Invisible Hand Process Simulation Based On Collective Intelligence Computational Model

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Abstract

In the modern understanding an Invisible Hand\(^1\) process, which is widely believed to be present in a Free Market, is perceived as something very general - a process in which the outcome is produced in a decentralized way, with no explicit cooperation between the acting agents. The second essential feature is that the process is not intentional; yet its impact on the market is very strong (Joyce, 2001). The agents’ aims are neither coordinated nor identical with the actual outcome, which turns out to be an unintentional by-product of those individual aims. The process takes place without the agents’ consciousness of taking a part in it this is why the process is called invisible. Such economical process surprisingly fits into computational model and the Collective Intelligence\(^2\) definition (Szuba, 2001b,a, 2002). This way it is intended to move from analyzing Free Market using objectual approach i.e. using money, production, transfer of goods, resources, agents, companies, etc. into mental analysis expressed through abstract computational processes. Hence, the paper discloses the concept, the implementation and the initial simulation results of the market simulation system which is targeted for such Collective Intelligence analysis. This system is expected to enable firing Invisible Hand process of simulated Free Market, and to allow on this basis the identification and formalization of computational processes underlying the Collective Intelligence of the market. The paper presents a concept of the simulation model that facilitates an observation of economic processes and enables prediction of the future based on given parameters.

**Keywords:** Collective Intelligence, Invisible Hand Process, Market Simulation, Molecular Model of Computation

1 Introduction

The object of the paper is to describe the concept which should enable capturing and further analysis of the process commonly described as Invisible Hand of the market. This section contains state of art in the area of market simulation and later gives the definition of that process and briefly introduces the Collective Intelligence computational model.

\(^1\)http://en.wikipedia.org/wiki/Invisible_hand

\(^2\)http://en.wikipedia.org/wiki/Collective_intelligence
1.1 State of Art

Although significant number of attempts to build market simulation framework have been made in the past (ex. (Jorion, 2005) (Schnabl, 1996) (Ygge, 1998)) the focus of the research was different to the one presented here. Some of those research streams focused on designing new approach based on abstractions taken from the theory of economy (such as prices and demands) and computer science (multi-agent systems) to solve resource allocation problem in general (Ygge, 1998). Other focused on detailed investigation of the Invisible Hand process in equilibrium price problem in the aspect of evolutionary market theory (Schnabl, 1996). There have also been made several attempts to design market simulators for the purpose of games. From our point of view the nearest stream of the research is the area of Agent-Based Computational Economics (ACE). A central concern of ACE researchers is to understand the apparently spontaneous formation of global regularities in economic processes, such as the unplanned coordination of trade in decentralized market economies that economists associate with Adam Smith’s Invisible Hand process. However this approach is still too much objectual because fully bases on real elements of the market, whereas Collective Intelligence theory allows abstract computational processes derived from the real system. The toolkit that was developed as a branch of this research is called Repast (REcursive Porous Agent Simulation Toolkit) and is a freely available agent-based simulation toolkit specifically designed for social science applications. Repast permits the systematic study of complex system behaviors through controlled and replicable computational experiments and the purpose of the framework is more general not limited to economic systems.

While the focus of the ACE is to analyze the trade; the goal of this paper is to propose general market simulation framework which is based on molecular model of computation introduced by Collective Intelligence. In our approach information molecules are equipped with a trading nature (Szuba, 2001a). The simulation model described by Artificial Collective Intelligence demonstrated that the agents created there (represented by information molecules - described further in the paper) will behave in more organized ways and also will more quickly create social structures to solve computer problems if they are designed to be able to buy resources for ”personal input” and are able to sell (trade) their output to other agents. In other words, in the background of certain activities (production in this case) trade exists, and they use money. Some of the research performed in the area of multi-agent systems (Weiss, 1999) proves that there is serious lack of clear general idea of how to define, organize and implement agent cooperation. It seems that use of the mechanism of trading based on the use of money is probably the easiest and best way to define and impose a stable advanced cooperation between agents in a system of distributed intelligence. Hence the idea of creating framework based on these paradigms seems to be reasonable.

