Concept for Geopolitical Crisis Simulation as Assistance During a Decision Making Process

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***Abstract* — In the aftermath of September 11, the classical term of security is not longer valid and has to be extended. The security forces and decisions makers are faced with new challenges posed by the phenomena of terrorism, piracy, climate change and new economic practical constraints. To cope with this task, they need some support. This paper describes a possible simulation concept of geopolitical crises. As part of the concept the theory of finite element method should be examined on practicability. The starting point is a hypothetical scenario of a fictitious country. Infrastructural, cultural and socio-political aspects will be taken into consideration for the prediction of future crisis developments.**

Keywords-FEM; crisis simulation; crisis management

I. Introduction

A. Definition of a Crisis

To simulate a crisis, one has to be able to understand and explain a crisis at first. In literature, there is no general definition of a "crisis" available; therefore, we will have to give an explanation of the crisis term to make sure, that a common understanding is guaranteed.

In the beginning of the 18th century, a "crisis" was based on the probability of revolutions, counter-revolutions, independence and civil wars [1]. Given the rapid development of peace research, this term was stretched frequently. The changing international environment assigns both stakeholders of the security (i.e., states, international / national organizations, etc.), as well as political decision makers faced with new problems and requirements. Therefore, it is important to derive a new common definition.

A "crisis" is a situation, in which a system or a part of a system is extinguished and destroyed. A system is a group of actors (states, organizations, resources, etc.) that interact together in one or more fixed patters and structures [2]. This increases the likelihood of a war or the usage of force [3]. Furthermore, if a decision-making process is subjected to time pressure to avoid a growing danger of hopelessness [4], a crisis is about to rise.

B. Crisis Management

In time of a crisis, citizens need the aid of their leaders. In other words, they are dependent on the leadership of their presidents, local politicians, public managers or religious mentors. These leaders must make decisions to minimize the damage of the crisis and they have to examine ways that will lead their people out of the critical situation. The management of a crisis is often a complex operation, which requires a lot of organization. The decision makers must supervise the whole crisis management process, communicate with stakeholders, discover what went wrong, define possible risks and they have to initiate improvements to overcome the crisis.

To make these important decisions, leaders must have an overview of the possible progress of a crisis. To support the decision making process, a tool for crisis simulation could be of immense value. Such a tool could be used to forecast upcoming events. Consequently, this will provide an edge to the decision makers in managing the crisis.

This paper will start with an introduction of some basic ideas for a simulation that has to be taken into consideration. After that, two basic principles, that seem appropriate for the simulation, will be shown and discussed. The next section will outline a possible simulation prototype to clarify a first simulation concept. Finally, a conclusion is drawn and an outline for further steps is given.

C. State of the Art

1) CASCON

Computer-Aided System for Handling Information on Local Conflicts (CASCON) is a computerized history-based conflict analysis and decision-support system. This system is based on Bloomfield-Leiss model [6] of local conflict, which represents conflict as a dynamic process that moves in time and space [5]. A local conflict is derived from the substantive dispute. The dispute can be caused because of the territory, ideology, power, race, religion, or whatever. It is derived in phases of varying durations. In each phase, there are factors-conditions, perceptions, situations, or relationships that generate conflict-relevant pressure.

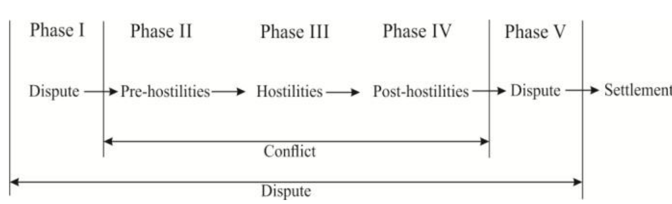

Figure 1. Phases of the Local Conflict Model [5].

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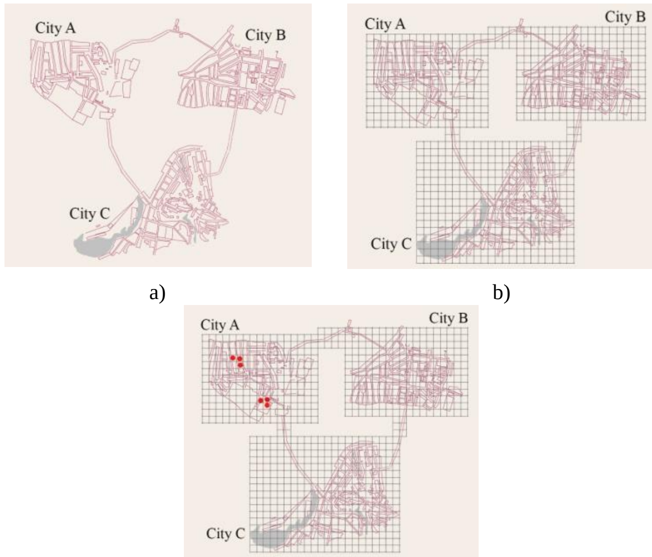

c)

Figure 2. a) A map of fictitious state. b) A map of fictitious state with a grid. c) Crisis points marked red in the map of fictitious state.

