Anticipation in Disaster Management

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Abstract
Planning for regional security and crisis management is identified as a multi layered system suitable for anticipatory modelling and simulation. Delays and inter level dependencies, however, have manifested themselves as dominant properties of such systems. This means that an action on one level will cause surprising impacts on the others, but first after some retardation. Fortunately, with help of anticipatory modelling and computer simulation it is possible to demonstrate the effects of those complex inter level interactions in a simulation model before a decision is realised and action is taken.
Keywords: Disaster and Crisis Management, Anticipatory Modelling and Simulation, Multi layered systems, Delayed systems, Territorial Concern.

1. Introduction

As manifested in the European FP7 research program[1], security has lately become a main issue in European Research and Technical Development (RTD). This broad area includes many topics. Among those, research on simulation, planning, and training tools for management of crisis and complex emergencies and disasters has recently emerged as a main priority[2].

Inter regional cooperation is another important issue of European concern. In this context the Cross-border program within the European Territorial Cooperation Objective [3] as as its prime goal to foster cross-border transnational and inter regional cooperation.

So, by merging those two interests, security in cross-border regions emerges as an urgent research area from at least two European perspectives. In this context simulation, planning, and training seem to be ideal application areas for anticipatory modelling and simulation (AMS). Despite that obvious potential, anticipation has not yet been identified as a core issue for simulation, planning, and training for management of crisis and complex emergencies.

Hence, in order to improve that situation the purpose of this paper is to increase the understanding of the feasibility and power of anticipatory approaches in crisis and security applications.

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[1] http://cordis.europa.eu/fp7/dc/index.cfm (2010-11-03)

[2] Call identifier: FP7-SEC-2009-1, Date of publication: 3 September 2008

[3] http://ec.europa.eu/regional_policy/sources/docoffic/official/regulation/content/en/02_pdf/00_7_i3_en.pdf (2010-11-03)

2. The Problem Domain

The Territorial Concern (TC) may be taken as a base concept for discussing regional and interregional security. A TC, as outlined in figure 1, being a community based organisation for the design, construction, and maintenance of order and security within a geographical territory or region. In other words, a TC is a homeostatic system, with the responsibility (the concern) to establish and maintain a satisfactory configuration of system components and processes and to keep a set of essential variables within critical levels (Holmberg, 1998).

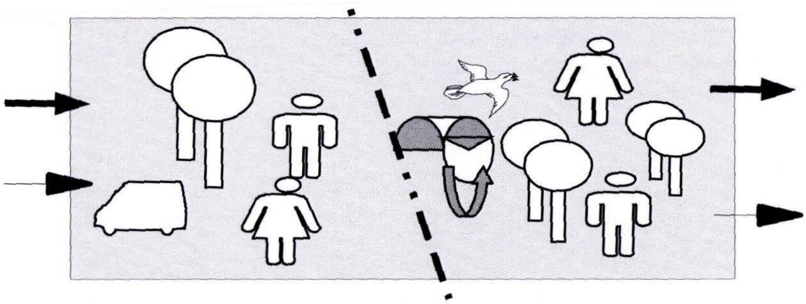

Figure 1: A Territorial concern (TC) with its flows, processes, and living and non-living inhabitants.

Coming to planning and decision making for security and crisis management within a TC a multi layered system with three logical levels will emerge. First, on the lowest operational level there are direct rescue work aiming at the re-establishment of a threatened order. On the next tactical level we find maintenance actions with the purpose to keep security equipment and procedures in an operational state. On the highest strategic level, at last, there are measures and actions for creating and building an as secure environment as possible. An environment there crisis and accidents never will happen. The security management within a TC, however, is heavily complicated by delays and interdependencies between levels. This means that an action on one logical level will have an impact on the others, but first after some retardation.

Building on earlier more general work by Dubois and Holmberg (2006, 2008) anticipatory modelling and simulation will here be applied as a tool for understanding and handling those challenges to the management of TC security. A solid argument for this approach is Ackoff 's (1981) statement that "*The future is largely subject to creation*", and "*the future depends at least as much on what we and others like us do between now and then as it does on what happened until now*". By this we deduce that it is necessary to develop a model (design) of the desired future and to take measures (actions) in order do attain that desired future, i.e. the design target. In terms of anticipation, this is exactly the same as prescriptive anticipation (PA) according to Holmberg (2002). Anticipation, with other words, is here interpreted according to the etymology of the word, which implies doing or acting in advance.