1.2 Invisible Hand and Collective Intelligence

Adam Smith introduced the concept of the Invisible Hand process by describing that as a process in which each individual (market participant) labors to render
the annual revenue of the society as great as he can. Smith proves that the individuals generally, indeed neither intend to promote the public interest, nor know how much they are promoting it. The theory explains and uncovers structures and processes which people unintentionally and without recognition perform as if they were guided by an Invisible Hand. By preferring support of domestic to that of foreign industry, the individual intends only his own security; and by directing that industry in such a manner as its product may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an Invisible Hand to promote an end which was no part of his intention. Nor is it always the worse for the society that it was no part of it. By pursuing his own interest he frequently promotes the interest of the society more effectively than when he really intends to promote it (Smith, 1954).

Nowadays, something much more general is meant by the expression Invisible Hand. An Invisible Hand process is one in which the outcome to be explained is produced in a decentralised way, with no explicit agreements between the acting agents (Joyce, 2001). The second essential component is that the process is not intentional. The agents' aims are neither coordinated nor identical with the actual outcome, which is a by-product of those aims. The process should work even without the agents having any knowledge of it. This is why the process is called invisible. The system in which the Invisible Hand is most often assumed to work is the Free Market (Joyce, 2001).

Such definition is surprisingly compliant with the definition of the Collective Intelligence (Szuba, 2001a). Hence, it seems reasonable for the authors to apply formalism, which is well described to analyze and study market processes in general and Invisible Hand in particular. The scientific concept of the model assumes that the market creates live computer (subconsciously for the market participants) which might be defined using the Collective Intelligence theory. The computational process in such computer is described using mathematical logic. Its computational nature is non continuous, parallel and chaotic. Reasoning which is realized by this computer refers to self-regulation of the market which was observed by Adam Smith.

1.3 Why Collective Intelligence

Collective Intelligence theory is based on the model which departs from the classic, deterministic computational model (realized in typical digital processor) and introduces molecular, non-deterministic computational process. The example of application such model is Adelman’s DNA-computer. The loss of determinism of computations is compensated by natural parallelism of computations - what gives the advantage in multithreaded computations. Natural parallelism is a dream of today computer scientists and engineers. There are only two object types in such computer: information molecules and membranes; from which the structure of the processor is built. Such structure affects the flow of the computations.

To simplify we could say that the information in such model is carried by information molecules which transport facts, rules and aims of the computation. Information molecules move in a quasi-chaotic manner in the environment configured by membranes. When two logic expressions meet (which we call rendez-vous)
and they have appropriate logical form the reasoning process is fired, which results in change of logical contents of the molecule or creation of new molecule(s) transporting the logical conclusions. The reasoning process is parallel, multi-threaded, chaotic, performing forward and backward inferences in the same time. It turned out during simulations that although such a computational model is surprisingly fast and efficient (Szuba, 1998), however the problem is with its physical realization.

It is clear that the nature of such process is very similar to logical behaviour of the agents on Free Market - common features are: parallelism, quasi-chaos behavior, single information molecules are not conscious about the global outcome of the process. Those features lead the authors to the assumption that the Collective Intelligence computational model perfectly fits modelling the market processes; including the Invisible Hand process in particular. The extraction of the features which made those assumption reasonable are listed below:

1. Entities cooperate with each other in a chaotic, non continuous way.
2. The behaviour is quasi-chaotic due to the chances and risks of everyday and longer period life.
3. The behaviour is quasi-chaotic due to the chances and risks of everyday and longer period life.
4. The actions are not coordinated, parallel with reasoning processes being initiated, suspended and resumed.
5. Processes interfere with each other in difficult to control way.
6. Contradictory reasonings happen in the same time pretty frequently
7. Supplies are randomly distributed in the environment, among the entities and appear/disappear in non-deterministic way.
8. It is hard to identify individual elements e.g. transfer of valuable information.
9. Pretty frequently we can observe a process(es) without possibility of giving its reliable interpretation (e.g stock fluctuation in case of market).
10. Free Market and Collective Intelligence processes are temporary - it might show out and disappear after short period of time. The basic difficulty is that efficient implementation of Collective Intelligence methodology lays in the design of the mapping between structure of Free Market and molecular computational model - which is not an easy task. Our approach is to build at first simple simulation model of the Free Market as the Layer I. Above, linked with Layer I will be build Layer II, where the Collective Intelligence processes derived from the market will run and finally on the Layer III the Invisible Hand of market will be summarised.

