFT correspond to periods of substantial violence such as the first and second *intifadas* and Israel's 1982 invasion of Lebanon. Theoutbreak and decline of the first *intifada* from December 1987 to August 1990 shows the same exponential-decay shape that is seen in Goldstein-scaled data for the period (Schrodt and Gerner 1994). Similarly, the negotiations following the Oslo agreement in September 1992 and prior to the outbreak of the second *intifada* in September 2000 are evident.

The surprising aspect of these two graphs is the juxtaposition of TFT conflict *and* cooperation during the post-Oslo period. This is not an error and is an illustration of the utility of objective events patterns over vaguely remembered narratives: one tends to forget that while the Oslo period saw nowhere near the levels of violence seen in the second *intifada*, there were periods of substantial conflict, such as the four suicide bombings in Tel Aviv and Jerusalem and subsequent Israeli reactions to these in the spring of 1996, shortly after Israel's military withdrawal from Palestinian urban areas. Conversely, negotiations have continued at both the official and unofficial levels (e.g. the recently concluded Geneva Accords between Israeli and Palestinian citizen elites) during the second *intifada.*

Olive Branch Rule

The second set of rules we looked at were the "olive-branch"—instances where one side engaged in cooperation despite having experienced conflict from the other side. These instances are shown in a 32-day moving total in Figure 6.

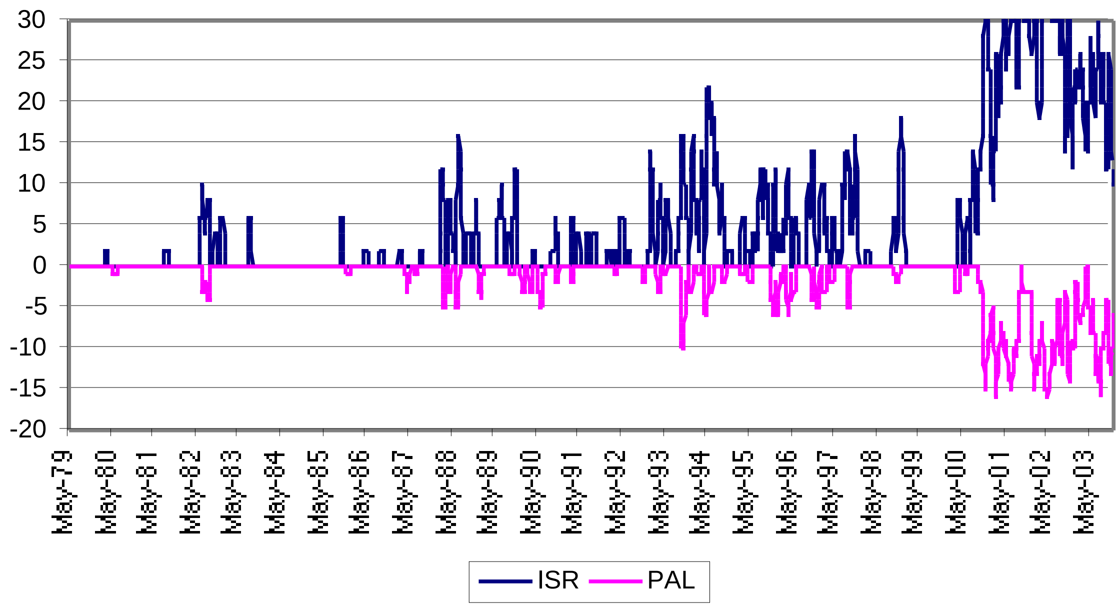

Figure 6. Olive branch pattern

The olive-branch pattern turns out to be far better than the cooperative TFT pattern at delineating the Oslo period. Like cooperative TFT, one also sees olive-branches occurring during the second *intifada*, but we believe that this is consistent with the narrative record. It is also interesting to note that one sees a number of olive-branch instances following the outbreak of the first *intifada*, and continuing in a sporadic pattern until the Oslo agreement. This would appear to be consistent with changes in Israeli policy as they experimented with a variety different levels of response to the *intifada*, and to international pressure for a resolution of the dispute following the first Iraq war in 1991.

The olive-branch patterns show substantially less symmetry than was seen in the TFT graphs, even in the post-Oslo period. Some of this may be a calibration issue: events with Israel as an actor are consistently reported more frequently than events with Palestine as an actor. However, this is unlikely to be the only explanation, given the symmetry for the TFT rules. A more likely explanation is that the Palestinians, as the weaker party, are more likely to be the follower than the leader in offering cooperation. This story is also consistent with the pattern seen in the cooperative TFT graph prior to Oslo: there are a number of instance when the Palestinians engaged in cooperative TFT—that is, cooperated following cooperative behavior by Israel—but this was rarely reciprocated, as seen by the absence of spikes above the X-axis. This might have led the Palestinians to get less inclined to initiate olive-branches, since their experience is that unilateral cooperation would not be reciprocated. A final possible explanation may simply be the fact that Israel has a major stronger and cohesive state structure and is therefore better able to implement policy shifts.

An interesting example of the olive-branch pattern in the display can be seen in Figure A3 in the Appendix. We selected this because it was a frame that “jumped out” when the display as a whole was being scanned—suddenly a long series of orange arrows (the olive-branch indicator) appear on the Israeli side, with some limited reciprocity on the Palestinian side.

This appeared sufficiently unusual that we went back to the original source texts to see what was going on. As the figure caption indicates, this was the period of U.S.-mediated negotiations at the Wye Plantation conference center that attempted to get the Oslo process back on track amid a deteriorating security situation. As the negotiation were presented in the press reports, Israel—under U.S. pressure—was offering a number concession, while the Palestinian negotiators were generally considering that the U.S. was taking a position that favored Israel’s interests and did not consider these offers to be adequate implementation of Oslo. While the display obviously does not provide all of that information, it does signal that something interesting is going on, and in this instance, we were alerted to this by the display.

Meta-Rules

Our final set of experiments dealt with looking at the incidence of "meta-rules." These were implemented as four boxes of different colors at the right-hand edge of the display, and were intended to detect both the level of escalation and de-escalation in the activies, as well as its consistency. The four rules are

Red box	Meta-rule 2: no cooperation in previous period; only one side using conflict
Black box	Meta-rule 1: no cooperation in previous period; both sides now using conflict
Purple box	Meta-rule 3: no conflict in previous period; currently mixture of conflict and cooperation
Yellow box	Meta-rule 4: no conflict in previous period; currently cooperation only

In essence, the red and black boxes represent *escalation*; the purple and yellow *de-escalation*. If none of the meta-rules apply, the final column is left blank.

