Source Finder and the Entrance to Hidden Economy

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Abstract

We have investigated whether a society or a social or economic system can learn and adapt to the environment as a whole. Our investigation was based on the suggestion that people can learn and adapt to their environment. For that purpose, we have created two simple models which allowed us to see that cognitive processes originate through the evolution where, on one hand, less capable individuals are taken out and, on the other hand, capable individuals survive. We have experimented with and tested a simple economy based on the Cobb-Douglass production function. Our goal was to create a simple and understandable model of a complex system, not a sophisticated replication of the world. As we wanted to avoid the falsification of the experiment, we used as little of our preliminary knowledge as possible. Our aim was to achieve explicitly created evolution leading from the simple to the complex using minimum assumptions. Our experiment confirmed that the evolution was a spontaneous process that was changing the environment independently of one s mind and that the process of cognition can evolve in a such simple model.

Introduction

People can learn and adapt to their environment. The question is, whether a society or a social and/or economic system[1] can also learn and adapt to the environment as a whole – and vice versa – the environment can also learn and adapt to given economic system. Really can? We suggest it can. It takes quite a long time to observe this learning process in reality, though. Nevertheless, it is possible to do experiments with computational models of social systems in very short time intervals. We will investigate how learning of very simple social systems works and we will try to draw analogies between those models and the real life.

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[1] We state that economic systems are always social ones.

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For better understanding of the observed issues, we will deal with very simple models. However, we will not include widely accepted social properties. Despite that fact, we are expecting some simple properties of social systems to evolve. Our assumptions included within the models do a priori affect the results, so we will minimise them as much as possible. L. Andrášik called this approach *the minima principle* of model builder prejudice (see Zapletal, 1996; Andrášik 1997, 2002).

We will create models on which we will test simple economy and on which we will observe learning of a system through evolution. Our assumption is that the economy is based on the Cobb-Douglass production function, although possible variations of this economy can be made.

1. Basic model

1.1. Source Finder

In a deserted land a wanderer makes a trip, searching for an endless source of energy. As he walks, he consumes his energy. So, with each step he takes, his energy supply decreases. Despite that, he needs to find the energy source as soon as possible. In our model, the wanderer does not think about his path and he takes steps in random directions. Not to get lost, and for the simplification of our model, we made him to decide to walk only in two directions – either towards the North, or towards the East. Wanderer s destiny is determined by two options – to find the energy source, or die. If he cannot manage to find the energy source before his supplies are empty, he dies. If he manages to find the source, his energy supplies are refilled and thus he is transfered by a strange force to the starting point, so he can start a next trip. Moreover, he will remember the path of the trip he had just taken. On the next trip, the wanderer may choose between taking a path he had already taken, or exploring a new path. Of course, this choice is random. He is not thinking about his decisions at all. From now on, we can call the wanderer an agent and the space the agent is walking on is a toroid. So far, we have described a model with the following properties of the environment:

- Toroid represented by a grid with some given width and height,
- Location of energy source on the grid,
- Initial source energy,
- Amount of energy which is refilled into the source,
- Starting location,
- Initial amount of agent s energy supply,
- Amount of energy compensation drain,
- Amount of energy consumed per one agent s step.

In our model, there are three random generators. The first one is for deciding about the agent s direction. The second one is for choosing whether the agent learns in the environment by taking a new path or whether the agent uses its own memory. The third one is for choosing a particular path from the agent s memory. However, it seems there is no, or very little chance for the population to survive for a long time. In the experiment, to give that population a chance to survive, we allow all agents to use their ability to reproduce. The rule will be that everyone who possesses enough resources, i.e. energy, will produce an offspring. The parent will pass on all its knowledge (all paths to the source that it knows of) to its offspring. Moreover, the parent passes half of its energy supply to its offspring. Our model is then extended with:

- Initial count of agents,
- Amount of resources required for creating an offspring.

Model like this clearly shows that, sooner or later, the wanderer will die as a consequence of a bad trip path choice. The environment properties are acting like a filter of knowledge. The knowledge that will lead the agent more quickly to the energy source will survive. The other knowledge will be eliminated from the population as a consequence of the agent s death. The quality of knowledge di ers from agent to agent and it depends on the amount of compensation and on the number of steps leading to the source. The experiment demonstrates the onthogenesis of an agent, which in this case is analogous to the cognition of the whole population.

The process of evolution is created by the process consisting from a generation of random decisions and filtration. The whole population acts as a meta-agent, i.e. an agent consisting of other agents. The agent represents the knowledge and is a hypothesis of a meta-agent.

