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Simulating actors' behaviors within terrorist attacks scenarios based on a multi-agent system

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Abstract

Terrorist attacks entail significant social costs, especially for citizens and government forces. It is therefore necessary to explore the possible processes of the terrorist attack scenarios. In this work, the agent-based model is applied to explore the dynamics of a terrorist attack unfolding under specified assumptions. Parameter traversal and repeated scenarios' simulations are also exploited to obtain robust results and to study the impact of the different agents, as well as their effects on the attacks' progress along on the number of assaults. By exploiting our knowledge on the military field, we propose, in this paper, different activity diagrams for modeling the behaviors of four main agents: Population agent, Governmental force agent, Basic terrorist agent, and Intelligent terrorist agent. In fact, terrorist attacks scenarios have been simulated to study the impact of the presence of intelligence terrorist attacks comparing to that of basic terrorist attacks.

Keywords: Multi-agent model; Simulation; Terrorist attacks; Dynamic behavior;

1. Introduction

Terrorist attacks become more and more regular and bold since the September 11st attack in the USA. In fact, each year, 26400 people are killed within 10900 terrorist attacks according to Global Terrorism Database (GTD). That fact makes a need to study, model and simulate the history of attacks in order to analyse organisational planning as well as to understand time of intervention and/or to predict behaviors of terrorists, population, and governmental forces. In addition, that builds the need to study the impact of actors' characteristics on the attack's threat degree.

Actually, multi-agent system (Dorri et al., 2018) could be a good alternative to represent and model such terrorist events. Actors and functionalities could be well modeled and simulated through a set of agents that interact with each others. By hypothesis posed within the present research work, agents are situated in the same environment which is urban area. A multi-agent system has been proposed in our preliminary work entitled MAMCT for *Multi-Agent Model for Counter Terrorism* (Kebir et al., 2020c; Kebir, 2021) to model terrorist attacks with different agents and databases. In this work, we pay a particular attention to the most important agents which are Population agent, Governmental force agent, Basic terrorist agent which models an untrained terrorist, and Intelligent terrorist agent which is defined as trained terrorist. Then, we represent and describe agents' behaviors by modeling both computational and organisational process of each agent during an attack. To do, we present straightforwardly the intuitive behavior of each agent using an activity diagram(Kebir et al., 2020a).

The rest of this paper is organised as follows. The next Section enumerates and reviews works aiming to model and simulate terrorist attacks, in the defense field, based on multi-agent systems. Section 3 details our proposal

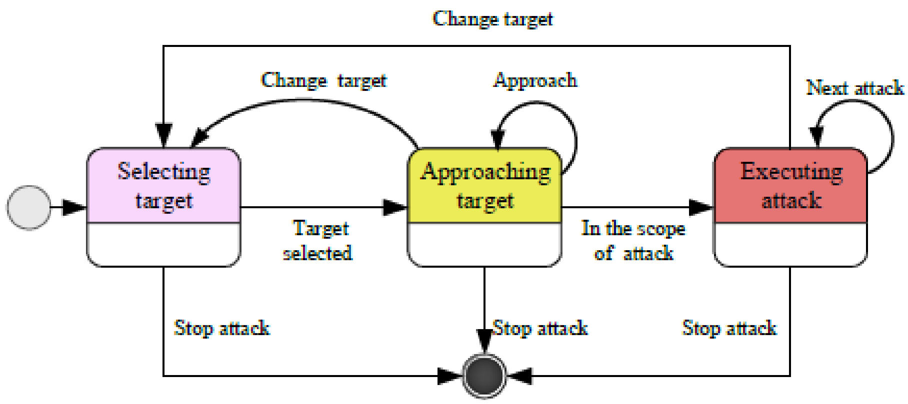

Figure 1. Finite state machine for terrorist attack process (Zhang et al., 2020)

regarding the multi-agent based modeling and representation of the dynamic behaviors of terrorist, population and governmental force agents during a terrorist attack. It has been done using activity diagrams. During Section 4, we define materials and methods for our experimental investigation. Besides, the impact of agents' number and characteristics on the final state of the attack will be discussed. Finally, we conclude in Section 5.

2. Related works

Agent-based modeling and simulation have been widely used in social and behavioral science. Since we need to study the behaviors of several types of autonomous agents within a terrorist attack such as civilians, terrorists and government forces, we provide the following related work.

