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FINDING HARBINGERS OF VIOLENT CONFLICT: USING PATTERN RECOGNITION TO ANTICIPATE CONFLICTS

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Abstract. This paper describes a particular use of pattern recognition techniques to identify pre-conflict situations. The goal is to find particular circumstances (which appear as patterns) in the descriptions of individual countries' situations before the outbreak of violent conflicts. If we find such patterns, we can then scan for them in current news reports. If we find a pattern in the current description of a country, we can then say "When we have seen this pattern before, 'x' percent of the time a conflict has erupted within 12 months." To accomplish this, the paper describes methods for getting alerts that a conflict is about to erupt, the information needed to get those alerts, how to organize that information, and a procedure for searching for patterns in that information.

INTRODUCTION

Considerable attention has been devoted in the past few years to the idea of getting an early warning of violent political conflicts. Besides a number of papers, various conferences and workshops have been held on this topic (Gurr and Harff, 1994; Bond, Lee, and Rothkin, 1995).

The goal of conflict early warning is straightforward. If the international community can be alerted that a violent conflict likely to result in bloodshed and/or a significant number of displaced persons (refugees) is going to occur in the near future with a high probability, international organizations, non-governmental organizations, and country governments can then initiate actions to prevent that bloodshed or displacement. These actions include preventive diplomacy (sending in mediators to establish and facilitate negotiations between the parties of the brewing conflict), preventive peacekeeping (sending observers into an area to deter entry by (usually armed) groups whose presence in that territory would be incendiary), and applying political and economic pressure. Early warning and the associated preventive actions are desirable because it is almost certainly less costly in terms of both money and human lives to conduct those activities than it is to mount a major peace enforcement operation like Somalia or Bosnia where violence has already erupted.

An individual who is expert in a particular country or region may be somewhat bemused by the notion of early warning. Such an individual may say something to the effect, "Hey, I could have told you that *Country X* was a powder keg because of the tensions between *Group A* and *Group B*." That may be true, but the real problem is two-fold. First, the number of staff in ministries of foreign affairs or organizations such as the UN or Red Cross, whose job it is to monitor what is going on in the world in order to provide early warning to their superiors, is typically quite small. The harried individuals in these organizations cannot each be experts in the dynamics of 20-50 countries. They may be able to give a summary of what is happening in any one of those countries right now, but to expect that they can keep track of how events and conditions are unfolding and project with confidence that something bad is going to happen (or not happen) in 2, 6, or 12 months in all of them is unrealistic.

The problem is more than just inadequate staff and resources. Staffers can and do warn their superiors about emerging problems in different parts of the world, but only to see nothing happen. The higher-level decision makers usually have more than enough "fires on their desks" that need to be put out or political infighting to deal with. Such a decision maker in general does not welcome a new, uncertain, potential problem. In terms of getting the attention and acceptance of a decision maker who would have to authorize and—worse—obtain funding for preventive initiatives, the individual bringing the news would probably be able to make a stronger case if she or he could say something like, "There is a 70 percent probability that *Country Y* is going to see fighting erupt between *Groups C, D, and E* within 9 months."

To achieve an early warning capability that provides thorough coverage and a strong probability assessment without a large staff almost certainly entails operation of a computerized system that pulls together news and other information sources from around the world on a constant, semi-automated basis. A computer system that provides such an early warning of a violent conflict will be referred to as a Conflict Alert System (CAS) in this paper. I use this term rather than the oft-used term 'Early Warning System' (EWS) because EWS means different things in different contexts. An early warning system can be (and has been used as) either the mechanism that provides an alert (such as a CAS) or the broader institutional and procedural environment that takes early warning alerts, processes them, and brings them to the attention of appropriate individ-

uals and organizations (Dedring, 1994; Rupesinghe, 1994). 'Early warning system' has also been used to refer to systems focused on other human calamities besides conflicts, such as famines or epidemics, or even natural disasters, such as volcanic eruptions or earthquakes (Whitcomb, 1994). By specifying and limiting the focus to conflict alert systems, I hope to minimize confusion and narrow the domain of the problem.

This paper describes a method for the development of one of the key capabilities needed for a conflict alert system: the ability to identify pre-conflict situations in current information describing countries or regions. Because of the nature of the conflict early warning problem, this paper argues for the use of pattern recognition techniques to find the pre-conflict situations. The paper does not cover other aspects of a conflict alert system, such as data gathering or bureaucratic resistance to its use in an organization, which have been articulated by a number of authors (Bond and Vogele, 1995; Brecke, 1992; Laurance, 1990). This paper concentrates on the recognition of pre-conflict situations because if we do not have the capability to pull out harbinger patterns of early warning indicators from the deluge of information emerging from all parts of the globe each day, we simply will not have an effective conflict alert system.

More specifically, this paper delineates the steps needed to identify harbinger configurations of early warning indicators and how these configurations would be used to generate conflict alerts. Early warning indicators are particular types of information, which can be collected over time for different countries and regions, that have been demonstrated to be—or are at least believed to be—portents of violent conflict. Examples of these indicators are the level of income inequality and the level of support for the government. Harbinger configurations are particular combinations of values of those indicators that—historically and for a number of countries—have consistently appeared a number of months before the outbreak of violent conflicts. The key is finding harbinger configurations from the historical record. If harbinger configurations exist and can be identified through the procedure described below, they can serve as templates against which current country or region situations are compared. If the combination of indicator values for a particular country at some point in the future matches one of the templates, the fact that the country is in a situation that in the past and for other countries has consistently led to a violent conflict provides evidence that the country may befall a conflict as

well. Harbinger configurations are valuable for conflict early warning because they provide a way to link historical information with current news.