Figure 1 shows the phases of the local conflict based on the Bloomfield-Leiss model. Phase I defines a dispute that will be waged at the polls, in the press, economically, politically without military participation. Phase II defines a conflict (pre-hostilities) with an option of military introduction. Phase III, hostilities, arises when one side actually inserts military force to resolve the dispute. When hostilities are terminated, it skips to phase IV, post-hostilities. Phase V is entered when the dispute is no longer vied in military terms. The conflict is settled, when the dispute ends [5][6].

The users of the CASCON system can access the database. They can record the data about a new case or they can get the information about previous conflicts in a particular phase. The system can recommend steps at the onset of the dispute rather than at the outbreak of hostilities.

This system is very complex. With our simulation, we want to visualize possible spread of the conflict in a region. Actually, we do not need a database with historical data, but rather certain parameters, they must be defined later.

2) Plague Inc.

Plaque Incorporated is a strategic game that is developed by Ndemic Creations [7]. The aim of this game is to destroy the world with a deadly pathogen. The game uses a complex epidemic model to implement a realistic simulation.

Gamers play against the world's population. The earth is modeled as a game map. The map is divided into different states. The states have at its real existing models adapted factors, which can be divided into four areas: economic power, rainfall, temperature, and population density.

The game begins at the current day and then runs on a daily basis. The gamer can select a country, where the pathogen begins. First person will be infected. People can be healthy, infected, and dead. The disease spreads through country infection, ships, aircraft or animals.

If the world's population discovers the disease, it begins with the development of a cure. The more severe the medical condition is, the more money must be invested in the remedy. Economically powerful nations have an advantage for fighting the pathogen. A gamer has possibilities to fight back against the cure, such as the development of a resistance or the formation of a new disease. The player wins, when the world population is completely annihilated before a cure was cultivated. The world wins; if the world population develops a cure or kills the pathogen and support before all people infected [8].

This game would be a good template for a simulation of crisis spreading. But the project is commercial; there is no access to the methods and models that have been applied on the development of this game.

In our research project, we want to develop a crisis simulation based on "Plaque Inc.". We need to examine models and methods, which are descriptive of the crisis spreading more realistic. We want use the CASCON system, to define the influencing factor of crisis spreading. With the aid of Finite-Element-Method (FEM) [9], we want to present the geographic extension of a region, because this method is parallelizable and well scalable in computer power [10].

II. Basic Idea of Simulation

For our investigation, we will use a fictitious country. In Figure 2a, one can see that country, which consists of three cities. Furthermore, the cities are connected via infrastructural objects (i.e., roads). At that point, the development of one or more crises, which were triggered in one or more parts of a city, shall be examined.

To analyze the dispersion of a crisis from one point to another, a grid is placed on the cities and their compounds. The grid can be viewed in Figure 2b. Points that will represent a crisis, are placed on one or more grid locations. In Figure 2c, you can see the crises points marked as red dots. Now, for each part of the grid we could define some characteristic traits. These traits can be used to simulate infrastructure, regional and political states in that particular location. The main idea to model the interaction of every trait with a crisis point. To achieve this, we want to use differential equations. At the next step our work; we want to define these equations. The type and order of the using equations are dependent on the kind of interaction and its complexity. This leads to a convenient way of describing the underlying dependencies. The variables of differential equations could be defined using the CASCON system by providing the single factors.

III. Basic Principles

A. Finite-Element-Method

Taking performance considerations into account, it would not be a good choice to consider the complete map for our simulation. It is possible that the largest part of the observed country is devoid of infrastructure or important objects (forest, grassland, mountains, etc.), but another part is of major interest and only that part is in the need of closer investigating. Hence, the map should be divided into areas. As stated in the previous section, each location has particular properties and a degree of influence on neighboring locations. The fundamental dependencies are simulated via differential equations.