We find, in the literature, various research works studying terrorist attacks, in general, and those that have occurred frequently in recent years, in particular. Among these attacks, we cite mass shooting (Hayes and Hayes, 2014), biochemical weapon (Song et al., 2013), poison gas (Wan et al., 2014), Manchester attack (Han et al., 2021) and Bardo attack (Kebir et al., 2021)(Kebir et al., 2020d, 2022).

In addition, Liu (2018) extended the social force model and studied the effects of spatial layout, number of terrorists, and initial distribution on the consequences of this type of events. Chen et al. (2018) studied the evacuation process, and analyzed the effects of sensitivity factors, attack intensity, and population density. Wang et al. (2019) studied crowd dynamics in public space using video. Recently, authors in (Lu et al., 2021) built an agent-based model to explore heroes role during terrorist attacks. By using three main categories of agents (civilians, terrorists and heroes), a simulation of the Peshawar School Case (Pakistan, 2014) has been investigated. In addition, some researches have been interested on the behavior of terrorists and civilians during terrorist attacks. For instance, Kuligowski investigated World Trade Center survivors during the 9/11 incident (Kuligowski, 2011), and proposed a model for predicting human behavior during building fires (Kuligowski, 2013). In 2020, Zhang et al. (2020) proposed a civilian behavior model based on the perception-decision-behavior framework and developed a simulation software based on a multi-agent model.

We note that researches treating population and terrorist behaviors in terrorist attacks are not enough(Kebir, 2022). In addition, some of existing related works have used multi-agent systems to model and simulate actors behaviors, but they need to vary and exploit possible and intuitive agents' reactions and behaviors in such context. In this work, we simulate terrorist attacks scenarios using an agent-based model which takes into account various behaviors according to the situation. For instance, (Zhang et al., 2020) modeled the process of an attack process as mentioned in Figure 1, while we will focus in detailing the behavior of every agent according to the possible conditions occurred during a terrorist attack. In addition, we distinguish between two kinds of terrorists in order to study the impact of their practice degree on the attack threat and final scenarios' states.

3. Simulating and capturing the dynamic agents behavior during a terrorist attack

Based on our expertise on military field and inspired from the above mentioned related works, we present, the main assumptions in which our multi-agent model is based, the description of the proposed model settings, and our proposal for modeling agents behavior during a terrorist attack using activity diagrams.

3.1. Assumptions

Our multi-agent system for terrorist attacks modeling is based on the following main assumptions, which have been accredited in several related research works:

1. Government forces neutralize the terrorists without civilian casualties.
2. Terrorists attack both government forces and civilians.

3. The four agents have the same initial level of health.
4. The process ends when government forces, terrorists, or civilians are reduced to zero.

3.2. Agents presentation

In this work, we model a terrorist attack through capturing intuitive behaviors/actions of the four following autonomous agents that simulate persons:

- Population agent: Each population agent refers to a civilian. A civilian is a person from a population who is not active duty with military, naval, police, or fire fighting organization. So he is generally untrained and panics easily within uncomfortable situations.
- Governmental force agent: This agent presents a participant of the armed intervention units provided by the government.
- Basic terrorist agent: A terrorist is a person who uses violence to create a general climate of fear and assault in a population to achieve a particular political objective. In this work, we refer the basic terrorist agent to an untrained person. In fact, most terrorists lack training and expertise.
- Intelligent terrorist agent: Based on the previous item, we conclude that this agent refers to a terrorist that has been formed and trained. His reactions are therefore better calculated.

3.3. Agents behaviors modeling

During this section, we describe our model composed by the previous mentioned species of agents interacting in a grid that presents our 2D environment (See Figure 2). The behavior of the four agents is ruled by the latter assumptions presented in Section 3.1.

In addition, we suppose that the neighbors of an agent in a grid, as mentioned in Figure 2, are those situated in orthogonal neighbor cells i.e. upper cell, lower cell, left cell and right cell.

Moreover, we assume that each agent has an initial energy that may decrease over time during the attack. In this work, we model this energy by the *level of health* and calculated as mentioned in Algorithm 1.