This paper establishes the steps needed to find harbinger configurations and describes work in progress to execute those steps. The argument proceeds as follows: Step 1: Methods for obtaining conflict alerts. Step 2: Conflict early warning through pattern recognition. Step 3: Indicators of pre-conflict situations. Step 4: Different types of violent conflicts for which early warning is needed. Step 5: A procedure for searching for patterns. Step 6: Other issues to be resolved.

METHODS FOR OBTAINING CONFLICT ALERTS

There exists a variety of methods or methodologies for gleaning from data signs of impending conflict. These methodologies tend to be tied to different models of how the political-economic world works, and a number of models currently vie for acceptance as the best method for achieving conflict alerts. They are:

- Correlational Models
- Sequential Models
- Conjunctural Models

The Correlational Model approach is based on the assumption that certain indicators or measures of the political, economic, and social situation in a country covary with a measure of the level of violence in that country.[1] One tries to find out how much they covary by putting them in a multiple regression (or a logit analysis) equation. On the right-hand side of the equation exists a (sometimes very large) number of factors (indicators) believed to contribute to the likelihood of whether a situation will become a violent conflict or not in the not-too-distant future. On the left-hand side is the outcome indicator with values such as conflict or no conflict or close to a conflict or possibly some more precise measure of the level of violence. The goal is to find the influence or weight that each factor has on the outcome. Those factors that turn out to "weigh heavily" on the outcome become key components of a correlational model of the outbreak of violent conflict.

Elaborating on this approach in order to make it useable in a computerized CAS reveals that the correlational model approach turns out to have two distinct facets. The first is to develop and validate a correlational model (Gurr, 1994). This involves using data from the past to find the relationship between each factor and

the outcome.[2] The second step is to assume that the correlational model is reasonably correct and robust and then apply current values to each of the factors. (In effect, the equation(s) describing the model changes its (their) nature from stochastic to deterministic.) If the values of those factors reach values such that the calculated value of the outcome corresponds to a violent conflict, there then exists a reasonable basis for a conflict alert. In order to get current (or most up-to-date) values for the factors, data must be constantly fed into the system from different information sources. These values would be deposited into appropriate "slots" within the system's database, and then be used in the model's equation(s) to calculate the likelihood of a violent conflict. Onishi (1994) describes the use of a model in this manner to achieve an early warning of displaced persons.

A variation on the correlational model that entails a trigger mechanism is also possible. Whereas the correlational model rests upon the notion of an outcome indicator (more or less smoothly) covarying with one or more factors, the trigger mechanism model is based upon the idea that a violent conflict may erupt in response to one or more factors passing some threshold value(s).

The Sequential Model approach is a very different method for achieving conflict alerts. Rather than describing a causal structure that involves some number of independent variables pointing to a dependent variable such as the likelihood that a conflict will erupt, as is done with a correlational model, a sequential model consists of a "mechanism" that describes how changes in an environment bring about a specific event (or events) or a change in some specified variable. For example, whereas an extremely simplistic correlational model might represent the theoretical argument that the level of violence in a society is a function of the degree of wealth inequality and the unemployment rate, a similarly simplistic sequential model might be expressed as:

> If the unemployment rate in a society is rising, the level of discontent among the workers will rise. If the level of discontent is at a high level and the government drastically raises the price of bread, then violence is likely to erupt.

The element of time is much more integral, much more explicit in the "explanation" of how a conflict comes about.

Events fit more easily within a sequential model than they do in a correlational model. Events typically trigger changes in a sequential model. They can cause relationships between different elements of the model to become either active or inactive. Alterna-

tively, they can cause a change in the tempo or dynamic of a relationship. For example, two groups in a society may coexist with some tension but essentially peaceably. If members of one of the groups begin to verbally attack the other group, accusing them of being the cause of increased crime, for example, that event or series of events is likely to increase the tensions between the groups, probably inciting increased verbal and written exchanges of both a provocative and conciliatory nature by different individuals in the groups. At another level, if there is an incident in which members of one of the groups attack and kill members of the other group, this event is likely to provoke retaliation by the second group, which establishes a relationship of violent exchanges that did not exist before.

Harff (1994) describes a sequential model that incorporates this general concept with respect to genocide and politicide: one looks for *accelerators*, events that, when they occur, tend to lead to a cascade of events resulting in a genocide/politicide (with politicide defined by Harff as situations in which groups are victimized primarily because of their political opposition to the ruling regime instead of their communal characteristics such as ethnicity or religion). However, Harff appears to be slightly in error in her description. If one examines her list of background condition indicators and accelerators, it is only in part the case that accelerators increase the level or significance of the background conditions, as she asserts (28). Just as often accelerators accentuate or polarize the dynamics between the groups and institutions within the society and in some cases instigate a cascade of events. Accelerators serve as catalysts or trigger events as well.

If one considers a sequential model in terms of what it is doing if it were implemented in a computer simulation, one sees that it attempts to simulate the processes that occur in "the real world" but that it does it in accelerated time inside the computer. Namely, in the model one year transpires in something much less, perhaps one minute. It is in this manner that the model provides an early warning. One might say that the model has been to the future before the world has gotten there.

Consequently, a sequential model would be used to provide conflict alerts in the following way. As in any formalized conflict alert system, information from current news feeds and new publications is processed and entered into the database subsystem, probably on a daily basis. From the database the CAS extracts or calculates the indicators which serve as inputs for the model. These

inputs become the initial values for the variables within the model, and as such serve as starting points for the model's calculations. The model is then run in order to simulate the "world" it represents. If the simulation run, given new input data that arrived since the last run (perhaps on the previous day), results in a conflict that did not occur in previous simulations, it is providing a conflict alert.

