Innovation Process Simulation on the Base Predator and Prey

Victor P. Romanov, Helen A. Agafonova, Saltanat S. Sandybaeva, and Nikita S. Mullin

***Abstract*—The paper is devoted to the simulation of two populations coexistence, one of which represents old big corporations and the other one – small innovative business. It is hard to imagine modern digital world without such combination of words as computer modeling and simulation. This discipline gains popularity throughout the whole scientific world. In our paper we examine such phenomenon as emotion simulation. It contains as a review of emotion simulating research as some original results on the innovation simulation based on predator and prey model.**

There is widely spread opinion, that modern information technologies provide us an opportunity to simulate emotions and feelings. Simulation of conflicts, cooperation, and the emotion simulation are often used to explain the nature of human behavior, depending on different factors such as personality, emotional state and mood at the specific moment in time. For instance, we can consider large company, which faces some troubles, as feeling some hunger and to satisfy it, the company tries to absorb some other smaller firm.

The most important result of our research is the discovery of such parameter's values interval in which great firms and small businesses (start-ups) can grow and raise simultaneously.

***Index Terms*—Acquisition, emotion simulation, innovation, predator, prey.**

I. INTRODUCTION

In these latter days the researchers are more and more interested in problems of modeling emotions and feelings, which became important part of more general models of social and economic processes. So, for example emotions such as happiness and satisfaction are used in wealth distribution models, mutual understanding and sympathy. In their work "Generic Personality and Emotion Simulation for Conversational Agents" Arjan Egges, Sumedha Kshirsagar and Nadia Magnenat-Thalmann describe a generic model for personality, mood and emotion simulation for conversational virtual humans.

Modeling social groups and government like hierarchical social structures are often based on such emotions as understanding and sympathy. Dissimilarity and rave are applied in conflict modeling.

Separately it is worth mentioning hunger emotion modeling as the feeling lack of energy and pursuit of fulfilling it through absorption of weaker representatives of another species.

In this paper an overview of researches in this sphere, based on next references [1], [2] is given, but the main focus will be on new kind of model "predator and prey", in which a portion of predators are being shot and their furs are being sold, and money received is partially spent on buying food (carrot) for preys (rabbits).

A positive feedback is included in a system this way. The model has an obvious interpretation in economics – the government taxes big corporations and uses a portion of that money for funding small businesses and start-ups. The most interesting is the population growth dynamics with different levels of taxation and grants. One of questions of this paper is whether the stable growth of both populations is possible, and if it is so, then at which parameters it can be reached? Today this is the main problem of technological progress.

Technologies of agent simulation provide possibility to emulate such processes in the modern economy as the acquisition of one company by another. Thus, according to this model large and successful company is regarded as a "Predator" and the small one that has innovation technologies, as a "Prey". "Predator and Prey" model can pick out and explain general factors influencing the course of the acquisition process, possible ways of development, its results and profits. Using the Lotka-Volterra model, the process of merger and acquisition as Predator and Prey interaction was formalized. This model shows population growth change depending on the level of inter specific competition, the level of taxation and start-ups donation.

We also question whether the stable growth of both populations is possible, and if it is so, then at which parameters it can be reached. The model has an obvious interpretation in economics – the government taxes big corporations and uses the portion of that money for funding small businesses and start-ups. The most interesting is the population growth dynamics with different levels of taxation and grants.

The remainder of the paper is organized as follows. In Section II, we take a look at a formal model of emotional state. The logical modeling of emotions is presented in Section III. The hunger is being examined as a feeling in Section IV. In Section V we define the algorithm of hunger satisfaction in the model. Section 6 is completely dedicated to the studies, where "Predator and Prey" concept is based on Lotka-Volterra model, realized as a computer program. In the last section we make a review of the paper and share with the future plans.

II. A FORMAL MODEL OF EMOTIONAL STATE

In this section, the generic emotion model will be

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introduced. Firstly, we need to define exactly what we mean by emotional state and other related concepts in order to describe how they can be simulated and used by other systems.