Algorithm 1 Level of health (LH)

Require: Agent A; Terrorist attack; degree of resistance ϵ;
Ensure: LH(A);
  $LH(A) \leftarrow 1$
  while (ongoing attack) && ($LH(A) >= \epsilon$) **do**
    if $\forall Agent\ X \neq A$; X *attacked* A **then**
      $LH(A) \leftarrow LH(A)/2$
    end if
  end while

Actually, different methods could be used to estimate

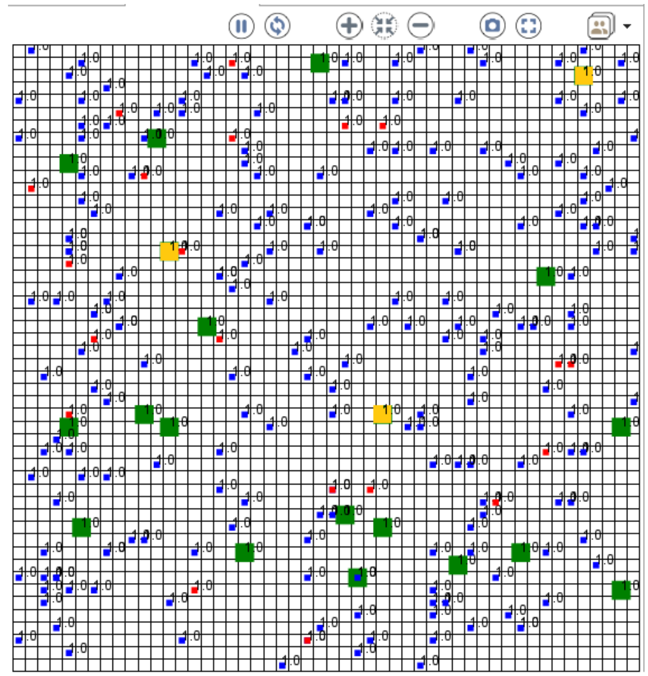

Figure 2. The 2D grid for simulating the real environment (blue: population agents ; green: basic terrorist agents ; yellow: intelligent terrorist agents ; red: governmental forces agents)

the value of this variable. For instance, the model presented in (Kebir et al., 2020c,b) proposed a mathematical formula to specify the amount of energy lost by each agent during the attack.

As we have already mentioned in the assumptions, terrorist agents attack population agents and governmental forces agent which causes a progressive loss of energy that will lead to death (Level of health < ϵ). Similarly, governmental forces agent attacks terrorist agent which could cause their death. Each agent moves through an algorithm described in figures 3, 4 and 5. Only the death of the agent stops its movements. By taking into account the interaction between agents, we describe, in the rest of this Section, the behaviour of each agent.

3.3.1. *Population agent*

We model, by the population agent, the reactions of a simple citizen during a terrorist attack. This agent selects a neighbor cell randomly, then, it verifies if it contains a terrorist agent or not. If the presence of a terrorist agent is confirmed, then the population agent moves directly to another random cell. This reaction shows the frustration state of the citizen. In case of negation, the agent checks for a second time the presence of another population agent in the neighbors of the selected cell. If it is true, then the agent moves to this cell. In the other case, the process will be restarted. The psychological impact of fear on people reactions is modeled in this part. Peoples under high level of fear have tendency to flow the crowd to feel safe and secure (Sinclair and Antonius, 2012; Zanette and Clinchy, 2017). The health level is checked after a contact with terrorist agent. We formally show the latter discussed behavior in Figure 3.

3.3.2. Basic terrorist agent

As mentioned in Figure 4, Basic terrorist agent reactions depend on the type of agent in the neighbor cells. The process starts by attacking the governmental forces agent if it is located in the neighbor cell and checks for each iteration the health level. Otherwise, basic terrorist agent attacks population agent in the neighbors cells. If the neighbors cells are empty, the basic terrorist agent moves to one of them randomly.

3.3.3. Intelligent terrorist agent

Actually, this type of agent is designed to make more complex decisions than the basic terrorist agent. As shown in Figure 5, the reaction is different when confronted with more than one government forces agent in nearby cells. In that case, the Intelligent terrorist agent flees and moves to other nearby cells at random. In addition, this type of agent checks the threat level and proportionality before moving after neutralizing a governmental force agent. It verifies the size of the government agents in the neighboring cells selected to move towards it. The intelligent terrorist agent has a relatively better chance of neutralizing the government forces agent than the basic terrorist agent. This is due to the complex reaction of the intelligent terrorist agent in its process of selecting its movement based on the threat level.