1.2. First Experiment

Question is: Can a reasonable strategy evolve and sustain making the population stable? We will seek for the answer in our experiment created by using (see Urbánek). We do not know precisely what will happen in the experiment and we do not want to falsify the result. Therefore are going to minimise usage of our preliminary knowledge.

We started up with a set of initial simulation properties. By varying those properties, we observed the impact of each property on the behaviour of the simulation. After several iterations, we have come up to the initial experiment setup shown in the Table 1.

With this initial variable setup, we got the following results. In all graphs, the horizontal axis represents time in simulation steps.

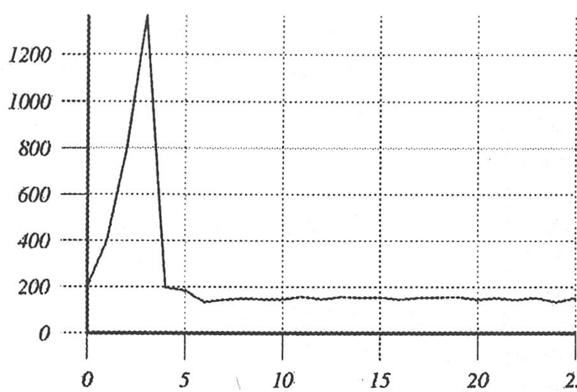
Table 1

Initial Properties

Property	Value
Grid size	10 x 10
Initial source energy	100 000
Source location	5 x 5
Source refill	1 000
Agent count	100
Agent energy	100
Divide energy	200
Compensation drain	80
Energy consumption	1

Figure 1

Population Size (Number of Agents)



In the Figure 1, there is shown a change in the population size. The population grows because agents have enough energy for producing an offspring. Moreover, they have enough energy so they can afford longer trips, and the source has enough energy to serve larger number of agents.

After the fourth simulation step, there was a dramatic drop in the population size. The Figure 2 illustrates why this rapid drop in the population size happened. In the third step, the agents have completely drained the source. Only those agents who came to the source earlier received a compensation. The agents who took longer trips came too late, and because the source was empty, they received no compensation. Without compensation, those agents who were late, had very little energy at disposal, compared to those with a shorter trip length, and therefore, there was a larger threat that they will not survive.

The average energy of agents, shown on Figure 3, was decreasing at the beginning of the simulation.

Figure 2

Source Energy

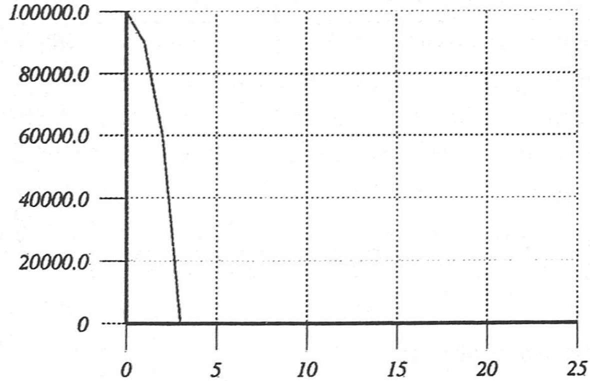


Figure 3

Average Agent Energy

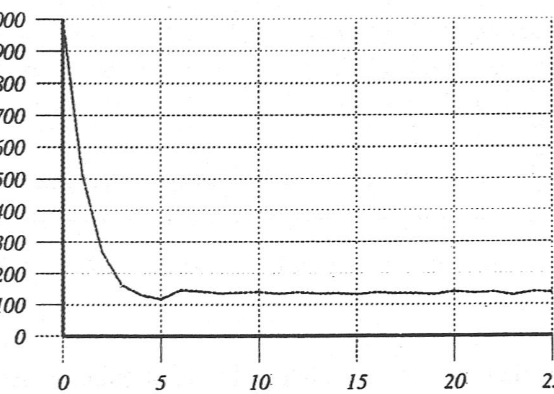
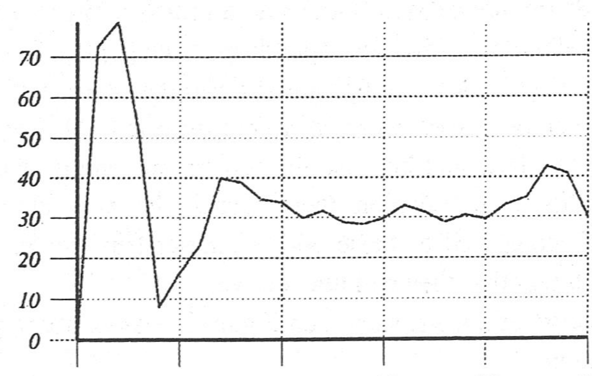


Figure 4

Average Length of Last Trip of Successful Agents



Agents have used the energy for dividing themselves and producing offsprings. The average energy was stabilised at the value around 140. This value depends on the energy that is necessary for division and depends on energy compensation. This value is about half of their sum. Average trip length of an agent is another thing that can be observed, as it is shown in the Figure 4.