An individual is an entity that is constantly changing (having different emotions, moods, etc.). Therefore, when we speak of an individual, we always refer to it relative to a time *t*. The moment that the individual starts existing is defined by *t* = 0. The abstract entity that represents the individual at a time t we will call It from now on. The emotional state is a set of emotions with a certain intensity. The size of this set depends on the theory that is used. For example, in the OCC model, 22 emotions are defined, while Ekman [6] defines that are used as a basis for facial expression classification. The emotional state is something that can change over time (for example due to a decay factor). Therefore, when we speak about an emotional state, we speak of it relative to a time t. Authors Arjan Egges and Sumedha Kshirsagar [1] define the emotional state as an m-dimensional vector, where all m emotion intensities are represented by a value in the interval [0, 1]. A value of 0 corresponds to an absence of the emotion; a value of 1 corresponds to a maximum intensity of the emotion. This vector is given as follows:

$$e_t = \begin{cases} \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_m \end{bmatrix}, \forall i \in [1, m] : \beta_i \in [0,1] & \text{if } t > 0 \\ 0 & \text{if } t = 0 \end{cases}$$

III. Logical Modeling of Emotions

Emotions determine the quality of our lives. They occur in every relationship we care about—in the workplace, in our friendships, in dealings with family members, and in our most intimate relationships. Emotions are essential to intelligence. The make us, humans, have a better creativity and flexibility when we face problems.

Emotions are very complex and widely spread. They influence on how we think, adapt, behave in certain conditions, and communicate with other human beings. Emotions play an important and key role in decision-making process, too.

Emotions can, and often do, begin very quickly, so quickly, in fact, that our conscious self does not participate in or even witness what in our mind triggers an emotion at any particular moment.

Recently, some researchers working in the multi-agent systems (MAS) have been interested in developing logical frameworks for the formal specification of emotions. All proposed logical frameworks for the specification of emotions are based on the BDI (belief-desire-intention) logics. BDI logics were developed in the last fifteen years. BDI logics are multimodal. Agents' attitudes such as beliefs, goals, desires, intentions, etc. are formalized in this logic.

They are usually expressed by corresponding modal operators and their interaction properties.

The operator Bel_i is used to show what a certain agent i believes. The operator $Goal_i$ expresses what a certain agent i wants. The operator X expresses those facts that will be true. Here is an arbitrary formula φ of the logic:

- $Bel_i\ \varphi$: agent i believes that φ;
- $Goal_i\ \varphi$: agent i wants φ to be true;
- $X\varphi$ is meant for: φ will be true in the next state of the system.
- $Poss_i\ \varphi$ is meant to stand for: agent i thinks that φ is possible.

BDI logics disambiguate the different dimensions of emotions. Here are some examples of how the previous modal operators for belief, goal and time were used to formalize some emotions. An agent i feels joy about a certain fact. This can be expressed as follows:

$$Joy_i\ \varphi = Bel_i\ \varphi \wedge Goal_i\ \varphi$$

This can be explained as following: agent i feels joy about φ if and only if i believes that φ is true and wants φ to be true.

IV. Hunger in the Emotion and Feeling Simulation Model

In psychology, emotion is often defined as a complex state of feeling that results in physical and psychological changes that influence thought and behavior. In the science of artificial intelligence, this definition has also found its reflection, but it is necessary to define various types of emotions relative to agent's goals and plans. This also applies to certain feelings, too.

Exactly this point of view allows us to determine the hunger as a feeling because at the time when individual is hungry, he/she directs the most of the forces on its quenching and all actions are determined for this purpose.

Huge companies behave in some crisis just the same way.

V. Algorithm of "Satisfying Hunger"

In order to continue to study the concept of "Predator-Prey", it is necessary to define one common mechanism by which absorption occurs either as merging firms.

In this model, two participants coexist. Primarily, the company-predator, which is a big enough and successful corporation, but it has its vulnerable "narrow" places that it seek to compensate by absorption of a small business.

The second equally important participant - just a small business, in particular cases it can be a start-up. It is a "prey" that has not yet "matured", but has its own area of specialization, in which it has not the last, but not the first place in terms of efficiency and, thus, having an acceptable price for the acquiring corporation.

In addition to the main representatives of this process there is also a registry - some database from which the corporation will choose the most suitable target company-prey for itself.

Therefore, for the most successful takeover "predators" must go through the following steps:

1) Primarily determined that company-predator begins to experience "hunger", i.e. there is a drop in profits because of the reducing the effectiveness of any of its divisions, branches, etc., or thereof combinations.