Making sense of the meta-rules has thus far proven more difficult than we anticipated, in part because they fluctuate quickly. Graphs similar to those used for tit-for-tat and the olive-branch rules are not particularly informative, so instead we spent some time simply looking through the entire display and trying to determine patterns using that highly sensitive pattern recognition device, the human visual cortex. Using this method, two "meta-patterns" seem to be evident.

First, to use Wolfram's phrasing, "purple grows." In the parts of display prior to the Oslo Agreement in 1993, signals are usually umambiguous: there is either conflict or the absence of conflict, and the meta-boxes are either black, red, or absent (cooperation is rare during this period, as we saw in Figure 5). In the post-Oslo period, in contrast, purple becomes more and more dominant, indicative of mixed conflict and cooperation.

This is, in all likelihood, a reflection of a critical change in the situation: the rise of Islamic militant groups to challenge the legitimacy of the Palestinian Authority and the Palestine Liberation Organization as the sole "voices" of the Palestinian opposition to Israel. A second factor that may also be contributing to this is the increase in visible international mediation, particularly by the United State and Europe, who know strongly encourage talks between Israel and Palestinian representative even there is a high level of violence on the ground. Prior to Oslo, when there was no mutual recognition between the two sides, talks (if present at all, and they usually weren't) were in secret or through intermediaries, whereas now both sides have to respond to public calls for negotiations even in times of conflict.

The second meta-pattern that we have noted is that the majority of the meta-boxes are red: following a period of no cooperation, conflict is initiated by one side or the other, rather than simultaneously. Lest this seem obvious, one should note that this is quite a different pattern than one sees in a conventional war, where the normative pattern would be that the two sides "meet on the field of battle" and engage in conflict simultaneously. In the Israel-Palestine conflict, the dominant is instead *asymmetric* conflict incidents, typically in the form of brief Israeli military raids and even shorter small-scale Palestinian attacks such as violent demonstrations, attacks on Israeli settlements, and (following 1996, when the tactic was introduced) suicide bombing. While generally these occur in a tit-for-tat fashion, there is a significant time lag between the stimulus and response and this therefore triggers a red meta-rule.

A couple of other patterns appear to suggest themselves, but we need to do further systematic analysis to determine whether these are actually occurring at a level beyond that expected by chance. First, it appears that in the pre-Oslo period, Israel tends to get the "last word" in a period of extended conflict—that is, it is an Israeli action that triggers the last occurrence of a red meta-box. Following Oslo, these shift over to the Palestinians. If this shift is in fact real, it may be another manifestation of the decentralization of Palestinian militant activity following Oslo.

The other general change between the pre- and post-Oslo pattern—and this involves an overall assessment of the display, not just the meta-rules—is the increase of material cooperation (typically, agreements) by the Palestinians. Prior to Oslo, "cooperation" by the Palestinians was simply the absence of conflict; following Oslo we start to see cooperation events, even during periods of conflict. Again, much of this can be explained by the fact of mutual recognition that came with Oslo—prior to Oslo, the two sides had no public arena in which to cooperate. Israel, as the occupying power, could engage in unilateral concessions to the Palestinians (for example easing restrictions), but there could be no parallel official Palestinian response. This situation changed following the Oslo agreement.

Conclusion

Event data have in employed in the analysis of international behavior for over four decades, but arguably we are still trying to learn how to use them effectively. This type of data—a nominal time series—is rarely encountered in other fields such as economics and medicine that make extensive use of statistical methods, and consequently there are relatively few places from which we can borrow techniques. Instead we must invent our own.

This paper has been an initial foray into the realm of using discrete patterns similar to those pioneered by Wolfram as a tool for event analysis. Our work here has been primarily a descriptive validation of the potential of this approach: since no one had looked for patterns in this fashion before, we first needed to demonstrate that we could find them, and that the patterns had some plausible correspondence to our underlying qualitative understanding of the situation we were analyzing.

One of our concerns when we embarked on the analysis was whether we would posit plausible patterns and find nothing in the data. Our experience has, instead, been the opposite—the problem is not that we are finding too little, but we are still finding too much. When one combines the remarkably rich set of patterns that can be constructed using the quite simple methods aggregation methods available in the pattern-specification language with the ability to rapidly construct colorful, web-based displays at a very fine time interval, it is difficult to figure where to go next with the analysis. On the other hand, with a few exceptions, we are finding very credible "patterns in the patterns"—these do not occur at random, but instead their rise and fall generally tracks changes in the political situation which we know about from qualitative narratives.

In this conclusion, we will suggest three issues that we see most readily in need for further research using this method. These are: calibration of the thresholds; the interaction of multiple sets of rules; and the issue of developing abstract representations for rules.

Calibration

The time lags and event-count thresholds that we used in this analysis were arbitrary first-guesses based on our general familiarity with this data set. One calibration decision we made—the use of different event count thresholds for Israel and Palestine—was clearly correct: with the distinct thresholds, the patterns frequently track each other nicely, whereas if we had used the same threshold for both actors we would have had severe problems with either over-counting or under-counting. However, as was evident in all of the figures, we have at least one calibration problem: Reuters-based data versus AFP-based data. It is possible, however, that there are others as well—for example the period around 1982 and 1985 appear a bit too quiet.

Calibration will become an even greater issue if we start comparing rules across different cases. While we have done all of this analysis on the Israel-Palestine case, there are about a dozen different data sets available for analysis on the web site, and clearly one cannot use the same thresholds for each of them due to the differences in the level of media coverage.

Ideally one would like to find some sort of "scale-free" patterns that would give similar results for various different levels of event densities: in other words, patterns that would be sensitive only to the *relative* frequency of events rather than to the *absolute* frequency. It may also be possible to construct rules that can automatically compensate for lower levels of media coverage by looking at longer periods of time. That is, if one has a region that receives, say, only 10% of the media attention that the Israel-Palestine conflict receives, adjust for this by aggregating over periods that are, in some sense, ten times longer.

The second issue in calibration is simply to see how the conflict appears at increasingly higher thresholds, almost as though one was focusing a telescope or microscope to get an optimal view of a specimen. When the threshold is set too low, a pattern will fit too easily, and the resulting series will largely consist of noise. When the threshold is set too high, the pattern fits too rarely and almost never occur. In between these two extremes the pattern fits "just right" and provides the best analytical view of the situation.

