

VISualization of Threats and Attacks (VISTA): A Decision Support Tool for Urban Threat Environments

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Abstract

Urban threat environments, including urban warfare and disaster scenarios, can be characterized as complex systems. Decision making in urban threat environments may be difficult because the underlying system exhibits non-linear and path dependent behavior that humans, unassisted by computers, have trouble understanding and reasoning about. Thus, it may be difficult to predict how the consequences of an action may unfold. VISTA, a computational model is presented as a decision-support tool to be able to help the analyst understand the complexity of an urban threat environment, thereby enabling forecasting of conditions and the exploration of potential consequences of potential actions. A demonstrative use-case is presented along with hypothetical results to illustrate the tool's potential usefulness. Attention is also paid to the usefulness and challenges of providing an "explanation" of the tool's results. Initial approaches to the problem are presented.

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The VISTA Model

VISTA is a multi-agent tool that intelligence analysts can use to visualize the sudden, non-linear, emergence of events that can characterize asymmetric threat operations in an urban environment. The model is composed of a set of agents and relations among them, the actions they take, and the effects of those actions on each other. Diedrich et al (2003) give a preliminary description of the model, its purpose, and areas of potential usefulness. The VISTA system consists of a number of interacting parts, formalized in terms of the organizations and groups that operate in a city and the different parts, or sectors, of a city. The different parts of the system act and react to conditions in the system according to defined rules. The model draws on theories on complex systems and social networks to inform the framework of the basic architecture of the model. Theories of conflict, disaster response, and social construction are used to design the behavior of the different parts of the model.

The agents are the players, or participants, in the conflict in the urban environment. Three types of agents exist in the VISTA world: the hostile actors, the stakeholders, and the sectors of the city. We model hostile actors and the stakeholders at the organizational level. Agents can take a variety of actions, either hostile or friendly. The sectors in the model represent different neighborhoods of a city or areas of strategic interest.

The relations modeled between the agents define how the agents react to each other's behavior and characteristics. These relations include Influence (Hostile Actor x Hostile Actor), Criticality (Hostile Actor x Sector), and Bias (Hostile Actor x Sector).

During each run of the model, actors in the system may take a variety of actions based on their capabilities. The likelihood of their actions is probabilistically defined using historical data and is influenced in part by their tension levels. The target of an action is dependent on the relations that are defined between the agents. Actions taken in the system affect tension levels among the agents. The system runs for a number of time periods, after which measurements are aggregated and reported. An extended description VISTA and its functional abilities are presented by Carley et al. (2004).

Use Cases

A typical user would be a military intelligence officer who reports to a commander or an analyst who reports to a disaster manager. We expect the user to be interested in performing the following four functions: 1) assessing the current threat level in different parts of a city, 2) determining possible future consequences of taking a hypothetical action, 3) determining how sensitive the results are to different actions and to alterations to the environment, and 4) determining the effects of taking an action or an alteration of the environment at a specific point in the future.

Data

Three databases serve to provide historical context, city characteristics, and entity characteristics. The Historical Database can contain background information on historical events related to either disaster responses or urban operations such as those in the Northridge earthquake, Mogadishu, Pristina, Mitrovica, Port-au-Prince, and Beirut. The City Database will contain information on the city being evaluated, both in general and by region or sector within the city (City Database). This will include information such as the size of city, population density, poverty levels, and locations and types of key infrastructure. The Entity Database contains information on the characteristics of different organizations operating in the environment. These may be either friendly organizations such as the Red Cross or Federal Emergency Management Agency (FEMA) or "hostile agents" such as a paramilitary faction or terrorist cell. Data on cities has been collected for Mitrovica, Beirut, and Port au-Prince. We plan to collect data on more cities.

Measurements

Tension. We expect the analyst to be principally interested in how likely certain events or actions will be and where these are to be most likely to occur. We measure the relative likelihood of events of interest occurring by keeping track of and adjusting a variable we refer to as "tension" for each agent in the model. Tension for each agent is a measurement ranging in value from 0 to 1, with 0 representing a situation with the least threat and 1 representing a situation of greatest threat. Tension is adjusted according to a weight and adjustment formula that considers both the nature of the event that occurred and the nature of the target(s) affected. For sectors we can

consider tension to be the relative likelihood that an event will occur in the area. For hostile agents, tension is correlated with the likelihood that the agent will take a hostile action in the next time period.