2) "Predator" evaluates its real competitive advantages and disadvantages. It should keep the identified strengths, developing them as far as possible, and get rid of the weak, or at least minimize them. Companies strive to achieve the necessary results, resorting to a business combination. Its plan of acquisitions should be formed primarily from the strategic plan the corporation, i.e., it must be an organic combination of the company's objectives and plan of merger or acquisition of enterprises.
3) "Predator" establishes for itself the basic indicators that it wants to achieve by including some new enterprise in its structure. This step is quite important in terms of analysis of the results of this transaction between "Predator" and "Prey". If these criteria were not defined, respectively, as a result the company does not know what to strive for, what results should have been achieved. As a rule, criteria that were set, should give a definite competitive advantage or enhance the existing. For most companies the main parameter is a rate of return on invested capital.
4) Based on the foregoing it is necessary to put forward clear criteria that must be inherent in target company-prey. In order to have a successful merger or acquisition it is usually chosen not the leader in a particular industry or a particular geographic market, etc., and at the same time not the weakest company, but second or third in terms of efficiency. This is primarily due to the fact that big corporation have to pay a high enough price for a company with a leading position, and at the same time that is really difficult to turn the weak one into a well-functioning business.

VI. "Predator and Prey" Concept Basedon Lotka-Volterra Model

A lot of papers are devoted to the Lotka-Volterra equations to model competition and technologies development [3]-[7].

Let F denote the population of foxes at time t and R denote the population of rabbits. The Lotka-Volterra equations for this Predatory-Prey model are as follows:

$$\frac{dR}{dt} = a_R R - c_R RF, a_R \succ 0, c_R \succ 0 \qquad (1)$$

$$\frac{dF}{dt} = -a_F F + c_F FR, a_F \succ 0, c_F \succ 0 \qquad (2)$$

In this set of equations a_R, c_R, a_F and c_F represent the growth constants and proportionality constants for rabbits and foxes, respectively. As it can be observed from the set of equations, there are the following assumptions in this model.

For the most populations, the growth rate *f(R)* decreases with increasing *R*, so the simplest choice of a decreasing linear function of $f(R) = a - a \cdot R / k, a \succ 0, k \succ 0$ is made. By substituting *f(R)* in (2), it can be written as follows:

$$\frac{dR}{dt} = a \cdot R - {aR^2}/{k}, a \succ 0, k \succ 0 \qquad (3)$$

The essence of this application is fairly simple. It counts rabbits and foxes' population depending on various factors. In this paper will be regarded foxes as huge corporations. In order to survive and prosper they feed on rabbits (start-ups).

In this section of the work, idea of the simple "Predator-Prey" model is deployed in order to represent realistic state of affairs in today's economy and trace reactions on different changes in some typical situations. It looks like this: the government flays "foxes" (i.e. taxes huge companies) and gives carrot (i.e. donations) to rabbits (start-ups). By putting wanted coefficients and by customizing some values you can plot the graph and watch how the growth of population changes. Bellow there is a picture that shows working window of the program (see Fig. 1).

Fig. 1.Preview window of application for working with.

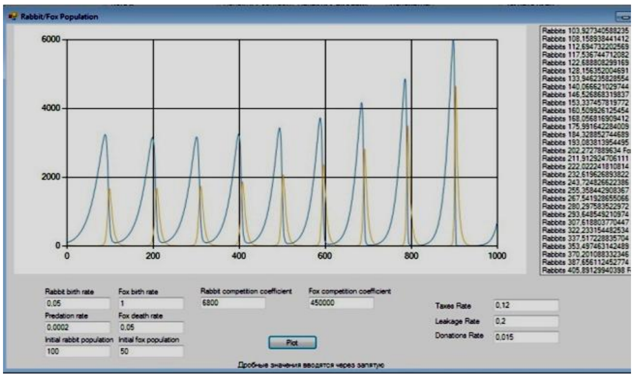

Fig. 2. The graph shows that the growth of foxes and rabbits population is weak.

