Simulation of Patrols with the GAMMA Model

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BACKGROUND

In the context of the SFOR mission in Bosnia-Herzegovina, patrolling is an important activity to support various tasks, such as:

- Protecting returning refugees.
- Protecting endangered areas.
- Supporting embargo.
- Preventing unauthorised movement.
- Detecting road blocks.
- Monitoring troop movements.

While everybody agrees that patrolling is an important activity, nobody can describe exactly the impact of patrolling on the number of incidents, on the various actors' behaviour and so on. Therefore we used simulation in order to get some insight into the interaction mechanism of a number of more or less independent agents and patrol units.

The GAMMA model, which is under continuing development at the NATO Consultative, Command and Control Agency (NC3A) was used for the simulation. The concept of GAMMA is based on an open structure. Objects, such as military units, assets, geographic objects etc. are described in very general terms. New types of entities, for example new military unit types of all services or non-military elements such as refugee treks, civilian population of specified areas, groups of civilian organisations, infrastructure objects, such as power plants or cities can be defined and instantiated easily without any program changes required. Other than in cold war oriented "classical" war games, GAMMA is not restricted to a fixed, two party friend-enemy scheme. Instead, any number of factions may be grouped into any number of coalitions, the mutual relations of them may vary from "allied," "friendly," "neutral," "suspect" to "hostile;" In a war fighting simulation, not only attrition caused on the combatants but also collateral damage on civilian objects can be calculated.

In addition, certain types of objects can act as entities called agents. Agents have the following properties:

- They have own, internal goals and objectives.
- They have got a memory.
- They are able to interact with their environment.

These properties enable agents to a certain extent able to act on their own, and make thus scripting an extent scenario much easier.

The immediate trigger for the begin of this study was an invitation NC3A received from the German Armed Forces Staff College in Hamburg in October 2000 to participate in the preparation of an exercise in order to test the capabilities of the GAMMA model in a multi-sided low intensity conflict scenario and to evaluate the results from this simulation in order to improve and enhance the model

THE SCENARIO

The scenario was based on fictitious countries in a real geography (Spain). The military conflict of two hostile countries (BLUELAND and REDLAND) had been ended by Allied Forces intervention and a 50 km. demilitarised zone had been established on each side of the border. Compliance with the requirements of demilitarisation within the buffer zone had to be monitored by six reconnaissance platoons.

In the buffer zone, terrorist and paramilitary groups of both, BLUELAND and REDLAND nationality, were creating all kinds of incidents, such as terrorising the civilian population of opposite affiliation, attacking refugee treks, which were crossing the buffer zone, sniper ambushes, robberies and so on. In addition, groups of local inhabitants (in particular peasants) which were dissatisfied with the current situation were organising demonstrations and thus creating confusion and disturbance.

At the same time two treks with refugees of REDLAND ethnicity are moving from Kurinesia into the buffer zone in order to reach refugee camps which are situated in the buffer zone and two Kurinesian refugee treks move from Relinesia through the buffer zone to their home places in BLUELAND.

Apart from monitoring the compliance of demilitarisation agreement, the Allied Reconnaissance platoons were tasked to avoid those incidents as far as possible. The challenge for the GAMMA model was to find a way to map the essential constituents of this situation properly. The expected outcome of the simulation was an assessment of the effectiveness of the patrols provided by the Allied Forces.