Historical Events. An analyst might also be interested in knowing what types of events are most likely to happen given the current environment or given some action that can be taken. Further, they would also be interested in what periods of time in the future these events are most likely to occur. We measure the likelihood of events occurring at each point in time via Monte Carlo simulation. These distributions can be viewed for each time period and for each sector and the city as whole.

Virtual Experiment

To demonstrate the potential usefulness of the model, we designed a virtual experiment using real data collected on Mitrovica, Kosovo. Data included information on different sectors in Mitrovica and the different organizations operating within the city.

For the virtual experiment, two conditions were run: 1) a condition that considers the insertion of peacekeeping forces in a sector and 2) a condition where no peace keeping forces are inserted. The experiment was run using the “What-if” function of the model. A “What-if” experiment is designed by selecting one or more variables, a value for each variable, a time step, the number of runs, and the number of time steps per run. During the experiment, VISTA will change the selected variables to the specified values at the specified time step and then continue running the model. For both conditions, VISTA was run 500 times for 10 time periods in each run. In the peace keeping condition, the presence of keeping forces was inserted into a single sector in the fourth time step. In the other condition, no variables were altered during the runs of the model. Figure 1 shows a screenshot of the “What-if” function of the VISTA model.

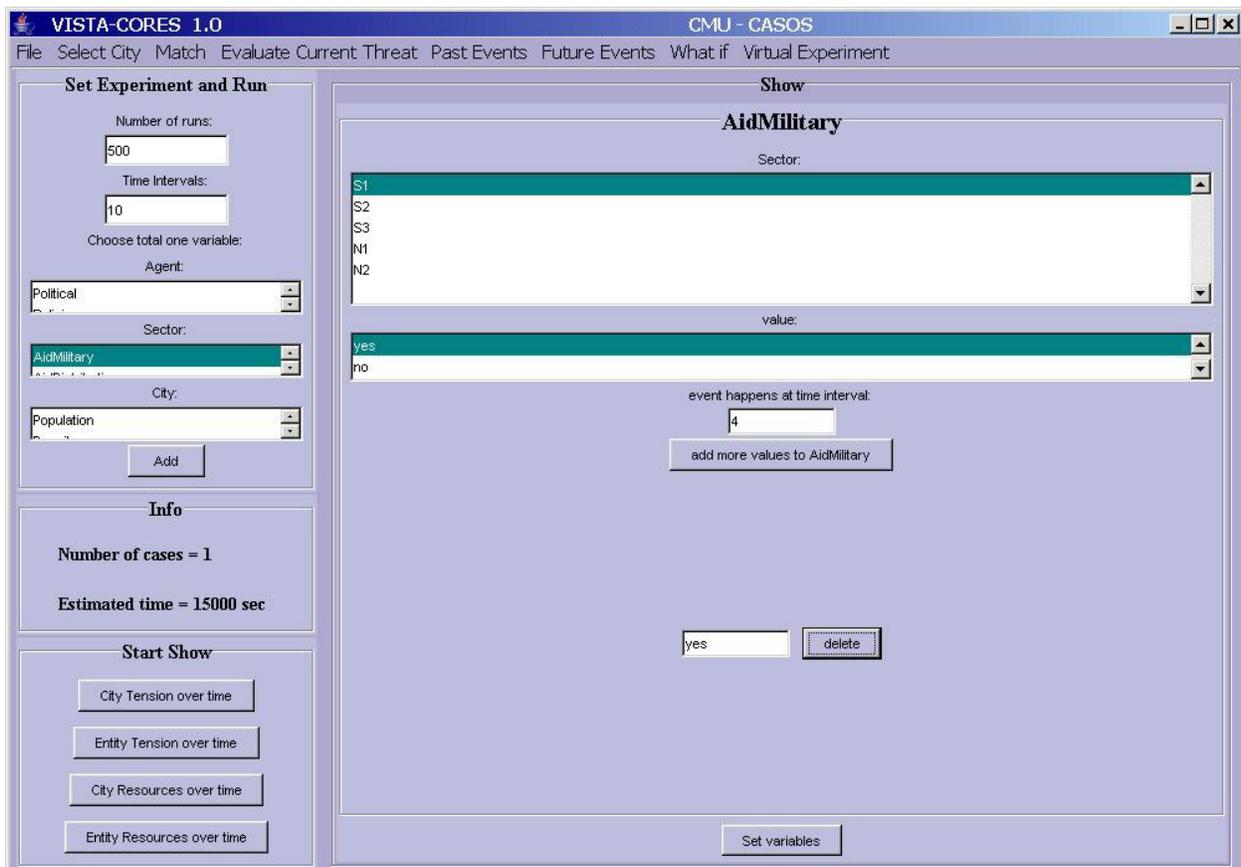


Figure 1. The screenshot shows how a user would design a virtual experiment using the "What-if" function of VISTA.