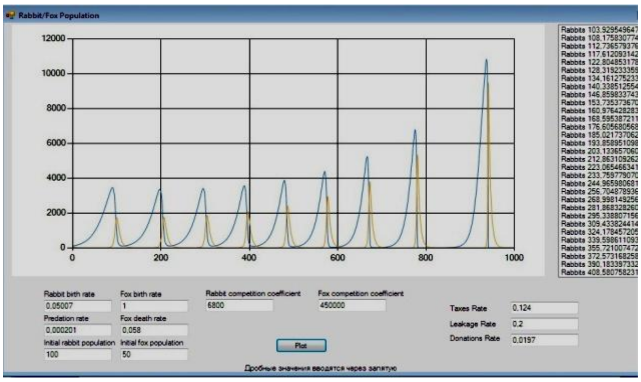

Fig. 3. The population growth is stable. The number of rabbits exceeds the number of foxes.

User enters data about rabbit and fox birth rate, initial rabbit and fox population. In addition, coefficients of predation rate and fox death rate should be specified. Finally, user sets desirable tax level and the level of subsidies. After pressing “Plot”, the graph appears on the screen, showing population growth at different levels of taxes and donations.

Onward different situations of population growth are shown, using various parameters of birth and death rate; taxes, donations and leakage rate, etc. In Fig. 2 there is shown situation when the growth of foxes and rabbits population is weak.

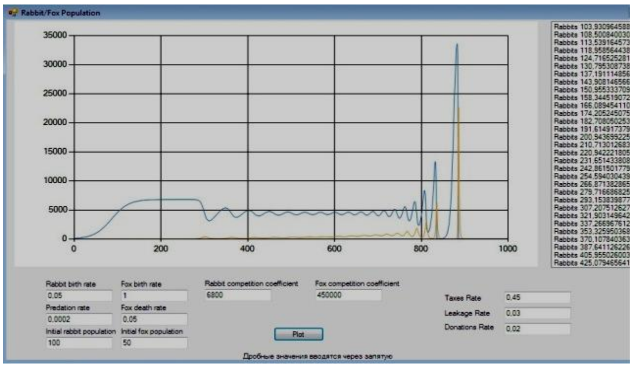

Fig. 4. Unstable condition. Due to high taxation, the population of foxes is small; the situation with rabbits is opposite.

In addition, final variant of the “Predator-Prey” model now takes into account intraspecific competition (competition for resources among rabbits and foxes themselves). The program allows you to adjust:

- x_0,y_0: initial population of rabbits and foxes respectively;
- α, δ: fertility *rates* of rabbits and foxes respectively;
- γ: the mortality rate of foxes;
- β: coefficient of predation;
- k_x for rabbits and k_y for foxes - coefficients of intraspecific competition;
- H: happiness multiplier (determines the effectiveness of state aid to start-ups);
- τ: the proportion of foxes shot;
- T: taxes collected for all periods;
- D: the share of taxes, going to the rabbits aid;
- L: part of the tax that is lost from the treasury (i.e. corruption).

If taxes are spent on improving infrastructure:

$$x_t = x_{t-1} + \alpha x_{t-1} - x_{t-1}y_{t-1}\beta - \frac{\alpha x_{t-1}^2}{k_x + T*D*H} \quad (4)$$

$$y_t = (1-\tau)(y_{t-1+}\delta x_{t-1}y_{t-1} - \gamma y_{t-1} - \frac{\delta y_{t-1}^2}{k_y}) \quad (5)$$

$$T_t = T_{t-1}(1-D) + y_t * \tau - L \quad (6)$$

If taxes are spent on direct subsidies:

$$x_t = x_{t-1} + (\alpha + T*D*H)x_{t-1} - x_{t-1}y_{t-1}\beta - \frac{\alpha x_{t-1}^2}{k_x} \quad (7)$$

$$y_t = (1-\tau)(y_{t-1+}\delta x_{t-1}y_{t-1} - \gamma y_{t-1} - \frac{\delta y_{t-1}^2}{k_y}) \quad (8)$$

$$T_t = T_{t-1}(1-D) + y_t * \tau - L \quad (9)$$

The situation when the population growth is stable and the number of rabbits exceeds the number of foxes is shown in Fig. 3.

There may exist unstable conditions as you can see from Fig. 4.