Multiple rules and actors

The analysis we have done in this paper is at a very high level of aggregation. "Israel" includes not just all parts of the Israeli government—including the actions of opposition leaders and parties—but also non-governmental actors such as settler groups and citizen activists. "Palestine" is even more diffuse, and encompasses over time the PLO, various militant groups such as Hamas and Islamic Jihad, the quasi-governmental Palestinian Authority (after 1994), and individual Palestinians.

Each of these groups may be operating according to rules, but they are not necessarily the same rules. In some instances groups that we have included within a single actor are working directly at cross-purposes. The on-going competition between the PLO/PA and Islamic militant groups is probably the most important example in the data, but conflicts have also occurred between the Israeli government and settler groups, and within Israeli governments. One can extend this further to note that standard theories of bureaucratic behavior would suggest that the operating of competing rule sets will be the norm rather than the exception in political behavior.

In the analysis we have presented here, we have not explicitly represented these alternative rules, although we can see at least one cases where they were applied: the patterns of tit-for-tat cooperation that occur simultaneously with the tit-for-tat conflict during the second intifada period (Figure 5). Islamic military groups and the Israeli military are engaging in high levels of conflict, while simultaneously one gets externally mediated negotiations between Israel and individuals representing the Palestinian Authority and, at the very end of the series, the independent "Geneva Accord" negotiations between non-governmental elites from both Israel and Palestine.

A potential strength of the pattern-based approach would be the ability to explicitly model these multiple agendas. That modeling could be further enhanced if we used the full capabilities of automated coding to code sub-state actors.

A Language of Patterns

The final issue we wish to consider is the question of how patterns should be represented. W have an abundance of choices, and only time will tell which is the most effective method.

Wolfram's work is all done using a very simple graphical representation of rules: he simply shows what pattern will replace each possible existing pattern. The rules are—somewhat ironically—implemented in the mathematical programming system *Mathematica*, which was originally designed to work with the continuous variable equations of the type that Wolfram now seeks to replace as the foundation of analytical work in the natural sciences. This simple method of representing rules was sufficient to keep Wolfram busy for ten years producing *A New Kind of Science*; the fact that Wolfram developed *Mathematica* and owns the company of produces it gave him the wherewithal to take ten years on the project.

When Hudson and Schrodt originally thought about this project, they envisioned something similar to Wolfram's rules. However, as they worked with Whitmer, who has done extensive computer programming for Web-based applications, it was clear that because of the stochastic aspects of event data and the lag times involved in political behavior, we would need a more complicated representation. Whitmer, using the general-purpose programming language Java, developed a pattern description language that provides only a small number of operators for specifying patterns—basic arithmetic, time lags and intervals, and the minimum and maximum functions. However, consistent with Wolfram's core notion that complex systems can be built from very simple components, these rules were quite adequate to develop a rich set of patterns, rules, and meta-rules; in fact we have just begun to explore the possibilities with this.

But there are still [many] other alternatives. Early in the project, Schrodt decided to do a quick run through the data looking for tit-for-tat patterns to make sure that these existed and had a reasonable qualitative interpretation before we invested a lot of additional effort. Most of Schrodt's recent programming has used the text-processing language perl, which contains it's own very rich set of textual pattern recognition operators based on the "regular expressions" used in Unix. To look for tit-for-tat using regular expressions, the event stream was first converted to weekly strings of text where "C" and "c" represent cooperative events (WEIS <110) for Israel and Palestine respective;"D" and "d" represent conflictual events (WEIS>=110). This reduces the event stream to a series of lines that look like the following, where the date is in <>.

```
<871115>cC
<871122>DcDcCcD
<871129>DdCCCDDcd
<871206>DdDDDCDcCD
<871213>dDDDDDDDcdDD
<871220>DDDdDDDDcdDCD
<871227>cDCdddDD
<880103>DDdDDDDDCDDDDcDcDdDdDddDdDD
<880110>DCdCDddDDDDDDdcDDdDcdCcDdDDddCDCddDdDDDDDDDDCcdcd
<880117>cccCCDcCcDDDdddDDCddDdddDD
<880124>dCDDCDdDCdDdDDDDdCdDDD
<880131>dDDDDcDDDcdDDCCdDccdDcDcdDDDDDcCDD
<880207>ddDDDDDDDCDcCcCcddDDDDCCcDDcC
<880214>CccCDCDDDcCDCcDDDDDDDD
```

Using this as the input, tit-for-tat on a weekly basis can be found using a short perl program where the core code is:

```
if (($last =~ m/(C[^C]*){$thres,}/g) && ($line =~ m/(c[^c]*){$thres,}/g))
   {$ic = 1;} else {$ic = 0};
```

```
if (($last =~ m/(D[^D]*){$thres,}/g) && ($line =~ m/(d[^d]*){$thres,}/g))
   {$id = 2;} else {$id = 0};
if (($last =~ m/(c[^c]*){$thres,}/g) && ($line =~ m/(C[^C]*){$thres,}/g))
   {$iC = 3;} else {$iC = 0};
if (($last =~ m/(d[^d]*){$thres,}/g) && ($line =~ m/(D[^D]*){$thres,}/g))
   {$iD = 4;} else {$iD = 0};
if ($iC || $iD)  {$iISR = 2;} else {$iISR = 0};
if ($ic || $ic)  {$iPAL = 1;} else {$iPAL = 0};
```

In this program fragment, `$last` is the string from the previous week; `$line` is the string from the current week; and `$thres` is the minimum threshold for the number of events. The variables `$iISR` and `$iPAL` take the value zero if the actors are not using tit-for-tat and non-zero-values if they are. When these variables are read into Excel, this produces a chart such as the one in Figure 7.