3.3.4. Governmental force agent

As shown in Figure 6, Governmental force agent is always looking for a terrorist agent, its intelligence comes from its ability to choose the best situation to start with. If there is a terrorist agent in the next cell, then he attacks it without any consideration. In other cases, this agent chooses to support other agents of the government forces in their mission, as well as to help the population agent facing the terrorist agent. These reactions promote the safety of the governmental forces agent and save his life. The agents of the governmental force tend to support each other in the fight against both types of terrorist agents. The act of concentrating in space makes them stronger than the basic terrorist agent and have the ability to defend themselves against both types of enemy agents

4. Results and discussion

During our experimental investigation, we used the platform GAMA as a modeling and simulation development environment for building spatially explicit agent-based simulations.

Concerning the datasets, we built some data referring to the initial state of terrorist attacks, as mentioned in Table 1. Then, we kept the simulation of our proposed model providing the number of agents having $LH > \epsilon$ at the end of the attack. The idea is to choose scenarios data by fixing

Table 1. Initial states of terrorist attacks scenarios

	Civilians	NbTT	NbBT	Armed forces	Total agents
Scenario 1	200	1	19	20	220
Scenario 2	200	4	16	20	220
Scenario 3	200	6	14	20	220
Scenario 4	200	10	10	20	220
Scenario 5	200	12	8	20	220

the number of population agents, the number of governmental forces agents, the number of total terrorist agents and varying the rate of trained terrorist agents comparing to untrained ones. This allows us to study their influence on the final state of the terrorism attack in term of number of casualties.

In fact, in this study, we mainly focused on studying the impact of the evolution of the trained terrorist agents number regarding the number of untrained ones. To do, we define a new variable NT having the following equation:

$$NT = \frac{NbTT}{NbTT + NbUT} \tag{1}$$

where NbTT and NbUT are respectively the number of intelligent agents and the number of basic terrorist agents (Trained Terrorist agents and Untrained Terrorist agents). Consequently, the values of NT for the five scenarios indicated in Table 1 are respectively 0.05, 0.2, 0.3, 0.5 and 0.6.

In term of results, Figure 7 is a 3D curve that presents the evolution of the number of population agents and the number of governmental forces agents in function of the variable NT for Scenarios 1, 2, 3, 4 and 5 respectively (see Table 1).

We note from Figure 7 that the aggregation of the final number of Population agents and governmental forces agents is somehow correlated to the variable NT which is calculated from the initial values of terrorist agents. In fact, we remark from Equation 1 that the variable NT is normalized within the interval $[0, 1]$. The number of trained terrorists regarding the total number of terrorists at the beginning of the attack influences the total number of assaults at the end of the attack (even among civilians or armed forces).

5. Conclusion

The proposed multi-agent system allows the adhesion of four kinds of agents that refer to the main actors presented in real terrorist attacks, which are : Population agent, Basic terrorist agent, intelligent terrorist agent, and Governmental forces agent. The behavior of each agent has been analysed and modeled in order to simulate a terrorist attack in real conditions. The purpose of this simulation is to highlight the impact of an intelligent terrorist agent that represents the best trained terrorist and the ability of government forces to deal with it. In addition, we distinguished between terrorists types and we modeled them as

