INFORMATICA, 2002, Vol. 13, No. 4, 501–512

Simulation of Conflict in an Agent World: Access to Resources and Possibility of Termination of the Population

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Received: July 2002

Abstract. The goal of the paper is to create a model for investigating the character of relationships between the freedom and restrictions in the terrorism context, in order to find out how sensitive is the probability of the population survival to small changes in these two parameters. A model for simulating relationships between access to resources and possibility of termination of the population is presented. The model comprises an agent world, its properties, interactions, and a world life cycle algorithm. As the "right" properties and interactions of the model are a question of experimentation, the model is introduced in two steps: a general model and a specific sub-model. Preliminary analysis of results received on a sub-model implementation demonstrate that in certain cases the relationship between the level of access to information and the overall aggressiveness value implying the end of population may has a stepwise character.

Key words: software agents, intelligent agents, simulation models, terrorism, models of co-operation and conflict.

1. Introduction

Following recent terrorist events there have been many discussions regarding the possibility of restricting the influence of terrorism in the situation, where more and more power and information will be in the hands of every individual. As an example, it is easy to get through Internet detailed instructions on preparing explosive materials, even atomic bombs. Many people are afraid that wide dissemination of information needed for terrorist acts, as well as resources necessary for that purpose, may result in a situation where literally all population will be subject to terrorist threats. It could be possible to restrict both information and resource flow, however it is costly, reduces individual rights, and slows down innovation.

It is therefore important to keep a reasonable balance of freedom and restrictions. Where is that balance? It is not known, and an interesting question is whether this balance is stable or not. If small changes in availability of resources and information can result in disastrous consequences, then the balance issue must be treated very carefully, and it is better to err in the side of being more restrictive. In the case when the balance is stable, it can be handled with less care and restrictions, resulting in a trial and error process.

Recent investigations on terrorism simulation (Epstein *et al.*, 2001; Smith, 2002) stress the importance of simulation in counter-fighting terrorism and present various frameworks for such simulation. The current paper is based on earlier research on intelligent agent societies (Tepandi, 1999; Tepandi, 2001). Its goal is to create a model for investigating the character of relationships between the freedom and restrictions in the terrorism context, in order to clarify how sensitive is the survival probability of the population to small changes in these two parameters.

The following research problems are studied.

1.1. *Research Problems*

P1: Which kind of relationship exists there between (1) the various parameters defining the properties of the population and the power and frequency of terrorist attacks, and (2) the possibility of the termination of the population, from the other side?

Example: suppose that access is made easier to information about preparing explosive materials. Is the relationship between this variable and the probability of the end of population (a) linear, (b) algebraic, (c) exponential?

This research problem can be modified in the following way.

P2: Which kind of relationship exists there between (1) the various parameters defining the properties of the population and the power and frequency of terrorist attacks, and (2) the duration of life of the population?

These two problems are interdependent but different. In what follows they will be dealt with in parallel.

1.2. *Methodology*

The following methodology is used to answer the research problems:

1. Elaboration of the research problem, development of the simulation model and its parameters. As the "right" properties and interactions of the model are a question of experimentation, the model has to be introduced in two steps – first, a general model, and second, a specific sub-model.
2. Development of the simulation environment. Getting answers to the research problems posed requires an environment, which allows adding and modifying properties and their interactions – they cannot set up completely during the first experiment.
3. Simulation experiments in the world of software agents with a number of properties (for example, access to information of individual agents, access to resources, level of frustration, speed of dissemination of frustration and so on).
4. Analysis of the results and conclusions.

The current paper focuses mainly on Step 1, to some extent also the other steps are considered.

1.3. *Results and Implications*

These results may be useful for giving recommendations to stakeholders concerning, for example, countermeasures to terrorism or restriction of access to information, resources etc. They deepen also our understanding of the nature and processes of terrorism, as well as of its spreading mechanisms. For example, strategies of handling restrictions or countermeasures should be radically different in the case of linear and exponential relationships mentioned above.

1.4. *Notations*

The following notations are used throughout this paper:

- italic font is used for the property, interaction, variable, function, and other identifiers;
- bold and capitalised font is used for the keywords in the algorithms.

1.5. *Overview*

This work presents the general model of the simulation environment, one specific sub-model, and overview of preliminary implementation results.