The Conjunctural Model approach focuses on combinations of conditions and events that lead to violent conflicts. The underlying premise is that different combinations of a country's circumstances lead to different outcomes. For instance, some situations lead to violence in the form of a guerrilla war against the government, while others lead to an inter-ethnic group conflict, while yet others do not lead to violence at all. Schock (1996) presents a weak form of a conjunctural model that explores whether political context moderates the influence of economic inequality on political conflict. This manuscript introduces a stronger form of conjunctural model that allows for the exploration of a large variety of combinations or conjunctures that lead to violent conflict. Most of the remainder of this paper describes the author's project to implement and test a conjunctural model.

CONFLICT EARLY WARNING THROUGH PATTERN RECOGNITION

The correlational model approach has seen wide application in conflict early warning or related efforts, primarily determining the causes of war (Jongman, 1994; Singer and Wallace, 1979). Most of the effort has centered on wars between countries, but conflicts within countries are increasingly drawing researchers' attention. Correlational models have enjoyed limited success in the conflict early warning role. The problem may be the assumptions behind them. One of the assumptions with this class of model is that it starts from the premise that the explanatory variables covary with the output or dependent variable. In addition, the correlational model assumes that the explanatory variables do not covary with each other as they covary with the dependent variable. The explanatory variables are supposed to be independent from each other. If the explanatory variables covary with each other quite closely, a problem of multicollinearity emerges, and as any introductory statistics text explains, multicollinearity makes it effectively impossible to ascertain the relationship between the explanatory and dependent variables (Wonnacott and Wonnacott, 1977).

It may be the case that neither of these two assumptions holds true with respect to the conflict early warning problem, making the correlational model approach unsuitable. The key feature of the relationship between early warning indicators and violent conflict may not be how they covary; it may be the occurrence of a particular combination or configuration of them at some point in time before the conflict erupts. Moreover, the notion of independence of the explanatory variables (early warning indicators) may be inappropriate because it may be their interaction that is important. For these reasons, this project is taking a different approach.

The sequential model assumes a process model. Unfortunately, to implement a process model of the emergence of a violent conflict within or between societies, even if one already possessed the complete set of theoretical statements needed for such a model, is in all likelihood a very large, very difficult task. For this reason, this project is taking a different approach.

This project implements the conjunctural approach by transforming it into a pattern recognition problem. This results in an analytical approach that emulates what a typical international affairs expert appears to do. To illustrate, consider the following. When such an expert focuses her or his attention upon a country to decide whether it is likely to experience political violence and then makes a determination, that individual has in all likelihood used pattern recognition. More specifically, the individual examines the country's situation, which includes both its history and its current condition, in terms of both events and variables describing underlying processes. The individual (consciously or not) compares the situation with other countries' situations, both current and in the past, to find analogues. The individual can find an analogue through two paths. First, the other case (or cases) can be empirically almost identical, a parallel case. In international affairs so much variation in country descriptions exists that such an outcome is unlikely. The second path is that the other case (or cases) can be sufficiently similar such that given the analyst's theoretical (mental) model of how the "world" works, the analyst judges the cases to be analogous. Deviations—even significant deviations—in the cases are possible, but if those aspects of the situation as determined by the theoretical or mental model to be important to the countries' dynamics are the same, then the cases are believed to be analogues. If the analogous case or cases subsequently evolved to violent conflicts, then the analyst is likely to believe that the particular country of interest is also likely to suffer a conflict.

In searching for analogues, the analyst is looking for certain combinations of features in the descriptions of the countries' situations. This is pattern recognition. The next three sections of this paper describe how one pattern recognition technique is applied to the problem of conflict early warning.

INDICATORS OF PRE-CONFLICT SITUATIONS

When searching for harbingers of violent conflicts, a critical design decision is: What is the information upon which one should focus? What are the indicators to be collected that give one the best chance of finding patterns? For this project, four overarching principles guided the choice of the types of information. Pinard's (as presented in Rule, 1988) theoretical orientation "mobilization in the context of grievance" gave a sharper focus to the choice of the actual indicators.

Alternative Lists of Early Warning Indicators

There are many possible indicators for a conflict alert system. Identifying the best indicators is probably more than anything else the key to conflict early warning. Besides its practical importance, determination of the best predictors has important ramifications for the theoretical debate about the causes of political violence. Particular theoretical schools obviously are bolstered when variables and indicators they emphasize turn out to be strong or effective early warning indicators, but more interesting is if the set of effective indicators supports more than one theoretical perspective, for this outcome will motivate new or refined theoretical formulations.

Interestingly, there exists an enormous gulf between the approach taken by most theoreticians and the approach typically taken by those who are attempting to empirically find conflict alert indicators. This difference appears most starkly in the number of factors contained within the theories or models employed by the researchers. Theoreticians tend to argue for rather simple models based on a theoretical argument. The theories, and hence the models embodying them, emphasize a particular mechanism to explain the outbreak of violence such as rational choice decision making, collective behavior, response to relative deprivation, social mobilization, or class conflict (see Rule, 1988; Rummel, 1975). Empirical evidence marshaled to buttress a particular theory is (not surprisingly) focused on particular pieces of information that support or disconfirm the theory.