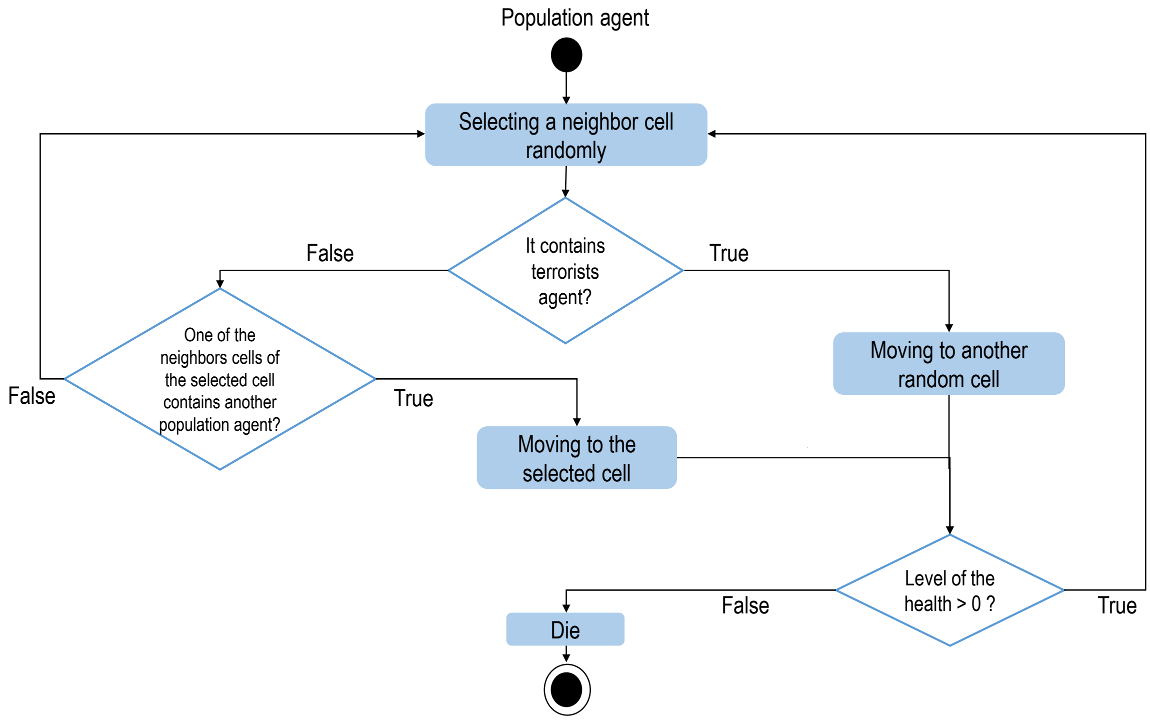

Figure 3. Activity diagram to model Population agent's behavior during a terrorist attack scenario