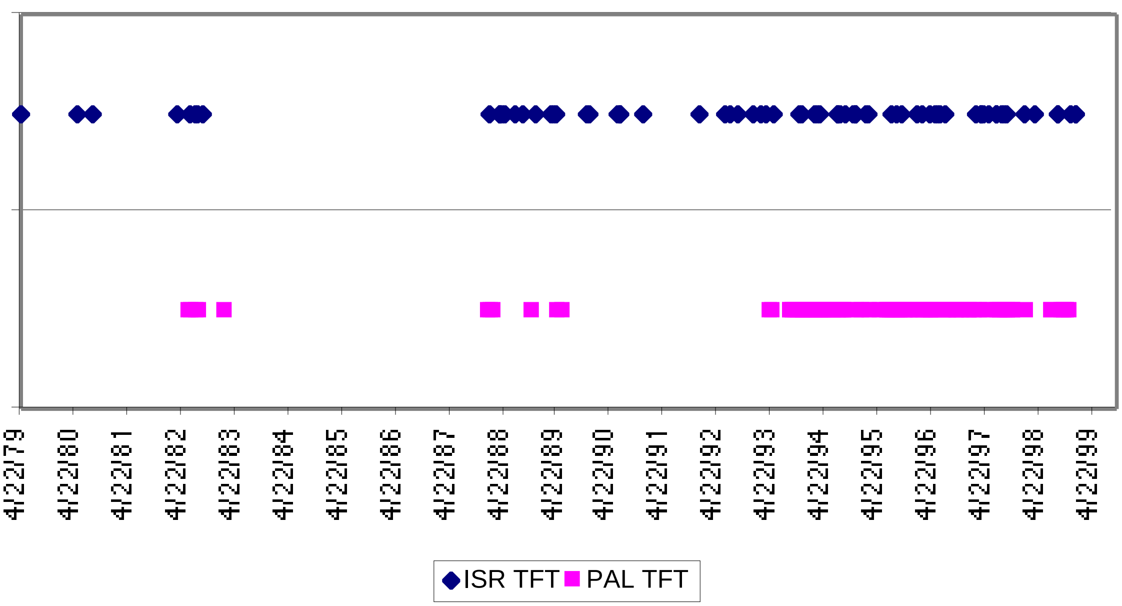

Figure 7. Weekly tit-for-tat behavior computed using a perl regular expressions

So, one year into this project and we have at least three very different ways of representing patterns: Wolfram's graphs, Whitmer's set of arithmetic operators, and Unix/perl regular expressions. All three methods are very abstract; all three methods are capable of expressing a wide variety of rules.

Which method is "best"?—we don't know, and at this point we don't want to know, since we are still in the early stages of investigating this mode of research. Our point is simply that we need to develop a language (or languages) for expressing patterns, much as mathematicians in the 16th and 17th centuries found ways to standardize the notation and operations of classical continuous variable mathematics. The power of any notation comes from its ability to express complex ideas in a compact form, and the ability of the user to quickly read "idiomatic" expressions in that notation. We expect (sometimes in vain...) that our students can recognize that the statement

$$4x = 2x - 2$$

can be solved to give a unique value for "x." With a bit of coaching, we can get them familiar with the fact that

$$y = ax + b$$

is a line, and then gradually—provided the student has sufficient background in algebra and calculus—introduce idioms such as the calculation of a variance from a sum and sum-of-squares, interpretation of the logit equation, and eventually derivation of the ordinary least squares estimator in matrix notation.

However, we are able to do this with suitably trained and motivated students because 99% (in fact usually 100%) of the notation was standardized outside of the field of political science: a student who learns matrix algebra in the mathematics department or economics department—or for that matter learns it in China before attending graduate school in the U.S.—finds no changes when applying that notation to the analysis of political behavior. This is not the situation with abstract pattern recognition.

Computer languages such as perl may, in fact, be the first step in such a standardization.

> One of Perl's key features as a language is regular expressions; in fact, Perl has probably done more to evolve regular expressions than any other language. If you are not familiar with regular expressions, think of them as the ultimate string manipulation tool for serious string processing. *Regular expressions are to strings what math is to numbers.* Andrew Clinick, Program Manager, Microsoft Corporation, January 22, 1999 (http://msdn.microsoft.com/workshop/languages/clinic/scripting012299.asp; accessed 18 December 2000)

However, the utility of perl depends on one's ability to read the language idiomatically, and until one has had considerable experience with abstract syntax of regular expressions, perl is anything but transparent. Whitmer's arithmetic rules have the advantage of being built from simple operations that any student who remembers middle-school algebra should be able to understand. However, even though the operations are simple, figuring out their combined effects, and learning the idiomatic "tricks" that one uses to get the arithmetic expressions to effectively describe patterns that fundamentally are not arithmetic patterns is still a complex process. We undoubtedly still have a ways to go on this issue.

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Appendix 1: Instructions for Using the JHAX Event Pattern Web Site

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1. Introduction

The JHAX Event Prediction Website `http://ep.jhax.org`.is a web-based program that manipulates and displays data about world events. This page focuses on the technical aspects of the program, ignoring many significant things such as qualities of the data and the search for rules that might usefully predict events, etc.

2. Source Code

The Java Programs and Java Server Programs on these pages were written by Ray Whitmer and have been released under the GPL, meaning roughly that anyone can use them freely (both in terms of source rights and cost) as long as they are not redistributed as part of a non-free program. The sources may be viewed or downloaded on the internet without registration of any form.

When you follow the Java Programs link above, you see a list of several files that contain some of the main parts of the code. If you click on the version number, you will that version of the file. From either of these links, you can click on "download" to get an exact copy of the file. Clicking on the file name takes you to a history of the file.

EventDisplay is the main object that constitutes the event display of the program. It knows what all the program parameters are, how to get them and send them, and how to use them to create a textual or graphical display. Event is a simple object representing a single event that may be read from a file. EventTypePattern assigns a name to patterns of these event types, each interfacing to the scheduling. Servlet causes a virtual graphic to be drawn from a special graphics URL referenced by pages where a graphical display has been requested. Mostly this just calls back into the EventDisplay class. Displayable controls drawing each symbol for the graphical display.

The JHAX.org main source page has links to sources and documentation of various systems.

3. The Page is the Program

The main page of the web site presents a set of field values that control the program, filled in with working default values. This page describes how to modify the values to get exactly the desired output. When the form values have been modified, pressing any button at the bottom of the form causes the values to be incorporated into the URL shown at the top of the browser, so the address of the page with the settings built-in can be easily bookmarked or emailed.

3.1 Data Source

The data source field allows selection of which file of data to filter and display. Currently only one may be selected at a time. Each data source is displayed by the name of the file as unarchived from http://www.ukans.edu/~keds/data.html. See that website information on the data sets, and to see what each contains. When using a data set with the program, it may important to know when the data set starts and ends, which actors are represented in the data, and so on to produce a non-empty display.

3.2 Actors' Map

The actors' map field identifies all actors in the data that will be uniquely represented on the display, as defined further on in the display description. This field value might typically map source actors to A and B, for dyadic interactions between two parties. Event data often has far more actors represented than can be well-represented seperately in the display. Mapping specific actors to generic names (letters of the alphabet) also permits the same patterns and display description to be more-easily reused with different actors.

The actors' map field may be changed to map different primary actors into the existing scheme, to add more specific mappings into the dyadic scheme, or to go beyond the dyadic scheme (for example using further letters of the alphabet for n-way event displays). All otherwise-unmapped actors are mapped to UNK, which can also be referenced in the patterns or display.