Asproth et al. (2010) provides a somewhat deeper discussion of the problem domain and the inter regional security challenges.

3. Current Research Status and Steps Beyond

Rodrígues et al. (2006) have in their compilation of current disaster research shown that research on crisis and emergency management have both broadened and intensified over the last years. Hence, as demonstrated in their book, nearly all branches of social science are now engaged in the research on disaster management and risk handling. Further, Dubois et al. (2010) represent a first attempt to apply anticipatory research and anticipatory modelling and simulation on disaster management.

Asproth et al. (2010), at last, find that even if many important insights have been gained so are several of them, at least apparently, contradictory. Also, a great part of them have not yet been field tested or verified in practical disaster work. With that reservation, this paper will anyhow build on the following conclusions, which are drawn from current research insights (Rodrígues et al., 2006; Asproth et al., 2010):

- Final outcome of a disaster is highly due to preparations and training. Anticipatory modelling and simulation will play an important role in that preparation.
- Many types of actors with different skills and cultures will be involved during rescue and recovery. It is of paramount importance that they have a common understanding of the situation and that they are informed about the decisions of the other actors.
- Communication and Coordination will be more important than Command and Control
- Social media may play an important role in providing a virtual meeting room and a means for coordination of actions.
- The information to the public of different nationalities and natal languages will be a special challenge.

4. The netAgora Solution Framework

Asproth et al. (2010) propose the netAgora portal, i.e. a computer and net based integrated environment for mutual preparation and training for disasters and complex emergency situations according to figure 2. The netAgora environment will be all comprehensive with a disaster simulator, a scenario editor, and an assessment kit included in its core. It will support cooperation, coordination, training, preparation, and learning on individual, group, and organisational levels. The netAgora will further include support for an exchange of experiences, tools, and models of response to emergence situations with a special emphasis on handling of cultural differences.

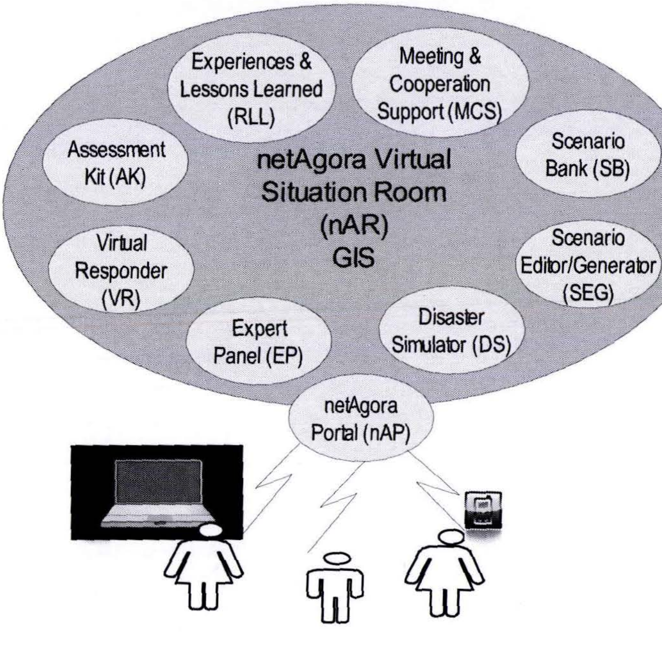

Figure 2: The netAgora Environment.

Main components in netAgora are shown in figure 2. The Virtual Situation Room (nAR) serve as a container for a set of service components. It is reached over internet via access point netAgoraPortal (nAP). nAR may be freely adopted to meet the specific requirements of different user categories.

The Virtual Responder (VR) is a system component, which simulate the behaviour of other responders. From the point of view of the player there is no difference between a virtual actor and a real actor. This means that in netAgora there are always several actors, real or virtual ones, which you as user have to coordinate and communicate with.