2. The General Model

As the “right” properties and interactions of the model are a question of experimentation, the model will be introduced in two steps. In this section, a general model will be presented, which will be a basis for specific sub-models.

The general model underlying the simulation experiments comprises the following components:

1. a set (world) W of agents,
2. a set WP of global properties,
3. a set P of local properties,
4. a set I of interactions between the agents,
5. an algorithm *LifeCycle* determining the life cycle of the world W.

2.1. *The Agents, Properties, and Interactions*

The model comprises, first, a set (world) W of agents a: $a \in W$. Let $|S|$ denote the number of objects in a set S. The agents interact using the interactions from the set I, the world W evolves according to the algorithm *LifeCycle.*

The world W is complemented by a set of WP of global world properties wp: $wp \in WP$. Properties may have values. For a world W, the value of property wp is denoted by $VAL\,(W, wp)$. Possible global world properties may determine the level of an agent's general access to information, general starting level of aggressiveness for an agent, general probability of a terrorist attack performed by an agent given its aggressiveness level and level of resources. Example: a condition that in a specific world W, the value of the *AccessToInformation* property is in the range of 0 to 1, may be expressed by $0 \leqslant VAL\,(W, \mathit{AccessToInformation}) \leqslant 1$.

A set P of local agent properties $p \in P$ determines the agents. Agent properties may also have values. For an individual agent a, the value of property p is denoted by $val\,(a, p)$. Possible agent properties may determine the agent's level of aggressiveness at a given moment, its level of resources at a given moment, location and neighbours. Example: a condition that for a specific agent a, the value of the *AggressivenessLevel* property is in the range of 0 to 1, may be expressed by $0 \leqslant val\,(a, \mathit{AggressivenessLevel}) \leqslant 1$.

A property p may have an initial value for all agents of the world W, such an initial value is denoted by $\mathit{ival}\ (W, p)$.

The sets of properties may be symmetrical in the sense that each property may have an opposite (dual) one. The influences of the dual properties are contrasting. For example, peacefulness exists in parallel with aggressiveness, access to resources – in parallel to restriction on exercising the terrorist acts. The opposite properties may or may not be balanced.

The agents participate in interactions from the set of interactions I during the world life cycle. During these interactions, the agent properties may change according to the property values of its neighbours, random influences, and other factors. For example, an agent can acquire resources form its neighbours; a charity act increases the peacefulness of its neighbours; a terrorist act increases aggressiveness of its neighbours.

2.2. *The World Life Cycle*

Given a world with its agents, properties, and interactions, this world may be "launched", letting the agents act and interact. This process may exist in a long-term or infinite continuous interaction. It may also end in termination of the population (all agents are destroyed as a result of terrorist attacks) or in stable non-interacting situation ("the agents know everything and are peaceful"). The first situation occurs most probably when the opposite properties are balanced, the other two – when they are out of balance.

With these concepts, the general lifecycle of the world W may be formalised as the following pseudo-code algorithm.

Algorithm *LifeCycle*

```
    Set initial values for the world and agent properties;
    PopulationHasTterminated:=False; StableNonInteraction:=False; Lifetime:=0;
    While Not (PopulationHasTterminated) And Not (StableNonInteraction) And the
    values of certain properties are within given limits
        Recalculate the properties of individual agents according to the interactions
        between the agents;
        Recalculate the value of the PopulationHasTterminated variable;
```

```
        Recalculate the value of the StableNonInteraction variable;
        Lifetime:=Lifetime+1;
    End while
    Return (PopulationHasTterminated, StableNonInteraction, Lifetime, the property
    values)
End LifeCycle
```

Unspecified components of this algorithm, such as the condition when the population has survived, have to be made more precise in a specific sub-model.

2.3. *Solving the Research Problems*

When two adequate worlds are launched, they will behave adequately. However, if the value of one property $wp \in WP$ is kept constant and the others randomly fluctuated within certain boundaries, the outcomes may differ. Given a sufficiently large number of experiments, it is possible to evaluate the value of $P(W, wp, v, F)$ – the probability that the population of the world W will terminate given the property wp has a value $v = VAL\,(W, wp)$ and the fluctuations are defined by the expression F.