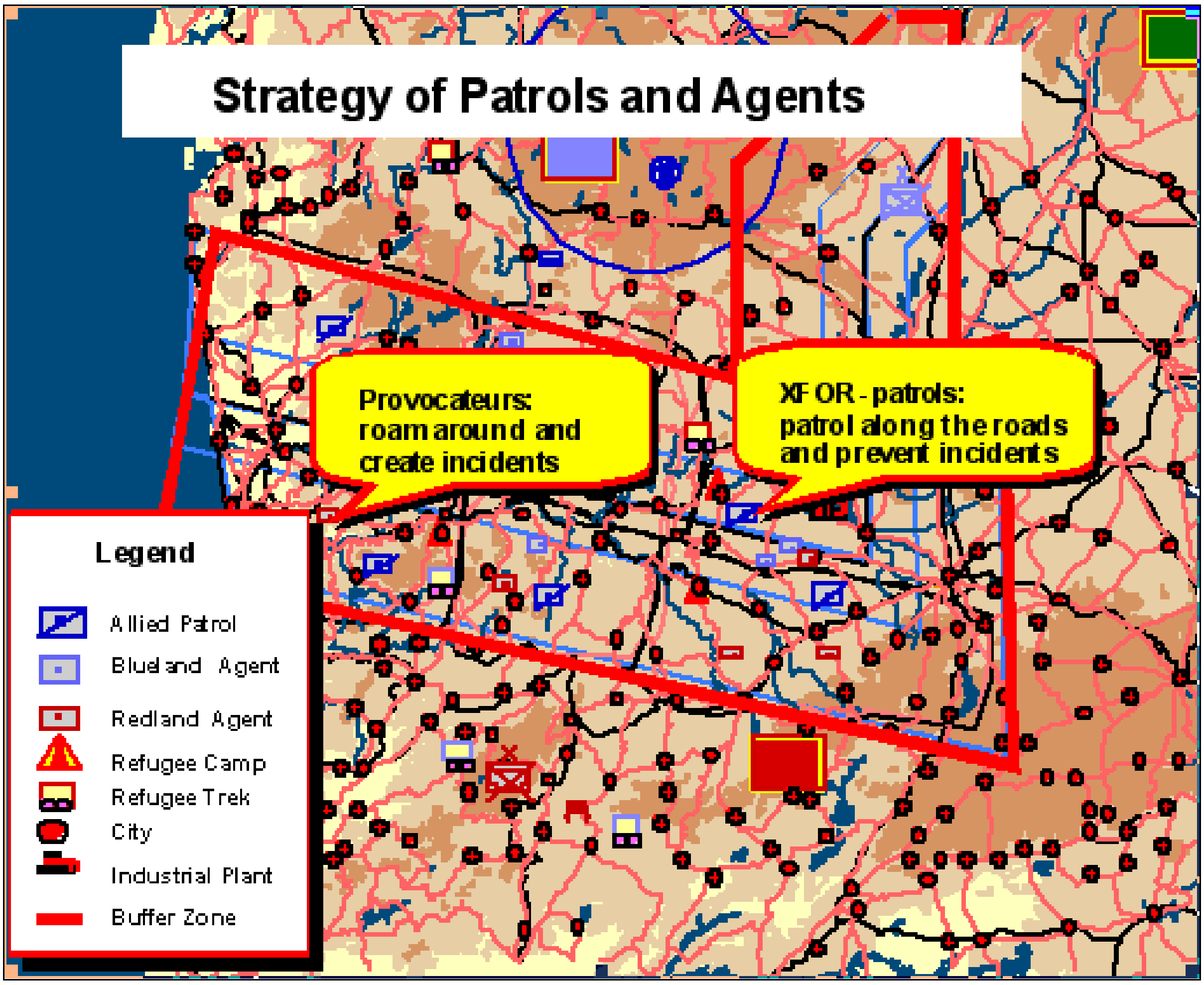

Figure 1: Snapshot of the GAMMA simulation model map display.

REPRESENTATION OF THE SCENARIO IN THE GAMMA MODEL

MODELLING BEHAVIOUR AND ACTIVITIES OF THE ACTING GROUPS

In this scenario, three types of elements are acting:

- Allied Forces Reconnaissance platoons.
- Terrorist /paramilitary groups.
- Dissatisfied groups of local civilian population.

Terrorist/paramilitary groups and dissatisfied groups of local civilian population are represented as agents. There are three prerequisites in order to regard an element as an agent:

1. It must have some internal goals (independent of the current environment).

2. It must have a memory function in order to include events which happened in the past into its strategic reasoning.

3. It must be able to react to the environment, for example to include environmental influences into its reasoning

In the GAMMA model, each element (agent and non-agent) has a memory stack, which can hold the information of various types of past events and thus provide the required memory function. Elements, which can act as agents, have to have certain properties which make them an agent. Allied Forces Reconnaissance platoons do not have the agent properties, but they have got the memory stack.

The following list shows the properties assigned to a GAMMA agent type element. The property agent tells GAMMA, that this element has agent properties (Figure 2). The properties written in italics define the elements goals, the properties: moral, risk, all, and agit determine, together with information from the past stored in the memory stack, whether and how activities will be started in order to achieve the goals

41		element type indicator
agent		element type name
53		number of properties
agent	agent indicator	indicates that this element has agent properties
s	side	side to which the element belongs
st	strength	fraction of the original strength (based on allocated holdings)
all	allegiance to side	0<= all <= 1; measure for the element's independence from the faction's attitude
moral	moral level	0 <= moral level <= 1; 0 = criminal, 1 = saint
risk	readiness to risk	
agit	agitation level	readiness to initiate some activity
pagit	previous agitation level	not used at the moment
hyst	hysteresis factor	not used at the moment
pol	*political ambition*	italic text describe the
mil	*military ambition*	agent's goal vector
econ	*economic ambition*	
ecol	*ecological ambition*	
human	*humanitarian ambition*	
info	*information interest*	
psi	*psycholog ambition*	
ego	*egoistic gain*	
……	Other parameters	

Figure 2: Properties of GAMMA Agents.