The actors' map value is a list of comma-seperated mappings. Each mapping has a source followed by equals and a target name, as follows:

<source actor>[*] = <target actor>[, ...]

Like most parameters of this program, the source and target actors are case-sensitive, so the display description must be coordinated using the proper case.

The source actor may end in an asterisk to map all actors that start with that source. Where multiple mappings match the same source actor, the first matching declaration takes precedence. For example, the in the mapping list FO*:A,BA*:B,BAR*:A, the mapping BAR*:A does not map anything since BA*:B already included everything starting with BAR*, but in the example FOO*:B,FO*:A,BAR*:A,BA*:B, the mappings FOO*:B and BAR*:A make exceptions to FO*:A and BA*:B respectively since they occur first.

3.3 Event Codes

The event codes field maps the numeric codes of source events to a usually-smaller set of event types to be presented in the display.The comma-seperated values in this list alternate target verbs and the source integer codes in ascending order starting with the target for negative infinity and concluding with the target for positive infinity, as follows:

<code>[, <verb>, <code>[...]]

For example the list previous,10,foo,100,bar,500,unknown maps all values below 10 to previous, values from 10 to 99 inclusive to foo, values from 100 to 499 inclusive to bar, and values greater than or equal to 500 to unknown. The values previous, foo, bar, and unknown will be presentable in this case in the display description. To add a distinct verb for code 200, the list becomes

previous,10,foo,100,bar,200,distinct,201,bar,500,unknown.

Note that the bar mapping has to be reinstated at 201 or the distinct mapping would have been in effect until 500.

3.4 Days per Unit

The days per unit field contains an integer that controls, among other things, how many days of events will be displayed on each line of the display. When the number of days per row is changed, this also affects patterns that all reference time units explicitly or implicitly. With 2 days per unit a sum of 10 units duration will sum events from 20 days, with a week per unit this becomes 10 weeks, and with a day per unit, this becomes 10 days, etc.

Although the default setting is 2, a better choice for the setting may be 1, because it does not degrade the acuracy of the data source and interprets durations more-simply as days. This would double the size of the output and represent fewer events per row, which may also be a good thing.

3.5 Patterns

The patterns text box allows assignment of names to counter expressions, one per line. Assigned pattern names may be used in other patterns or in the display. Each line has a pattern identifier followed by the counter expression, as follows:

<pattern identifier> = <counter expression>

Counter expressions are described in section 4.

3.6 Display

The display text box specifies how specific events will be represented on the display. Each line of text consists of four comma-seperated values, as follows:

<column number>, <symbol shape>, <symbol color>, <counter expression>

A description follows of these fields except for the counter expression, which is described in section 4.

3.6.1 Column Number

The column number specifies the column of the graphical output to which the line outputs symbols (the column's width, symbol size, offsets, etc. are governed by the previously-described fields). If two lines in the display description output symbols to the same column, the symbols come out in the order that the lines appeared in the display description. Referencing higher column numbers causes the the graphical output to become wider to include the specified column.

0 is interpreted as the number of an invisible column, which can be used to temporarily remove something from the graphical output. Positive column numbers produce output of symbols in the respective columns starting at the left side. Negative column numbers output to the same columns as the corresponding positive numbers, but starting at the right side of the

column and proceeding to the left, possibly colliding with output to the positive column number, but with reverse offset to avoid collisions as long as possible.

3.6.2 Symbol Shape

The symbol shape specifies the program-supported shape that is to be drawn to symbolize the particular output. The program originally supports BoxFill, PointFill, BoxOutline, and PointOutline, which correspond to boxes or arrow-points that be filled or drawn as an outline. The arrow points always have their tip in the direction of progression, meaning that outputting to a negative column number makes them point left and outputting to a positive column number makes them point right. Support for additional symbol shapes will likely be added at some time in the future.

3.6.3 Symbol Color

The symbol color specifies which color to use to paint the symbol using an 8-digit hexadecimal (base 16 with digits 0123456789abcdef) number which specifies, two digits at a time the value of the alpha, red, green, and blue components of the color (00,01,02,...fd,fe,ff).

The red, green, and blue components specify how much of the respective colors are mixed to produce the corresponding color simulation in humans (dogs and partially-colorblind humans detect two color components, shrimp detect twelve, and publishers may only detect one or less, making the system biased towards normal humans).

The alpha component tells how opaque the color is.

For example ff000000 is opaque black (red green and blue all 0), 00000000 is transparent black (totally invisible), 80000000 is half-transparent black (things show through 50%), e00000ff is an eighth transparent blue (things show through 12.5% with non-zero blue), e0808080 is an eighth transparent gray (things show through 75% with red green and blue equal), etc.

3.6.4 Counter Expression

The counter expression describes the counter which specifies how many of the symbols to draw on a particular row of the display. See the section on counter expressions.

3.7 Starting and Ending Date

Starting or ending date fields may be used to limit (or even artificially extend) the display. This is especially useful to spare the browser (and the web server) the load of redisplaying the entire data set graphically. A browser which is in the process of downloading too much data might also be stopped by pressing the stop button or escape key (or closing and restarting the browser). If left unspecified, the starting or ending date of the data source will be used.

A properly-specified date for this program consists of 8 digits which are run together with no seperating spaces or punctuation. The first four digits are the year number, the next two the month, and the last two are the day, as follows:

<year digit><year digit><year digit><year digit><month digit><month digit>
<day digit><day digit>

Anything else (except leaving the field blank to specify no date) should cause an error.

3.8 Symbol Size

The symbol size field tells the program how many dots high and wide in the resulting display of a symbol should be in the graphical output. If specified as a single number, the same value is used for width and height, but two comma-seperated values may be given to independently specify width and height for less-symmetrical sizes as follows:

<symbol width>, <symbol height>

For example, 6,12 specifies symbols that are twice as high as they are wide.

Changing the symbol size is one easy way to change the width and length of the resulting page since symbol size directly contributes to page size.

3.9 Pixel Offset

The pixel offset field tells the program how many dots to shift when offsetting symbols to avoid total occlusion of different symbols in the graphical display. This effects the total width of the display, because when space is reserved for symbols in the display, each possible offset reserves this much space horizontally and vertically. If specified as a single number, the same value is used horizontally and vertically, but two comma-seperated values may be given to independently specify the horizontal and vertical pixel offsets, as follows:

<horizontal pixel offset>, <vertical pixel offset>

These values may also be specified as negative numbers to cause the offsetting to occur on the opposite side of the symbol, i.e. the value 0,-3 eliminates horizontal offsetting and makes the vertical offsetting occur by three pixels at each offset in the opposite direction from default offsetting. The offsetting is also reversed when dealing with left-justified versus right-justified columns in order to make total occlusion of symbols from opposite sides of the column less likely.