Empirically-oriented researchers tend to be less concerned with particular schools than with finding something that can serve as a predictor. These researchers typically develop lists of indicators that are germane to a variety of theoretical schools, collect data based on these indicators, and statistically test the data to see whether any turn out to be good predictors. Dolnykova (1986) approached some kind of upper limit for this approach by developing a list of about 700 indicators; almost anything one could imagine having a relationship to the outbreak of a conflict made the list.

An alternative approach is to focus on a particular type of conflict and develop a list of indicators appropriate for that type. For example, for his model of communal or ethnopolitical conflict, Gurr (1994) proposes 15 indicators grouped into background conditions, intervening conditions, response conditions, and an example list containing 9 accelerators.

For genocides/politicides, Harff (1994) distinguishes between background conditions, intervening conditions, and accelerators (also called precipitating events). Background conditions are further broken down into international and internal background conditions. She offers a list of 19 indicators.

Fein (1994) for the most part agrees with Harff, but she has her own set of indicators pointing towards genocide/politicide. Her 18 indicators break down into three categories: conditions from the past, recent background conditions, and precipitating events.

For the much broader class of conflicts that cause humanitarian relief operations and refugee flows, Schmid and Jongman of the PIOOM program at Leiden University in the Netherlands have developed a list of 70 background conditions indicators and 118 situational circumstances indicators (1995, personal communication).

Indicators Used in This Project

The first general principle shaping the choice of indicators is that before defining a list of indicators, one profits by first establishing the thing or things for which one wishes to receive warning. There are two key dimensions to this narrowing of the subject. The first is, what is the time frame of the warning? Does one wish to have a forewarning of a problem that is likely to emerge in 20 years or 2 months? A severe imbalance in the number of men being born compared to women, such as what we are seeing in a number of Asian countries, may be a harbinger of social problems and possi-

bly violence in a couple of decades as the current imbalance manifests itself in a skewed male/female population ratio as this cohort reaches reproduction and marrying age. However, the demographic indicators pertinent to that kind of long-term early warning, birth rates by sex, play almost no role in the situation where one wishes to get an early warning of a conflict breaking out within a country or between two countries within the next few months. Other indicators such as whether soldiers are getting paid or the degree of harmony between groups in opposition to the government are almost certainly of much greater importance.

The other dimension to the narrowing of the subject of an early warning alert is the type of event. For this project we trim the possibilities immediately by stating that we want to focus on the outbreak of violent conflicts. We are not interested in disputes whose salience to the actors is such that they are not inclined to violence. However, we are interested in both inter-state and intra-state conflicts. The subsequent, more difficult decision is what kind of violent conflict. There exist a number of possibilities, and a subsequent section elaborates on this point.

The second general principle guiding the choice of indicators is captured by a slight rephrasing of a maxim of Sherlock Holmes pertaining to the solving of a crime. One should look for both motivation and capability. To be more specific, while reports that groups are becoming agitated and psychologically mobilized for some action are very important because they indicate motivation, one also wants to know whether these groups possess the organizational capabilities to carry through with their apparent intent. Consequently, the list of indicators should include examples that provide information about both facets of a group's situation.

Third, as articulated by Gurr and Harff (1994), one needs to think in terms of events and actions taken within the context of a particular history. To be more specific, one must consider background conditions in conjunction with intervening conditions as setting the potential for violence, which then erupts when certain events or other catalysts occur. This project follows this approach by distinguishing between background conditions and catalysts in the list of indicators.

Fourth, one must look for early warning indicators that occur early in the sequence that leads to violence. It is too late for early warning if the indicators are measuring violence already being perpetrated. This means that one must look for instances where individuals or groups attempt to mobilize other individuals or

groups to take action against some "enemy," be it other social groups, other countries, or the government. Several indicators listed below attempt to capture this phenomenon.

Within the framework established by the preceding principles, the theoretical approach guiding the choice of indicators is the "mobilization in the context of grievance" approach of Maurice Pinard (Rule, 1988). For this project "grievance" appears in the background conditions indicators. "Mobilization" appears in the catalyst indicators. The following items are a partial list of background conditions. The complete listing and theoretical justification of these and other indicators listed in subsequent paragraphs is beyond the scope of this paper and can be found in Brecke (1998). One intent of that paper is to illustrate how relevant bodies of theory, such as conflict theory, contribute to the choice of indicators.

1. Has life expectancy at birth been declining?
2. Has the level of malnutrition been increasing?
3. Has there been a history of violent acts between different groups?
4. Has one group been in a relatively long-term dominant position within the society or, conversely, has one group been in a subservient position?
5. Has the dominant group used the state's police powers to keep the subservient group down (has there been significant repression)?
6. Has the dominant group used legal devices to maintain its position?
7. Are there identified resource or property issues that can serve as a point of conflict between groups?
8. Has one of the social groups fairly recently (within the past 500 years) entered and settled the territory of the other group(s)?
9. Did that group come in as a conqueror?
10. Is a subservient group gaining on the dominant group in terms of population growth or economic development?
11. Is the dominant group supported by one or more outside powers?
12. Is a challenging group supported by one or more outside powers?

Given the preceding as descriptors of background conditions, the following is a partial listing of catalyst indicators:

1. Individuals or organizations begin to criticize or attack another group and raise the issue of the separateness of that group in terms of their culture, language, or religion.
2. Individuals or organizations begin to criticize or attack another group and invoke the past history of atrocities that group has perpetrated.
3. Individuals or organizations begin to gain support for claims to territory or resources that another group possesses.
4. Individuals or organizations begin to assert that another group has designs on their property or resources.
5. Individuals or organizations begin to draw attention to disparities between themselves and a ruling group that is perceived to be (and probably is) better off.
6. Individuals or organizations begin to draw attention to the fact that another group has fairly recently entered the society.
7. Individuals or organizations begin to draw attention to the external support another group is receiving.
8. Individuals or organizations begin to raise the specter of another group overwhelming them.
9. Individuals or organizations are beginning to mobilize a portion of the public against the government.
10. Individuals or organizations are beginning to mobilize a portion of the public against another group.
11. An event or date that draws attention to the disparity or the history is approaching.