POSSIBLE INCIDENTS

Agents can create certain type of incidents, which are listed below (Figure 3).

type	name	target object category	target object type	moral quality	agitation level	political impact	military impact	economic impact	ecological impact	humanitarian impact	information interest	psycholog impact	egoistic gain
1	demonstration	1	10	0.9	0.8	-0.7	0	0	0	0	0.01	-0.5	0
2	public riot	1	10	0.8	0.8	-0.5	0	0	0	0	0.01	-0.5	0
3	occupation of media	1	10	0.6	0.8	-0.6	0	0	0	0	0.01	-0.3	0
4	occupation od embassies	1	10	0.6	0.8	-0.7	0	0	0	0	0.01	-0.3	0
5	intimidation	6	95	0.4	0.8	0	0	0	0	0	0.01	-0.6	0
6	blackmail	6	95	0.3	0.8	0	0	0	0	0	0.01	-0.7	0.5
7	kidnapping	6	95	0.1	0.8	-0.5	0	0	0	0	0.01	0.5	0.5
8	robbery	6	95	0.2	0.8	0	0	0	0	0	0.01	-0.4	0.7
9	eviction	6	95	0.1	0.8	0	-0.7	0	0	0	0.01	-0.9	0
10	destruction of private propert	6	90	0.2	0.8	0	-0.5	0	0	0	0.01	-0.9	0
11	destruction of civ. infrastruc	6	91	0.3	0.8	0	-0.7	0	0	0	0.01	-0.6	0
12	murder of selected persons	6	95	0.1	0.8	-0.6	0	0	0	0	0.01	-1	0
13	killing any people	6	95	0	0.8	0	0	0	0	0	0.01	-1	0
14	bomb attack	6	95	0	0.8	0	0	0	0	0	0.01	-1	0
15	destruction of mil. infrastruc	1	22	0.6	0.8	0	-0.4	0	0	0	0.01	-0.3	0
16	attacking soldiers	6	95	0.2	0.8	0	0	0	0	0	0.01	-0.7	0
17	attacking military units	1	1	0.7	0.8	-0.5	-0.3	0	0	0	0.01	-0.6	0
18	sniper attack	1	1	0.2	0.5	-0.4	0	0	0	0	0	-0.9	0

Figure 3: Types of agent incidents.

Each of the incident types shown in the list needs a certain type of target object to be performed on. Target objects are characterised by a category they belong to and by a type within this category. For example, robbery is only possible if there are people which, in GAMMA, belong to category 6 (assets) and the type 95.

Next, a moral quality indicator is assigned, (0 <= morale <=1) which more or less correlates with the Criminal Code (**1** = this activity is not listed in the Criminal Code, **0** = murder 1st degree) . The next column in the table shows the agitation level necessary to create this type of incident. The following 8 columns in the table show the incidents impact vector.

CALCULATING PRIORITIES FOR INCIDENT TYPES

If an agent is about creating an incident, he selects from the list of possible incident types those:

1. For which suitable victims are available.

2. The risk is below his accepted risk threshold.

3. The moral quality is equal or higher than his moral level.

4. The required agitation level is equal or less than his current one.

From the remaining list of incident types which meet all four criteria, the agent selects the one which best serves his goals, by calculating a priority for each and selecting the one with the highest priority.

The priority for an incident of type i is calculated according the following formula:

$$P(i) = \text{relation} * \sum_{j=1}^{j=\text{Size of goal/impact vector}} \text{goal}(j)*\text{impact}(j)$$

where the term: relation describes the relation between agent and victim, and where: hostile = -2; suspect = -1; neutral or friendly = 1; and allied = 2.