2 Simulation model summary - concepts

The market simulation model is based on premises given in previous sections. The parts of the market are: agents which exchange goods among each other, agents are placed in the environment which supply them with energy and some supplies (renewable and non renewable). To simplify the model the quantity of the goods
exchanged is reduced but it is possible to build the hierarchy among them - there are goods which are gained directly form the environment and goods which are produced form other goods (higher level goods). The list of model elements is given below:

- Environment: space in which agents exist supplying them with energy and some low level goods (2 dimensional in the model).
- Agent: market participant existing in the environment and capable of making transactions with other agents. We can distinguish two agent types:
  - Basic agent - consumer and the supplier of the goods. Each agent has three main attributes: happiness level, assets (money + goods) which are affected by goods consumption/production.
  - Financial agent - emulates "bank" - gives credits and allow investment of capital.
  - Government agent - collects ad redistribute taxes.
- Good: the object of exchange between agents produced from other goods or gained from the environment. Goods might be consumed by agents and increase happiness level.
- Money: measures the value of the good; transactions are made using money.
- Time: time is discrete and measured in turns/rounds.

3 Experiments

After implementation of the system in compliance to summary of the concepts given in previous section the experiments have been made which purpose was to analysis of the processes running in Free Market including Invisible Hand in particular. The experiment described in this paper was aimed to analyse the link between real sphere and financial sphere in economic system. It is widely known that one of the main roles of the financial sphere is stimulation production in real sphere. Authors designed numbers of simulations which enable verification of the model against this law form one hand and analysis of such the process together with invisible hand process on the other hand.

Ten simulations have been made for following situations (10 simulations per each situation):

- Economic system without financial sphere.
- Economic system with financial sphere.

The results have been comprised by following factors: GDP, inflation, number of transactions.

3.1 Initial situation

The environment has been configured with the following parameters: size (30 x 30), three low-level goods with random distribution, eleven agents divided two
three groups\(^3\) (type 1 (action rules implemented as Java code): 5 agents, type 2 (action rules modelled in Drools): 3 agents, type 3 (action rules modelled in Jess): 3 agents) distributed randomly. The values of the parameters are as follows:

1. Type 1 (Java agent), attributes: energy - 130, money - 150, gatherSpeedModifier - 3, gatherQuantityModifier - 2, energyLossModifier - 1.8, taxRateModifier - 1.3,taxReceiveModifier - 2, produceEnergyLossModifier - 2
2. Type 2 (Drools agent), attributes: energy - 140, money - 200, gatherSpeedModifier - 2, gatherQuantityModifier - 1.5, energyLossModifier - 1.3, taxRateModifier - 1.3, taxReceiveModifier - 2, produceEnergyLossModifier - 2
3. Type 3 (Jess agent), attributes: energy - 120, money - 150, gatherSpeedModifier - 2, gatherQuantityModifier - 1.5, energyLossModifier - 1.5, taxRateModifier - 1.3, taxReceiveModifier - 2, produceEnergyLossModifier - 2.2

In the second simulation - economic system with financial sphere - six financial agents have been added distributed in the random way (but the same distribution was used in each of 10 ten simulations). Actions rule differ a bit - two types with different action rules (more liberal in given credits and stricter).

3.2 Results

For each situation described above, ten simulations have been made with the results collected in tables below.

### Table 1: Average agent attributes values (no financial sphere)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>161</td>
<td>296</td>
<td>198</td>
</tr>
<tr>
<td>Money</td>
<td>122</td>
<td>58</td>
<td>336</td>
</tr>
<tr>
<td>Happiness</td>
<td>119</td>
<td>217</td>
<td>59</td>
</tr>
</tbody>
</table>

### Table 2: Average agent attributes values (financial sphere)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>104</td>
<td>225</td>
<td>210</td>
</tr>
<tr>
<td>Money</td>
<td>10</td>
<td>-56</td>
<td>217</td>
</tr>
<tr>
<td>Happiness</td>
<td>112</td>
<td>321</td>
<td>120</td>
</tr>
</tbody>
</table>

\(^3\)The Jess agents and Drools agents where used Just to demonstrate the capabilities of the Framework - from the functional point of view the agent behaviour might be modelled using both engines and the high-level editor which enables intuitive modelling without Jess/Drools syntax knowledge is provided.
Table 3: Number of transactions comparison