The Disaster Simulator (DS) is the core of netAgora. DS can calculate (simulate) the dynamic evolution of a set of crucial disaster variables and react on different user decisions and actions. The ability to handle geographical or spatial information (GIS) is a crucial faculty of the DS. The user can select a scenario, i.e. disaster, from the Scenario Bank (SB), set up a new one, or change an existing one, with help of the Scenario Editor/Generator (SEG).

The Assessment Kit (AK) helps the user to evaluate the decisions and actions taken during the playing of a scenario. Experiences and Lessons Learned (ELL), at last, is a knowledge bank with tested and verified disaster and crisis knowledge. Via the Meeting and Cooperation Support (MSC) the user can interact and discuss with other disaster responders and via the Expert Panel (EP) she or he can put disaster related questions to a group of disaster experts and researchers.

To sum it all up, the main objective of netAgora is to provide, in one place, all the necessary resources and functions for a best possible preparation, training, and learning in relation to crisis and complex emergency situations. Those objectives will be reached by developing the netAgora environment as a training tool and disaster simulator that are: inter active, situation flexible, cross platform, co-creating, computer and net based, based on open source, and usable in different social situations.

5. Anticipatory Approach

The anticipatory capabilities of netAgora will be due partly to the anticipatory thinking of its human users and partly to the anticipatory properties built into the Disaster Simulator (DS). On that later point Dubois and Holmberg (2006) have already presented a multi-level simulation model with anticipation and delay. Though originally envisaged for a management application, Dubois et al. (2010) have demonstrated that the model can easily be adapted to the case of inter regional disaster management.

So, according to figure 3 at the current time (t) we have direct rescue actions (r) on the operational level, preparation, training, and maintenance (p) on the tactical one, and creation (c) of new secure environments and milieus on the strategic one. Further, as the arrows in figure 3 indicate, the operational, tactical, and strategic actions are mutually interdependent. Energy and resources allocated on one level will be taken from the other two. One crucial security decision will hence be to find a good balance between the three levels. A simulation tool has here the potential of supporting that decision.

The situation, however, is complicated by delays. This, for example, means that an action (p) on the tactical level will not impact the operational one directly but first after a certain delay (d). Hence, the rescue (r) job you have to undertake at time (t) is to a certain degree predetermined by the preparations (p) undertaken at time (t – d).

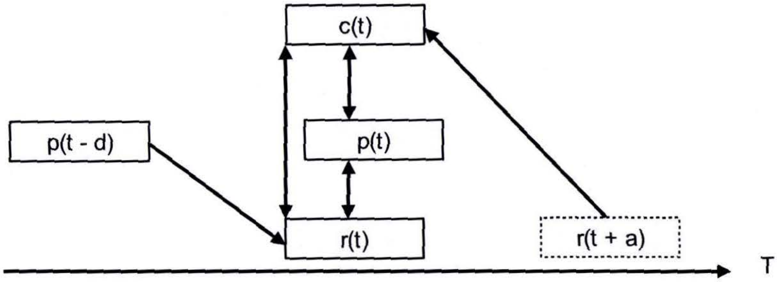

Figure 3: A multi level security system with anticipation and delay.

At last, due to delays it is not appropriate to look at current rescue work (r) on the operational level when creating (c) new secure environments. That because the current operational situation (r) may never be impacted by current security increasing activities (c) on the strategic level. Instead it is necessary to look at the target security situation that is wanted at the time (t + a) the actions will have their effects on the tactical level. That means that a future security situation is anticipated by current security actions on the strategic level. Even this decision may be supported by the simulation tool we are aiming at.

6. Anticipation Put into Practical Work

The practical work with the Disaster simulator (DS) in real crisis and disaster management could be based on the so called ACADA approach (Holmberg, 2006). So, in any disaster management situation it would be advantageous to be able to test and verify a decision before it is executed. One way of doing such a verification is to express the design as a formal system and to simulate the system development in that formal model, possibly with help of computer support. Hence, in so doing an anticipating anticipatory system will emerge. In figure 4, a scheme for implementing such an Anticipatory Computer Aided Decision Approach (ACADA) is proposed.