3.10 Dimensions

The dimensions field contains three other comma-seperated values that are used in the layout of the graphical output, as follows:

<column width>, <height>, <offsets per row>

Column width is the number of symbols that may be placed in each column. As with symbol size and pixel offset, this directly effects the total width of the graphical output.

Height is the number of rows of symbols that may be placed in a single graphic before exhausing the space. This effects the total height of each graphic and inversely effects the total number of graphics that will be required to present the requested output.

Offsets per row is the number of offsets that can be distinguished in a particular row before total occlusion occurs. Together with pixel offset, this controls how much extra space is reserved for each symbol to allow offsetting, also effecting the width and height of the graphical output.

3.11 Image Type

The image type field specifies which browser-supported image format to use, Jpeg or PNG. The best choice is according to what your browser supports. While JPeg is slightly older and may be supported in more browsers, PNG is more-suitable to the task because Jpeg is designed to compresses pictures containing continuously-varying shades and loses things in the process, which means that if you choose Jpeg, the graphics will take longer to download and the symbols will be fuzzier in color and position.

GIF is an older format that deals better with non-continuously-shaded graphics such as the output of this program, but after the format became popular, Unisys made it legally risky to use the format in a program, which is why the World Wide Web produced PNG (Portable Network Graphics) an unencumbered and more-advanced replacement that is supported by later versions of standards-compliant browsers.

3.12 None, Graphic, and Text Buttons

Pressing one of these buttons makes a request of the server to incorporate the current form fields into the URL (so they can be bookmarked), adding the specified display of events to the page.

- If none is pressed, any graphic or text display of events is removed, which may be useful for bookmarking the undisplayed form.
- If graphic is pressed, the graphical output of the program is displayed.
- If text is pressed, a textual version of the output of the program is displayed.

4. Counter Expressions

A counter expression computes some number usually based on event counts. This can be an event type, a pattern name, a number, or an expression.

4.1 Event Type

When as a counter expression, the event type refers to the number of matching events in the current unit of time.

An event type is a source actor, followed by dash, followed by a target actor, followed by dash, followed by the verb, as follows:

<source actor>-<target actor>-<verb>

The event type is aways interpreted after mapping the actors and codes, so the source and target actors must each be targets in the actor map field and the verb must be from the event codes field. If, for example, the actor map produces source and target actors A and B and the code maps to the target verb MaterialCooperation, then the corresponding event type to refer to the count of such events is A-B-MaterialCooperation.

4.2 Pattern

A pattern is a name (with no dashes) that refers to the counter expression of a previously-declared pattern.

4.3 Number

A number is an integer constant that is returned instead of a counter. This is most-useful as part of a more-complex counter expression, since it is boring to display the same number of symbols on every row of the display. Asking for the sum of a constant over a time range will return the constant once for every time unit, because it behaves like other expressions during ranges, but as a constant value rather than as the result of counting something.

4.4 Expression

A counter expression describes how to combine event counts in the data set to determine how many symbols to output for identifying interesting patterns. The expression is represented as an operation type (sum, min, or max), followed by parentheses encloding one or more comma-seperated constants, event types, or nested counter expressions that describe what is to be summed, minimized, or maximized. Optional brackets may follow the parentheses-enclosed values, allowing the operation to gather data from before the current time being presented. Inside of the brackets is a non-negative integer specifying how many units before the current time the operation begins. A colon and second number may follow the first number specifying in how many time intervals the data should be processed. An optional slash and divide value may follow the operation and optional bracketed numbers.

Note that in the random sampling of examples follow, with descriptions of the interpretation by the program, previously-defined patterns can be used instead of event types.

sum(A-B-MaterialCooperation,A-B-VerbalCooperation)

The sum of material and verbal cooperations from A to B at the current time.

sum(A-B-MaterialCooperation,A-B-VerbalCooperation)[5]

The sum of material and verbal cooperations from A to B five units of time before the current time.

sum(A-B-MaterialCooperation,A-B-VerbalCooperation)[0:10]

The sum of material and verbal cooperations from A to B during the ten units of time ending at the current time.

sum(A-B-MaterialCooperation,A-B-VerbalCooperation)[5:10]/3

The sum of material and verbal cooperations from A to B during the ten units of time ending five units of time before the current time, divided by 3.

min(A-B-MaterialCooperation,A-B-MaterialConflict)

The lessor of the material cooperation or the material conflict from A to B at the current time.

min(A-B-MaterialCooperation,A-B-MaterialConflict)[0:50]

The least count material cooperation or material conflict from A to B in the 50 days ending at the current time.

min(sum(A-B-MaterialCooperation,A-B-MaterialConflict))[0:50]

The least of the sums of material cooperation and material conflict in each day from A to B in the 50 days ending at the current time.

min(sum(A-B-MaterialCooperation,A-B-MaterialConflict)[3:5])[0:50]

The least of the 3-day-old 5-day sums of material cooperation and material conflict from A to B in the 50 days ending at the current time.

min(sum(A-B-MaterialCooperation,A-B-MaterialConflict)[0:5])[3:50]

The same interpretation as the previous example.

min(max(sum(A-B-MaterialCooperation)[0:1])[0:1])[0:1]

Since minimums, maximums, and sums of a single value are that value and an age of 0 and duration of 1 is just default interpretation in the current time, this expression should be simplified to the unadorned event type with no additional expression, i.e. A-B-MaterialCooperation.

min(A-B-MaterialCooperations)[5]/2

Which operator (min, max, or sum) was specified is irrelevant since it applies to a single event type and time unit, but some operator was required so that dividing and aging could be specified.

Note that the division makes little sense in this sort of case because the counter is at most 1.

min(A-B-MaterialCooperations)[0:5]/2

The operator is now relevant, because minimization is applied over a period of 5 units of time, the result of which is divided by 2.

min(1,sum(A-B-MaterialCooperations,B-A-MaterialCooperations)[0:5]/10)

Count the number of material cooperations between A and B in either direction over the latest 5 days, scaling by a tenth so that a symbol for 10 or more, but never display more than 1 symbol.

sum(-1,min(1,sum(A-B-MaterialConflict)[0:5]/10),min(1,sum(B-A-MaterialConflict)[0:5]/4)[5])

Return 1 symbol whenever at least 4 material conflicts from B to A spread over at most 5 units of time is followed by at least 10 material conflicts from A to B spread over at most 5 units of time.