The problem *P1* about the reasonable balance between freedom and restrictions can now be reformulated as the problem of determining the character of the relationship between v and $P(W, wp, v, F)$. For example, if small growth of the parameters defining availability of resources and information can result in fast increase of $P(W, wp, v, F)$, then the balance issue must be treated very carefully, and it is better to err in the side of being more restrictive. In the case when the balance is stable, it can be handled with less care and restrictions, resulting in a trial and error process.

Similarly, the research problem *P2* concerning the relationship between the parameters defining the properties of the population and the duration of life of the population is solved by the following sequence of steps.

1. Select a property $wp \in WP$ and change its value $v = VAL\,(W, wp)$ within certain limits. For each selected value v, let the other properties vary according to given rules.
2. Run the *LifeCycle* algorithm for a number of times for every value of wp and calculate the average value of lifetime of the population *AverageLifetime*(v) as a function of the value v.
3. Investigate the character of relationship between v and *AverageLifetime(v)*. Is there any relationship? Is it linear? Algebraic? Exponential?

A specific sub-model will define the specific properties, their initial values, interactions between the agents, as well as the *LifeCycle* algorithm attributes, such as the stability or termination conditions.

3. A Sub-Model

For the purpose of initial experiments, this section presents a sub-model based on the general model.

3.1. *The Agents, Global and Local Properties*

It is assumed that there exists a distance measure $D(a,b) \in [0,1]$ defined for any two objects a and b of the world W. It is also assumed that there exists a neighbourhood function N such that objects a and b, for which $N(a,b) =$True, are defined to be neighbours.

The sets of global and local properties for the sub-model are given in the Tables 1 and 2, respectively. All the properties are defined to have values between 0 and 1.

Table 1

The set of global properties for the sub-model

Property	**Interpretation and remarks**
Reproduction	Reflects the probability of reproduction for an individual agent
Expiration	Reflects the probability of expiration (death) of an individual agent. It is suggested that *Reproduction*$>$*Expiration* reflecting the growing population of the world
AccessToInformation	Reflects the overall level of access to information in the world W. As an example from the real world, wide use of Internet has significantly increased the level of access to information
AccessToResources	Reflects the overall level of access to resources in the sub-model. As an example, widespread use of chemistry products in households has significantly enhanced preparation of explosive materials
Influence	The greater *Influence*, the more objects will be influenced by surrounding objects
Violence	Reflects various influences on the ability to perform terrorist acts, for example the overall characteristics of the agent population, or countermeasures taken. If *Violence*$=0$, no terrorist acts will be performed at all
GlobalEndOfPopulation	If the ratio (number of survived objects)/(initial number of objects) is less than or equal to *GlobalEndOfPopulation*, the population is considered to be terminated
StablePopulation	If the ratio (number of changed objects)/(current number of objects) is less than or equal to *StablePopulation*, the population is considered to be stable

Table 2

The set of agent properties for the sub-model

Property	**Interpretation and remarks**
Knowledge	Level of knowledge for an agent
Resources	Level of resources for an agent
Agressiveness	If *Agressiveness*$(a) = 0$, the agent a is peaceful, if *Agressiveness*$(a) = 1$, it is aggressive

3.2. *Interactions*

In every iteration of the world's life cycle, interactions are triggered for every agent a. The summary of the interactions is given in Table 3. The interactions are performed in the order given by the table. More detailed explanations are given in the text below.

The following functions are used. The function $\mathit{Random}(a,b)$ generates a random value between a and b. The function $\mathit{Abs}(a)$ returns absolute value of a. The function $\mathit{Nsum}(a,b)$ returns a normalised sum of its arguments. Typically such functions must satisfy the following axioms for both a and b between 0 and 1:

- $\mathit{Nsum}(a,b) \in [0,1]$;
- $\mathit{Nsum}(a,b) \geqslant \max(a,b)$;
- $\mathit{Nsum}(0,b) = b$;
- $\mathit{Nsum}(1,b) = 1$;
- $\mathit{Nsum}(a,b) = \mathit{Nsum}(b,a)$;
- $\mathit{Nsum}(a',b) \geqslant \mathit{Nsum}(a'',b)$ for $a' \geqslant a''$.