The crucial measure of that operation is to make the correct associations between the variables and operators of the formal system and the corresponding features, actions, and measures of the concrete real world system. It is not obvious that it is always possible to do such associations but, as Warfield (2002) has pointed out, the usefulness of Bool's algebra is due to the successful realisation of such associations. Hence, we initially assume that they will be possible also in the case of disaster management.

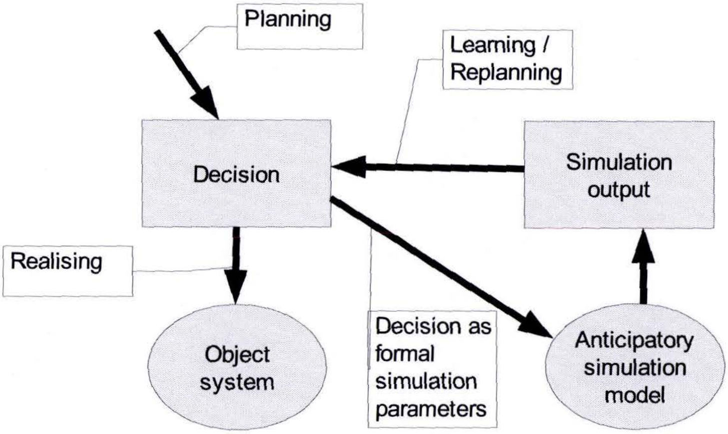

Figure 4: Anticipatory Simulation Aided Decision Approach.

Putting the previous discussion together, the following iterative steps could constitute a workable procedure for an anticipatory simulation supported decision making for disaster management:

1 Develop the preliminary decision.
2 Transform the decision into formal simulation parameters.
3 Perform (computer supported) anticipatory simulations in the formal model
4 Associate variables and operators in the formal model with features and actions in the concrete system.
5 Act in real system according to outcome of simulations, or refine the decision and go back to point 2.

7. A Simple Demonstration

In many cases the original system, i.e. the system before intervention or redesign, may be what Rosen (1985) calls a reactive system. That means that the formal reactive system (sr) is developing only according to a reactive or deterministic function R, which is only reacting on the system's historical states sr(h) according to equation 1 (Holmberg, 2006).

$$sr(t+1) = R[s(h)] \tag{1}$$

In this case, an actor or stakeholder has no possibility to influence the outcome of future system states. Seen in the light of systemics, this have a clear similarity with what Ackoff (1981) calls a reactive planning attitude. The (re)design (D) of R, however, could transform it into an anticipatory function (A) according to equation 2. In Ackoff's parlance, a preactive or interactive planning attitude has emerged. With this new function, future anticipatory system states (sa) may now be calculated in an anticipatory mode, i.e. due also to system objectives (o), and future system states (s(p)) according to equation 3.

$$D{:}R \rightarrow A \tag{2}$$
$$sa(t+1) = A[s(h), s(t), s(p), o] \tag{3}$$

In this anticipatory case (equation 3), system targets, or objectives (o), will have an influence on future system states. This means that the system will become controllable and by associating objectives (o) in the formal system with actor and stakeholder objectives in the real world system it becomes possible to test and validate decisions developed for concrete purposeful systems. This main idea will be exemplified in the following section.

7.1 Simulation Example

An example given by Holmberg (2006) can be used to illustrate the power of an anticipatory approach also in this context. The well known Pearl-Verhulst function according to equation 4 is strictly deterministic and reactive. Further, it also exhibits a chaotic behaviour for certain values of the "regeneration" variable (r). However, the function may be transformed or redesigned in order to change its behaviour and characteristics. Equation 5 shows such a redesign according to Holmberg's (2000) WIP approach.

$$sr(t+1) = r\, s(t)\, [1 - s(t)] \quad (4)$$
$$sa(t+1) = wh\, [h(sa(t-n,..,t))] + wa[r\, s(t)\, [1 - s(t)]\,] + wp[p\, (sa(t), o)] \quad (5)$$
$$\text{with } wh + wa + wp = 1$$

