Title: Determining Event Probability with Geographical Information Systems (GIS)

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Abstract:

When a significant event occurs, the time it takes to determine if the event was accidental or deliberate is crucial to providing the appropriate response. This decision affects the deployment of very valuable resources at the local, state and federal levels. An analysis of the geospatial characteristics of the specific event plays a crucial role in helping to make this decision in a quick and efficient manner. Geographical Information Systems (GIS) can determine the geographical or geospatial relation of this incident to other predefined critical points of interest. Some of these critical points might include population and/or what other sectors of infrastructure in the nearby area may be affected such as energy, water, telecommunication, industry, government installations, etc. These attributes can be examined against those of similar past events. Using Bayesian and Neural analysis techniques, a statistically backed assumption can be made regarding the initial or resulting cause of the incident.

Problem:

When an emergency event occurs, standards are put in place to respond as quickly as possible without all the information concerning the event being available. In certain cases there may be secondary, tertiary, or even additional multiple layers of cascading events or impacts associated with the primary (emergency) event as shown in Figure 1. The reaction(s) taken to each level of event(s) might assist in resolving the initial event, but might also trigger the additional layers of events, each needing a new response. Identifying these potential additional layers of events as quickly as possible can help determine the correct response to mitigate the total number of events that can occur. In this paper we will look at how using some types of probability analysis tools built on different logic models can assist in identifying some characteristics common to events. This in turn will make it easier to formulate educated decisions regarding the event and appropriate responses in relation to events that could have been intentionally planned and carried out such as terrorist attacks.

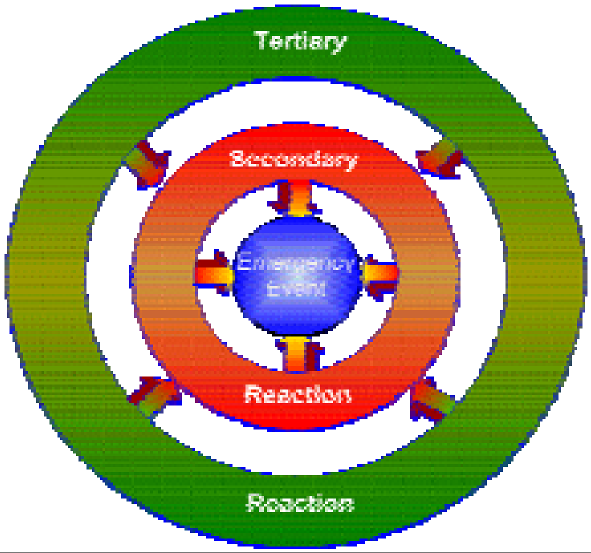

Figure 1

As shown in Figure 2, some examples of the impacts resulting from an emergency event include:

- Communication. All forms of communication have been identified in almost any event, terrorist attack, or natural disaster as a barrier to response.
- Infrastructure. This is a very broad subject, but in this paper we will focus on areas of transportation, buildings, and natural landscapes that can be a barrier to response.
- Basic Need Items. The need for the influx of basic need items for any victim(s) and/or first responders – food, water, shelter, medical supplies, etc. All of these items are dependent based on the size and duration of an event.

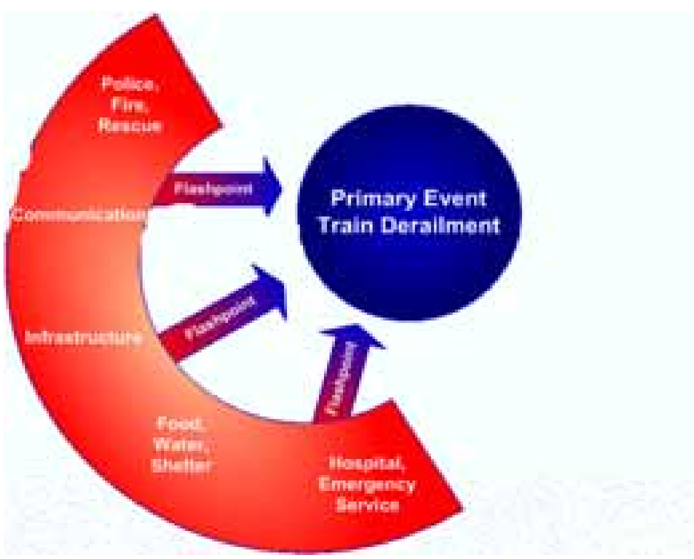

Figure 2

Tertiary level impacts refer to things in a long-term aspect. The ability to maintain these services long-term and mitigate items that may or may not be obvious that will affect these areas over time.

Figure 3 depicts the following items that are needed over the long-term:

- The ability to maintain governmental services.
- The ability to regain and sustain communications.
- The ability to anticipate long-term affects on buildings, structures, transportation and infrastructure (economic, utilities, etc.).
- The ability to anticipate the effects of the living conditions and environment.
- The ability to mitigate the effects on long-term heath care issues.