An example of *Nsum* is given by $\mathit{Nsum}(a,b) = a + b - a * b$. In the case of more than two arguments, similar axioms apply.

The function $\mathit{Ndiff}(a,b)$ returns normalised difference of a and b. For *Ndiff*, parallel axioms with *Nsum* may be proposed.

In the current sub-model, both *Birth* and *Death* of an agent are considered simple activities. In the more advanced sub-models, these interactions may involve more than on parent. As a variation to the interactions given in the table, an agent may have multiple lives, with an interaction $\mathit{Lives}(a) := \mathit{Lives}(a) + 1$ triggered with probability *Reproduction*.

For the *SocialInteraction* property, a function is needed which moves $\mathit{Agressiveness}(a)$ value for an object a towards the value of average *Agressiveness* of neighbours of a, and does so the more the greater the value of *Influence*. Let F denote the function needed, r denote the $\mathit{Agressiveness}(a)$, and g denote the value of the average *Agressiveness* of neighbours of a. Then the function $F(r, g, \mathit{Influence})$ has to have the following properties:

- $F(r, g, \mathit{Influence})$ is between r and g;
- $F(r, g, 0) = r$ (no influence);
- If $i' < i''$ then $\mathit{Abs}(F(r,g,i') - g) \geqslant \mathit{Abs}(F(r,g,i'') - g)$.

An example of such a function is given in Table 3.

3.3. *The Sub-Model Life Cycle*

With the concepts defined above, the life-cycle of the world W in the current sub-model may be formalised as follows.

Table 3

The activities triggered for each agent a

Activity name	Activity	Interpretation and remarks
Birth	For every agent a, a new agent is generated with probability *Reproduction*	Birth of a new agent. The new agent inherits all properties of the parent
Death	As a result of this interaction, an agent a is removed with probability *Expiration*	Death of an agent
Learning	$\mathit{Knowledge}(a) :=$ $\mathit{Nsum}(\mathit{Knowledge}(a),$ $\mathit{Random}(0, \mathit{AccessToInformation}))$	In each step, agents get more information
Forgetting	$\mathit{Knowledge}(a) :=$ $\mathit{Ndiff}(\mathit{Knowledge}(a),$ $\mathit{Random}(0,\mathit{AccessToInformation}))$	In each step, agent information is both learned and lost
Earning	$\mathit{Resources}(a) :=$ $\mathit{Nsum}(\mathit{Resources}(a,$ $\mathit{Random}(0, \mathit{AccessToResources}))$	In each step, agents get more resources
Spending	$\mathit{Resources}(a) :=$ $\mathit{Ndiff}(\mathit{Resources}(a,$ $\mathit{Random}\ (0, \mathit{AccessToResources}))$	In each step, agent resources are both earned and consumed
SocialInteraction	$\mathit{Agressiveness}(a) :=$ $\mathit{Agressiveness}(a)+$ $(g-\mathit{Agressiveness}(a))*$ $\mathit{Random}(0,\mathit{Influence})$, where g equals the value of average *Agressiveness* of neighbours of a	*Agressiveness* value for an individual agent is moved towards the value of average *Agressiveness* of neighbours, and so the more the greater the value of *Influence*
TerroristAct	An object a performs a terrorist act with probability $\mathit{Nsum}(\mathit{Violence},$ $\mathit{RelativeAgressiveness}(a),$ $\mathit{RelativeKnowledge}(a,$ $\mathit{RelativeResources}(a))$. As a result, a neighbour agent b of agent a will be removed with probability $1 - D(a, b)$. In addition, for any agent b, $\mathit{Agressiveness}(b) :=$ $\mathit{Nsum}(\mathit{Agressiveness}(b), (1 - D(a, b)))$.	An object a performs a terrorist act with probability proportional to the overall violence level and its own knowledge, resources, and aggressiveness levels. As the result of the act, the neighbours of a will be removed with probability adversely proportional to the distance form a (nearer neighbours suffer to a greater extent). The *Agressiveness* of the neighbours will increase in adverse proportion with the distance from a (nearer neighbours are more influenced)
Charity-act	Mirrors the Terrorist-act	An object a performs a charity act with probability reverse proportional to *Violence* and *Agressiveness*(a), and proportional to *Knowledge*(a), and *Resources*(a). As the result of the act, new neighbours of a will born with probability adversely proportional to the distance form a. The *Agressiveness* of the neighbours will decrease in adverse proportion with the distance from a (nearer neighbours are more influenced)

```
Algorithm SubModelLifeCycle
    Set initial values for the world and agent properties defined in Tables 1 and 2;
    InitialPopulation := |W|
    PopulationHasTterminated := False; StableNonInteraction := False; Lifetime := 0;
    While Not (PopulationHasTterminated) And Not (StableNonInteraction)
        Update the world $W$ performing the activities from Table 3 in the order given
        in the table and calculate the number Nchanged of objects changed during the
        activities;
        If $|W|/InitialPopulation \leqslant GlobalEndOfPopulation$ Then
        PopulationHasTterminated:=True;
        If $Nchanged/|W| \leqslant StablePopulation$ Then StableNonInteraction:=True;
        $Lifetime:=Lifetime+1$;    End while
    Return (PopulationHasTterminated, StableNonInteraction, Lifetime, the property
    values)
End SubModelLifeCycle
```