At the beginning of the simulation, agents had plenty of energy available, and therefore, they could afford to do longer exploration of the toroid space. At the same time, when the source energy was exhausted, only fastest agents survived. And because those agents who survived had knowledge of the shortest paths, they consumed less energy than they received for the compensation. Thus, the result was a small energy increase. They were able to take longer paths with this energy increase, and consequently, an average trip length has increased.

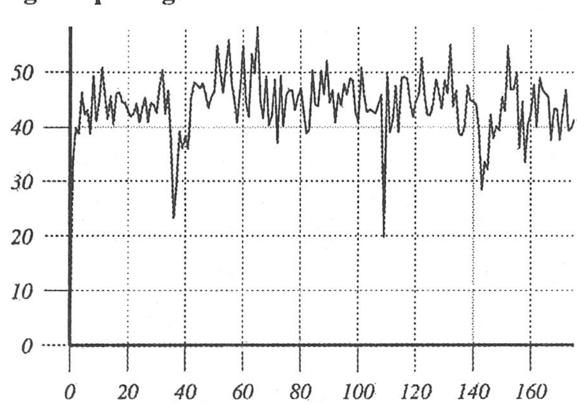
In this simulation, there are several implicit dependencies between simulation properties. We will mention those most obvious. As stated above, average agent energy depends on the energy compensation and the energy required for the producing an offspring; the trip length depends on the agent s energy; the population size is tied by the available source energy, which is later equal to the amount of energy refilled to the source.

1.3. Oscillations

We have run another simulation with the same initial parameters as the previous one, but with a small modification. We have set initial agent energy to be 100. With a given smaller amount of energy, agents with a longer trip length were filtered out in the few first steps of the simulation. However, the average trip length, as shown in the Figure 5, in this simulation is greater than it was in the previous experiment.

Figure 5

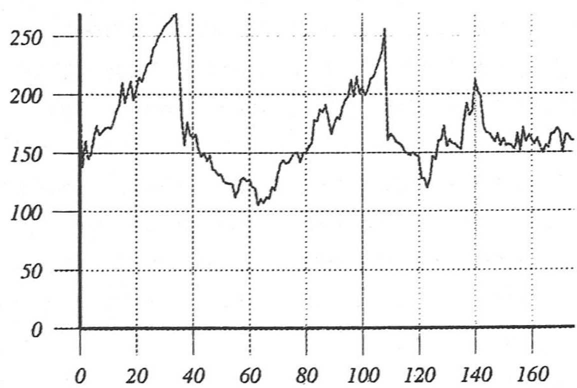
Oscillating Average Trip Length



Agents had enough energy to produce offsprings. With the population growth (Figure 6), there was a larger consumption of source energy (Figure 7) until the source is completely drained around the simulation step 35. This source drought caused the death of slower agents, which is obvious when we compare the graphs in the Figure 5 and Figure 7.

Figure 6

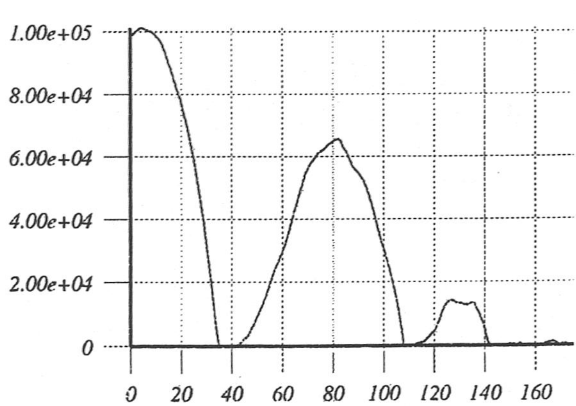
Oscillating Population Size (Number of Agents)



Fewer agents result in less energy consumption, and thus faster refill of the source energy. As mentioned above, faster agents can get more energy than they consume on a trip, and therefore, they can produce more offsprings. The more offsprings, the larger is the population; the larger is the population, the larger energy consumption; the larger is the energy consumption, the less is the source energy. This causes oscillation of both the population size and the source energy.