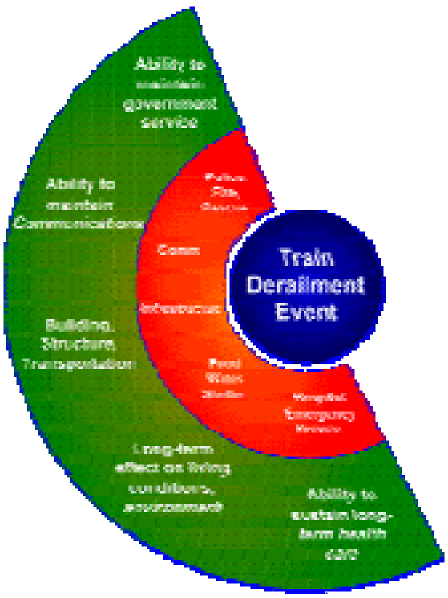

Figure 3

<u>Logic Modeling – Basic Concepts:</u>

The term “Logic Modeling,” as used in this paper, can be seen as a set of rules based on historical analysis or known facts that can be applied to an event to arrive at additional information about the event with a reasonable level of confidence.
Looking at Logic Modeling in these terms we can start by asking some of the basic questions:

- WHAT?
  - Conceptual computer-based model to allow emergency management to anticipate the secondary and tertiary events post emergency event.

- WHY?
  - Mitigate secondary and tertiary geometric impact of an emergency event.
  - Determine probable causes of an event with a level of confidence.

"Why" is an important question because it can assist with the determination of whether the event is accidental or intentional or if this is the final outcome or will the event create a ripple effect resulting in secondary, tertiary, etc.

Logic Modeling tools can assist in the following areas of emergency events:

- Planning; it will provide insight to improve decision makers by giving them a level of Situational Awareness and the ability to potentially mitigate unforeseen problem areas in secondary flashpoints. Planning will assist in providing long-term response mitigation and take historical data from past events built into a computer software program and provide predictable outcomes. All of this together will facilitate a timely effective response – which is the ultimate goal.
- Execution; it will provide the first responder command element with an enhanced span of control and help decrease the guess work during the initial response to an event allowing the first responders the ability to concentrate on their areas of concern. Relevant information to that particular event will also be provided with historical and infrastructure data to reflect current conditions.

The Logic Modeling Tool may require good data mining to get the data it needs to perform its analysis. The data can be mined from relevant, reliable sources of data. These sources can include but are not limited to: Event Reports; GIS Data (such as parcels, utility networks, population, etc.); Emergency Response resources such as Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives (CBRNE) data, known effects, required resources, etc.

Boolean Logic is a form of algebra in which all values are reduced to either TRUE or FALSE. Boolean Logic is especially important for computer science because it fits nicely with the binary numbering system, in which each bit has a value of either 1 or 0. In other words, each bit has a value of either TRUE or FALSE. Boolean Logic is the fundamental basis of nearly all of the modern conventional information retrieval systems.

Boolean Logic uses:

And Not Or Nor

For example:

Strawberries *and* Vanilla *and* Chocolate
Strawberries *and* Vanilla *not* Chocolate
Strawberries *or* Vanilla *or* Chocolate

For the purposes of this tool, a simplified model will establish rules and relationships between events and inputs, then map those events to predict a predetermined outcome. Boolean Logic only facilitates comparable data, not contrasting data; therefore, to accomplish this function other types of logic models are needed.

Fuzzy Logic is a superset of conventional logic that has been extended to handle the uncertainty in data. Fuzzy Logic recognizes more than simple "true and false" values.

For example: Standing in a doorway…I am not entirely in the room; I am a percentage in and a percentage out.

Fuzzy Logic assigns values (weights) to each of the recognized states between TRUE or FALSE. This starts with and builds on a set of user-supplied human language rules. This simplifies the job of the computer and results in much more accurate representations of the way systems behave in the real world. Fuzzy Logic has proved to be particularly useful in expert systems and other artificial intelligence applications. A good example of this is the spell checker in most applications that not only identifies the misspelled word, but also suggests a list of probable words to replace a misspelled one.

Fuzzy Logic also adds a human pattern… the *If/Then Concept*:

- *If* the engine is hot, *then* turn the engine off
- *If* a chemical agent has been used, *then* check the water for contamination

Bayesian Networks are a specific type of Fuzzy Logic that uses the probabilities of related event(s) to determine the probability of a single event. Bayesian Networks provides this resulting prediction based on a level of confidence.