In light of the second overarching principle to include motivation and capability, this project extends Pinard's approach by including a second set of indicators that pertain to capability. Like the grievance/motivation indicators, these capability indicators can also be divided into background conditions and catalyst categories. Examples of background indicators in this set include:

1. The group raising charges against another group controls many of the tools of the state, in particular the police and military.
2. The history of the military's role in favoring a particular (probably the ruling) group.
3. The coherency and discipline of the military.
4. The breadth of the political regime's support.
5. The degree to which the government is distracted by other challenges to its rule.

Examples of catalysts include:

1. Military begins increasing weapons production or purchases.

2. Organized political groups are procuring weapons, probably from the black market.
3. Vigilante or other irregular armed forces begin to form and become organized.

It is clear that the catalyst indicators differ in terms of the immediacy of an outbreak of violence to which they point. For example, news media and word-of-mouth attention to someone's utterances is much earlier and "iffier" than if someone is actually mobilizing people for demonstrations and other acts, to say nothing of actually committing acts of violence. It is possible that different configurations of indicators can contribute to different levels of alert: yellow, orange, and red, to use a common coloring scheme.

DIFFERENT TYPES OF CONFLICTS FOR WHICH EARLY WARNING IS NEEDED

The previous section discusses a set of indicators that "point" toward future conflict. This section examines the other side, the conflicts one would wish to prevent with a conflict early warning system.

If life were easy, this project would identify a combination of indicators that augurs a conflict. Other combinations would have no discernible connection to future conflict. Such an outcome is unlikely. More likely is that some combinations of indicators point towards one kind of conflict while other combinations point towards other kinds of conflicts. To rephrase, the heterogeneity of conditions that lead to a conflict is probably too high for us to be able to find one "mapping" from a set of indicators to whether there will be a conflict or not. However, if one distinguishes between different kinds of conflicts, one may be able to reduce the variation in the conditions preceding each particular kind of conflict such that we can recognize harbinger patterns.

Brecke (1997) describes a taxonomy of violent conflicts for the purpose of conflict early warning. The following list gives the reader a small sample of the types of conflict likely to be within the taxonomy. The intent behind presenting this partial list is only to make it clear that different kinds of conflicts have different causes and that an attempt to find harbinger patterns among the indicators without distinguishing between conflicts is at best a difficult enterprise. Discussion of the myriad other issues surrounding the development of a taxonomy is beyond the scope of this paper.

- Conflicts in which one or more organized political/military groups are challenging the government in order to achieve control of the state.
- Conflicts in which one or more organized political/military groups attempt to expel an army of another state that is occupying their state's territory.
- Conflicts in which an organized political/military group is challenging the government in order get it to change its policies.
- Conflicts in which a minority cultural/ethnic/racial (c/e/r) group is challenging a government controlled by a larger c/e/r group in order to achieve control of the state.
- Conflicts in which one or more minority cultural/ethnic/racial groups are challenging the government for control of some fraction of the state territory in order to create new, separate states.
- Conflicts in which a majority cultural/ethnic/racial group is challenging a government controlled by a minority c/e/r group in order to achieve control of the state.
- Conflicts in which two or more organized political/military groups fight against each other in order to wrest control of a state in which there is no effective government.
- Conflicts in which outside power is aiding the groups out of sympathy for their situation and/or goals.
- Conflicts in which an outside power is using the groups as a proxy to achieve changes in the government's makeup or policy.
- Conflicts in which an outside power is attempting to support the existing government against its challengers.
- Genocide

A PROCEDURE FOR SEARCHING FOR PATTERNS

This section describes the approach taken in this project to identify configurations of the early warning indicators described above. Since a key element of the approach of this project is combinations of indicators, there is a need to make the combinations explicit for the analysis. This is accomplished by creating a grid. To illustrate, think of a rectangular grid. The columns of the grid are the background conditions indicators; the rows are the catalyst indicators. A separate grid picture or snapshot "exists" for each country or region (territory) for each day of the time period

covered by the data for that territory. In other words, a snapshot describes a territory's situation with respect to the two sets of indicators and their combinations for a particular day. (The reader may note that with over 200 countries and in many cases more than 50 years (over 18,250 days) of post-World War II history, there is potentially a very large number of grids that can serve as observations or data points.)

Each cell or square of a grid embodies the intersection of one background condition and one catalyst indicator. A square can take on one of four values. This is because in the interest of simplification the indicators are defined in such a way so that they are either true or false (they exist or do not exist) for a given country on a given day.[3] On the grid, the four values manifest themselves in the following way:

1. If the background condition exists (or is true) and the catalyst exists (or is true), then the square is black.
2. If the background condition exists but the catalyst does not exist, then the square is dark gray.
3. If the background condition does not exist but the catalyst exists, then the square is light gray.
4. If the background condition does not exist and the catalyst does not exist, then the square is white.