Figure 7

Oscillating Source Energy



1.4. Summary of the First Experiment

Comparing the basic model with the real world we can find a number of analogies. Searching for a path to the energy source can be compared to searching in the objective reality or to a creative activity when an agent invents a new plan. While inventing a new plan, for example, a business plan, the agent is learning and remembering all actions it takes. Finding an energy source is like the implementation of the plan, and energy compensation is a reward.

We can consider the population to be an industry, sector, national economy, international economy, or global economy. We can aggregate agents and create multiple levels and the agent population will be learning at each of those levels.

2. The Hidden Entrance

With a business plan, one can enter the economy and receive a compensation for his investments. We will change our model by replacing the infinite source of energy with an entrance to a hidden economy. Our wanderer will be searching for a business plan which we call a path to the entrance of hidden economy.

When the wanderer finds the entrance and enters the economy, the production will begin. The production is based on the Cobb-Douglas production function:

$$Q = F(K, L) \tag{1}$$

In the function (1), Q denotes the produced quantity of goods, K represents the size of the capital portfolio and L is the number of working time units. Another generic form of this function can be expressed as:

$$Q = AK^{\alpha}L^{\beta} \tag{2}$$

Here, the A is a level constant, α is capital input coefficient and β is labour input coefficient. When $\alpha + \beta = 1$, then the equation (2) will have a property of constant profits from the production.

$$Q = AK^{\alpha}L^{(\alpha\text{-}1)} \tag{3}$$

After the production is finished, the agent receives a compensation. It will not receive the compensation for nothing, as it was shown in our first experiment. The agent will be rewarded with regard to both its invested capital and labour he has devoted to the production. The compensation is in the form of a revenue for the agent's invested capital and the wage for the agent's labour:

$$revenue = \frac{\partial Q}{\partial K}K \quad wage = \frac{\partial Q}{\partial L}L \tag{4}$$

Because we are testing the Cobb-Douglas production function, we have replaced the energy source with that function. All agents that enter the hidden economy simultaneously, will begin a production.

$$Q = a\left(\sum_{i=0}^{n} K_i\right)^{\alpha}\left(\sum_{i=0}^{n} L_i\right)^{1-\alpha} \tag{5}$$

The equation (5) denotes the production function where n is the count of agents entering the production, K_i is capital invest by an agent i, and L_i is labour given by an agent i. From the equation 5 we get:

$$revenue_i = \frac{\partial Q}{\partial K} K_i = a\alpha K^{\alpha-1} L^{1-\alpha} K_i \tag{6}$$

$$wage_i = \frac{\partial Q}{\partial L} L_i = a(1-\alpha) K^{\alpha} L^{-\alpha} L_i \tag{7}$$

The process is a continuous cycle of searching, production and reward, and it is irreversible in time.

2.1. The Second Experiment

We set up our second experiment. With our extensions to both the environment and the agents, the simulation was launched with additional properties as described in the Table 2. Other relevant values are the same as it is shown in the Table 1.

Table 2

Initial Properties for the Second Experiment

Property	Value
Initial source energy	1 000
Source refill min	0
Source refill max	40
Source richness period	500
Sell energy (per cent of energy)	80
Buy energy (per cent of capital)	70
Move cost	1.2
Energy price	1
α	0.75
Level constant (a)	1.5
Agent labour	60

To simulate some external influences on the source, we refilled that source according to a source richness function. To make it simple, we have decided that our richness function is a simple sinusoidal function. Other parameters affecting the source refilling are Source refill min and max, which denotes the scale of the sinusoidal function, and Source richness period, is length of one period of the function in simulation time units.

Agents do not receive the energy from the source for free. They have to buy it. The coefficient Buy energy denotes the portion of the agent's capital invested into the energy. The agent receives some amount of energy depending on the amount of invested funds and Energy price.