Results

When peace keeping forces are inserted into a sector tension levels decreased on average over the 500 runs for the next three time periods. Tension levels then spike again, resembling tension levels close to what the tension level would be at the same time period when no peace keeping forces were inserted. While these results can be argued to be intuitive and the rules governing the behavior of the agents when peace-keeping forces is in line with past-experience, we should nonetheless maintain reservations. The virtual experiment and results presented here are intended to demonstrate the potential usefulness of VISTA.

Tension Overtime: Insertion of Peace Keeping Forces Compared to No Peace Keeping Forces

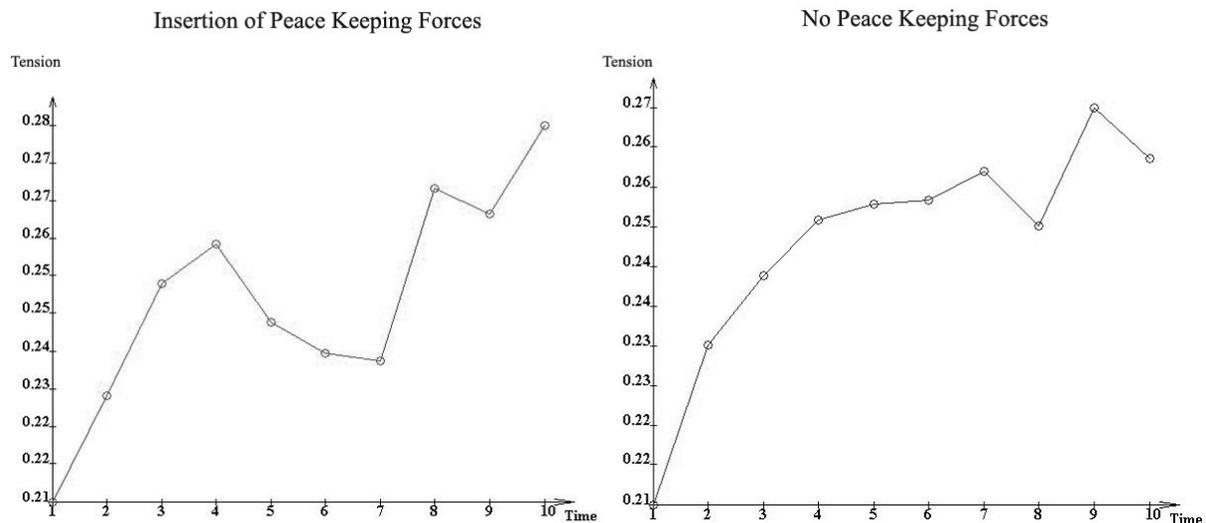


Figure 2. When peace keeping forces are inserted in a sector, the tension in that sector goes down temporarily and then rises to levels that match the tension reached when no peace keeping forces are inserted.

Providing an “Explanation”

A decision-support tool should do more than just provide results for a series of model runs, especially when the model producing the results has a high degree of complexity. The decision-support tool should also explain how and why the tool produced the results it did. Similar efforts have been made in creating explanations from expert systems [Swartout, Paris & Moore, 1991; Bazilay et al., 1998] and for probabilistic systems [Chajewska & Halpern, 1997]. In VISTA, it is important that the results produced are “explainable” to assist the analyst in making informed recommendations. For example, the results that show tension declining after peace-keeping forces are inserted do not explain *why* tension declined. An explanation might consider the types of knowledge, or rules, used to modify the behavior of the agents in the system and the conditions that existed in the system at different points in time. An explanation would also need to present this information in a manner that is easily understood by a person. Explanations also assist in the validation process. By presenting a justification of the results it has produced, a subject matter expert can decide whether the results being produced are make sense given the explanation provided.

We show how the notion of explanation can be extended to VISTA and to multi-agent systems in general and where work still needs to be done in this area.

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