Element Nr: 560 Symbol : 41 REDLAND Bandit group. Type 41 agent	
agent indicator (agent)	1.000
side (s)	6.000
strength (st)	1.000
allegiance to side (all)	0.500
moral level (moral)	0.300
readiness to risk (risk)	0.300
agitation level (agit)	0.950
previous agitation level (pagit)	0.000
hysteresis factor (hyst)	0.000
political ambition (pol)	0.700
military ambition (mil)	0.000
economic ambition (econ)	0.000
ecological ambition (ecol)	0.000
humanitarian ambition (human)	0.000
information interest (info)	0.000
psycholog ambition (psi)	1.000
egoistic gain (ego)	0.600

Figure 4: Selected agent properties define agent activities.

As an example, an agent with the properties shown in Figure 4 would exclude the following activities for moral reasons:

- Kidnapping.
- Robbery.
- Attacking soldiers.
- Sniper attacks.
- Eviction.
- Destruction of private property.
- Murder of selected persons.
- Murder of any persons.
- Bomb attack.

For victims with hostile relation, the agent would calculate the following priorities.

Demonstration	1.98
Destruction of civilian infrastructure	1.20

Thus, under those conditions, the agent would prefer a demonstration rather than destruction of civilian infrastructure.

RISK ASSESSMENT

Each asset a combat value score can be assigned to. In order to assess the risk an agent is running while creating an incident, he divides the sum of the scores of all elements he is in contact with be the sum of his own scores, If this quotient is equal or less the value specified in his *readiness-to-risk* property, then he will take the risk and create the incident, otherwise he won't. The asset scores are defined in one of the GAMMA input files.

ADDITIONAL ASSUMPTIONS

There is not very much knowledge about how a paramilitary or bandit group would behave:

- after having created an incident,
- when getting aware of military patrols who try to prevent incidents, and
- when meeting such patrols directly.

and so on. Thus, some assumptions had to be made. These they are:

- whenever an agent (provocateur, bandit group etc.) has created an incident; it will stay silent for 24 hours, and

- the same happens, if he does not create an incident because of a too high risk or if he meets an Allied patrol platoon.

THE SIMULATION

The simulation was run over a time period of 10 days, first no with patrolling at all, and a second time with six reconnaissance platoons each of them patrolling along the road network within a defined patrol area within the buffer zone.

Agents move along the road network within a given area and try to create an incident whenever they meet a suitable victim. They select their route in a way that they try to move first to those network nodes they have not passed recently. Allied patrol platoons move in the same way. The simulation results produced by the GAMMA model are shown in Figures 5 and 6.

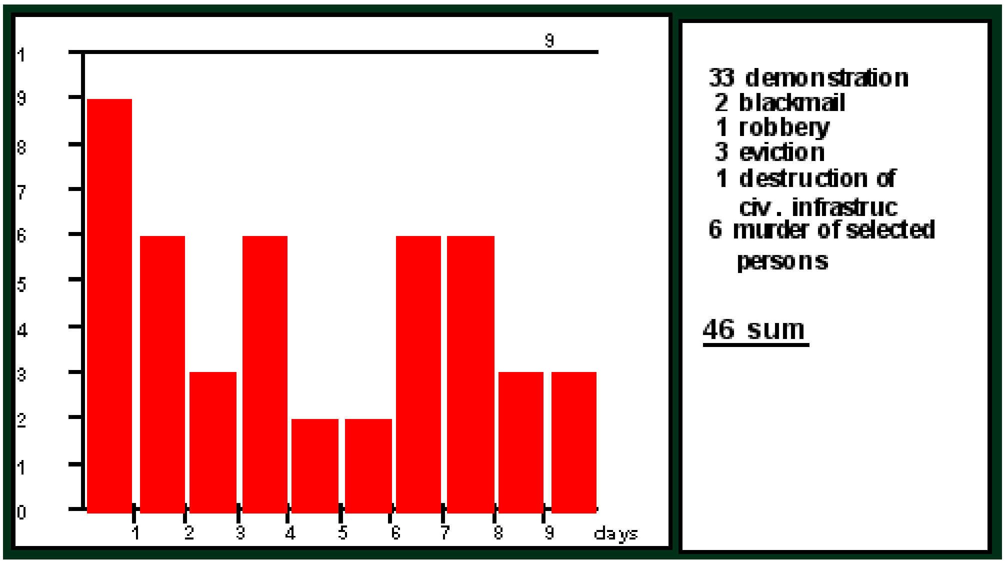

Figure 5: GAMMA model output for no patrol activities for the total area, reporting all incident types.

With six patrol platoons, the number of incidents decreased form 46 to 38. However one of the incidents created while the patrols were active was a sniper attack directed against the patrols.