At this point, FEM, as a numeric technique for solving differential and integral equations, could become handy. A region, in which we seek a solution for the underlying differential equations, is divided into a finite number of elements. For each of the elements FEM provides an approximating function. Function values at the boundaries of the elements are the approximated solution of the differential equations and hence the solution of the fundamental problem. The coefficients of the approximating functions are determined by the condition of the values of neighboring functions on the boundaries between the elements. These coefficients are expressed through the values of the functions in the elements [9][11]. At this point, it becomes clear that the basic idea of the simulation and the basic principles of FEM are strongly related. Therefore, it is of high interest to examine this approach as possible solving mechanism of this kind of simulation.

B. Game of Life

Besides FEM, Conways “Game of Life” [12] appears to be a well suited template for this kind of problem. The “Game of Life” is a grid based computer simulator that was invented by Moler [12]. The population spreads over an infinite two dimensional squared field (universe). The population evolves at discrete time steps and depending on the neighborhood they stay alive, die, or bring new life to adjacent locations in the next time step. Every location in the underlying two dimensional grids is called a cell and every cell has two states (population alive or dead).

The fundamental concept of "Game of Life" is based on a very simple set of rules:

1. A dead cell with three living neighbors will become alive in the next time step,
2. A living cell with less than two neighbors dies in the next time step,
3. A living cell with more than three neighbors dies in the next time step,
4. A living cell with two or three neighbors will stay alive.

Though this concept is rather plain, it shows some similarities to the featured idea for crisis simulation. Crises could be regarded as the population and our region of interest is subdivided into cells on a grid. A crisis could appear (cell becomes alive) and it could disappear (cell dies). At this point, it becomes obvious that the set of rules have to be more complex to model the fundamental behavior of a rising or falling crisis and that is the point where a connection between FEM and "Game of Life" could bring a more desirable modeling quality.

IV. Description A Prototype of the Crisis Simulation

In this section, a possible implementation of a simple prototype for the simulation concept is introduced. An arbitrary two dimensional matrix *M* is chosen as a representation of our gridded country map. A second two dimensional matrix *C* is chosen as a representation of the crisis population. It becomes clear, that the fundamental problem is subdivided into multiple layers and each layer has its own matrix. The elements of the matrix *M*, which represent the cities and their infrastructural interconnections, are filled with ones (1). Empty spaces are marked with zeros (0). The same is true for the matrix *C*, a living cell is marked with one and a dead one with zero. Now, rules in favor of our special "Game of Live" represented by Matrix *C* can be applied. For the prototype, the following rules have been prepared:

1) A cell with a living crisis in matrix *C* can spread out (i.e., bring life) to another cell, if the corresponding cell in matrix *M* is defined with a one.
2) A living crisis can cause a new crisis in neighboring (adjacent) cells only.
3) A living crisis can spread out, if at least one neighboring element is also defined as a living crisis.
4) An element can be defined as a living crisis, if this element is not a crisis yet (dead crisis).
5) If a living crisis did not spread to a neighboring element in the previous time step, then it will die.
6) For each element, which is not a living crisis, is made a connection to every neighboring crisis element. To each connection the value 0 or 1 is assigned and that value is random generated with a probability of 50%. If at least one connection has the value 1, then this element will become a living crisis in the preceding time step.
7) The simulation ends after a predetermined number of iteration steps or if all of crisis elements are dead.

V. Conclusion and Future Work

The crisis management in geopolitical, economical and humanitarian area is a very complex topic. All these areas are highly correlated to each other. To make future statements about the development of a crisis, all factors must be regarded individually and collectively. To determine the dependency factors or the factors that have an influence on a crisis, the collaboration with political, economical and sociological institutes is planned.

It must be analyzed, which factor may affect the spread of a crisis from one to the other area and how a reasonable weighting of each factor with influence could be accomplished. A probable approach for accomplishing that challenge is to examine real crises and their development in the past in existing countries or regions. That is also a mandatory assignment for a validation of the simulation system, to prove correctness of the underlying algorithms.

All political and economic aspects have to be taken into account and neighboring regions must be analyzed. Once the most important factors and parameters are defined, the results can be simulated.

At this moment, an implementation of FEM was neglected in the simulation. That kind of methods will provide a more sophisticated simulation model, but this is only of any value after an interdisciplinary investigation of the whole topic, which is planned for the next prototype.

At last, it must be pointed out that the described prototype is at a very early stage of development. It handles a simple cellular automaton simulation with yet non-justified assumptions only. For further investigations, a validation and a probable reconsideration of the given rules have to be made. Obviously, it is a plain two-dimensional approach that solely relies on geographical distances. To reflect modern world scenarios, a multi-dimensional approach, which could simulate mass transit and electronic communication, has to be taken into consideration.

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