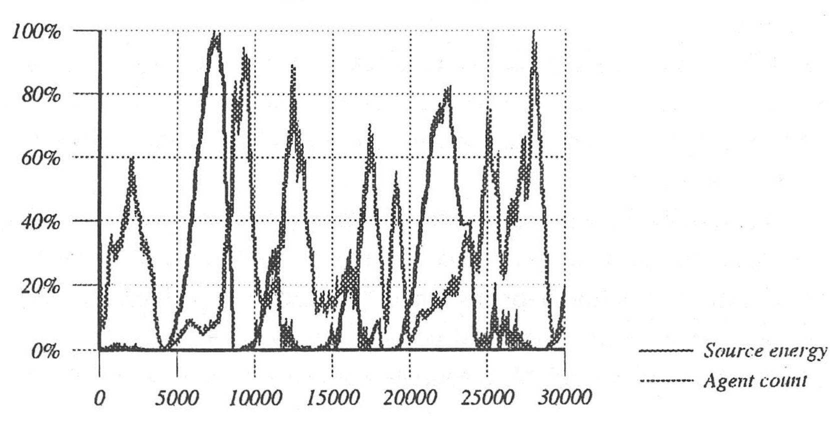
To maximise the agent's investments into the production, the agents have the ability to sell the energy and receive the capital. The agents sell a portion of their energy denoted by the Sell energy parameter and they receive the capital according to the Energy price; α and Level constant or a are parameters of the Cobb-Douglass production function. Moreover, we have decided, that agents will invest same amount of labour into each production.

Given the fact that all agents entering the entrance simultaneously will begin the production, we had to change the flow of simulation time. In the first experiment, one simulation step ended either when all agents found the source, or died. In this experiment, one simulation step is equal to one step of all agents on the toroidal space. This is necessary if we want to do the production with agents who entered the entrance simultaneously.

We have run this simulation for 30,000 steps and the results are as follows. The Figure 8 shows a scaled graph of available source energy after the production and the population size. To make it comparable, the values are scaled, so the graph shows their maximum values as same and minimum values as same.

Figure 8

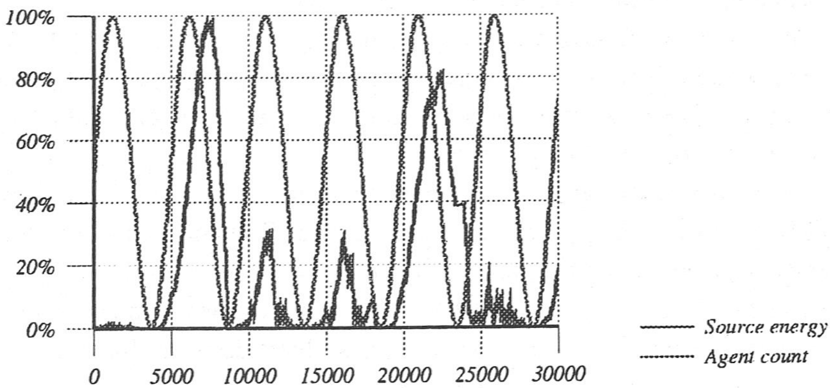
Comparison of Available Source Energy and Count of Agents



The Figure 9 shows the source richness function and source energy. A slight phase shift between those two graph curves can be observed.

Figure 9

Comparison Between Source Energy and Source Refill



2.2. Summary of the Second Experiment

In our second experiment, the agents are actors in a story with two parts:

- Searching for a business plan,
- Implementing the business plan.

In the first part of the story, Searching for a Business Plan, the agent decides on the way he will search the plan by. The energy used in our experiment represents the resources, gained knowledge, or personal contacts used for creating the business plan. He can either take risk in searching for a new plan, or he could choose one of the plans he had already used. The old plan has been proven to lead to success. However, the new plan is expected to be better, requiring lower resources spending. The problem is that it need not be better, well, that is a business risk.

In the second part, the agent implements the plan in the evolved environment. The agent makes decision on the way he will deal with available resources, then on the portion of the resources he will sell or buy, and on how much he will invest into the production.

In the simulation, there are many points where the weakest hypotheses are removed and the selection takes place. Moreover, there are many indirect dependencies. The main selection happens while the agent is searching for the plan. Those with the least efficient paths will not survive. Nevertheless, the agent's path depends on the agent's available resources and on the amount of energy he possesses.

The amount of energy depends on the financial resources available for the agent. Further, it depends on the available energy in the source, and on the agent's decision on how much he will invest into the energy before he starts a new search. Financial resources depend on the size of the agent's decision on investments, either in the form of capital or labour. There is an endless cycle of dependencies.

It is possible to remove some of our assumptions from the model and replace them with properties that can evolve. The variety of experiments is very wide. Here are examples of properties whose values can be learned through the evolution: • probability of agent's decision to make a risk and take a new path • portion of agent's energy to be sold • investments of capital and labour • amount of investment into the energy.