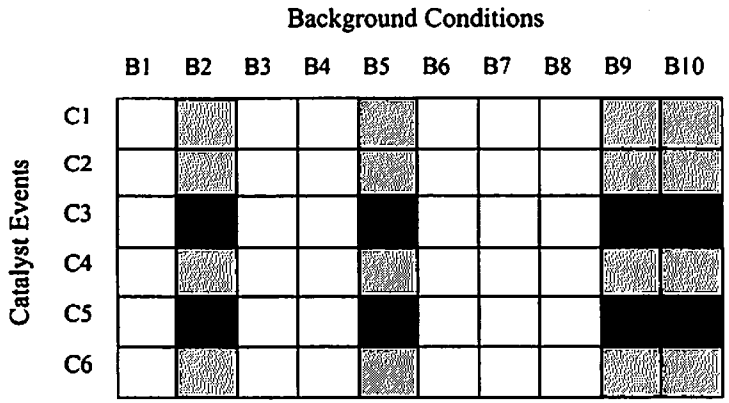
(In the neural network software being used to analyze the data, the "squares" actually take on values of 1.0, 0.667, 0.333, and 0.0, respectively.)

A grid, then, is some configuration of black, dark gray, light gray, and white squares, and it describes the territory's situation with respect to the combination of background conditions and catalysts on any given day. Each of these configurations is a pattern. Each of these configurations can also be thought of as a thematic map describing the situation of a country or region for one day. Figure 1 depicts a much-simplified grid to illustrate its essential components.

In this example, for a particular country on a particular day, background conditions 2, 5, 9, and 10 are true or do exist while the other background conditions are false or do not exist. Similarly, catalysts 3 and 5 exist (essentially, have occurred in the past year) while the other catalysts do not exist.

To make this more concrete, Figure 2 depicts a partial country situation pattern for Liberia for May 8, 1979. A partial and very much simplified diagram is presented here because a grid illustrat-

Figure 1
Simplified Example Grid for One Country-Day

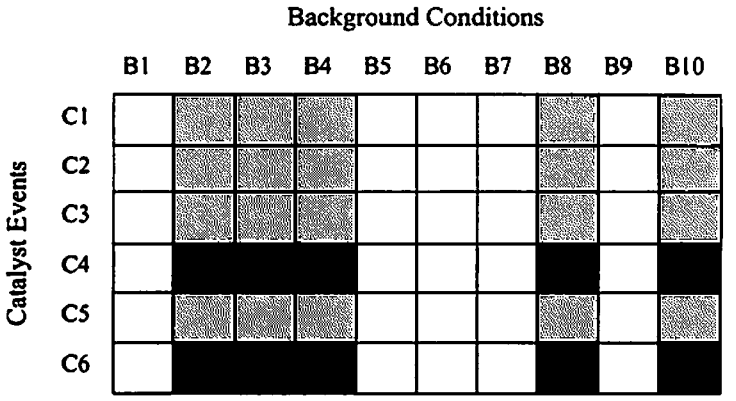


ing the entire set of indicators used in this project would have 40 columns and 30 rows. Such a grid would be difficult to clearly portray on a page such as this and it would take a long time to explain the 70 indicators. That task takes place in Brecke (1998)

Another useful way to conceptualize these grids is to think of them as "cards" that contain the configuration of the country or section thereof at a particular point in time. After the historical data are collected and assembled, the "history" of each geographical unit (with respect to the indicators and their combinations) can be represented by a "stack" of these cards. It should be noted that while one may wish in principle to have a separate card for each and every day, that is cumbersome and probably unnecessary. One can get by with a new card only when one of the cells in the grid changes—because one of the indicators has changed—as long as the date at which the change occurred is monitored and stored.

With this as a portrayal of the information, the next step is to search for harbinger configurations or patterns. The procedure involves scanning through the stacks for several (ideally all) countries or regions using pattern recognition software to find those special patterns. The first outcome is the most simple. That is, does pattern recognition software find a configuration (manifested in a particular pattern of the four different kinds of squares) that appears a few months before conflicts but that does not appear in situations that do not experience violent conflicts. If the analysis software can find such a configuration in the historical data for different countries, an early warning system would simply have to look for it in current news, and if the configuration was found, generate a conflict early warning alert.

Figure 2
Simplified Country Situation Grid
Liberia, May 8, 1979



B1 Has the level of malnutrition been increasing?
B2 Has one group been in a long-term dominant position?
B3 Is the society split along linguistic lines?
B4 Has economic growth relative to population growth been declining?
B5 Are there strong regional inequalities in economic development?
B6 Has the dominant group used police powers to repress other groups?
B7 Did the current government come to power through force?
B8 Is the military dominated by a particular group?
B9 Is there a history of violent acts between the groups in the society?
B10 Has the terms of trade index been declining for five or more years?
C1 Are groups or individuals drawing attention to disparities in government treatment of different social groups?
C2 Are groups or individuals drawing attention to the recent entry into the society of others?
C3 Are groups or individuals raising the issue of the separateness of others?
C4 Are groups or individuals mobilizing public opinion against the government?
C5 Has an outside power declared its policy is that of non-interference?
C6 Has the government recently cracked down on the media?

That outcome is *highly* unlikely. More likely is that there is no "silver bullet" configuration. Instead, the pattern recognition software may search for and identify a number of configurations that point to different kinds of conflicts with a reasonably high probability of success and with few false alarms. This is not a bad outcome. An early warning system can compare current events against a number of harbinger configurations almost as easily as against just one. Moreover, a probability of success measure alongside the alarm is also more realistic than a binary yes/no determination. A bonus of this outcome is that the research is likely to find that certain configurations correspond to certain types of conflicts. This kind of correspondence and delineation could help theoretical work on the emergence and evolution of conflicts.