The basic idea behind the WIP approach is that the system's development is due, not only to its history, but also to its actuality and future objectives. First, to a certain part the development is given by the history weight wh and the regression function h over the system's historical system states (sa(t-n,..,t)). Next, the actuality weight (wa) determines to what degree the current system dynamics, i.e. the original function according to eq. 4, will influence the system future. The potentiality weight (wp), at last, sets the strength of the impact of the system's objectives (o) by potentiality function (p). Hence, by varying the weights wh, wa, and wp it is possible to change between Ackoff's (1981) different planning attitudes. The planning or potentiality function (p) in equation 5, of course, may take many different forms representing different designs. In this experiment, however, of illustrative reasons a very simple approach is taken according to equation 6. The same for the history function according to equation 7 where we have only taken the two latest values into account.

$$p(sa(t), o) = [sa(t) + o] \times 0.5 \quad (6)$$
$$h(sa(t-n,..,t)) = sa(t) + (sa(t) - sa(t-1)) \quad (7)$$

Figure 5 shows an example of the WIP-function according to eq. 5 (resa) starting with wh equal to 1 but changing the weights in each step and ending with wp equal to 1. In the same plot also the corresponding reactive function (resr) and the objective function (reso). It is seen that in most weight combinations WIP will stabilize the function. It is also noticed that with high values on wp the WIP function will approach the objective function. Due to an epsilon value reflecting modelling errors, however, the fit will never be perfect.

This last example may mainly be of pedagogical value. With help of it the decision makers may have a live demonstration of the impact different planning attitudes will have on the outcome of any disaster situation.

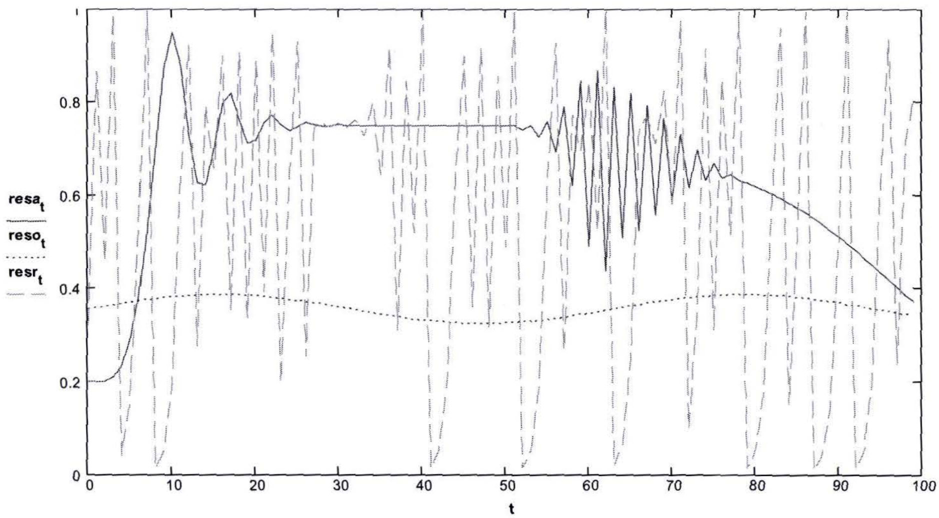

Figure 5: Example of simulation results according to the ACADA approach (Holmberg, 2006).

8. Conclusions

The main contribution of this paper has been a demonstration in what ways anticipatory thinking and anticipatory modelling and simulation could improve planning, preparation and training for disaster management. Further, with an adapted ACADA approach it is possible to implement an effective decision control and refinement system.

However, seen in the light of de Raadt's (2002) Multimodal Systems Model (MMSM) with fifteen levels and relationships in both directions between all levels, the modelling approach presented here may seem too simplistic. Anyhow, even if the modelling work has to further improve, already with this simple model some important properties of regional security systems have been demonstrated. Hence:

- Regional security is not just rescue work. Preparations and training, as well as strategic measures, have a great impact on the total security level in a TC.
- Anticipation is important in order to counteract the negative effects of delays in this type of multi layered complex systems.
- The realism and truthfulness of the model, however, will be of crucial importance in order to get it accepted by the regional security decision makers. Hence, great effort has to be put into the work of capturing scenarios and events from the real world and incorporating them into the simulation tool.

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