Note that the -1 sum of this expression could produce a negative result, but the display output treats negatives the same as zero, so it was not necessary to surround the expression with max(0,<expression>), which could have prevented negative results.

Examples of the display:

The following figures give examples of the display produced by the web site. The symbols are:

<u>Column 1:</u>

Green box	Palestine cooperation (empty for verbal; solid for material)
Green arrow	Palestine conflict (empty for verbal; solid for material)

<u>Column 2:</u>

Blue box	Israel cooperation (empty for verbal; solid for material)
Blue arrow	Israel conflict (empty for verbal; solid for material)

<u>Column 3:</u>

Green arrow	Palestine conflict above threshold
Red solid box	Palestine tit-for-tat conflict
Red empty box	Palestine unilateral conflict
Yellow solid box	Palestine tit-for-tat cooperation
Yellow empty box	Palestine unilateral cooperation

<u>Column 4:</u>

Blue arrow	Israel conflict above threshold
Red solid box	Israel tit-for-tat conflict
Red empty box	Israel unilateral conflict
Yellow solid box	Israel tit-for-tat cooperation
Yellow empty box	Israel unilateral cooperation

<u>Column 5:</u>

Black box	Meta-rule 1: no cooperation in previous period; both sides now using conflict
Red box	Meta-rule 2: no cooperation in previous period; only one side using conflict
Purple box	Meta-rule 3: no conflict in previous period; currently mixture of conflict and cooperation
Yellow box	Meta-rule 4: no conflict in previous period; currently cooperation only

Figure A1. 7-December-1987 to 8-March-1988: Outbreak of first *intifada*

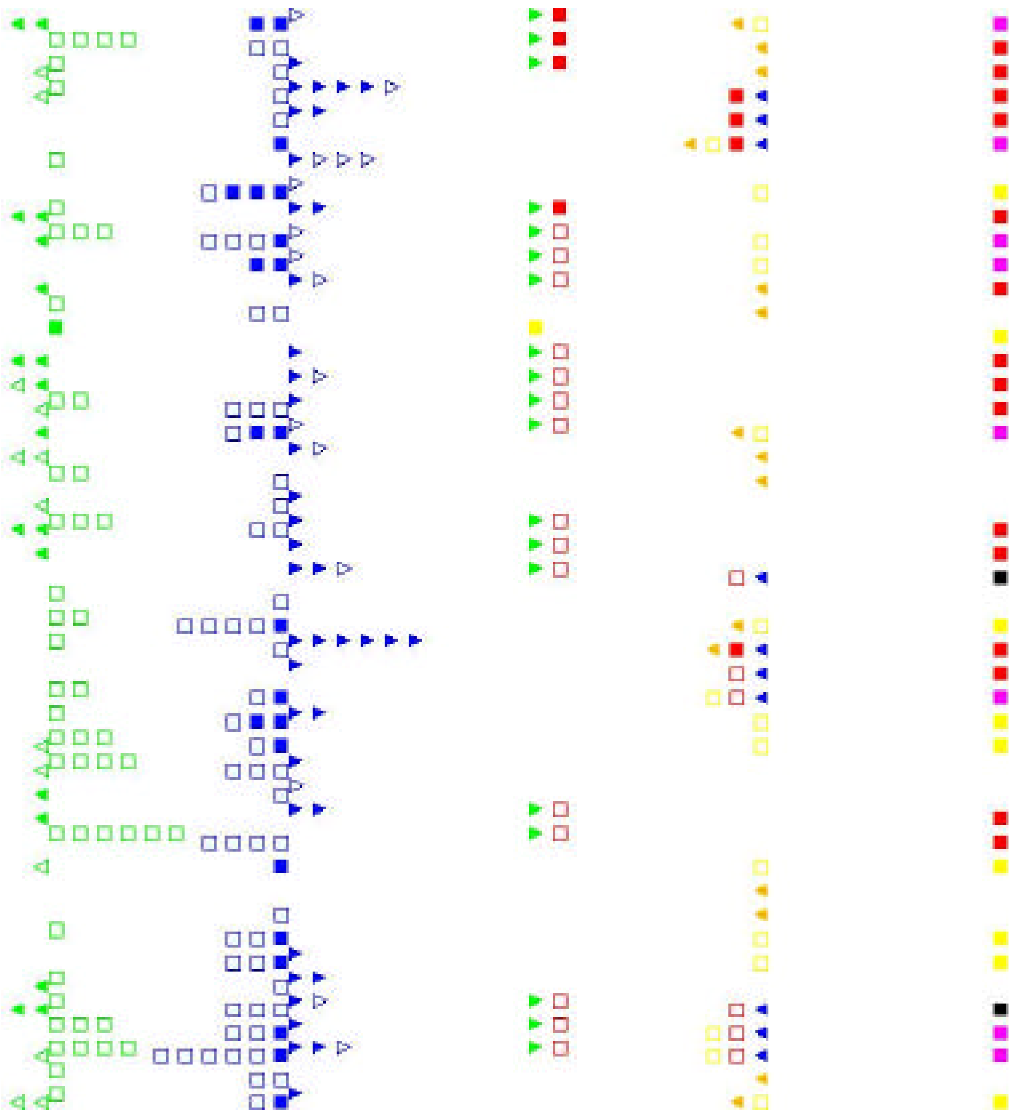

Figure A2. 25-March-1994 to 25-June-1994: Period between signing of Oslo Agreement and Rabin assassination