The most interesting result is presented in Fig. 5, as we can see both foxes and rabbits populations are growing exponentially at definite parameters values. This result supports our hypothesis that in this model may be conditions, under which both great companies and start-ups are developing without oscillations.

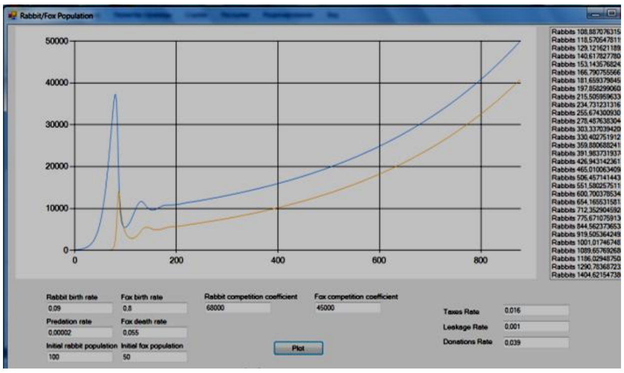

Fig. 5. Both foxes and rabbits population are growing exponentially.

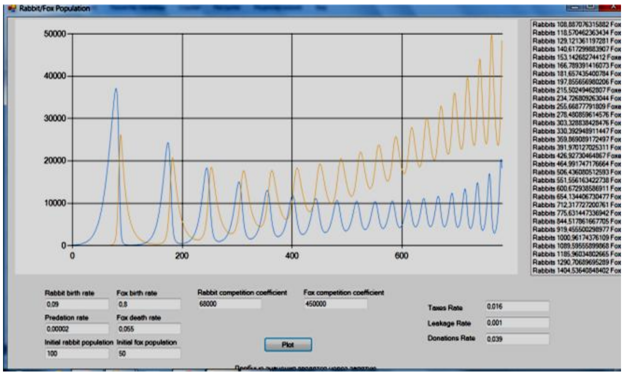

Fig. 6. Both populations are exponentially growing with oscillations.

HOWEVER, Fig. 6 shows those values intervals when the growth is possible without oscillation are narrow. Outside of this interval such growth is accompanied by oscillation.

VII. CONCLUSION AND FUTURE WORK

In this paper is presented the general concept of how emotions and feelings are formalized, several models were presented, including the most famous one - OCC model. Different possible ways of practical application of this kind of researches (logical view of one or the other feeling) are listed in our work. The most interest is presenting the “Predator and prey” model as a concept, based on the hunger, illustrating the process of acquisition of small companies – preys (start-ups) by huge companies (predators). In order to imagine how to formalize such event the algorithm of acquisition was defined, starting from the very first stage of realizing to absorb small firm and choosing of prey by the predator. Using the Lotka-Volterra model, the process of acquisition in terms of rabbits and foxes and their population was formalized. This model gives the possibility to consider interesting cases of population growth change, depending on the level of inter specific competition, the level of taxation and start-ups donation.

The most important result of our research is demonstration of existence such parameters values interval in which great firms and small businesses (start-ups) can grow and raise simultaneously. But this interval is quite narrow, so that even the slightest change (i.e. the change in the tax and subsidies, in our case) can lead to adverse situations in the virtual economy, such as the complete disappearance of large or small companies, or both.

Our future work will focus on the improving of this program. The aim is to investigate a feeling of hunger onwards, considering other situations that arise in the market economy by using different coefficients, parameter values and options of our application. In addition, plans to introduce new parameters needed for research. Moreover, this paper inspired us to study some new emotions and feelings from position logic in future and formalized them, using in different models of the economy and other important knowledge areas.In this paper is presented the general concept of how emotions and feelings are formalized, several models were presented, including the most famous one - OCC model. Different possible ways of practical application of this kind of researches (logical view of one or the other feeling) are listed in our work. The most interest is presenting the "Predator and prey" model as a concept, based on the hunger, illustrating the process of acquisition of small companies – preys (start-ups) by huge companies (predators). In order to imagine how to formalize such event the algorithm of acquisition was defined, starting from the very first stage of realizing to absorb small firm and choosing of prey by the predator. Using the Lotka-Volterra model, the process of acquisition in terms of rabbits and foxes and their population was formalized. This model gives the possibility to consider interesting cases of population growth change, depending on the level of inter specific competition, the level of taxation and start-ups donation.

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