A third outcome is possible. Namely, it is possible that no single snapshot configuration unerringly points to an upcoming conflict. Instead, the harbinger configurations may be particular "movies" of the grid patterns rather than snapshots. The way in which a configuration evolves over time as manifested in how the squares change (probably from white to gray to black) may be what appears consistently before conflicts rather than any single configuration. To visualize this it may be useful to think of the old viewers at county fairs or tourist "meccas" that contain a ring of pictures put together in a box such that when a person looking at the pictures turns a crank, the cards flip by in sequence and give the impression of a moving picture. An example would be a dancer going through a series of moves. Analogously, the pattern recognition software would search for "movements" in the grid patterns that consistently appear before a conflict and not in other situations. For example, a harbinger "movie" may be a situation where cells in the middle section of the grid switch from white to light gray to dark gray to black in a way such that a group of dark cells expands down and to the right. It does not matter precisely which cells change to which of the darker shades; the important harbinger is the growth of the dark "mass" of cells starting about in the middle of the grid towards the "southeast."

Finally, it is possible that no single configuration or even evolutionary path of a configuration points to a conflict. Simply when a certain percentage of the cells in the grid are black (or are dark gray or black) no matter what the pattern may turn out to be the point at which an early warning alert should be generated. Of course, it may be possible that harbinger configurations cannot be discerned.

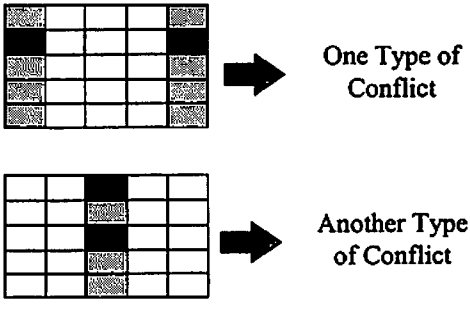
This project is developing artificial neural network (ANN) analysis software to do the pattern recognition task to find the harbinger configurations. While neural networks are quickly becoming a popular (some might say trendy) technique in the social sciences, with applications in economics (for example, Vishwakarma, 1994) appearing in the literature, this project is not "wedded" to neural networks. However, artificial neural networks are well-suited for this class of problem, pattern recognition, and software to perform ANN analysis is readily available at reasonable prices.

Proper use of neural networks for this type of pattern recognition problem mandates an additional piece of information. The ANN requires a rather unambiguous template for identifying a "positive" outcome, in this case a positive outcome being the outbreak of a conflict (even though that is not a positive outcome on normative grounds). Figure 3 portrays the problem. If we hope to identify one harbinger configuration for one type of conflict, say, a guerrilla war against a government, and another harbinger configuration for another kind of conflict, an ethnic conflict between two militias, we need to be able to distinguish between different kinds of conflicts on the basis of characteristics they possess.

The problem thus becomes: how can we portray those different characteristics such that pattern recognition techniques such neural networks can discern a connection between country situation patterns and a particular type of conflict?

We have chosen the following approach: each type of conflict is represented as a pattern on an output grid that superficially resembles the input grids. Each row of an output grid represents

Figure 3
Mapping from Country Situation Patterns
to Different Types of Conflict



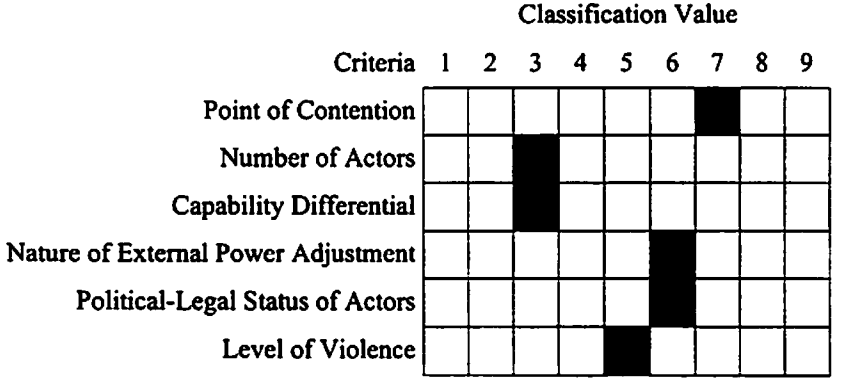
one of the criteria upon which the taxonomy of conflicts is constructed. Each column represents one of the possible states of a particular conflict with respect to each criterion. A black grid cell signifies that the particular type of conflict has that state or value with respect to the criterion. For example, a conflict in which the point of contention is that one ethnic group is attempting to secede from the rest of society and create an independent state would have a value of 7 for that criterion. Each conflict type possesses a unique output grid pattern. Figure 4 presents an example of a conflict description pattern.

Conflict description patterns are derived from the violent conflict taxonomy project referred to earlier. In that project clustering techniques identify groups of (historical) conflicts that share criteria such as in Figure 4. The values of the criteria associated with those groups, which are types or classes of conflicts in the taxonomy, determine what the conflict description patterns looks like for a particular type of conflict.

With the conflict description patterns, the problem now becomes a very clear pattern recognition task. The ANN software attempts to find strong mappings between particular input (country situation) patterns and particular output (conflict type) patterns as presented in a simplified manner in Figure 5.