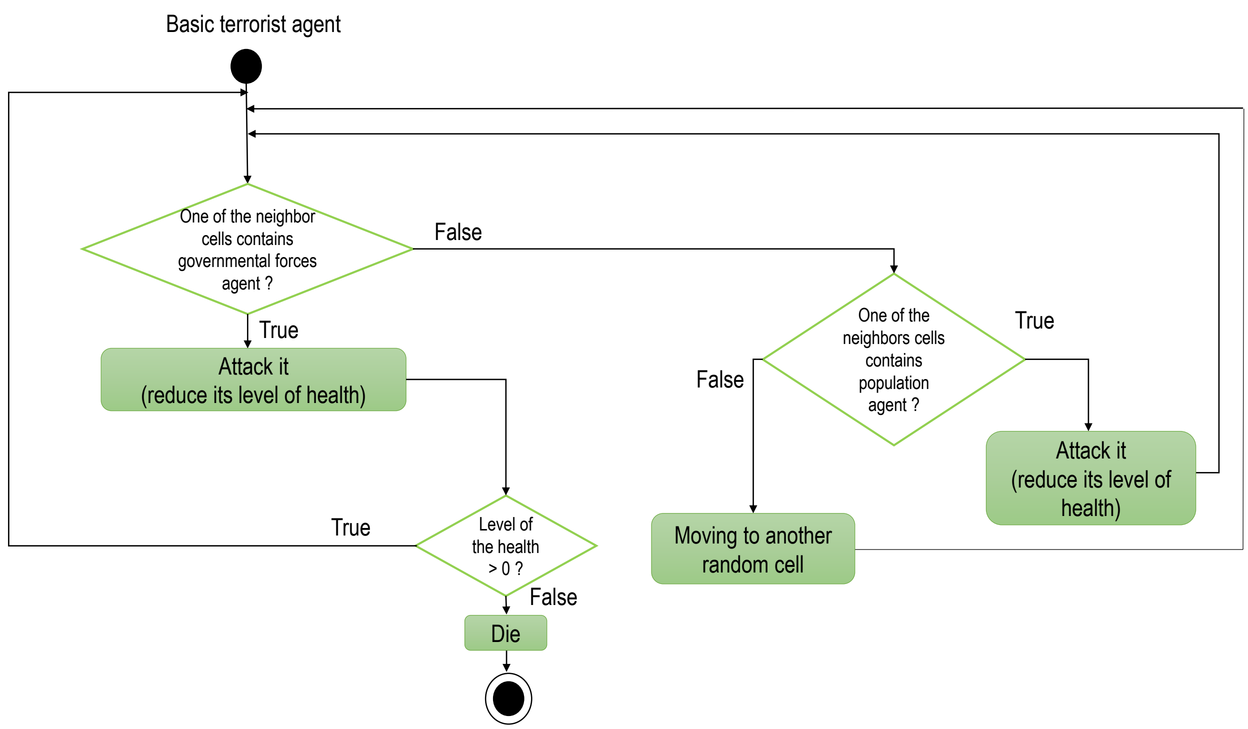

Figure 4. Activity diagram to model a Untrained or Basic terrorist agent's behavior during a terrorist attack scenario

two different agents.

Thanks to the simulation of our proposed multi-agent system, this paper has been able to present the impact of the presence of trained terrorist agents regarding the number of causalities. We aims, in the future, to extend this paper in order to develop the experimental study and

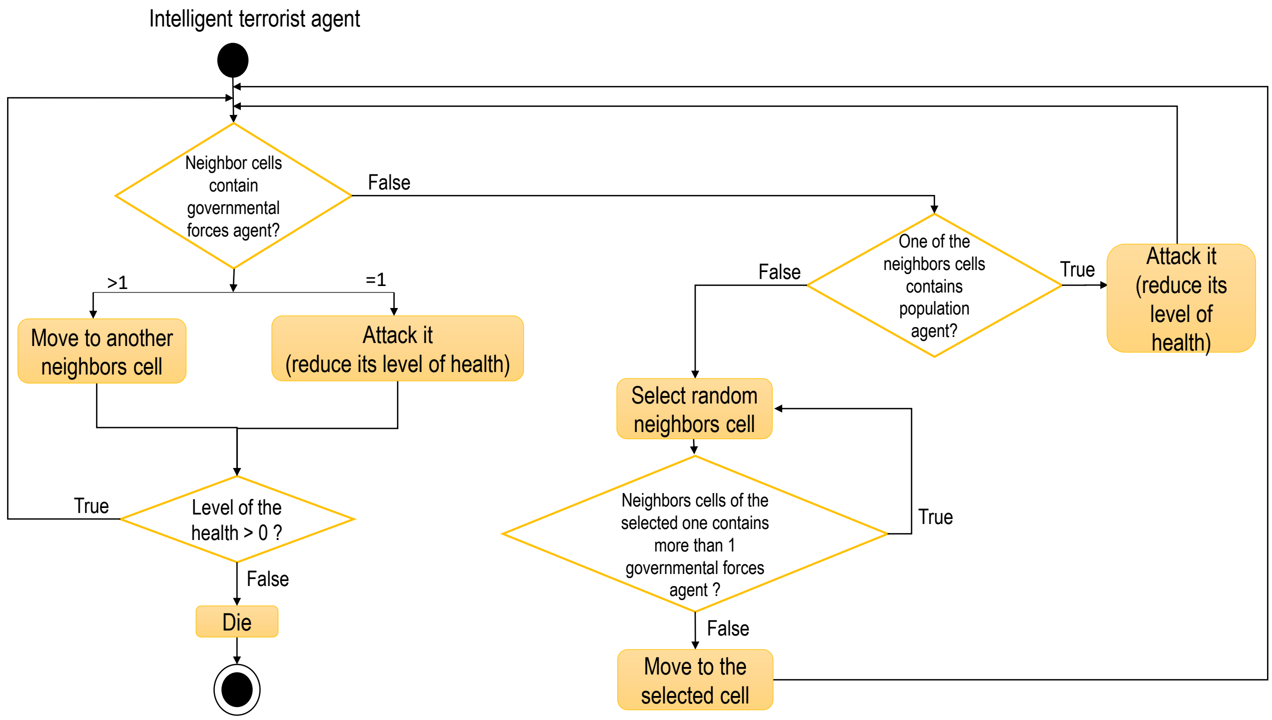

Figure 5. Activity diagram to model Intelligent or Trained terrorist agent's behavior during a terrorist attack scenario