4. Implementation, Experiments, and Discussion

A prototype system for investigating the agent worlds is implemented in Java language (Vassiljev, 2002). The current implementation is built with the following goals:

- it should allow creating new sub-models and changing existing ones;
- it should allow experimenting with sub-models;
- it should help collecting the test results;
- it should ease handling different versions of sub-models.

Handling of different sub-models is possible by using the Java programming language and appropriate design of new system. Design of the system is done using the Unified Modeling Language. The idea of the graphical user interface of the environment was to be simple and understandable. The agent world is represented as a field with agents on it. Each agent is represented as a coloured square. Agent's colour is dependent on aggressiveness level of the agent. Values of properties are given in textboxes.

The system has been used to implement a special sub-model comprising such agent properties as *Aggressiveness*, *Knowledge*, *Color* (indicating the condition of the agent), *Charity*, and *Violence*. The general properties of the world comprise *AccessToInformation* and *OverallAggressiveness*.

Preliminary analysis of results received on that sub-model demonstrate that in certain cases the relationship between the level of access to information, form one side, and the overall aggressiveness value implying the end of population, from the other side, indeed has a stepwise character. Further investigation needs to be done to find out what exactly is the relationship, how typical are the results received so far and weather they imply parallel conclusions for the research problems posed. It is also necessary to develop further the current sub-model and the environment.

One must be careful when interpreting the results of the current research in the real world. The approach is not meant to model or prevent particular terrorist attacks. Rather, the main idea is that the character of dependencies in the model and the real world can be similar. Based on the conclusions, decisions can be made concerning access to resources and knowledge.

Further research will include:

- performing experiments with detailed analysis of the relationships on the sub-model defined above;
- investigating new sub-models (with various parameters, interactions, and life cycles);
- improvements of the environment.

Acknowledgements

This work is partially financed through the ETF Grant No. 4296. The author thanks Mr. Stanislav Vassiljev for his implementation of the application prototype.

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Konfliktų modeliavimas agentų pasaulyje: prieiga prie išteklių ir galimybė reguliuoti populiaciją

Jaak TEPANDI

Šio straipsnio tikslas buvo sukurti modelį santykiams tarp laisvės ir suvaržymo tirti terorizmo kontekste. Norėta išsiaiškinti, kokia jautri populiacijos išlikimo galimybė, esant smulkiems pakitimams, atsižvelgiant į šiuos du kriterijus. Pateikiamas modelis, skirtas priėjimo prie resursų ir populiacijos pabaigos galimybės ryšiams simuliuoti. Modelis apima agentų pasaulį, jo savybes, sąveikas ir pasaulio gyvybės raidos ciklo algoritmą. Kadangi "teisingos" modelio savybės ir sąveikos dar tebėra bandomos, modelis pateikiamas dviem pakopomis: bendrasis modelis ir konkretusis submodelis. Gautų rezultatų, įgyvendinat submodelį, analizė rodo, kad atskirais atvejais priėjimo prie informacijos lygio ir bendro agresyvumo dydžio, reiškiančio populiacijos pabaigą, santykis gali būti pažingsninio pobūdžio.