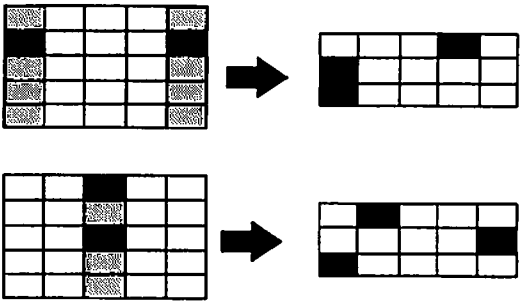
If the ANN software can find in the "stacks" of grids described earlier particular patterns analogous to those on the left side of Figure 5 that consistently appear before conflicts of particular types, and (nearly always) only then, the ANN software has found harbinger configurations. And to restate an earlier point, if we have harbinger configurations, we can take current descriptions of coun-

Figure 4
Example Conflict Description Pattern



try or region situations, transform those descriptions into the grid format, and compare the resulting country situation patterns to harbinger configurations or patterns. If there is a match, we can then say that a conflict of a particular type is likely to happen given the consistency with which that pattern has preceded that type of conflict in the past.

Figure 5
Mapping from Country Situation Patterns
to Conflict Description Patterns



OTHER ISSUES TO BE RESOLVED

Let us assume for the moment that harbinger configurations (or sequences) can be found. Two additional issues need to be addressed.

The first is the time lag between the appearance of a harbinger configuration and the outbreak of the violent conflict. Ideally, a harbinger configuration would—across several instances—consistently appear at a specific time preceding an outbreak, for example, 10 months. Almost as good and much more likely is that when looking at several cases, the times at which harbinger configurations appear before conflict outbreaks cluster around some amount of time such as 10 months. If we have such clustering, we can then say that "a conflict is likely in 10 months" as opposed to saying that "a conflict is likely within the next year" or whatever other time frame is appropriate.

As part of our procedures for searching for harbinger configurations, we keep track of when particular configurations appear before an outbreak so that we can analyze that information to find those clusters. Whether such clustering exists, of course, awaits the forthcoming data analysis. The reader must keep in mind that the

appearance of a particular configuration is distinct from the appearance or occurrence of a particular indicator. Considerable diversity in the timing of individual indicators for different countries does not necessarily affect the timing of a particular configuration.

The second issue is the degree of fit between a particular country's situation and a harbinger configuration. Stated differently, this issue concerns the extent to which two or more cases are considered to be effectively the same with respect to conflict early warning. This issue contains two facets. The first pertains to deriving harbinger configurations from the combined set of country situations, the stacks described above. The second, related facet involves the inverse, matching a particular situation to a found harbinger configuration.

Pattern recognition techniques such as neural networks allow for imperfect fits. This is necessary because when one is comparing a current photograph of an individual against an earlier photograph that is stored in a computer's memory, for example, one needs the ability to allow for differences caused by things such as the individual holding her or his head at a slightly different angle or having a different haircut. Placed into the context of the grids described earlier, the question is how many grid cells—effectively rows and/or columns—can we tolerate being different while considering two or more patterns to be a description of the same pre- conflict situation.

For the first facet of the problem, the question is, do we need to, and if so, can we "cluster" or "group" closely similar pre-conflict situations into archetypal harbinger configurations? The pattern recognition techniques we are using for this project allows us to do this clustering and to adjust our tolerance for different patterns being treated as similar. For the second facet, which becomes important when one is operating a conflict alert system that monitors news from around the world in order to update country situation grids, the question is (in the future), does this country's situation sufficiently match a harbinger configuration such that we should generate a conflict alert? To help resolve this question so that we can have confidence when generating alerts, we are conducting an analysis of how different tolerances affect the probability of the pattern recognition software finding a fit when using the country situation grids.

A third somewhat different issue is that of using the theoretical literatures, such as environmental conflict theory, to provide guidance regarding the combinations of indicators that may point to

particular types of conflict. Theory can and does point to some combinations, but its contribution to this problem is limited because the theoretical work tends to focus on a small number of indicators pertinent to a particular theoretical school. This project attempts to span different schools, and as indicated above, encompasses a significant number of indicators. At this point in time, and for this methodological approach, historical data are more likely to provide guidance as to the proper combinations. Indeed, a core element of this approach is to efficiently search through a large body of historical data to find those combinations.

CONCLUSION

The project described in this paper is very much a work-in-progress. Data for 20 countries for the period from 1945 to the present has been collected at this point. Once conflict description patterns have been identified, analysis to find harbinger configurations can begin.

If this approach proves to be fruitful in finding harbinger configurations, it can be readily adapted for use in a computerized conflict alert system. One strength of this approach is that it easily enables us to combine historical and current information. Historical information enters in two ways. It is used to find the harbinger configurations. It also provides the background conditions for each of the grids that describe the countries and regions monitored by a conflict alert system. Current information changes the values of the catalyst indicators. Over time current information also changes the values of the background conditions indicators. The frequency by which data are updated determines the delay in generating a conflict alert. For example, if the system were to be updated daily, a country's grid pattern could change from one day to the next, and in that one day a non-alert pattern could transform into one that would generate an alert.

The approach to finding harbingers of future conflicts presented in the pages above addresses many of the limitations of previous attempts to develop the foundations of a conflict alert system. Hopefully this work in conjunction with that of others will give us the capability to identify conflicts sufficiently in advance for conflict prevention activities to be initiated to keep the conflicts from becoming violent.

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NOTES

1. One can go further and argue on theoretical grounds that the variables represented by those indicators of the situation cause the level of violence, but that is not strictly necessary for obtaining conflict alerts.
2. Typically the concern is the weight or strength of the relationship, but the nature or functional form of the relationship can be ascertained as well.
3. Obviously, it is possible to extend this methodology so that the indicators can take on more values than yes/no, for example, scales or indices whose measure is of either an ordinal or interval nature. Depicting multi-valued indicators in this format would almost certainly entail depicting a country's situation with different colors. That may be visually attractive, but it is significantly greater work and will have to be deferred to the future.

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