<table>
<thead>
<tr>
<th></th>
<th>System with no financial sphere</th>
<th>financial sphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of transactions</td>
<td>17</td>
<td>31</td>
</tr>
</tbody>
</table>

3.3 Processes observed

There have been several processes observed during simulation. Figure 1 shows rapid decrease of inflation caused by dumping price of one good by the agent. However, larger demand for the good leads agent to increasing the price which affects the inflation factor, which gets back to initial level. The process is self-regulation of the price which is one of the symptoms of the invisible hand. But the most important thing observed in the experiments is real sphere stimulation by financial sphere. The results show that financial sphere did its homework as GDP factor increased significantly in comparison to the same system without real sphere. Not only did the GDP factor increased but the investment factor increased at the same time.

![GDP and inflation/Total investments](application screenshot)

Figure 1: GDP and inflation/Total investments - dumping good price (application screen shot)

Figures 2 and 3 show the significant difference in GDP and Investment factors in systems without and with financial sphere (GDP factor sometimes was even nearly three times larger). Such effect was possible with adding financial agents to the system. There is an additional thing we can observe on figure 2, which is an inflation impulse which was later compensated by the invisible hand.

3.4 Results analysis

Without financial sphere (driven by a presence of financial agents) market agents were focused on collecting goods from the environment and selling them to generate profits. The consumption was reduced, which affected global happiness level. Moreover, competition was less significant, which lead to bigger inflation together
with stimulation of the GDP which was partially caused by the increase of the number of transactions. Hence the experiments proved the importance of the financial sphere in the economic system.

4 Layer of molecular computational model

As mentioned before, this layer hosts translation of given model of Free Market into molecular model(Szuba, 1998) reflecting mental computational processes of Collective Intelligence nature, which are driving the market and in the result are leading to the Invisible Hand symptoms. This level is now partially ready, how-
ever we expect to show this at conference time. Mentioned model when simulated should lead to the same Free Market behaviour as "real model" presented above. Good analogy, is the concept of the body (Layer I) and the soul (Layer II) in "one human". Fundamental is that moving from Layer I to Layer II everything except information flow and processing is reduced. Basic agents will be directly mapped into information molecules carrying facts, rules and goals reflecting the nature of their Free Market activity. Such agents will have their own membrane enclosing facts, rules, goals and internal inference processes taking place inside e.g. the bank or the company acting on Free Market.

World of mental computations is virtual, thus displacements of information molecules will reflect not only "real geographical travel of agent’s body" but also telecommunication travel (telephone, mail, internet, etc.). Some agents in real world do not move at all, e.g. banks - they move only in terms of virtual travel. Thus rendezvous of two information molecules will take also place if two agents will make (and conclude) a business by e.g. phone. Additional information molecules will be introduced which do not have materialistic counterpart at Layer I i.e. information molecules of pure information. We do not plan to crate separate class of information molecules reflecting money. Financial resources will be considered in terms of facts which are carried internally by information molecules of agents. It is reasonable because in today economy somebody can believe that "now" has some money, however after rendez-vous with information molecule of information that the stock plunged, he will found that has no money more. Other resources will be considered in the same way.

5 Conclusions

The aim of the paper was to introduce an innovative concept of the market simulation model based on the theory of Collective Intelligence. Initial experiments with verification of some well-known economic laws lead us to conclusion that such model might be useful when analyzing the nature of different economic processes which are derived from Invisible Hand process. However further experiments are required, especially with much greater number of acting agents. The model enables observation and analysis of the process running in free market environment and further might allow predicting future based on given parameters. The authors made some more experiments with percentage rates impact on the market. In current situation when we face global financial crisis it would be interesting to emulate the cause of the crisis by simulating and analyzing some processes ex. "bad credits" which are suspected to be responsible for the crisis.

The aim of the paper was to introduce the concept of market simulator system which is based on Collective Intelligence computational model and further research in this area is expected to prove the usefulness of such approach in analyzing economic processes run in Free Market. Future work include mathematical description of layer 2 which was introduced in section 4 of this paper which is expected to allow thorough analysis of economic processes derived from Invisible Hand.
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