For example, Node A is related to Node B by an edge that represents that A is a cause of B, with a certain probability. Once a Bayesian Network is taught the symptoms and probable indicators of a particular event, it can assess the probability of that event based on the frequency of indicators. This example speaks of a "Given, pre-defined area, and weather specific to that area" – Our Rule Set Base. Outcomes are based on historical data for that area. Let us look at two events independent of each other, not yet connected, rain and the state of a given area of grass. The chance of rain is 50%; the odds of the grass being wet is 50%. Now, let us look at the same two events after drawing a connection between them, and see how Bayesian Networks can arrive at a new probability with a degree of accuracy when the probabilities of related events are known. If there is no rain, there is less likelihood of the ground being wet (but still a percentage allowing for sprinklers, dew, etc.) Let us take a third look at the same two connected events, if there is rain, the likelihood of the grass being wet is very high. Networks with many such interconnected nodes can be constructed.

Neural Networks are actually grounded in biology and the precise but complex connections that exist between different nodes. These nodes can be blood vessels, nerves, or in this case neurons. Neural Networks are a series of connections joining several simple processing elements into a single network to solve a more complex task. The primary result of these nodes being connected is learning. Iteratively running through the simple processing elements until the best and most efficient path along the network is reached. Theoretically, the more observations and runs through the network, the better the solution.

The combination of two logic systems such as a Neural Network and a Bayesian Network creates a system that will arrive at the best possible solution. This is called a Hybrid Intelligent System. The logic application can be a hybrid intelligent system which is a combination of basic modeling concepts such as Boolean and Fuzzy Logic providing probabilities can be established that support mitigation planning.

If a train is de-railed with specific cargo on board (dangerous/hazardous) and it is not near a large city then your next action will be to?

Or

If a train is de-railed with specific cargo on board (dangerous/hazardous) and it is near a nuclear facility, and near a large city, then our next action will be to?

As you can see these two scenarios have similar characteristics but would have much different outcomes as the next step to take in applying response. This is where the rule set comes into play.

GIS Supported Logical Networks:

Once a Bayesian Network is designed to provide probabilities for the problem, the supporting data needed has to be identified. For example, for past rail incidents that have been identified as being intentional we can look at the geographical properties surrounding this incident and use them for comparisons in future incidents immediately after they happen to determine a probability indicating if the recent incident is intentional. GIS models are built to analyze data and "fill in the gaps" of geospatial data not easily available.

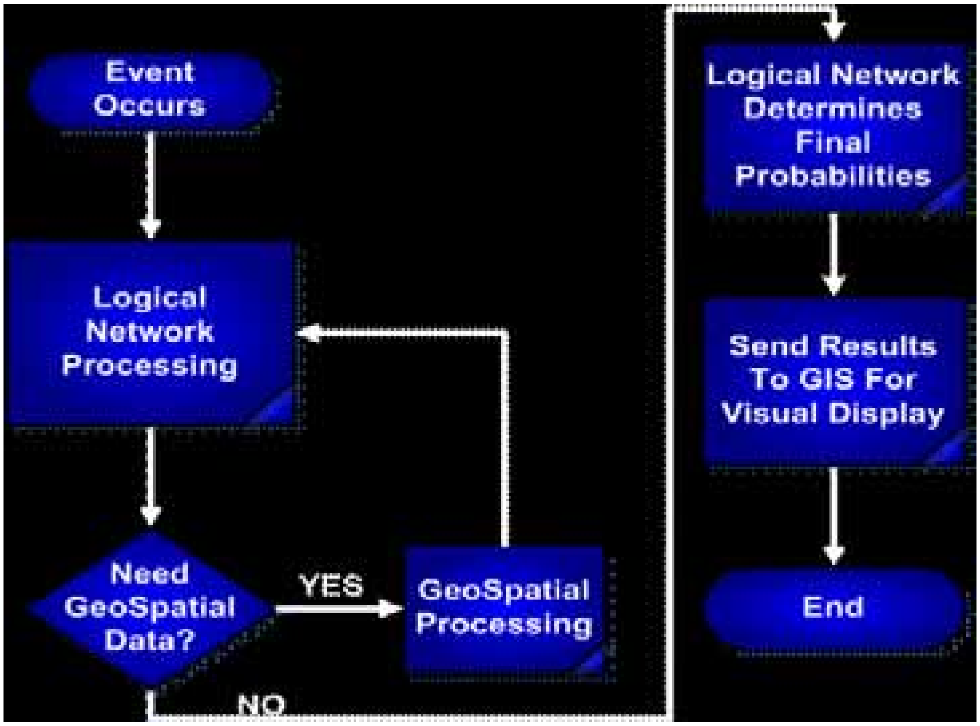

Figure 4

GIS receives the coordinates for the suspect event and the request for distance to surrounding structures. GIS models are built to read through the enormous amounts of data and fill in the "distance to *x* field." The Bayesian Network now has a piece of data needed to complete the execution of this model.

By building the Logic Modeling Tools necessary and identifying the gaps of geospatial data needed, corresponding GIS models can be constructed that provide this identified information and allow the model to run to completion (see Figure 4). The results of these tools should greatly assist in identifying the event as being primary, secondary, etc. and the results will also provide faster information for the responders to determine the proper resources for quicker response and minimize any potential events created by a "ripple effect."

References and Acknowledgments:

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