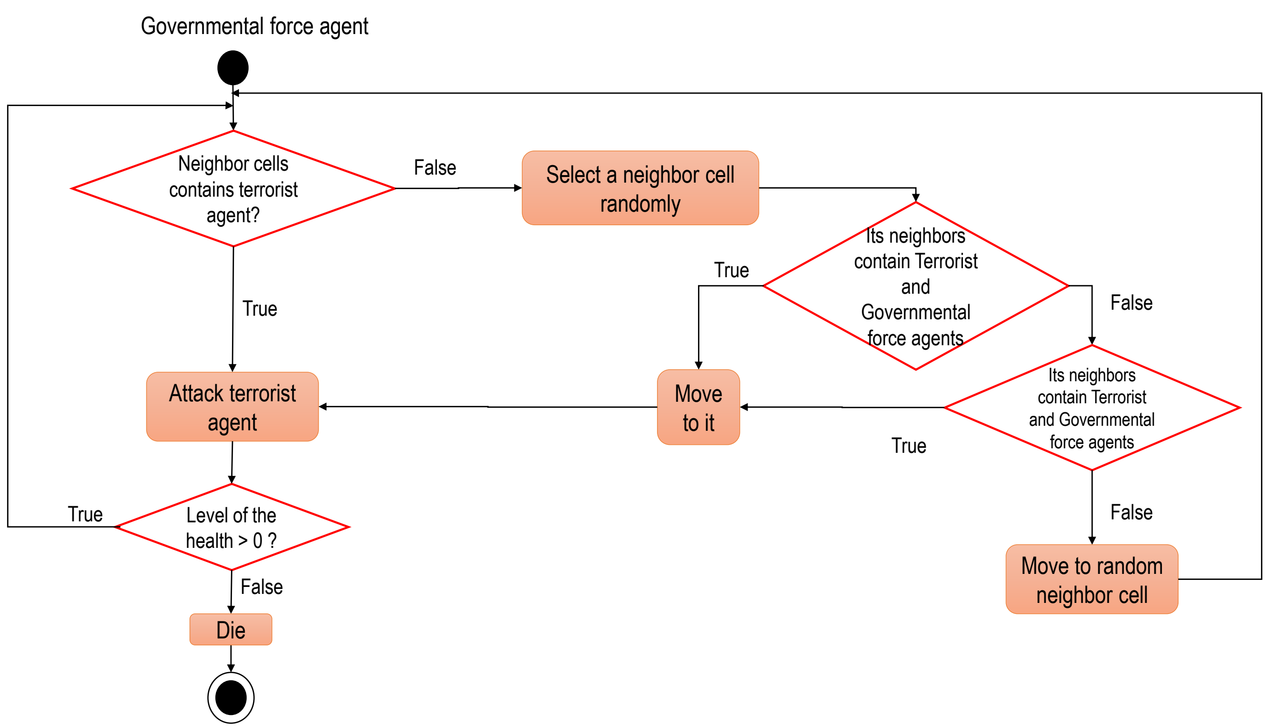

Figure 6. Activity diagram to model a governmental forces agent's behavior during a terrorist attack scenario

use our model to predict the number of assaults comparing to real cases, i.e. the final state of the scenario simulation accurately fits the real attack in question. In addition, we aim, to study the effect of varying the *level of health* (LH) function on the obtained final results.

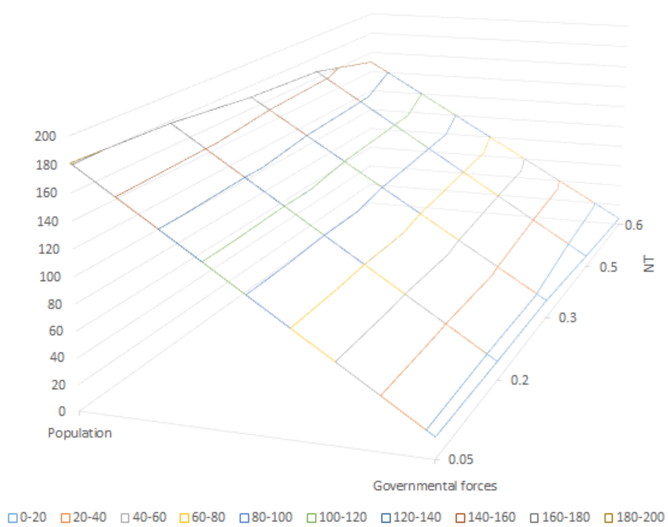

Figure 7. The impact of trained terrorists presence on the number of casualities within terrorist attacks

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