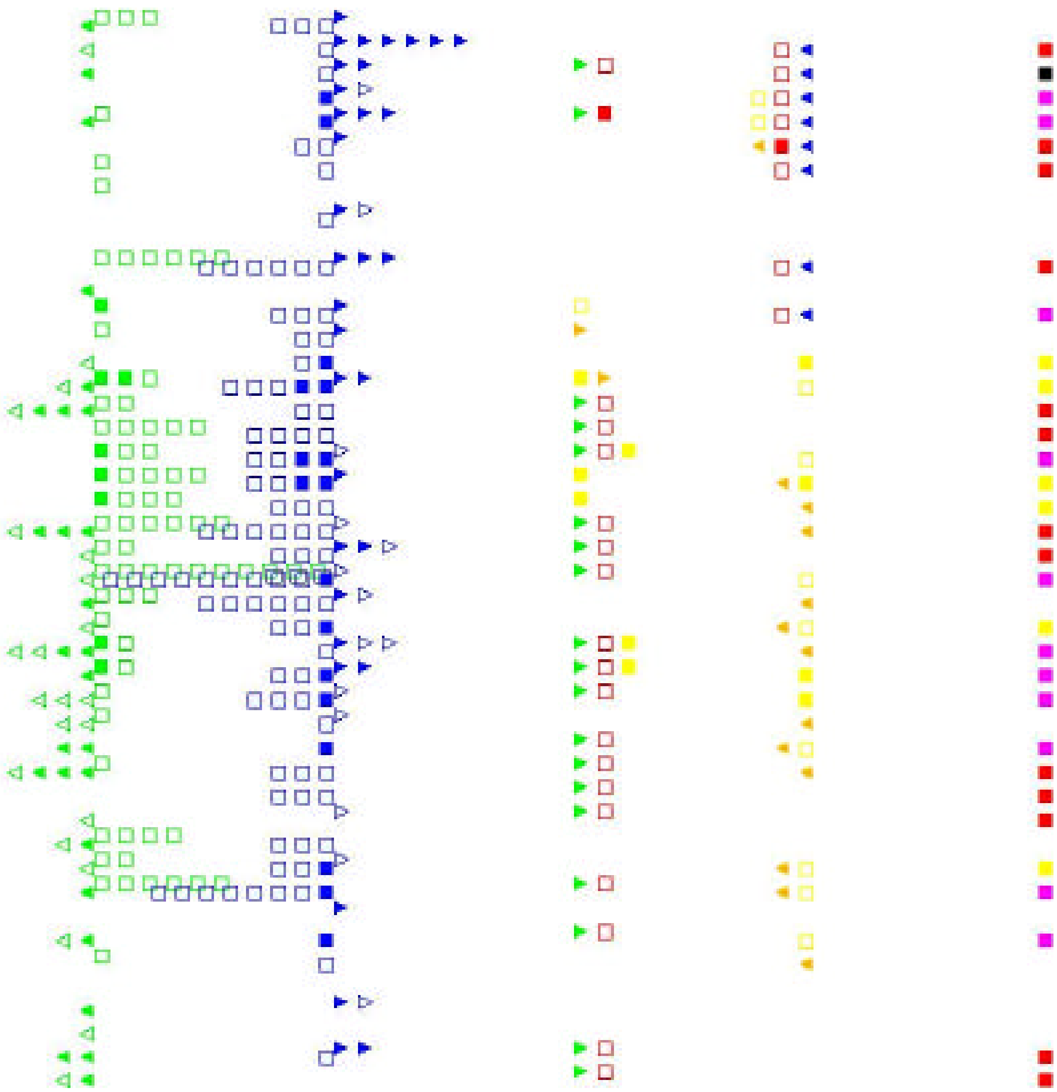

Figure A3. 6-October-1998 to 6-January-1999: U.S.-mediated Wye Plantation negotiations

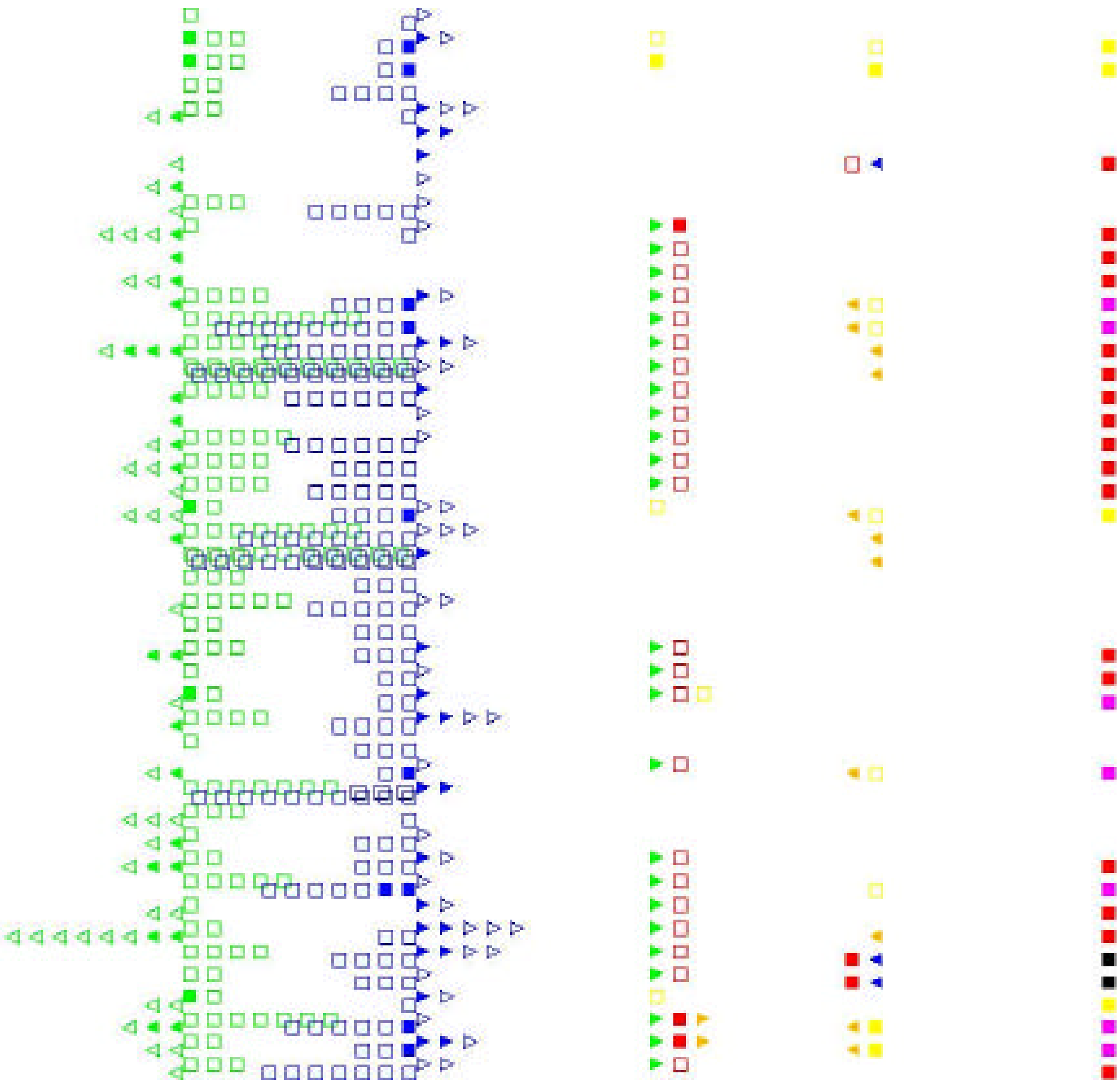

Figure A4. 11-July-2000 to 11-October-2000: Outbreak of second *intifada*