During the simulation, not only incidents, which really did happen are recorded but also incidents not created because of the risk being assessed as to high. It was very interesting to see that this happened 15 times, while at the same time the number of incidents were only decreased by nine. That means, preventing a particular incident does not necessarily result in a reduction of the overall number of incidents. It may happen, that, inhibiting a particular incident might cause another incident, which would not have happened otherwise. In fact, only 33 incidents are identical in both simulation runs. Doubling the number of patrols, where two patrols moved in each patrol area independently, reduced the total number of incidents to 33, but on day 4, there was one incident more with 12 platoons than with six.

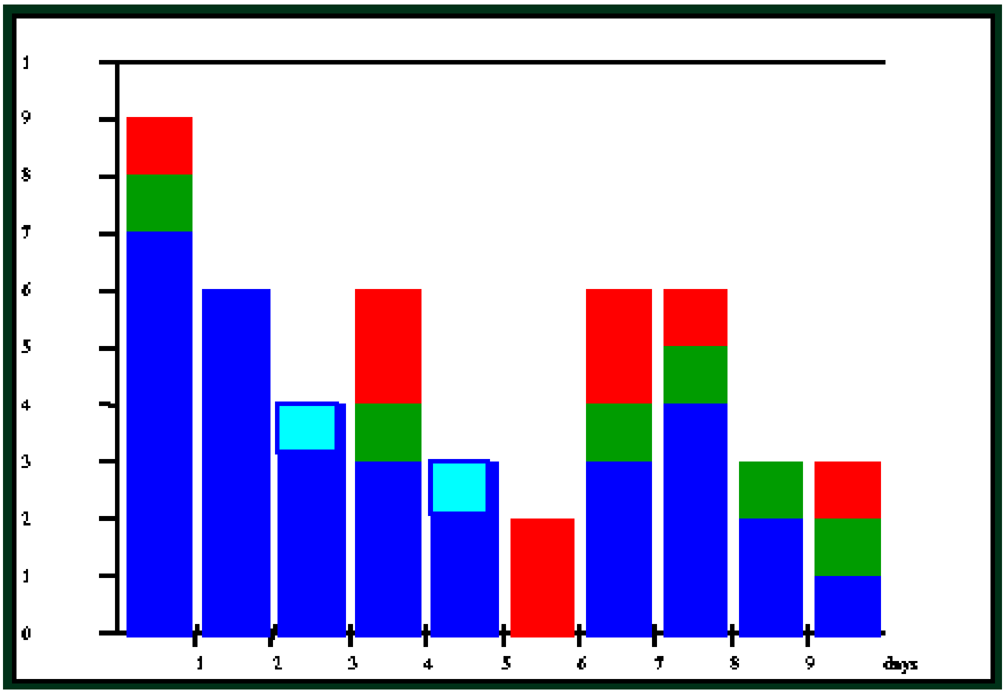

Figure 6: The impact of no patrols and of 6 and 12 patrol platoons.

In Figure 6, red fields represent the reduction of total number of incidents by six platoons patrolling. Green fields show the additional reduction of incidents by 12 platoons. The light blue fields show the increase of incidents on this day despite of more patrolling (On day 2: three incidents without patrol, four incidents with six and 12 platoons. On day 4: two incidents without and with six platoons, three incidents with 12 platoons).

ASSESSMENT OF THE SIMULATION RESULTS

The simulation offers a methodology, which is suitable to determine the impact of patrolling on the number of incidents in a particular environment. However, we do not know enough about the behaviour of real "agents" nor do we know how their attitudes are influenced by environment. Thus, the simulation results were based on many assumptions, which seem to be reasonable but are not validated at all.

As a next step, a more elaborate parametric sensitivity analysis should be undertaken in order to find those parameters the variation of its values has the most impact on the result. This kind of analysis then might show the direction of most promising further research, such as:

- Evaluation of psychological studies.
- Evaluation of historic situations.

In addition, it seems necessary to refine the algorithms, which govern the agent's behaviour. In particular, dynamic change of properties, such as:

- readiness to risk, vector of interest, and even morale standard might be influenced by events and thus changeable.

- thresholds for changing behaviour might also be subject to dynamic change (hysteresis effect).

Another important modelling aspect is the fact that an agent's interaction with his environment is driven by perception rather than by reality. But again, we do not know which factors influence an individual's perception of his environment.

Recently, development has begun on the production of a rule-based module to modify an agent's ability to assess environment interaction with an agent's properties. The idea is now to link this module with the dynamic GAMMA simulation model, in order to adapt an agent's behaviour interactively and event-driven.