Conclusion

We wanted to achieve explicitly created evolution leading from the simple to the complex using minimal assumptions. In our experiments, it is possible to see that cognitive processes happen through the evolution where less capable individuals decline and the capable ones survive. Our experiment with the model of the Cobb-Douglas based economy shows a cognition of a population of agents from which analogies with real world can be observed. The evolution in our experiments was spontaneous process that was changing the environment independently one's mind. We proved, that even in a such simple system a cognitive behaviour can emerge.

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HĽADAČ A VCHOD DO SKRYTEJ EKONOMIKY

Štefan URBÁNEK

Ľudia sa dokážu učiť a prispôsobovať sa prostrediu, v ktorom žijú. Otázne je, či sa dokáže učiť a prispôsobovať aj spoločnosť, sociálny alebo ekonomický systém ako celok. Nazdávame sa, že môže. Práve preto, že pozorovanie tohto procesu učenia sa trvá v realite dlhší čas, robíme experimenty s výpočtovými modelmi sociálnych systémov. Budeme zisťovať, ako funguje učenie sa veľmi jednoduchých sociálnych systémov a pokúsime sa načrtnúť analógie medzi týmito modelmi a skutočným životom.

Na lepšie pochopenie pozorovaní sa budeme zaoberať veľmi jednoduchými modelmi, medzi ktoré zámerne nezahrnieme široko akceptované vlastnosti sociálnych systémov. Aj napriek tejto skutočnosti očakávame, že sa objavia niektoré jednoduché vlastnosti sociálnych systémov. Naše predpoklady zahrnuté v modeloch ovplyvňujú výsledky experimentov, a preto sa budeme snažiť ich čo najviac minimalizovať.

Vytvorili sme dva jednoduché modely, na ktorých sme odskúšali jednoduchú ekonomiku a na ktorých sme pozorovali vznik kognitívnych procesov vďaka evolúcii. Modely boli zložené z agentov bez akéhokoľvek racionálneho uvažovania. Agent[1] náhodne prechádzal priestorom, v ktorom tvoril a hľadal cestu, aby našiel zdroj energie, ktorým by si uspokojil svoje potreby. Mechanizmus uvažovania agenta bol úplne náhodný a za agenta volil, či pôjde novou cestou alebo voľajakou už prejdenou. Keď agent našiel zdroj skôr, ako mu došla jeho energia, zapamätal si cestu a bol prenesený na začiatok. Ak agentovi energia došla, zahynul a bol odstránený z populácie.

Agent bol hypotézou meta-agenta – populácie, reprezentoval jej vedomosť. V modeloch bol jednotlivec nepodstatný, dôležité bolo správanie populácie ako celku. Vďaka spontánnej evolúcii, čo prebiehala v modeli, sa populácia učila. Agenti, ktorí sa vydali na zlú cestu, zahynuli a s nimi zahynula aj zlá vedomosť. Tí, ktorým sa podarilo nájsť zdroj energie, prežili, mali viac energie, mali možnosť množiť sa a tým ich vedomosť v populácii pretrvala. Touto evolúciou sme dokázali to, že aj v populácii s náhodne sa správajúcimi agentmi môžu vznikať kognitívne procesy a populácia sa môže učiť – ako celok.

Tento zjednodušený model by sa dal prirovnať napríklad situácii, keď firma hľadá podnikateľský plán v ekonomickom priestore. Ak je plán firmy úspešný, firma ho zrealizuje, získa kompenzáciu v podobe odmeny a tým prežije. Ak bol plán neúspešný, firma skrachuje a s ňou sa stratí aj vedomosť o neúspešnom pláne. Nakoniec pozorujeme učenie sa meta-agenta, populácie firiem, kde vidíme úspešné firmy.

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[1] Pomenovanie *agent* budeme v tomto článku skloňovať ako životné podstatné meno, pretože ho považujeme za model živých objektov a taktiež sa navonok správa, ako keby bol živý.

Naším cieľom bolo vytvoriť jednoduchý a ľahko pochopiteľný model komplexného systému, a nie vytvoriť takmer dokonalú kópiu skutočného sveta. Keďže sme sa chceli vyhnúť falzifikácii experimentu, použili sme čo možno najmenej našich predpokladov o správaní systému a o jeho parametroch.

Náš experiment potvrdil, že evolúcia je spontánny proces, ktorý mení prostredie nezávisle od nás a že kognitívne procesy môžu vznikať aj v takých jednoduchých modeloch, ako sú tie naše.